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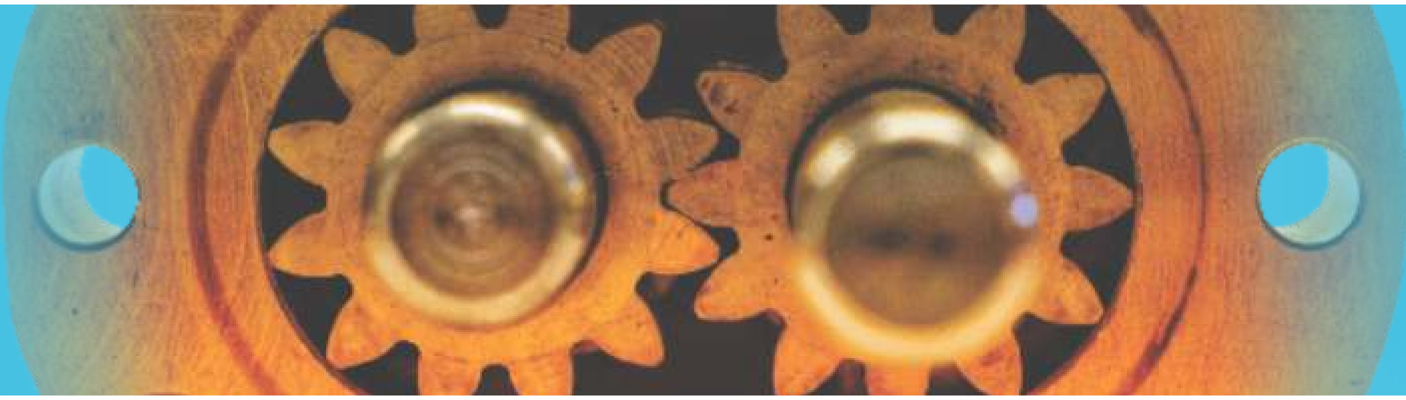

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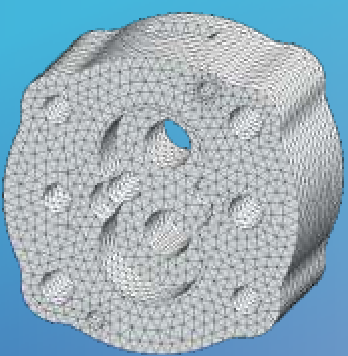

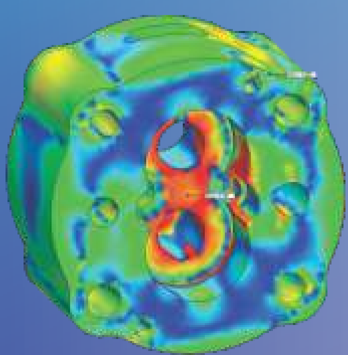

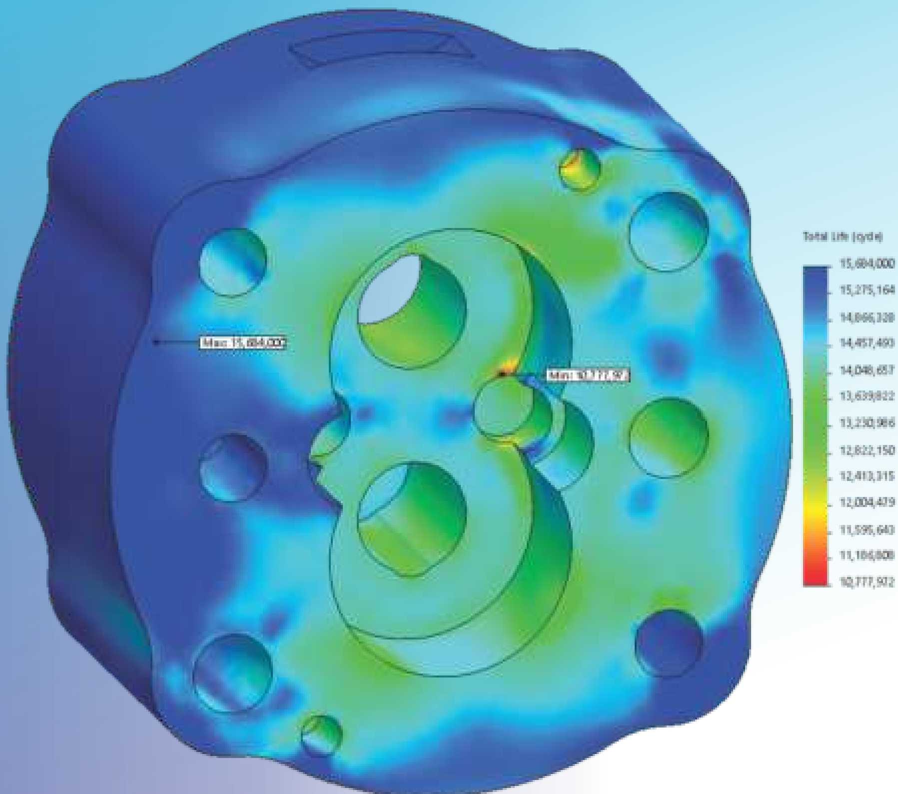

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EDITORIAL

But what about the competitors?

Ph.D.Eng. Petrin DRUMEA
MANAGING EDITOR

Several times I have presented my point of view regarding the people who rule the research field and the people who assess the research topics, highlighting the incompetence and partialism of some of them. But are not there equally serious problems concerning the research scientists themselves? Unfortunately, there are many serious issues in the field that scientific research should somehow get rid of. I will present only a few such problems without prioritizing them.

To begin with, I should point out that too many people use to consider themselves research scientists just because they graduated from university and eventually they are university professors. The editorial refers only to the engineering research activity, which should only be discussed if there is a laboratory or if there are practical achievements, in the process of commissioning or even operating somewhere in the economy. I do not support the idea that some fellows should lay the theoretical foundations, which in fact are neither foundations nor theoretical, without feeling the domain.

There is an equally damaging practice to the hydraulics field, namely the practice of periodically resuming certain topics which, anyway, are behind the technical and scientific state-of-the-art and have neither now nor in the future a user from the economy. Given the conditions that an applicant in a research project competition must meet, sometimes arbitrarily established by certain non-specialists, we discover that often the same "PhDs" are specialists in different fields, just because in their resume there is mentioned a paper related, even if unduly, to the topic in question.

Quite interesting is also the situation in which, in order to meet the demanding standards of the assessors, many research specialists explain in their written applications - although barely credible- that the proposed product or technology could have extraordinary economic impact which could make several large countries envious by a dramatic increase in industrial production.

Sometimes I am amused by the situation in which a research scientist puts down in the bibliography section hundreds of articles and books, in various languages of international circulation, while it stands to reason that he / she has not read even half of them, and - even worse – he /she does not know how important or essential they are for the topic in question. Is a credible research scientist the one who has in his / her 20 years of activity in the field published more than 5 technical books, more than 150 papers and has been granted more than 30 patents? I believe not, because in principle he / she should have worked, too, in this period.

Plenty of health to everyone!

Experimental Simulation of Pressure Losses in the Combustion Chamber of a Diesel Engine

Lecturer dr.eng. **Daniel OSTOIA**[1]

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Abstract: *The study of the influence of the fluid parameters that are introduced into the combustion chamber of an internal combustion engine has been a challenge for any engine manufacturer, as any modification of these parameters in the combustion chamber influences the energy and pollution performance of the engines. In this paper an experimental simulation of the pressure loss in the combustion chamber was performed during the operation of a diesel engine related to the pollution emitted by it respectively its power.*

Keywords: *Chamber combustion pressure, fuel pressure, leaks.*

1. Introduction

The optimum operation of an internal combustion engine involves an operation that generates as little polluting emissions as possible and consumes as little fuel as possible, while the engine must provide sufficient power depending on its destination. The increasingly stringent pollution norms imposed by the engines in the automotive industry, but for those whose destination is the agricultural field, constructions, involved a series of constructive changes without which the requirements found in the pollution norms cannot be met. The main constructive changes involved a management of the operation of the engine through an ECU (electronic control unit) that takes values of the parameters through the sensors mounted on the motor, and then on the basis of a calculation algorithm that provides information to its control elements. One of the parameters that influence the optimum operation of an engine is the maximum compression pressure retained in the combustion chamber (inside the engine cylinder), but its modification directly influences the operation in optimum engine conditions. One of the causes that can lead to the change of pressure in the combustion chamber is the loss through leaks due to wear, or due to spontaneously generated defects. In this work, a correlation was made between these pressure losses due to the leaks in the combustion chamber and the production of emissions, respectively the loss of power in a diesel engine of type M 511, correlated loss and validated through a simulation program.

2. The experimental stand

The experimental stand is composed of a motor stand fig.1, and the block diagram of the stand is shown in fig.2.. The experimental stand allowed the lifting of the power, consumption and pollution characteristics, the results being monitored with a Labview acquisition system, the engine stand also has a device to simulate a loss in the combustion chamber made by the author, respectively allowing the monitoring the cylinder pressure is also correlated with the fuel injection pressure monitoring. In the second stage, the energy and pollution parameters of the engine were determined based on the segments mounted on the engine. Thus it was determined:
-Effective power Pe [kW],
-Torque maxim [Nm],
-Hourly fuel comsumption c_h [kg/h],
-Bosch smoke degree (Opacity) [%]
At each test, the cylinder pressure for each RAC grade was purchased through the acquisition data.
The correlation between the evolution of the pressure in the combustion chamber and its degree of sealing, as well as the injection pressure for each RAC degree, was determined.

The block diagram of the stand is as follows:

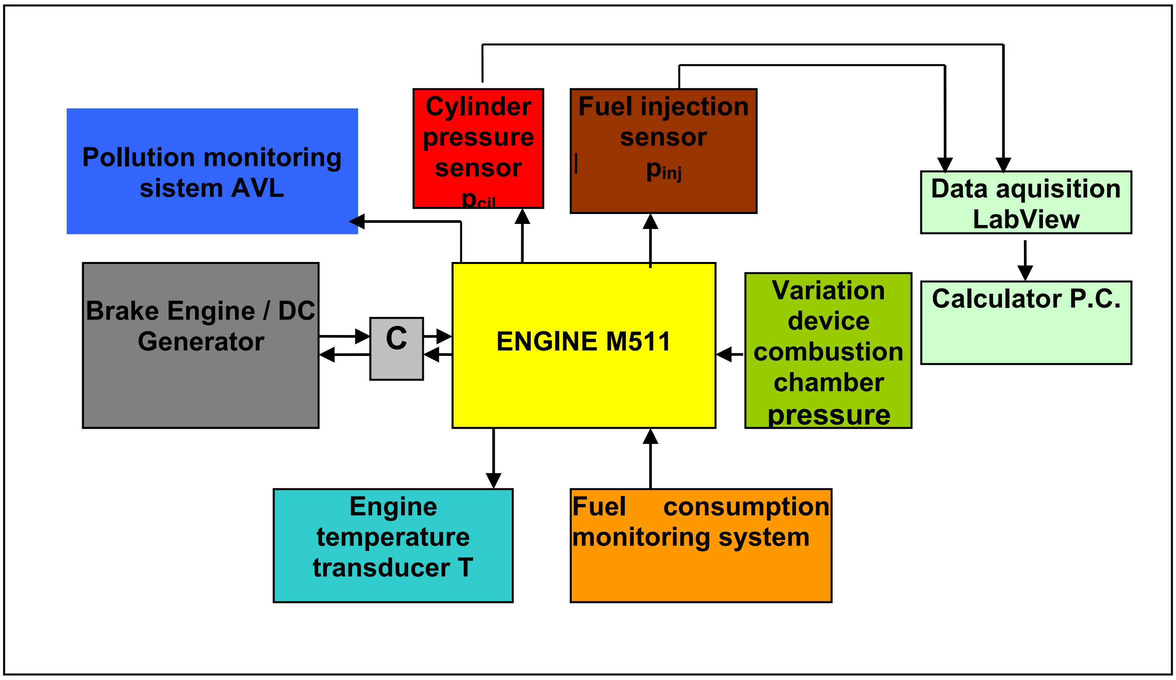

Fig. 1. Block diagram of the experimental stand

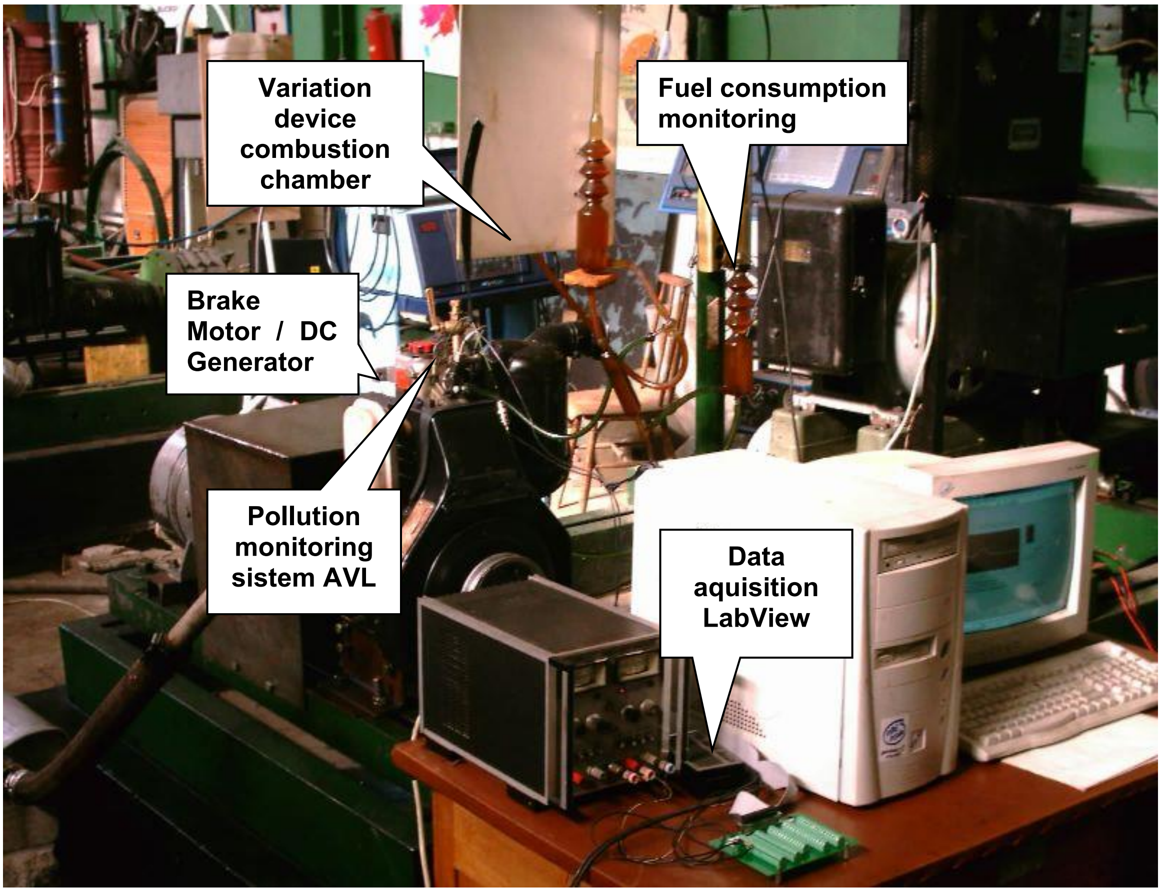

Fig. 2. The experimental stand

The pressure in the combustion chamber was monitored by means of a sensor mounted in the combustion chamber. The fuel injection pressure was p_{inj} was monitored by means of a sensor mounted on the high pressure pipe. Loss through leaks was simulated experimentally by means of a device mounted in the combustion chamber (fig.3), which can control / simulate the pressure losses in the combustion chamber, by opening a calibrated hole and correlated with the degree of wear [2], the validation of losses through non-intensities was performed on a seal set (piston rings) with high degree of wear [3]. The tests carried out aimed at determining the connection between the formation of the fuel mixture and the combustion by determining the consequences of the efficiency of the sealing of the combustion chambers on the engines with low liter compression ignition. The experimental data regarding the sealing efficiency due to the elastic contact pressure of piston rings obtained on the test stand were corroborated with those obtained in determining the wear of the piston rings. Thus, the sets of wear piston rings for the tests were selected based on wear and elastic pressure. The losses through the cylinder-piston rings gap were quantified by a pressure capture device which is mounted in the combustion chamber (Figure 3). The device construction has the possibility of mounting some calibrated holes (figure 4) that allow the simulation of the flow through the intersection of cylinder segments.

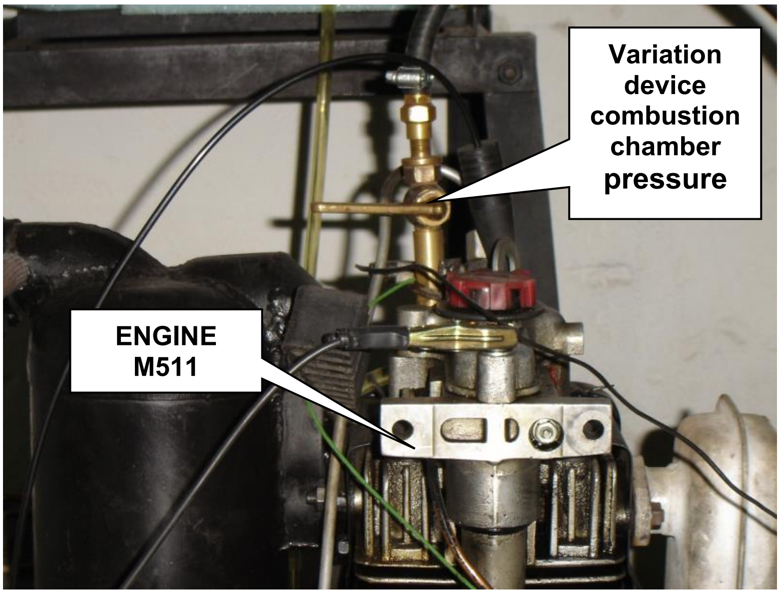

Fig. 3. Variation device combustion chamber pressure

Six nozzles with different diameters were used from the following range of values expressed in mm:

1.0	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**

The nozzles are shown in Figure 4:

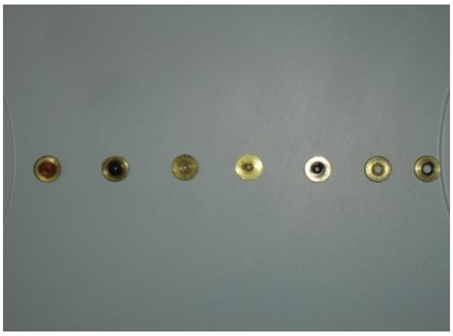

Fig. 4. Calibrated holes (nozzles)

The construction of this pressure controlled variation device is shown below fig.5, which is mounted in the combustion chamber fig.6:
1-device mounted in the combustion chamber cylinder head
2-tap closure
3-hole calibrated (nozzle)
4-hose connection cylinder-housing

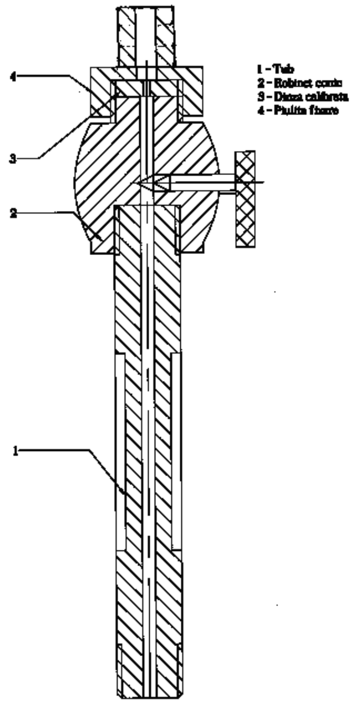

Fig. 5. Variation device combustion chamber pressure

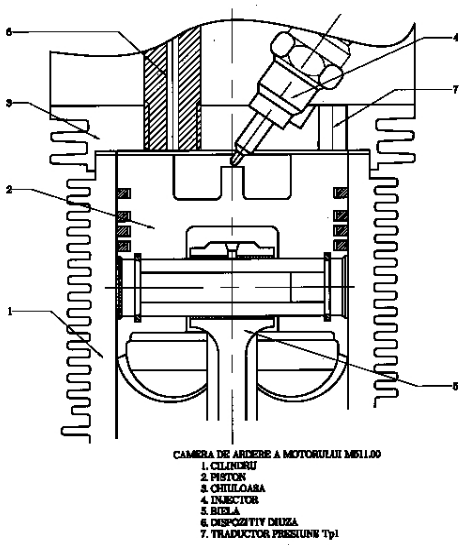

Fig. 6. Section through the combustion chamber

The tests were performed with the determination of the energy parameters obtained on the characteristic of regulator at partial loads, as well as those of pollution by determining the Bosch smoke degree (opacity) for all cases:
1.New piston rings-optimal sealing
2 Wear piston rings-low sealing
3.New piston rings with device / nozzle loss simulation
4.New piston rings with device losses / nozzles and high injection pressure at 200 bar, compared to the standard 175 bar variant.
The external determinations were corroborated with the data acquired through the LabView 6.6i acquisition system, which allows the acquisition of the pressure in the pcil cylinder, as well as the acquisition of the injection pressure p_{inj}. These acquired data will be able to be compared with those obtained through the simulated data through WordStar Professional Release 4, a program that allows numerical simulation of the process inside the combustion chamber.

3. Experimental results

The data obtained by acquisition from the experimental stand were juxtaposed with those obtained by simulation, with the help of the simulation program, the obtained results are validated.
In the case of equipping with new piston rings in which the wear was modeled only by different caliber of nozzles, it was proved correct from the point of view of the wear modeling, which can be confirmed with the situation of wear piston rings (new piston rings with 2mm nozzle molding is equivalent confirmed by allure of the p-v diagram with the situation of the wear piston rings).
In the case of simulation processing using the dedicated software, an optimal correlation of the pressure taken from the combustion chamber is observed with the pressure resulting from the simulation performed using the dedicated software.
Figure 7 shows the variation of the cylinder pressure retained on the engine but also through simulation.

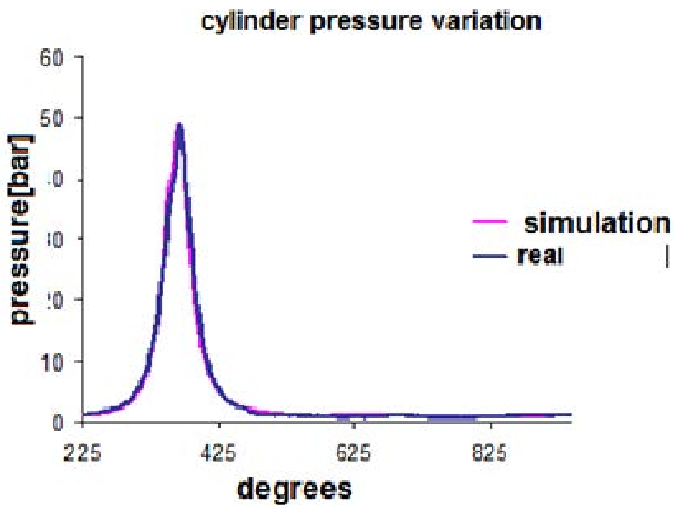

Fig. 7. Variation of cylinder pressures

The loss of pressure through leaks from the engine combustion chamber if the sealing piston rings have a wear of 0.0059mm at an engine speed of 2000 rot/min, was corroborated with a simulation that corroborates with the experimental results (fig.8).

Simulation-acquisition (real)

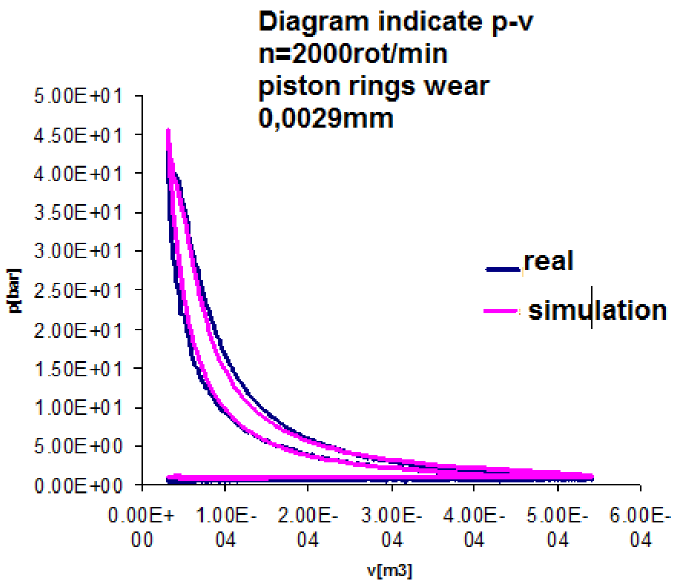

Fig. 8. Diagram indicate pressure

The evolution of the pressure losses in the combustion chambers due to their wear is appreciated by comparing the variation of the mechanical work indicated according to the engine speed (figure 9). It is observed a reduction with increasing wear due to the pumping in the cylinder, but with the tendency of increase with the engine speed.
The evolution of the coefficient of excess air is important from the point of view of the formation of the respective mixture of the combustion, but especially by its evolution with pollution that are formed. As the wear increases, the overall coefficient of excess air decreases, resulting in an increase in the degree of smoke (figure 9).

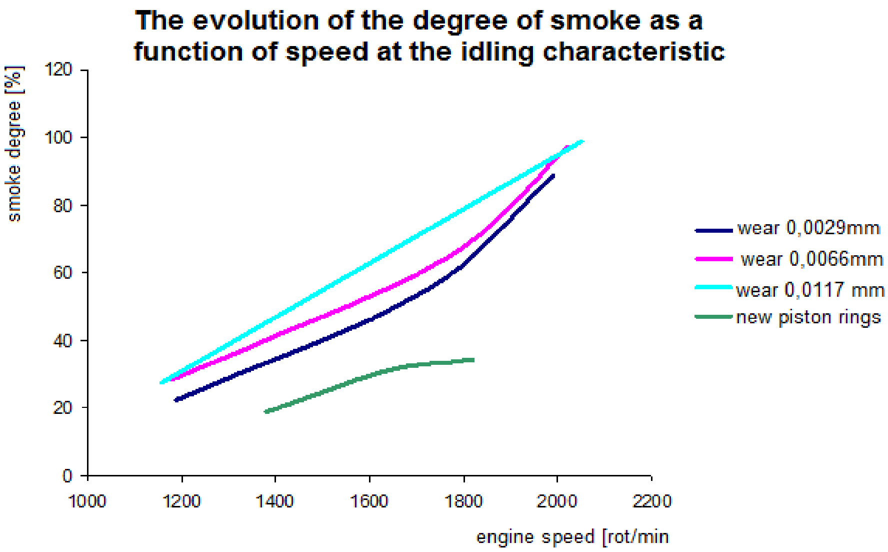

Fig. 9. The evolution of the degree of smoke as a function of speed at the idling characteristic

An important aspect was highlighted by increasing the fuel injection pressure, a parameter that can be increased in conjunction with the pressure losses in the cylinder, in this case the standard fuel pressure is 175 bar and the incresed pressure is 200 bar, resulting in a decrease in the degree of smoke and an increase in power, an aspect synthesized in the diagrams shown in figure 10 and figure 11.

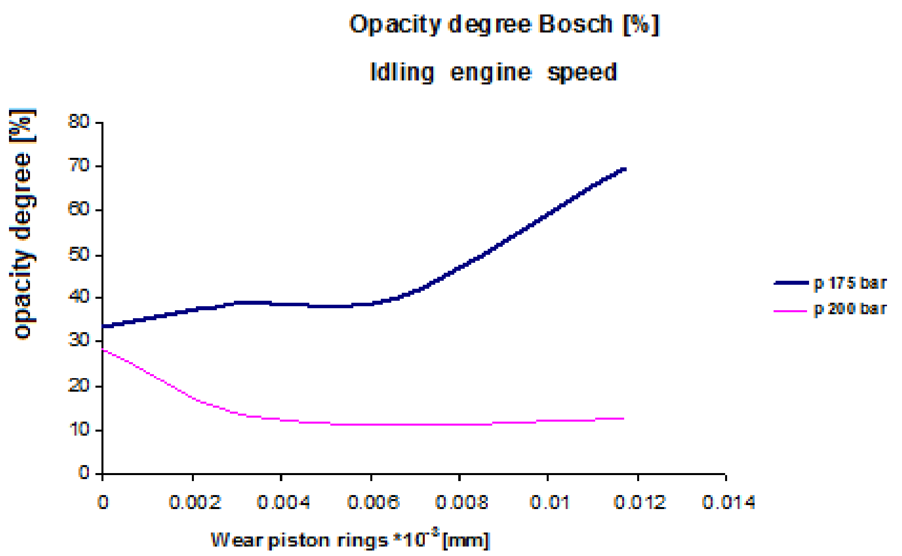

Fig. 10. Opacity variation with wear at different fuel injection pressures

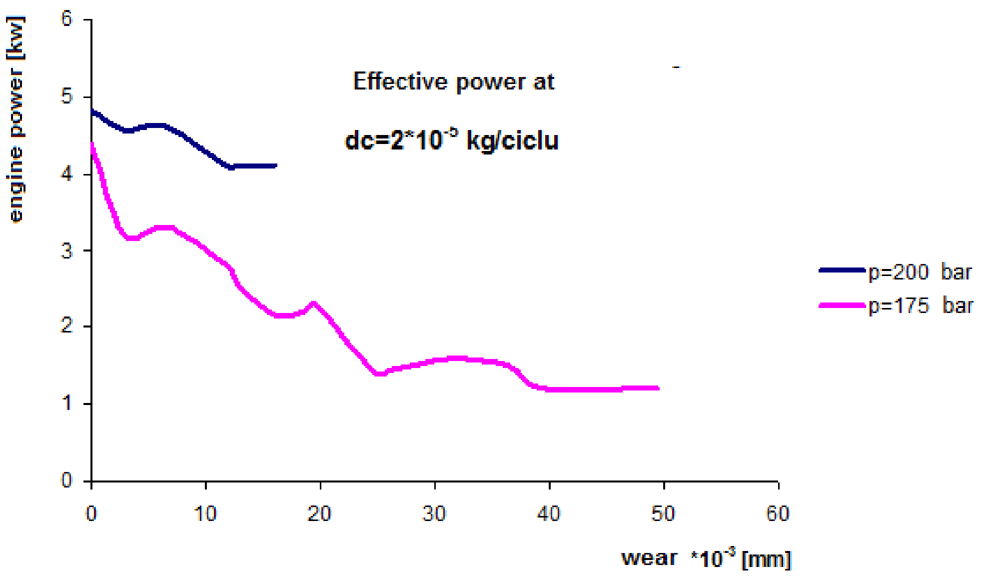

Fig. 11. Variation of the effective power at the same speed and cyclic dose as a function of wear

4. Conclusions

Following the study, it can be concluded that by quantifying the pressure losses through leaks inside the combustion chamber of a compression ignition engine, a correction can be made to the other parameters that contribute to the engine's functioning.
One parameter that can be adjusted by a modification of the ECU calculation algorithm without constructive intervention on the mechanical components, is the change of fuel injection pressure, so that the pressure reduction due to losses due to leaks in the cylinder can be compensated by an adjustment of the injection pressure within certain limits that return the output parameters of an engine to values close to the initial ones, but the proposed method involves a monitoring of the pressure on each of the cylinders of an engine correlated with the modification of the calculation algorithm from ECU.

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Application of Simulation Technology in Analysis of the Influence of the Casing Hanger Length on the Stress and Deformations of Suspended Casing

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Abstract: *Conventional wells consist of several steel casings; a surface casing, a production casing and a tubing pipe (retrievable pipe placed within a well to conduct fluid from the well's producing formation into the christmas). The surface casing commonly reaches a depth of about 10-100 meters and the production casing a depth of about 800-2500 meters. The casing diameters vary with regard to the depth of the wells. For well drilling the casing column is suspended in the wellhead through the casing hanger. Their dimensioning is done analytically, considering the maximum weight of the column of casing. Design loads according to API 6A, are the weight of the column and the pressure in the system. The loads to which the casing will be exposed during the life of the well will depend on the operations to be conducted. Casing suspending on casing hanger will result in radial (burst and collapse) and axial (tensile and compressive) loads on the casing strings.*

In this paper, using finite element analysis (ANSYS), we studied the influence of pressure on the casing resistance suspended into the 9 5/8 " casing hanger for three slip lengths (170 - resulting from analytical calculation, 120 and 220 mm).

Keywords: *Casing hanger, Finite Element Analysis, ANSYS*

1. Introduction

The wellheads are used to suspend casings and tubing and to seal the annular space between them, from 2 3/8 in - 21 ¼ in and 2000-10000 psi work pressure, in any combination. The typical wellhead assembly is shown in figure 1.

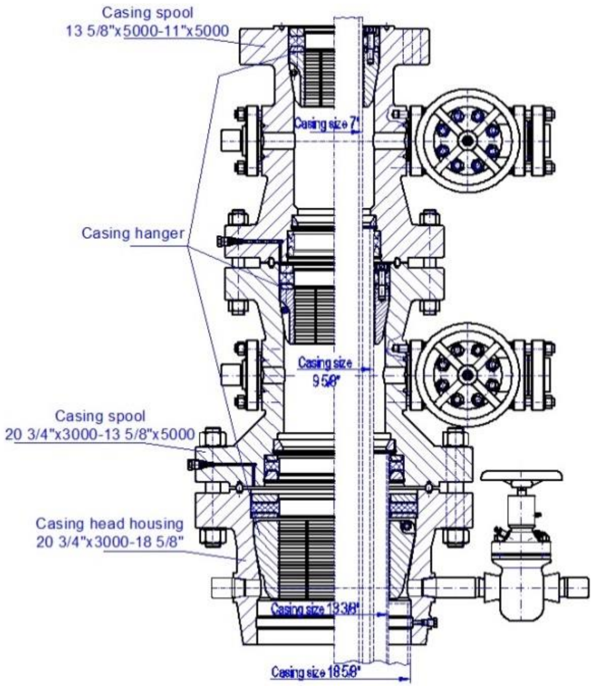

Fig. 1. Typical wellhead assembly

The Slip Type (SC) Casing Hangers (figure 2) has a medium capacity of suspension and includes a ring seal which works up to 10000 psi (68,9 MPa).

The seal energizing is performed by tightening the seals screws. This type of hanger is wrapped around the casing and then lowered until it sits inside the casing spool. The slips are automatically set when the casing is lowered (in a similar fashion to drillpipe slips) [1, 2]. These types of hanger are also used when tension has to be applied in order to avoid casing buckling when the well is brought into production.

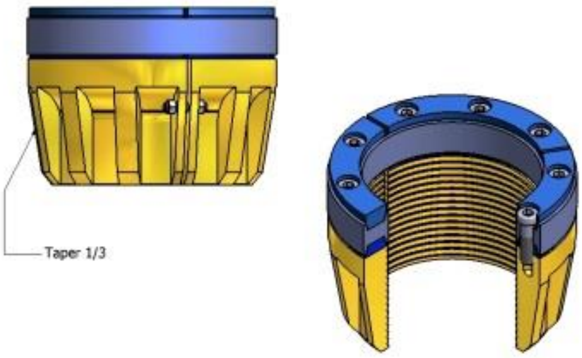

Fig. 2. SC Type- Casing hanger

2. Design methodology

2.1. Dimensioning of casing hanger SC 9 5/8 length

The load and pressure ratings for casing hanger are a function of the tubular grade of material and wall section.

According to API Specification 6A, casing hangers design will take into account [1]:

-radial load on hanger body due to settlement tapered surface;
-tensile loads directly distributed on hangers' body due to the weight of the suspended column of the casing;
-load distributed to casing hanger due the pressure test in field work.

For the suspension of the columns, the casing hanger slips lean on the internal tapering surface (1: 3) of casing spool (figure 3).

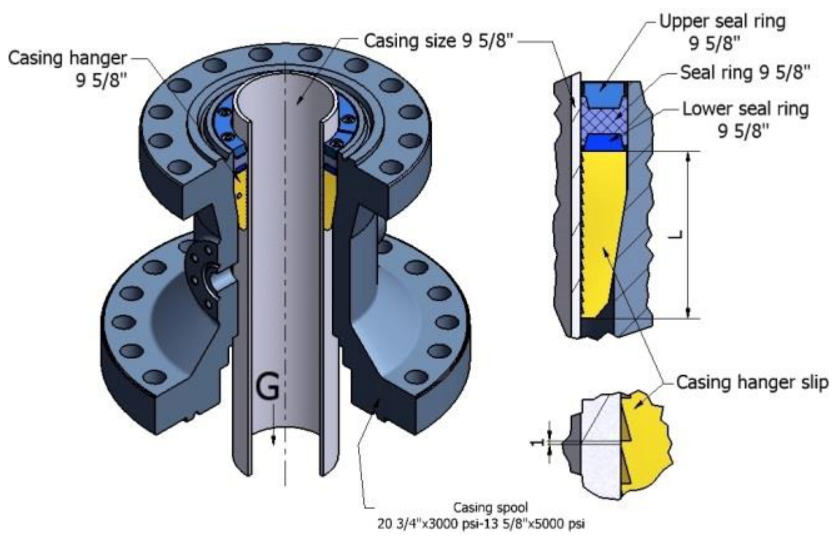

Fig. 3. Suspend and seal 9 5/8 in column on casing spool

To fulfil the role of supporting the weight of the column during tubing well works or in case of if hang off procedures during bad weather, it is necessary to (Figure 4).

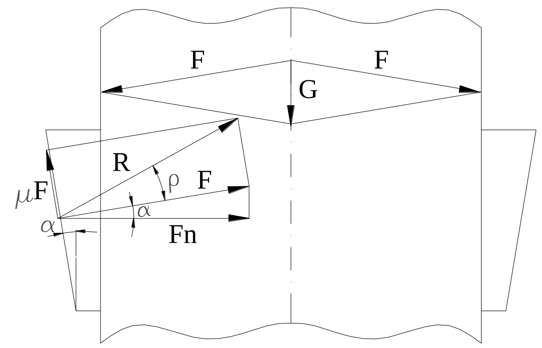

Fig. 4. The system of forces to hinge the column on casing spool

$$G = 2R\sin(\propto + \rho) \quad (1)$$

where: G - is the casing weight *(N);*

$\mu = tg\rho = 0{,}15$ -steel/steel friction coefficient

$(\rho = 8^{o}32')$

$\propto$ - casing hanger tapering angle

The tapered rough backs control slip assembly movement and the radial component F_n acting on tubular material are:

$$2F_n = 2Rcos(\alpha + \rho) \quad (2)$$

But,

$$2R = \frac{G}{sin(\alpha + \rho)}$$

$$2F_n = \frac{G}{tg\ (\alpha+\rho)} \quad (3)$$

Specific pressure p_s which develops on tapered surfaces of the spool and the casing hanger are:

$$p_s = \frac{G}{S \cdot tg\ (\alpha+\rho)} \qquad (N/mm^2) \quad (4)$$

where: *S*- the real contact surface between casing spool and casing hanger *(mm²).*

The length of the slip of a casing hanger is given by the need to ensure the suspending weight column, avoiding the collapsing of the tube in the hanging zone [2, 3] is:

$$l = \frac{G}{2\pi \cdot D \cdot \sigma_c \left[\frac{t}{D} - \left(\frac{t}{D}\right)^2\right]\left[1 - \frac{4G}{\pi\left(D^2 - D_i^2\right)} \cdot \frac{1}{\sigma_c}\right] \cdot tg(\alpha+\rho)} \qquad (mm) \quad (5)$$

In which: $\sigma_c = 720MPa$ the casing material specified (N80) minimum yield strength;

t - casing wall thickness;

D - casing outside diameter;

D_i - casing inside diameter.

It is considered the variant N80 material with higher mechanical characteristics and the smallest wall thickness t = 10.05 mm.

Thus, the dimensions of casing are:

$$D = 244.5\ mm$$

$$Di = 222.4\ mm$$

$\frac{t}{D} = 0.045 > 0.040$– thick-walled tube

For weight G =1810 kN of the 9 5/8 in casing, the calculated slip length is $l = 170\ mm$

The maximum load *T* with which the casing can be loaded [3] is:

$$T_{max} = \frac{\sigma_c \cdot S_m}{C_z} \tag{6}$$

Where: $S_m = 8104\ mm^2$ -average section of the 9 5/8 in casing:

$C_z = 1.8$ – tensile safety factor.

$$T_{max} = \frac{720 \cdot 8104}{1{,}8} = 3241.7 \cdot 10^3 N > G = 1810\ kN$$

In order to fulfill its functional role, it is necessary that the maximum loading does not exceed 50% of the allowable stress of the material of the casing [1].

2.2. Specific contact pressure

Under the action of forces $2F_n$, between the peaks of the teeth of the casing of the head slip and the casing, the specific pressure which should not exceed the yield strength of the material casing is developed. In order not to print permanent deformation traces through casing body, we will consider:

$$p_s = (0.75 \div 0.85)\sigma_c \tag{7}$$

The contact surface between casing hanger and tube is:

$$S_c = \pi \cdot D \cdot h_1 \cdot n \tag{8}$$

where: n – number of teeth on the inner surface of casing hanger;

h_1 – contact width of a tooth ($h_1 = 1mm$) ;

$$p_s = \frac{2 \cdot F_n}{S_c} = \frac{\frac{G}{tg(\alpha+\rho)}}{S_c} \tag{9}$$

Thus, for $S_c = \pi \cdot D \cdot h_1 \cdot n = \pi \cdot 244.5 \cdot 1 \cdot 15 = 11522\ mm^2$ the specific contact pressure is:

$p_s = 483\ N/mm^2 < (540 \div 612)\ N/mm^2 = (0.75 \div 0.85)\sigma_c$ for casing material N80.

Hanger teeth will not leave permanent traces through casing deforming.

2.3. Total deformation for material on casing surface

Under the action of specific pressure that develops on the surface of contact with hangers' teeth, the casing material deforms in the elastic area.

The penetration of the teeth in the outer surface of the casing can be calculated using the equation [1,3]:

$$\Delta l = \frac{2F_n \cdot D}{E \cdot A} = \frac{\frac{G}{tg(\alpha+\rho)} \cdot D}{E \cdot \pi \cdot D \cdot h_1 \cdot n} \tag{10}$$

The radial forces $2F_n$ will cause a dent in the material, below the surface of the teeth peaks, namely an agglomeration of material around these areas (Figure 5).

In this application the penetration of the teeth in the outer surface of the casing is:

$$\Delta l = 0.562\ mm$$

As there is no relative motion between hanger slips and tube, friction adhesion appears. The coefficient of friction of adhesion μ_0 is slightly larger than the coefficient of sliding friction, in motion μ .

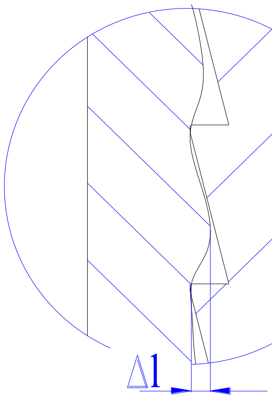

Fig. 5. Casing material deformation

For the steel / steel couple: $\mu = 0.15 \div 0.22$ and $\mu_0 = 0.25 \div 0.35$ [3]

Under the action of axial force G, the column of the casing tends to slip, which is opposed by friction adhesion and agglomeration of formed by deforming of the material.

$$G \leq \mu_0 \cdot 2F \cdot cos(\alpha + \rho) + n \cdot \pi \cdot D \cdot \Delta l \cdot \sigma_c \qquad (11)$$

If there were no friction, resistance that develops sill formed by deforming the material Δl will be:

$$\sigma_{ef} = \frac{G}{\pi \cdot D \cdot \Delta l \cdot n}$$

In this application: $\sigma_{ef} = 280 N/mm^2 < \sigma_c$

Since the yield strength of the material is not exceeded, the casing column do not slide down and the hanger teeth will not leave marks on the casing wall.

For the pipe not to slide on the casing hanger [6] it must be provided with teeth which achieves a higher coefficient of friction of 0.27. The configuration of this type of teeth generally provide $\mu_0 = 0.35$.

3. The length of the casing hanger FEM (ANSYS) verification and determination of the influence of the pressure (3000 psi) within the column

To validate the analytical calculation, in addition to experimental tests, we checked the behavior of the casing in the assembly (casing spool- casing hanger- casing column) loaded by the weight of the column, to which was added the system pressure (internal pressure) was added.

The program developed using ANSYS 14.5 [8] and the model was established from the conical part of flange (intermediate casing spool), slip type casing hanger assembly and 9 5/8 "casing of N-80 with a thickness of 10.05 mm.

Contacts, identified by the *program controlled*, between tapered surface of the flange and the casing hanger slips are defined *frictional type with 0.15 friction coefficient* and contacts between hanger inside and casing are defined *frictional type, with 0.35 coefficient.*

The meshing of the parts was done differently (in order to decrease the structural error to an acceptable level) [8, 9, 11].

- For casing hanger and flange - tetrahedrons method, patch conforming algorithm, element midside nodes- kept
- For casing - automatic method, element midside nodes- kept

Restraint and loads define the environment of the model. Fixed support was chosen on casing spool face and loads (weight force G=1810 kN for 9 5/8 in casing column).

The verifications were done in two stages (fig.6):

Stage 1: without pressure

Stage 2: with internal pressure - 3000 psi (20.684MPa)

for three hanger lengths (L =170, 120 and 220 mm)

To check the casing behavior, two patches length 400 mm, on two generators of outer surface of casing, in hanger area, were defined.

By solving the ANSYS static study the following solutions were calculated (especially on the two paths) as exemplified in Figure 7, 8 and 9 and centralized in Table 1.

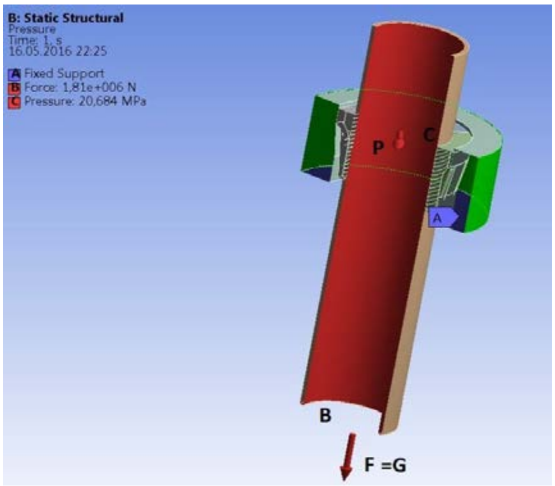

Fig. 6. Restraint and loads (stage 2) for static studies by ANSYS

- von-Mises Equivalent Stress (MPa)(fig.7, table 1);
- Directional deformation (X, Y and Z axis) on Path1 and Path 2 (table 1)
- von-Mises Equivalent Stress (MPa) on Path 1 and Path 2 (Figure 8, tabel 1)
- Total deformation (mm) on Path 1 and Path 2 (Figure 9, table 1)

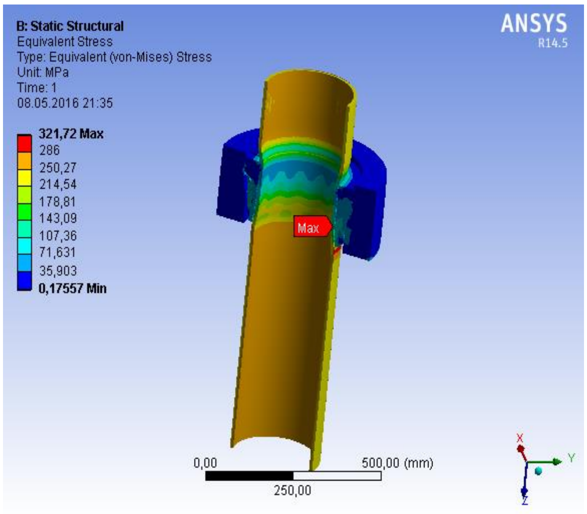

Fig. 7. Equivalent (vonMises) Stress

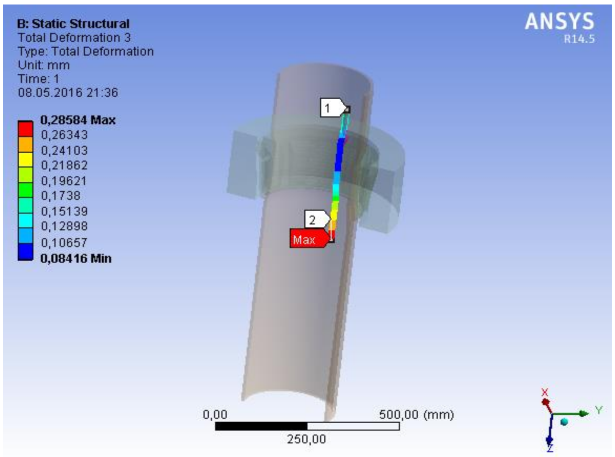

Fig. 8. Total deformation exemplification figure – cansing hanger node on Path 2(L=170 , stage 2)

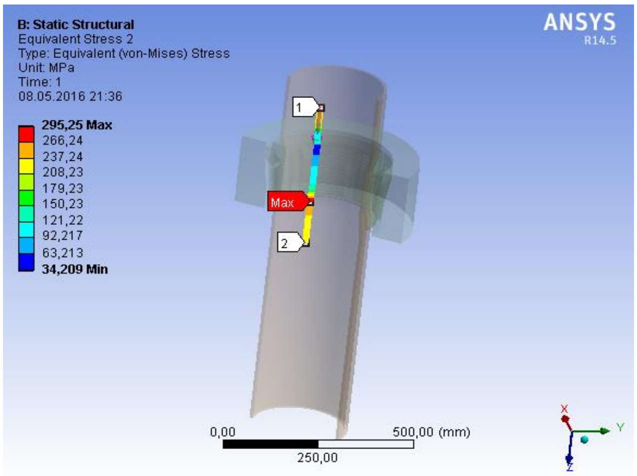

Fig. 9. Equivalent (vonMises) Stress exemplification figure – cansing hanger node on Path 2(L=170 , stage 2)

Table 1: The results of static analysis for three variants of casing hanger length and two load stage

Casing hanger dimension	**Equivalent stress**		**Total deformation**		**Directional deformation (Path 2)**		
	(Path1)	(Path2)	(Path1)	(Path2)	X axis	Y axis	Z axis
9 5/8 in	(N/mm2)		mm		mm		
L=170	293.91	296.34	0.3183	0.3186	0.0197	0.0096	0.31563
L=170 -internal pressure	295.25	290.49	0.2862	0.2858	0.0989	0.0997	0.2708
L=120	657.27	725.14	4.9349	4.9409	0.0093	0.0125	4.9407
L=120 -internal pressure	443.15	507.13	3.6526	3.6542	0.1043	0.1088	3.6532
L=220	474.76	538.64	3.0833	3.0868	0.0045	0.0082	3.0864
L=22 -internal pressure	299.77	330.12	1.8672	1.8711	0.0996	0.10389	1.869

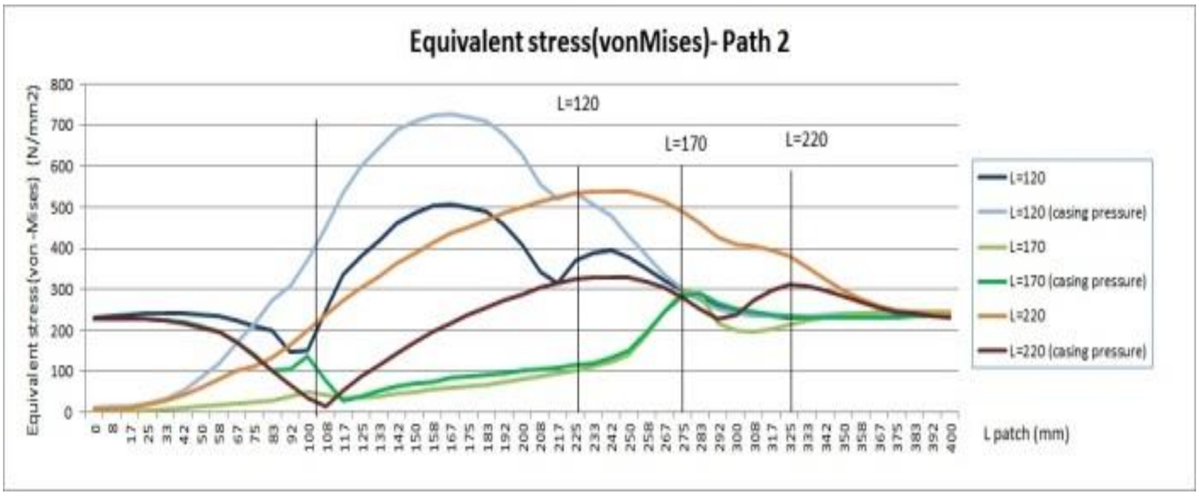

Fig. 10. Graph of Equivalent stress (von Mises) on path 2

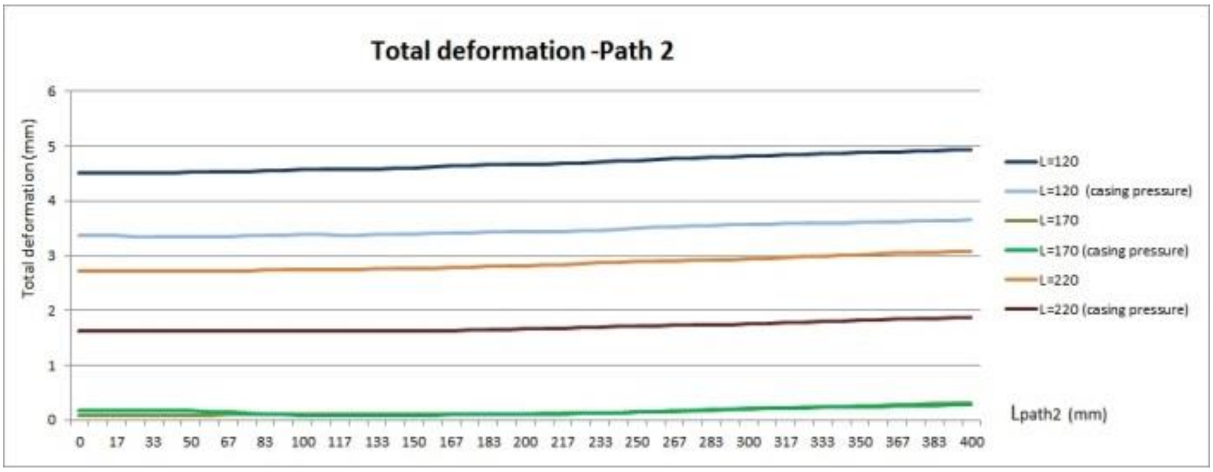

Fig. 11. Graph of total deformation on path 2

4. Conclusions

Trough the analysis of the values obtained for the equivalent stress (von Mises) for the casing hanger with length of 170 mm, we can observe that on a maximum load, with or without internal pressure, 50% of the yield strength of the material is not exceeded.

The equivalent stress calculated with to the distortion energy theory, also known as the Von Mises law, are compared to the yield strength of the material according to API Spec 6A [1 8.3.3.3] [1, 10].

For hangers with lower length (120 mm) or larger length (220 mm) an increase in equivalent stress is observed along the area of suspension, that exceed the yield strength of the casing material.

Total or axial deformation also certify analytical calculations, but also experimental observations (the approval tests of the product). The Casing hanger with 170 mm length produces a maximum of 0.3186 mm displacement for nodes located on the generating line of the casing, which is a coefficient of less than 3%, considered as an acceptance criterion of the slip performance [7].

The significant differences in the length of the casing hanger slips (± 30%) negatively affect its performance, while applying pressure to the interior, in the case of the hanger with 170 mm length, does not affect its performance.

So, the slips hangers length calculated from the condition to suspend the entire weight of the column of pipes, without permanent tube deformation in the mounting area, verified through the finite element method can reduce the risk of damage but also sliding of the tubular material.

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Reconstruction of River-Course Processes by a 1D Numerical Modelling

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Abstract: *The paper presents a 1D numerical approach aiming to analyse the river-course processes development as emphasised by the river left side upper bed scouring on Timiș River, West of Romania, downstream of a crossing road-bridge. The quasi-unsteady flowing regime is modelled over a hydrologically significant time interval during the spring season of 2005.*
The analysis looks to reconstruct the side scouring occurrence and progress as a result of river-bed sliding instability under given special conditions produced by accidental high-waters. By employing the HEC-RAS software package, the numerical simulation considers the river sector morphological conditions determined by the crossing structure as transiting the liquid hydrograph and the corresponding sediment transport.

Keywords: *River flow, bridge hydraulics, highwaters flow, sediment transport, river-bed process, numerical model.*

1. General situation

The numerical model covers a sector of about 6484 m length from Timiș River (figure 1) on the south edge of Șag Village in Timiș County, West of Romania. As the influence area of the concrete crossing bridge on National Road 59, the river sector is to transport the non-permanent flow under a quasi-unsteady regime. The discrete numerical modelling was studied by the help of HEC-RAS 5.0.6 specialized software [1].

Fig. 1. Aerial view (Google Maps) of studied Timiș River sector south bordering the Șag Village (flowing right to left)

There was considered a topographical data base as produced for the river sector area in 2005 [2], shaping the general plan view with 22 measured and 4 linear interpolated river cross-profiles. The river cross-profiles point out the geometrical configuration of the main river-bed and its sides flood plains.

The water surface level development in time, the flowing velocity regime and the sediment transport phenomenon on the considered river sector are to be reconstruct as corresponding to a given maximum flow of 1% overrunning probability developed by a specific high waters hydrograph. The roughness coefficients for the river-bed and flood plains area, the river sector hydro-dynamic gradient and the flow – level curve (as supplied for a downstream measured cross-section) were also engaged.

2. Numerical modelling of the liquid and sediment transport under the quasi-unsteady regime

The 1D numerical model was created by dividing the river sector in 25 straight segments as defined by the 22+4 cross-profiles [3]. Besides the ground geometry, the model considers an inherent bridge type structure. The actual model initiation was performed by following the common operations in HEC-RAS 4.1 [4,5] (figure 2).

The graphic image in figure 3-left presents the geometric characteristics of the inherent bridge structure (seen from the left bank to the right one) as modelling the concrete road bridge of six gaps (see picture presented by figure 3-right), two of them covering the thalweg river-bed, one connecting towards the right abutment pier, and three covering the upper bed towards the left abutment. As taken after the special hydrological events of the spring of 2005, the picture shows also the altered scouring on the left side upper bed.

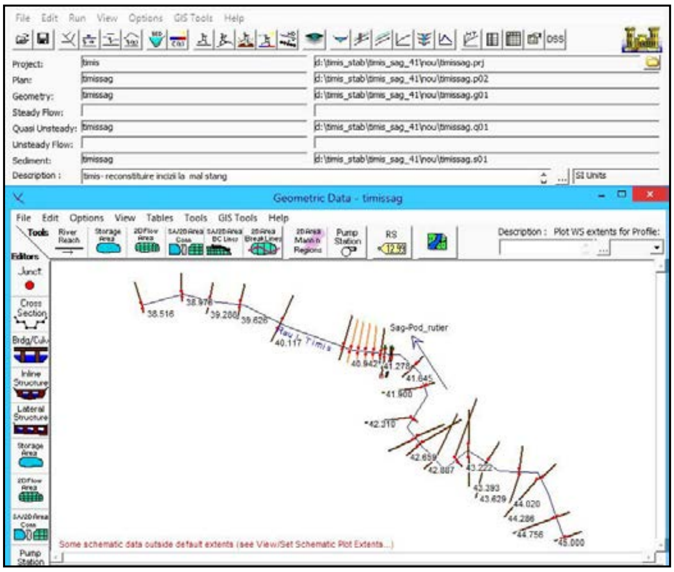


Fig. 2. Path view of the Timiş River sector 1D model also indicating the cross-profiles

Since sediments physical data are uncertain, the sediment transport modelling is a difficult problem. In the same time, one should be aware that the transport theory is largely empirical and so very sensitive to a significant range of physical variables considered as model parameters, especially hard to measure or estimate.

Among its several resources, HEC-RAS 5.0.6 also comprises specific modelling capabilities regarding sediment transport as ground (bed) movable boundary (surface), successively altering the cross sections geometry as a response to sediments dynamics [6]. The software can correspondingly simulate banks deteriorating processes and resulting alluvia transport.

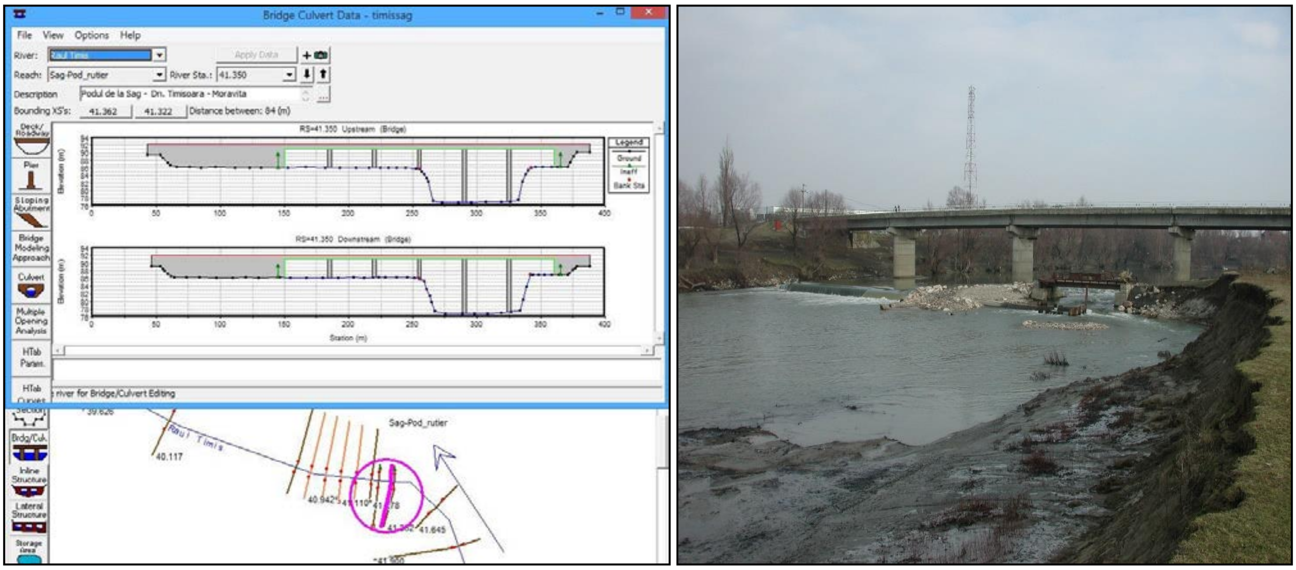


Fig. 3-left Geometrical and hydraulic characteristics of the bridge structure; **-right** Downstream view of the modelled concrete road bridge presenting the general scouring of the left side upper bed as produced by 2005 spring hydrological events

The sediment transport hydraulics is combined with the unsteady (transitory) or quasi-unsteady flow hydraulics. The quasi-unsteady flow model simplifies the phenomenon hydro-dynamics by considering the continuous hydrograph as modelled by a series of discrete constant flow profiles. For each given flow constant value, the software performs the transport calculations along the specific time step. Specifically, for each constant flow interval HEC-RAS 5.0.6 establishes the computational increments that model the hydraulic and sediment transport phenomenon development. So, the river-bed geometrical configuration and flow hydraulics are continuously updated along the simulation period.

Thus, by following the quasi-unsteady approach, figure 4 (left) shows the considered flow hydrograph [2] as altered in a series of constant flow value steps, the associated time interval for each step (Flow Duration) being adopted in this case as 24 hours. Further on, the adopted Computation Increment was one hour along all time intervals.

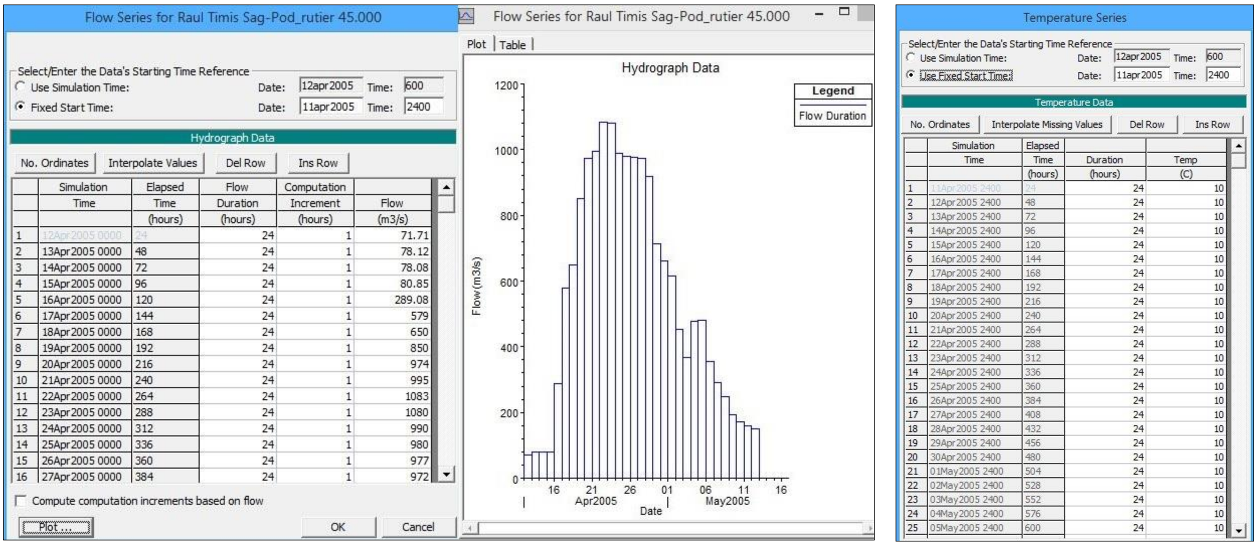
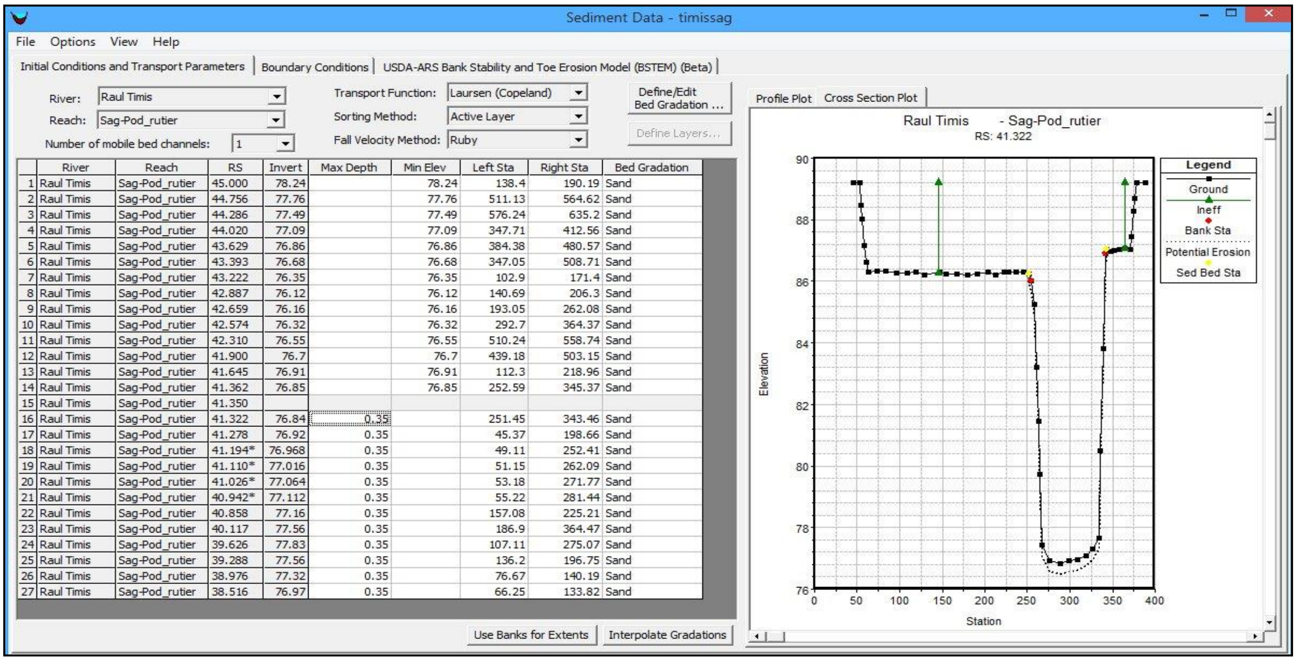


Fig. 4. Altered flow hydrograph covering the total simulation period, April 12th to May 12th, 2005, and the as adopted corresponding air temperature development

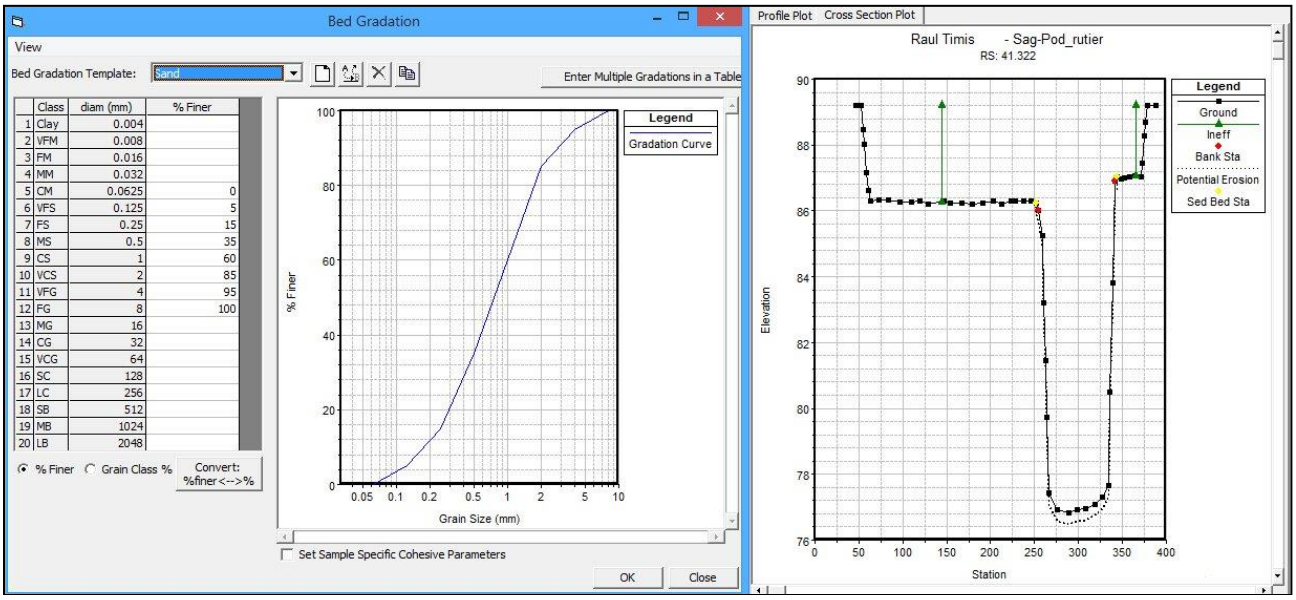
The graphical image in figure 4 also indicates the way of advancing through the specific facilities available for flow hydrograph editing, together with the accompanying daily temperature editing (even of no eloquent effect in this case).
As common procedure, the quasi-unsteady model in HEC-RAS 5.0.6 requires three specific files, one covering the flow data (constant or unsteady), one storing the geometry data and the third one bonding the first two. The constant or unsteady alluvia (sediments) flow analysis brings in a fourth distinct data file. The figure 5 specifies data regarding sediments and specific geometry elements. Some of the required sediment parameters are to be defined for each of the numerical model cross sections. The following options were considered for the sediments transport analysis: Laursen-Copeland model for the transport function, Active Layer method as the river-bed mixing simulation and the Rubey model as the fall velocity computing method.
There are three facilities with the sediment data edit menu (figure 5), the first two – Initial Conditions and Transport Parameters, Boundary Conditions – which need to be considered for any sediment transport analysis, and a third one – USDA-ARS Bank Stability and Erosion Model (BSTEM) – which is to be accessed in case of river-bed or banks failure and transport of produced material [7].
As given the site characteristics, the movable river-bed layers were defined of a single gradation feature (identified as Sand) by specifying the material granulometry (figure 6). Additionally, there were stated the parameters defining the bed and banks stability / failing processes for several bridge downstream cross-sections (figure 7).
We have to mention here that the employed data regarding the solid flow and temperature development along the considered simulation period (April 12th to May 12th, 2005) and also regarding the movable bed layers gradation curves and geometrical parameters, were only estimated with respect to site conditions as shown during site inspections, and so they are not supplied as measured and certified information. Some data range values were assimilated from example analysis offered by HEC-RAS 5.0.6 templates. Since the sediments transport numerical values were so adjusted according to the associated known liquid flow highwaters hydrograph, the foreseen results are expected in a feasible range of values for the studied river sector.
As regarding the initial and boundary conditions for the performed 1D numerical model, they were defined by the main Edit menu, employing the boundary conditions facility in Sediment Analysis sub-menu. The constant liquid flow steps duration (in hours), the constant flow values (in m^3/s) and

the computation increment (hours) were assigned to the entering cross section (river station 45.000) defined as BC Line. As the assimilated liquid flow hydrograph configuration show (figure 4), the given maximum value, designated as constant for the time interval from hour 240 to hour 264, is 1083 m^3/s. The hydrodynamical gradient of the river sector downstream part, known with the value of 0.000124, was assigned to the outgoing cross-section (river station 38.516).



	River	Reach	RS	Invert	Max Depth	Min Elev	Left Sta	Right Sta	Bed Gradation
1	Raul Timis	Sag-Pod_rutier	45.000	78.24		78.24	138.4	190.19	Sand
2	Raul Timis	Sag-Pod_rutier	44.756	77.76		77.76	511.13	564.62	Sand
3	Raul Timis	Sag-Pod_rutier	44.286	77.49		77.49	576.24	635.2	Sand
4	Raul Timis	Sag-Pod_rutier	44.020	77.09		77.09	347.71	412.56	Sand
5	Raul Timis	Sag-Pod_rutier	43.629	76.86		76.86	384.38	480.57	Sand
6	Raul Timis	Sag-Pod_rutier	43.393	76.68		76.68	347.05	508.71	Sand
7	Raul Timis	Sag-Pod_rutier	43.222	76.35		76.35	102.9	171.4	Sand
8	Raul Timis	Sag-Pod_rutier	42.887	76.12		76.12	140.69	206.3	Sand
9	Raul Timis	Sag-Pod_rutier	42.659	76.16		76.16	193.05	262.08	Sand
10	Raul Timis	Sag-Pod_rutier	42.574	76.32		76.32	292.7	364.37	Sand
11	Raul Timis	Sag-Pod_rutier	42.310	76.55		76.55	510.24	558.74	Sand
12	Raul Timis	Sag-Pod_rutier	41.900	76.7		76.7	439.18	503.15	Sand
13	Raul Timis	Sag-Pod_rutier	41.645	76.91		76.91	112.3	218.96	Sand
14	Raul Timis	Sag-Pod_rutier	41.362	76.85		76.85	252.59	345.37	Sand
15	Raul Timis	Sag-Pod_rutier	41.350						
16	Raul Timis	Sag-Pod_rutier	41.322	76.84	0.35		251.45	343.46	Sand
17	Raul Timis	Sag-Pod_rutier	41.278	76.92	0.35		45.37	198.66	Sand
18	Raul Timis	Sag-Pod_rutier	41.194*	76.968	0.35		49.11	252.41	Sand
19	Raul Timis	Sag-Pod_rutier	41.110*	77.016	0.35		51.15	262.09	Sand
20	Raul Timis	Sag-Pod_rutier	41.026*	77.064	0.35		53.18	271.77	Sand
21	Raul Timis	Sag-Pod_rutier	40.942*	77.112	0.35		55.22	281.44	Sand
22	Raul Timis	Sag-Pod_rutier	40.858	77.16	0.35		157.08	225.21	Sand
23	Raul Timis	Sag-Pod_rutier	40.117	77.56	0.35		186.9	364.47	Sand
24	Raul Timis	Sag-Pod_rutier	39.626	77.83	0.35		107.11	275.07	Sand
25	Raul Timis	Sag-Pod_rutier	39.288	77.56	0.35		136.2	196.75	Sand
26	Raul Timis	Sag-Pod_rutier	38.976	77.32	0.35		76.67	140.19	Sand
27	Raul Timis	Sag-Pod_rutier	38.516	76.97	0.35		66.25	133.82	Sand

Fig. 5. Specific parameters and geometry data for sediments along the river sector and with a graphical detail in a bridge downstream cross-section (river station 41.322)



	Class	diam (mm)	% Finer
1	Clay	0.004	
2	VFM	0.008	
3	FM	0.016	
4	MM	0.032	
5	CM	0.0625	0
6	VFS	0.125	5
7	FS	0.25	15
8	MS	0.5	35
9	CS	1	60
10	VCS	2	85
11	VFG	4	95
12	FG	8	100
13	MG	16	
14	CG	32	
15	VCG	64	
16	SC	128	
17	LC	256	
18	SB	512	
19	MB	1024	
20	LB	2048	

Fig. 6. Movable bed alluvia granulometry in the downstream area of the crossing bridge (river station 41.322)

The 1D sediments transport numerical model also requires the edit of daily solid flow quantity (tons/day) as associated to the liquid flow values by following a specific path from the main menu: Sediment Data → Data sediment – Sediment Series → Boundary Conditions → Rating Curve. The sediment load series is to be defined for each rating curve set, according to the solid material granulometry (figure 8). These values associated to the liquid flow levels are assigned to the river sector upstream entrance cross-section as sediments boundary condition.

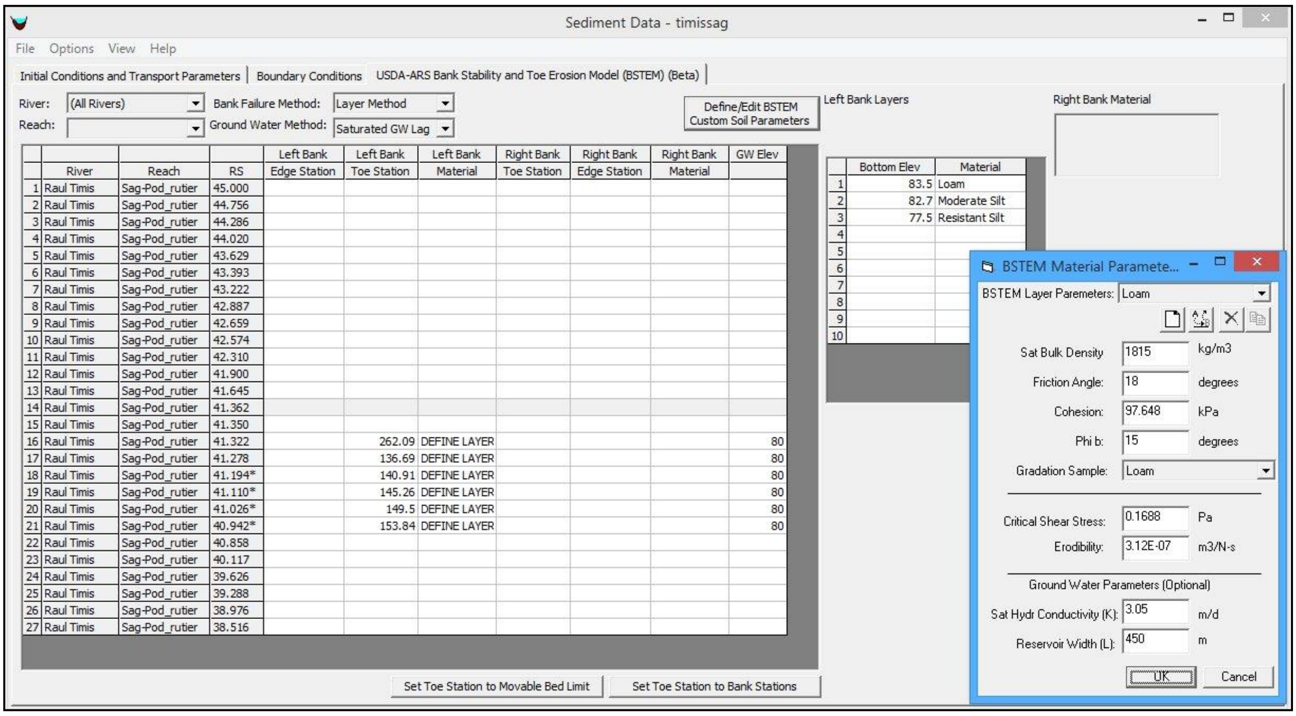


Fig. 7. Geometrical data and materials specific parameters regarding the river cross-sections

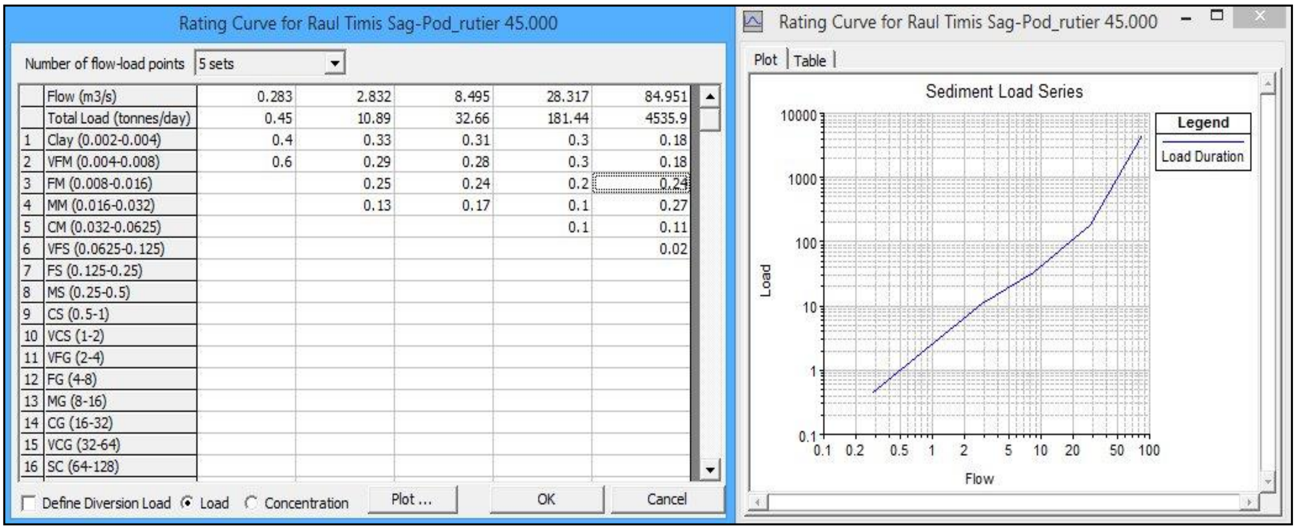


Fig. 8. Sediment load series definition in five sets as associated to liquid flow level

The actual numerical simulation of liquid and sediment transport by the considered Timiș River sector goes over a specific significant time interval in the spring of 2005, meaning from 06:00 on April 12th to 06:00 on May 12th.

3. Numerical simulation reached results

Constant and time dependent parameters, such as water surface levels, water flows and velocities, together with river-bed ground configuration development on the bridge downstream area, were obtained by running the numerical simulation.
The revealed numerical values are stored in specific files by performing the results postprocessing regular operations. The graphical representation in figure 9 stops at two pre-established illustrative moments, specifically the interval of maximum entering flow of 1083 m^3/s, April 25th (day 11), and the last constant flow interval of 149 m^3/s, May 12th (day 31).

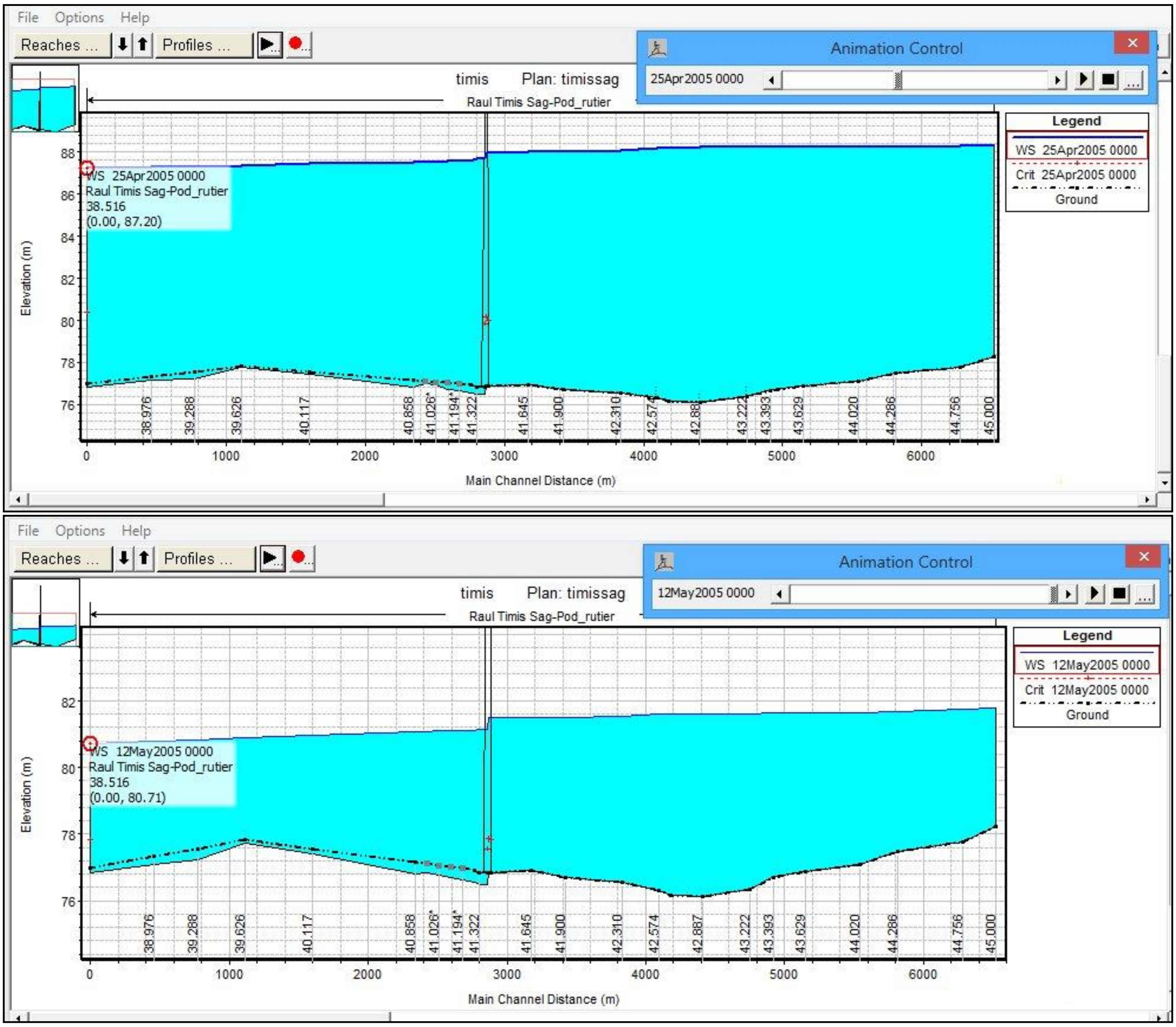


Fig. 9. Water surface and movable bed ground longitudinal development at two significant moments along the simulation period: upper - day 11 (April 25th), lower - day 31 (May 12th, 2005)

As regarding the results revealing the scouring process over time in the left upper river-bed downstream the crossing bridge, the following figure 10 brings up the geometrical configuration development of six specific cross sections (river stations 41.322; 41.278; 41.194*; 41.110*; 41.026*; 40.942*) of the most affected river stretch. There are indicated the initial (April 12th) and the final stage (May 12th) overlaid general configurations of the mentioned cross-sections, but also an upper left side detailed 11 steps phenomenon development (April 12th, 17th, 18th, 20th, 21st, 22nd, 28th, 29th and May 2nd, 6th, 12th) for each of these river stations.

By studying the visualised postprocessed scouring results from figure 10, one may point out the left side upper river-bed produced configuration (table no.1). There can be estimated the plan-view horizontal advance (Δx) and the elevation development (Δz) for each of the reference considered river cross-section. As with respect to the real scouring development due to the accidental highwaters hydrograph transited by the studied river sector along the special hydrologic phenomenon on the spring of 2005, there was possible to perform only late visual comparative estimations since any ground measurements were not available. Even if there is not possible to have a specific numerical judgement, one could still appreciate that the general estimated river-bed configuration closely simulates the real natural scouring phenomenon.

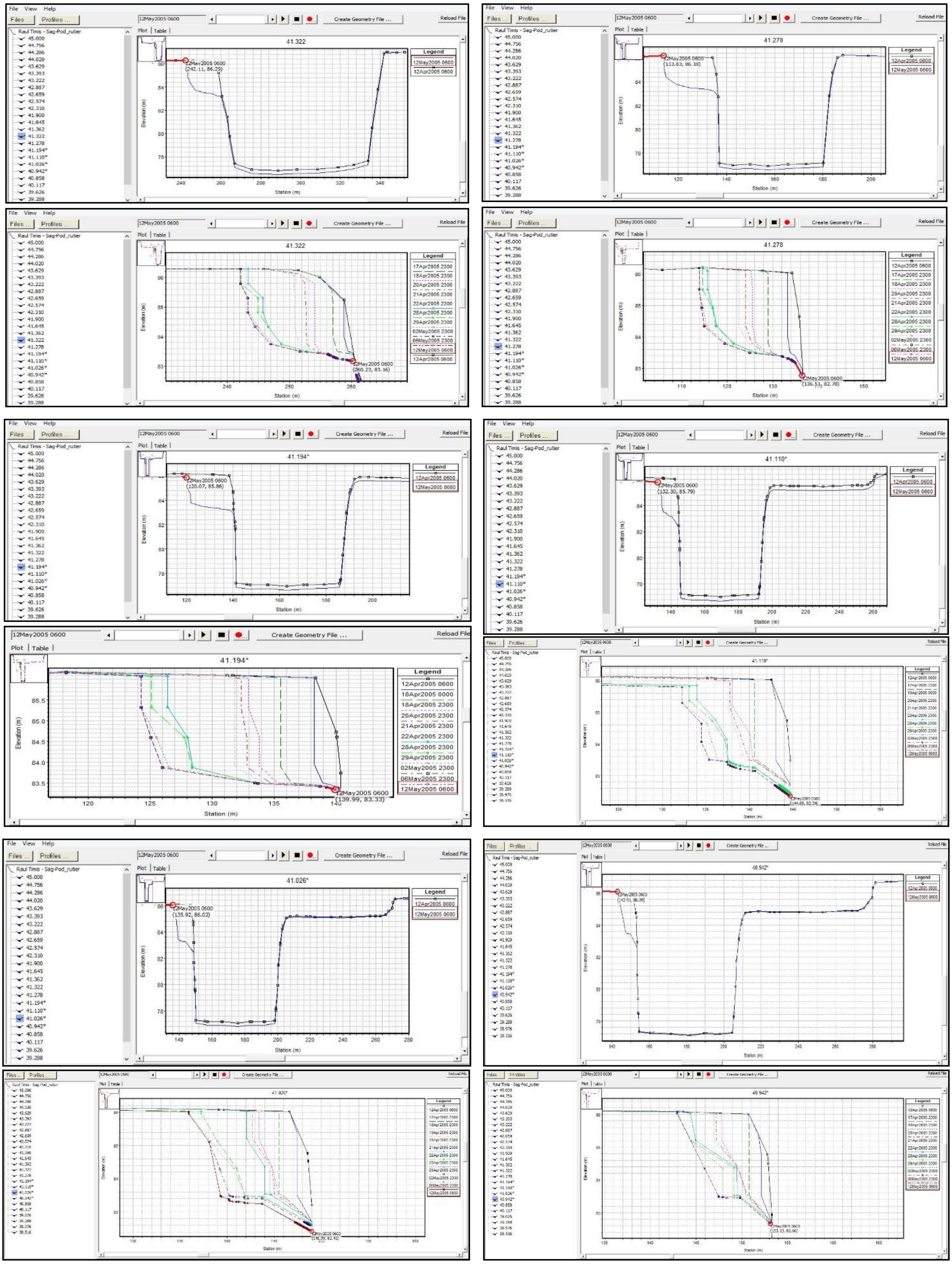


Fig. 10. Scouring process development on bridge downstream cross-sections 41.322; 41.278; 41.194*; 41.110*; 41.026*; 40.942*: beginning and ending moments overlaid general configurations, upper left detailed evolution along the simulation period (day no. 1, 6, 7, 9, 10, 11, 17, 18, 21, 25 and 31)

Table 1: Scouring geometrical values

River station	Scouring position (m)		Position advance ∆x (m)	Level (mSL)	Elevation difference ∆z (m)
41.322	Lower area	260.23	18.12	83.16	-3.13
	Upper area	242.11		86.29	
41.278	Lower area	136.51	12.68	82.78	-3.41
	Upper area	113.83		86.19	
41.194*	Lower area	139.99	19.92	83.33	-2.53
	Upper area	120.07		85.86	
41.110*	Lower area	144.69	12.39	82.34	-3.45
	Upper area	132.30		85.79	
41.026*	Lower area	148.99	13.07	82.41	-3.61
	Upper area	135.92		86.02	
40.942*	Lower area	153.13	10.22	82.66	-3.43
	Upper area	142.91		86.09	

4. Conclusions

The present analysis looked to estimate the river-course processes and so to numerically reconstruct the scouring phenomenon developed on a given sector of Timiș River, in the area of a six gaps national road concrete bridge, under special hydrological conditions that produced some natural river-bed morphological events. Besides the given accidental highwaters hydrograph and the available initial topography data, the study needed to correspondingly assume and adjust specific sediment parameters values due to lack of certified information.
One can first conclude that a sediments transport simulation under quasi-unsteady regime has to be considered in order to suitably fulfil the proposed task. As a result, by performing the liquid and solid transport 1D numerical modelling under the mentioned circumstances, there was still possible to estimate geometrical values defining a feasible and close to reality river-bed configuration.
Even if the site information allowed only a visual estimation of the numerical simulation results correspondence with respect to the real liquid - solid passage complex phenomenon, one may also conclude that the performed numerical modelling appropriately points out specific river natural events like banks failing (crumbling) and bed alluvia washing (scouring), accompanied by produced sediments flow transportation.
Further on, in order to determine general and local scouring ceasing along with gaps re-siltation, there can be appreciated as necessary the layout of a bottom-step at a proper distance downstream of the bridge structure.

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Testing of Digital Hydraulic Cylinders

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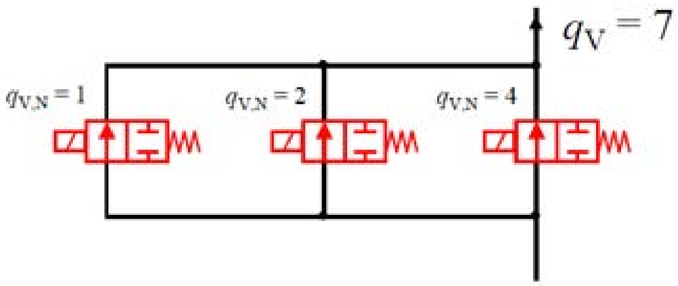
Abstract: *The article presents laboratory testing of an experimental digital hydraulic cylinder model with three surfaces that is powered by constant pressure and flow and achieves steps of force and speed actively controlled. The digital hydraulic cylinder has the piston surface divided into three annular, functionally independent areas, and by selecting the combinations of active areas, seven stages of forces or speeds result, that can be controlled by a dedicated distribution block and a dedicated computer system.*

Keywords: *Multiple-area cylinders, digital cylinders, Digital Hydraulics, digital cylinder test stand, multiple-area cylinder testing methodology*

1. Introduction

Digital Hydraulics is an alternative, recently developed, to replace drives with servo valves or proportional control valves. Digital Hydraulics means hydraulic systems that contain at least one hydraulic element to ensure discreet, accurate and actively controlled output values. This involves, besides the hydraulic digital elements, an adequate electronic command, so a good computerization of the system.
In classic hydraulic installations, force variation is routinely made by variation of pressure and variation in velocity through flow variation. The basic principle in Digital Hydraulics is section meshing and active control of split sections, and with constant supply pressure and flow rates, variable speeds or forces are obtained at the execution element.
Although the principles of Digital Hydraulics have been applied hundreds of years ago, starting in the year 2000, the foundations of the study of digital hydraulic equipment have been established in renowned universities. For example, version of Digital Hydraulics with parallel distribution developed by Prof. Lindjama of the Tampere University of Technology is based on high-speed on/off simple directional control valves, electrically controlled, that can either take one of two closed or open states by providing in the system steps of actively controlled flow [1].
Figure 1 shows the hydraulic diagram (a) and the table with number of resulted flow rate steps (b) of a 1961 USA patent. The three valves are of different nominal sizes and allow the passage of three different flow values in the situation of constant supply pressure and flow. The combination of the three flow rate values results in seven flow stages that can be actively controlled and delivered to the customers of the hydraulic system according to the system requirements.



V1	V2	V3	Q
0	0	0	0
1	0	0	1
0	1	0	2
1	1	0	3
0	0	1	4
1	0	1	5
0	1	1	6
1	1	1	7

a) b)

Fig. 1. Parallel distribution scheme patented in 1961 in USA. (US2999482) [2]

The purpose of this article is to give an example of a three-dimensional digital hydraulic cylinder that is powered by constant pressure and flow and achieves active steps of force and speeds. In the paper is presented the digital hydraulic cylinder, the test bench and the results of laboratory testing of the experimental model of hydraulic cylinder with three surfaces.

2. Digital hydraulic cylinder with three surfaces

Hydraulic cylinders, also known as linear hydraulic motors or power cylinders, are designed to be executed. They convert energy from hydrostatic energy into mechanical energy, characterized by two parameters, force and speed.
In a conventional hydraulic cylinder, a fluid at a certain working pressure acts on a piston with a particular working area, resulting in a specific linear output force, according to the load to be displaced. If another output force is required, the fluid pressure must be changed because the piston area remains unchanged. From a hypothetical point of view, if the active area of the piston could be changed or only part of the area could be used, the fluid pressure could remain constant and the output force could vary. Unfortunately, there is no means by which the liquid can only act on a portion of a piston, since the pressure fluid acts equally on the entire area containing it [3].
Hydraulic digital technology is a solution to this new approach. By dividing the working area of a piston into solid ringed areas, and by selecting the combinations of active zones, it results in stages of forces and speeds (Fig. 2) which can be controlled by a dedicated computer system in relation to the requirements of the system. The choice of individually or cumulatively selectable combinations of zones / sections leads to a range of 7 steps of forces / speeds outputs with supply at constant flow and pressure in the three-dimensional hydraulic cylinder.

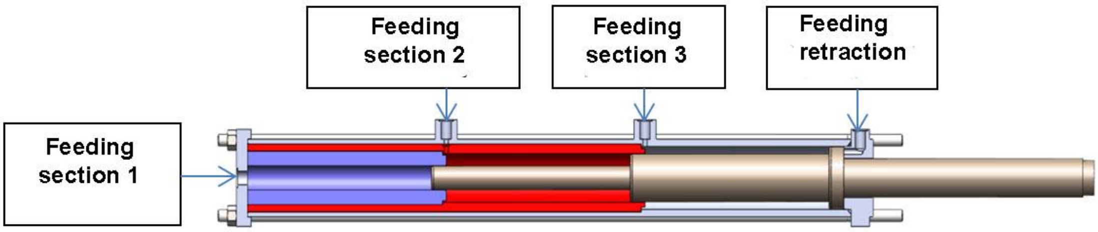


Fig. 2. Feed ports for the digital hydraulic cylinder [4]

The functional model of digital hydraulic cylinder under analysis was designed and manufactured with typical elements of cylinder liners. The construction features are shown in Table 1. The cylinder stroke was 250 mm.

Table 1: Dimensions of surfaces of the experimental digital hydraulic cylinder model

Current number	Cylinder with three surfaces	
	Surface [cm²]	Diameter [mm]
s1	4.906	Ø25
s2	14.712	Ø25;Ø50
s3	13.548	Ø50;Ø65
s retraction	20.606	Ø65;Ø40

3. Test stand for digital hydraulic cylinders

As a technical means of measuring the quality of hydraulic digital cylinders, the hydraulic stand (Fig. 3) is designed to provide the necessary test conditions for the submission of the hydraulic digital cylinders to the defining tests to demonstrate the operating principle V = f (Ai) = f (Ai) at constant pressure and determination of the design characteristics [5].

Fig. 3. Test stand for digital hydraulic cylinders

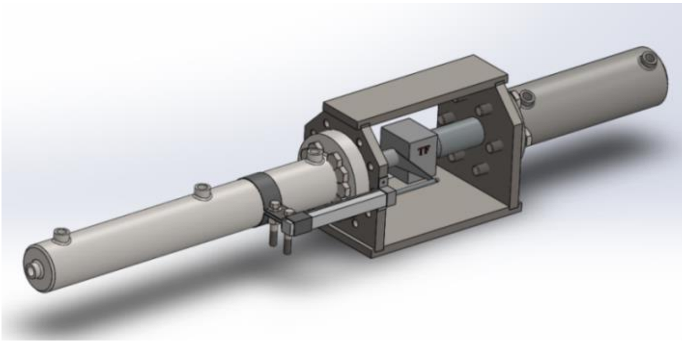


Fig. 4. Multi-surface cylinders testing device [5].

The test device (Fig. 4), together with the pumping station, the distribution block (Fig. 5), the acquisition board, the power supply, the computer and the virtual instrument application, form the test stand of the digital cylinders (Fig. 3).
According to the test stand diagram (Fig. 6), for the alternative pressure / tank supply of the piston surfaces, each of the hydraulic digital cylinder holes is connected to a group of two quick-opening on / off electro-directional control valves. The distribution block (Fig. 5) consists of on / off directional control valves of the same type from ATOS company and has the catalog code: DLEH-2C / CART LEH-2C. Maximum working flow is 12 l / min and maximum pressure is 350 bar.

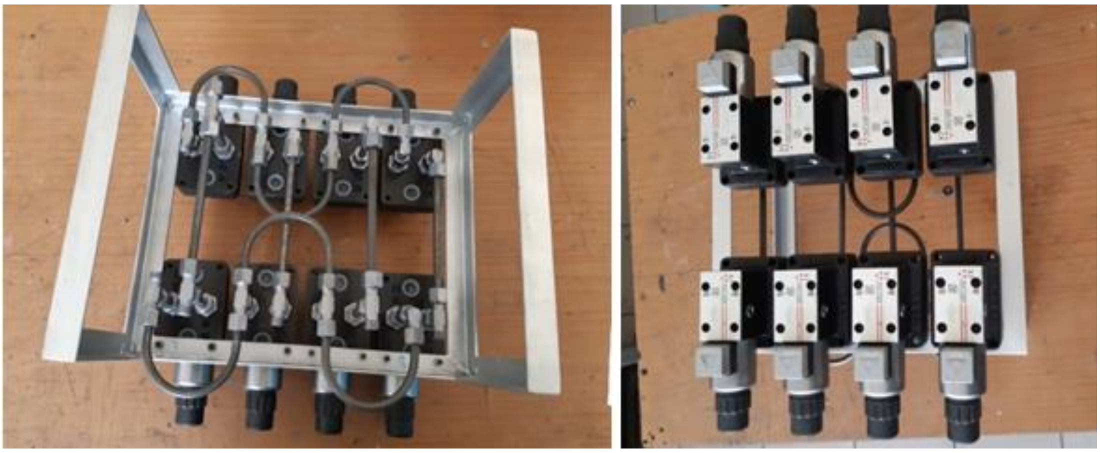


Fig. 5. Parallel distribution block.

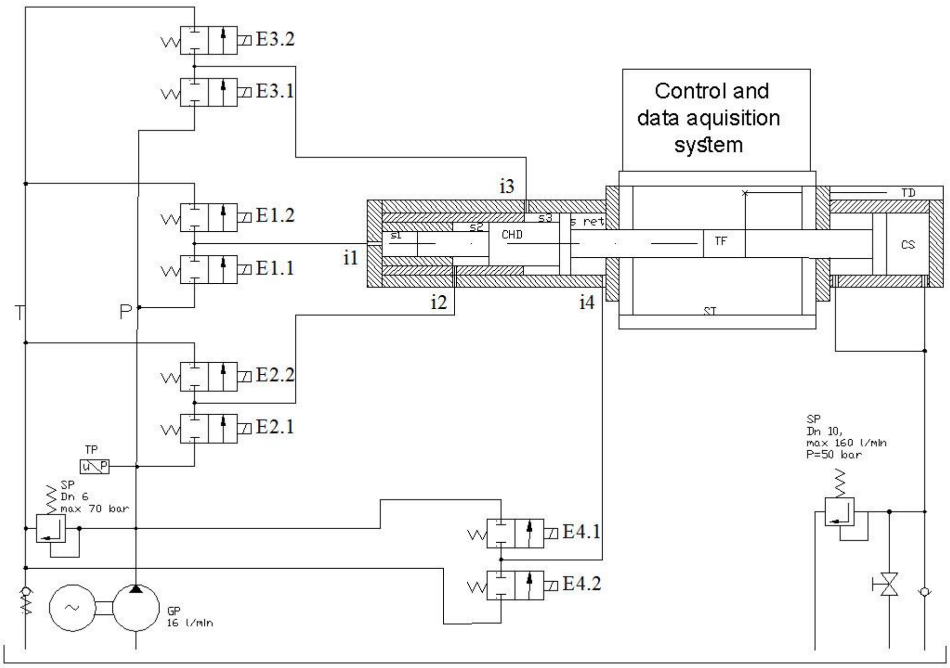


Fig. 6. Hydraulic diagram of the three-surface digital hydraulic cylinder testing bench

By the combination of active electromagnets, selected according to the cyclogram from the Table 2, the three feed surfaces and the retraction surface are properly connected to achieve a step of force and speed in the working range of the digital hydraulic cylinder.

Table 2: Control cyclogram for achieving the speed / force stages in the working range of the three-dimensional digital hydraulic cylinder

Command code Surfaces combination	Electromagnets commands (0=close circuit, 1= open circuit)								Active surface [cm²]	Calculated values at flow rate of 1.5 l/min and pressure of 65 bar	
	S_1		S_2		S_3		Retraction				
	E1.1 (P)	E1.2 (T)	E2.1 (P)	E2.2 (T)	E3.1 (P)	E3.2 (T)	E4.1 (P)	E4.2 (T)		Force [daN]	Speed [mm/sec]
0	0	0	0	0	0	0	0	0	0	0	0
1(S1)	1	0	0	1	0	1	0	1	4.906	318	51.02
2(S3)	0	1	0	1	1	0	0	1	13.548	880	18.52
3(S2)	0	1	1	0	0	1	0	1	14.712	956	17.00
4(S1+S3)	1	0	0	1	1	0	0	1	18.454	1199	13.87
5(S1+S2)	1	0	1	0	0	1	0	1	19.618	1275	12.75
6(S2+S3)	0	1	1	0	1	0	0	1	28.26	1836	8.85
7(S1+S2+S3)	1	0	1	0	1	0	0	1	33.166	2155	7.54
Retraction	0	1	0	1	0	1	1	0	20.606	1030	9.62

A virtual instrument application implements the command logic for feeding the digital hydraulic cylinder chambers and the data acquisition system for the measured signals.
The electric control block diagram consists of 8 transistors that control the relays coils that supply the solenoids of the hydraulic directional control valves. The commands for the different operating modes of the hydraulic cylinder are given by the virtual instrument application via the electric control block (Fig. 7) which interfaces the digital outputs of the acquisition plate with the parallel distribution block electromagnets.

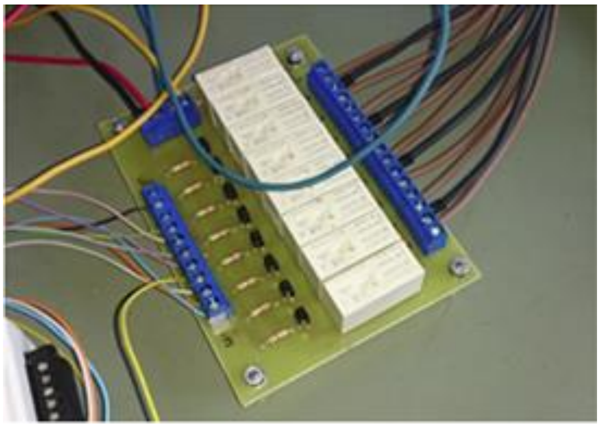


Fig. 7. Electrical command block

The graphical command interface of the application is shown in Fig. 8. The force/ speed step is selectable from the left table (V, F) and the active command of the electromagnets is symbolized by the ignition of a led in the connection diagram confirming the observance of the command algorithm for the three-dimensional hydraulic digital cylinder.

Fig. 8. The graphical interface of the application

LabVIEW offers a graphical programming approach that helps visualize every aspect of the application, including hardware configuration, measurement data, and debugging. This visualization simplifies the integration of measurement hardware, represents a complex logic of the chart, develops data analysis algorithms, and designs customized user interface for engineering.

4. Digital hydraulic cylinder testing with three areas

For the testing of the three-dimensional hydraulic digital cylinder, the test stand was assembled according to the test scheme, the hydraulic and electrical connections for the power and control were made, and the LabVIEW graphical interface was given commands for each combination of surfaces.
Saving experimental data is done automatically by saving the graphs (force, stroke, speed, pressure, flow rate) and the database purchased in real-time testing.

4.1 Test results for variable forces

The result of the variable force test, obtained under the established conditions, is shown in Fig. 9.
Because it is difficult to achieve variable resistive forces during a stroke and at the same time to synchronize with the rod advance steps commands for all the command codes we have opted to perform the variable forces test, at the end of the stroke, with the rod off, at the pressure power supply of 65 bar.

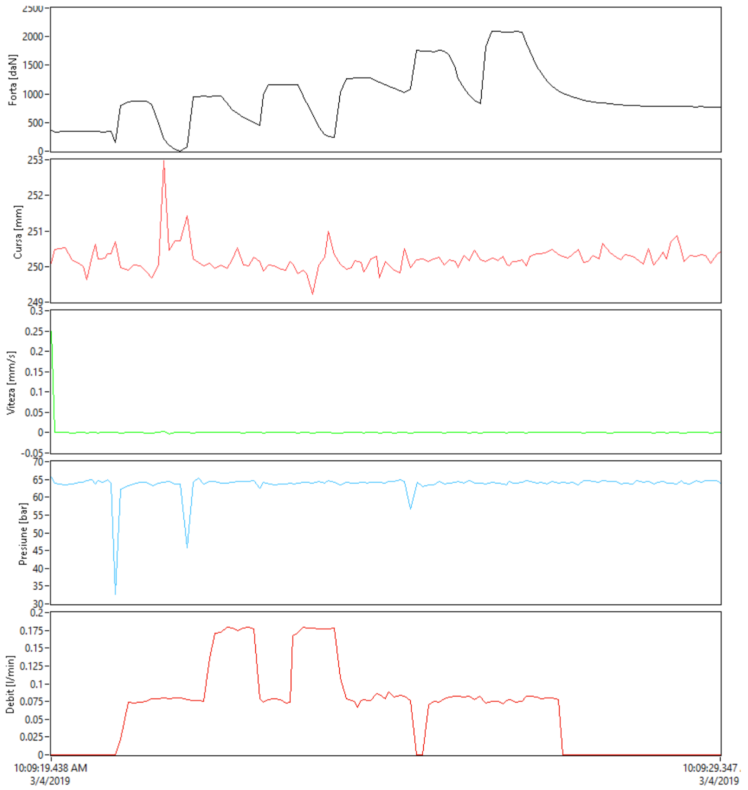


Fig. 9. The result of the data acquisition for the variable forces test at constant feed pressure.

Because it is difficult to achieve variable resistive forces during a stroke and at the same time to synchronize with the rod advance steps commands for all the command codes we have opted to perform the variable forces test, at the end of the stroke, with the rod off, at the pressure power supply of 65 bar.
To compare test results with calculated theoretical values of the strengths steps made by the digital cylinder at a constant pressure supply of 65 bar, these are shown in Table 3.

Table 3: Calculated values of the strengths steps made by the digital cylinder at a pressure supply of 65 bar

Surface	**Area [cm]**	**Pressure force of 65 bar [daN]**
1-S1	4.906	318.89
2-S2	13.548	880.62
3-S1+S2	14.712	956.28
4-S3	18.454	1199.51
5-S1+S3	19.618	1275.17
6-S2+S3	28.26	1836.9
7-S1+S2+S3	33.166	2155.79

It can be noticed that at the supply of the digital cylinder with a constant pressure of 65 bar, there were obtained levels of forces corresponding to the control codes with values very close to the theoretically calculated values.
The graphical command interface of the application allows for sequential control in automatic mode of the control codes according to the cycle with pauses between commands and for this reason,

after achieving a force, its value tends to drop to 0. The small variations of the flow and the supply pressure are due the switching times of the units in the control unit when the cylinder chambers are connected to the pressure or tank depending on the phase of the control cycle.

4.2 Test results for variable speeds

The result of the variable speeds test obtained under the established conditions is shown in Fig. 10.

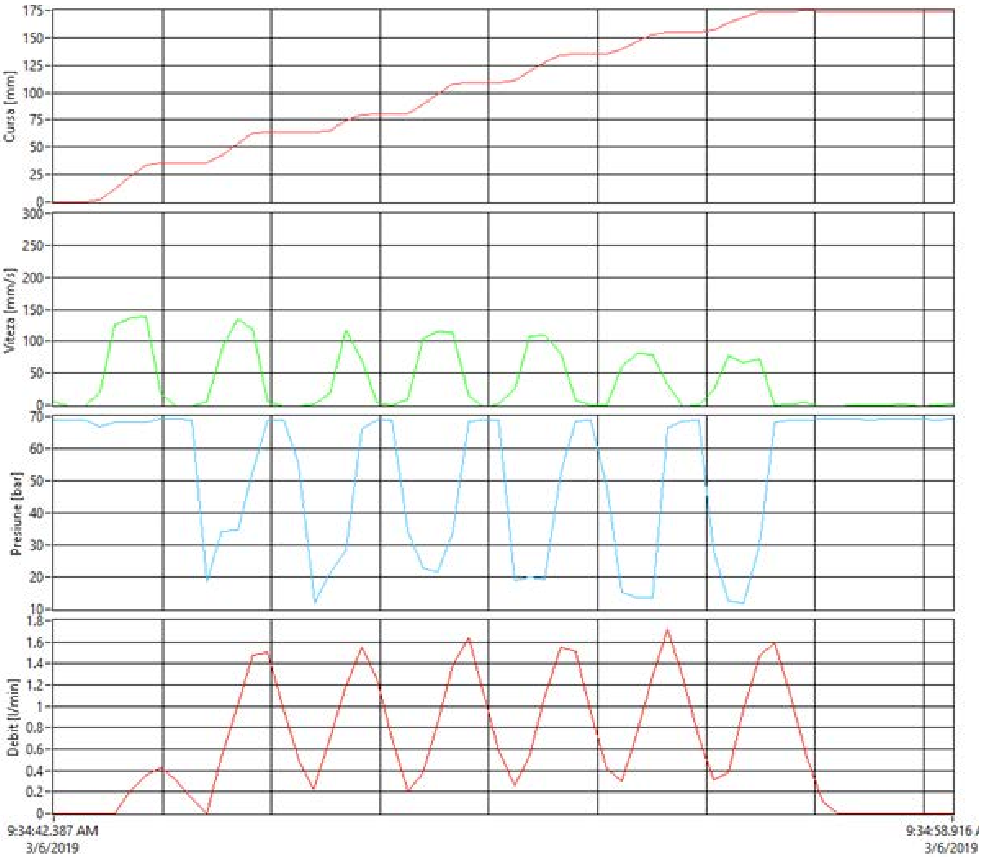


Fig. 10. Result of data acquisition for variable speeds test with constant feed rate.

The variable speeds test was executed in the time of rod advance stroke for each control code. The result of data acquisition for the variable speeds test with constant feed flow rate and the automatic speed steps control of the graphical interface created in the LabVIEW program is shown in Fig. 10.
It can be seen on the data acquisition graph the decreasing trend of the speed values for the seven stages automatic control. The variation of the pressure and flow between the speed steps ordered is due to breaks between commands when the cylinder holes are connected to the tank and the pressure and flow rates tend to drop to 0.
To compare test results with calculated theoretical values of the speed steps made by the digital cylinder at a constant flow rate of 1.5 l / min, these are presented in Table 4.

Table 4: Calculated values of the speed steps achieved at a constant flow rate of 1.5 l / min.

Surface	Area [cm]	Speed at feed flow rate of 1.5 l/min [mm/sec]
1-S1	4.906	51.02
2-S2	13.548	18.52

3-S1+S2	14.712	17.00
4-S3	18.454	13.87
5-S1+S3	19.618	12.75
6-S2+S3	28.26	8.85
7-S1+S2+S3	33.166	7.54

Calculation algorithm for maximum speed:

Calculation of maximum speed:

$$V_{max} = \frac{Q}{S_{min}} = \frac{1.5l/min}{4.9cm^2} = \frac{1.5\cancel{dm^3}}{0.049\cancel{dm^2}X60sec} = \frac{150mm}{2.94sec} = 51.02mm/sec \tag{1}$$

Large speeds of cylinder rod, made at small sections, generate increased flow rates to cylinder chambers with larger sections, which are connected to the tank, leading to large enough pressure drops on the exhaust circuits (basin) and negative influences in the operation of the digital cylinder, because of the created pressure drops, the safety valve of the station reaches to discharge at the basin some of the flow that is no longer constant. The control units in the distribution block must be chosen and dimensioned for the flow rates in each section of the digital cylinder.

5. Conclusions

Adjusting the force and speed of conventional hydraulic cylinders requires expensive and complex pressure and flow regulators, and often in classic control variants with significant energy losses and in demanding fluid filtration conditions.

When using hydraulic digital cylinders in installations that include Hydraulics, the regulation of force or speed can be done with classical instruments with constant flow and pressure supply, without pressure drops in appliances, under normal fluid filtration conditions. The dimensioning of the hydraulic digital cylinders can be done strictly on the desired field by determining the number of surfaces and their size.

Digital technology has the potential to make cheaper, more energy-efficient, more reliable hydraulic systems, but a decisive role will be given to research and technological development in the field. For the digital hydraulic cylinders segment, the challenge is to make simple, technologically feasible, more compact and cheaper technical solutions.

The approach is new and has some challenges. For example, controlling a low speed digital cylinder system is not as good as a proportional hydraulic apparatus, or a variation in the speed of switching of larger diameters digital equipment, or small variations in flow and pressure during switching, or the speed switching still small of the control device. All this is challenging for research in the field, and if solving the application of digital solutions could be a current practice. The first results are very promising, but additional research is always needed.

The hydraulic cylinder digital research stand presented is the first achievement in the field of Digital Hydraulics in the Hydraulics Institute and in the country and allows complete testing, in a dynamic regime, to determine the main functional parameters.

Over the next period, cost reductions and increased energy efficiency will be dominant as success factors for any industry. Hydraulic equipment manufacturers are now due to review their energy consumption solutions. Proper dimensioning and choice of the best technical and economic solutions ever since the design phase could make the hydraulic systems the fastest and most efficient form of power transmission. Energy savings resulting from the implementation of the right solutions can improve the technico-economic performance of the technological lines in which they are used, ultimately reflecting in the execution price of products placed on the market. At the same time, through energy savings and the efficient use of resources, it contributes to the foundations of sustainable development.

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Experimental Researches on Electricity Consumption in the Process of Water Aeration

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Abstract: *The paper analyzes two versions of water aeration:*
1) Atmospheric air is introduced into stagnant water;
2) A gaseous mixture of atmospheric air + ozone, supplied by an ozone generator, is introduced into the water.
The electricity consumption for the two versions and choice of the most economical version are highlighted.

Keywords: *Water aeration, oxygen meter, fine air bubble generator.*

1. Introduction

Manuscripts Water aeration is a fundamental process of thermodynamics, a process of transfer between water and air. The process is based on the transfer of oxygen from the air or the direct transfer of pure oxygen to a given volume of water [1] [2].
Aeration of water can be done mechanically or pneumatically [3] [4].
Pneumatic aeration has superior net performance compared to mechanical aeration systems.
The performance of the pneumatic aeration system is defined by two parameters: aeration efficiency and effectiveness [1] [2].
These parameters are determined by the efficiency of the compressed air production installation and the efficiency of air dispersing devices in the water.
The efficiency of pneumatic aeration systems is reduced with increasing water temperature because oxygen stability decreases when the water temperature rises.
Current scientific researches in the field of biochemistry ecology are concerned with the analysis of the possibilities of increasing the dissolved oxygen concentration in water.
This problem can be solved as follows:
a) By introducing atmospheric air into the water;
b) By introducing atmospheric air into water and oxygen from a cylinder;
c) By introducing low nitrogen (95% O_2 and 5% N_2) air supplied by oxygen concentrators;
d) By introducing a gaseous mixture consisting of air + ozone;
In the present paper only paragraphs a) and d) will be analyzed.
Ozone systems contain two elements:
- A compressor that introduces air into the ozonizer;
- An ozone generator producing 1.5 g/h ozone; on an industrial scale there are ozone generators producing 2 - 10 kg / h of ozone [5] [6].
These ozone generators are powered by atmospheric or oxygen air.
The introduction of atmospheric air or ozone-enriched air into the water requires compression of the air to overcome the hydrostatic load of water [7] [8].
Gas compression can be done with fans or compressors [9].
Performance fans can overcome a load of about 1 mH_2O, which is inefficient at the Olympic swimming pools where the water layer has 2-5 m.
The problem of air compression is solved by the use of piston or rotating compressors that provide an air pressure of 1-10 bars at their discharge.

2. Presentation of the versions analyzed in the paper

Two versions are analyzed:
- The version I: atmospheric air (21% O_2, 79% N_2) is introduced into the water (Figure 1);
- The version II: a gaseous mixture of air supplied by an electro compressor and ozone delivered by an ozone generator (Figure 3) is introduced into the water.
For each version, it is intended:
a) Changing the dissolved oxygen concentration in water in time: C = f (τ)

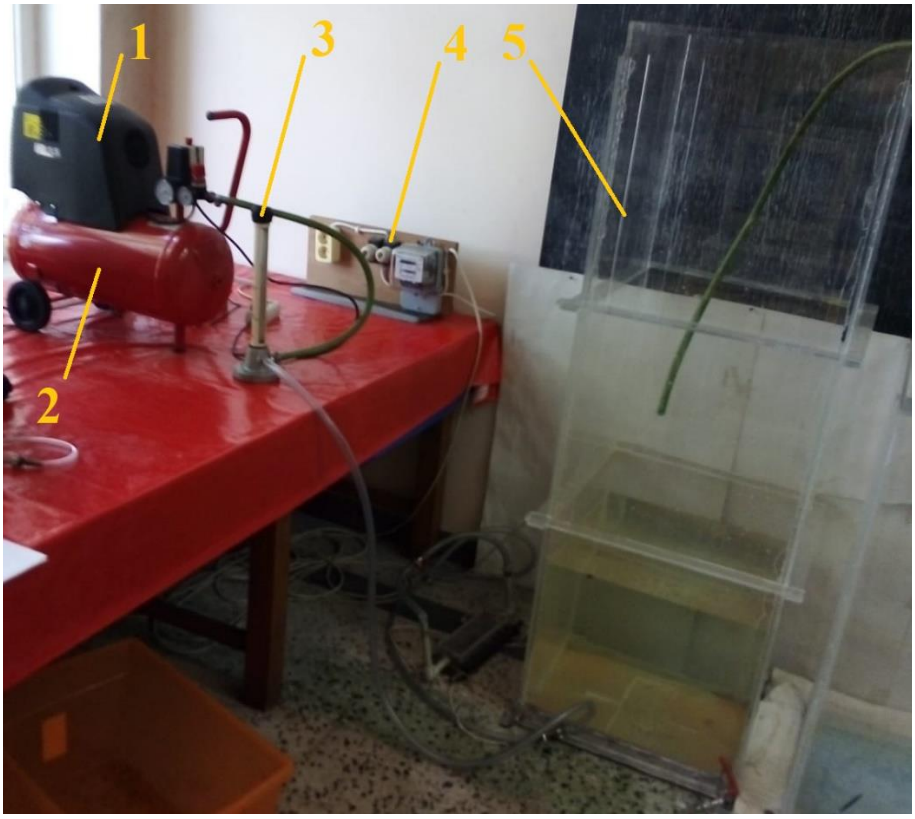

Fig. 1. Overview of the experimental installation for the version I
1 - electro compressor; 2 - compressed air tank; 3 - rotameter; 4 - electric meter;
5 - water tank

b) Measuring the electricity consumed until the initial concentration (C_0) of dissolved oxygen in water reaches the value of the saturation concentration (C_s). Item a) is presented in detail in the paper [10]. Figure 2 shows the graphical representation of the function C = f (τ) for the version I.

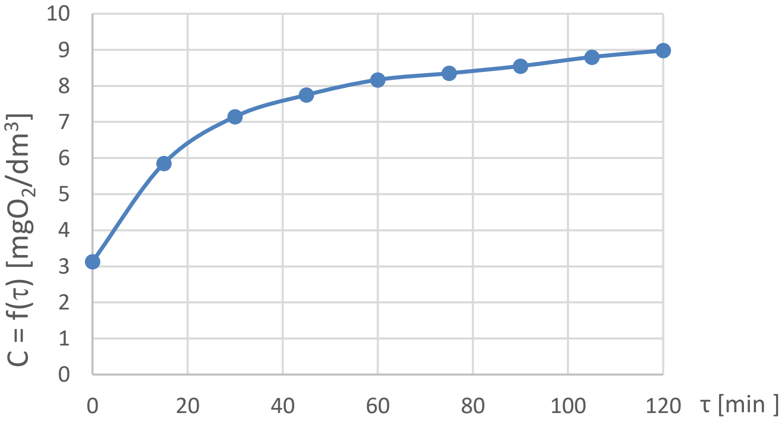

Fig. 2. The dependence of C = f (τ) in the version I

Figure 2 shows that the dissolved oxygen concentration in water increases from the initial concentration (C_0 = 3.13 mg / dm^3) to saturation value (C_s = 8.9 mg / dm^3) in 120 minutes.
Figure 3 shows an experimental installation containing, in addition to Figure 1, an ozone generator (3).

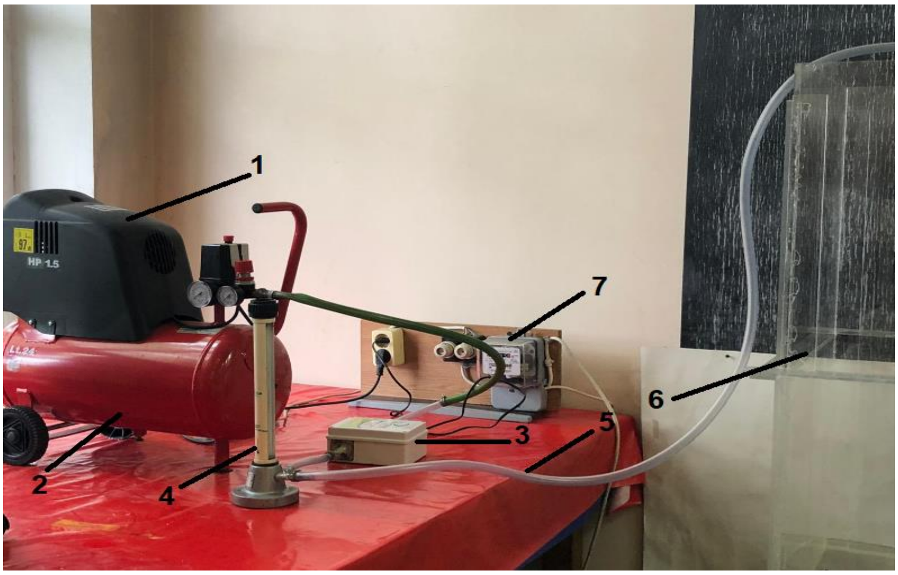

Fig. 3. Overview of the installation for water ozonation
1- electro compressor; 2 - compressed air tank; 3- ozone generator; 4- rotameter; 5- compressed air line to the fine bubble generator; 6- water tank; 7-electric counter

Figure 4 shows the function graph C = f (τ) for version II.

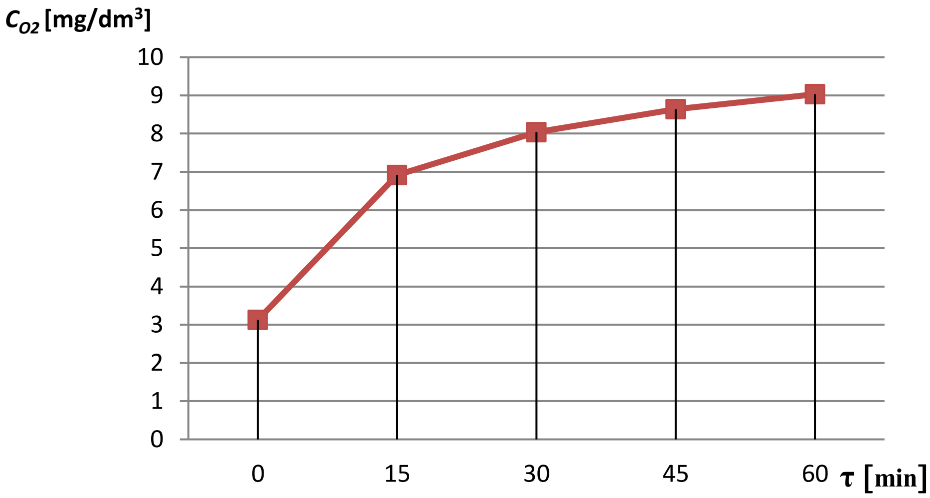

Fig. 4. Center The dependence of C = f (τ) in version **II**

Figure 4 shows that the saturation value of oxygen is reached in a shorter time than in version I.

3. Experimental researches

3.1 Scheme of the experimental installation

In the version I, when the fine bubble generator is supplied with atmospheric air, the experimental installation comprises (figure 5) the electro compressor, the rotameter, the water tank, and the devices panel.

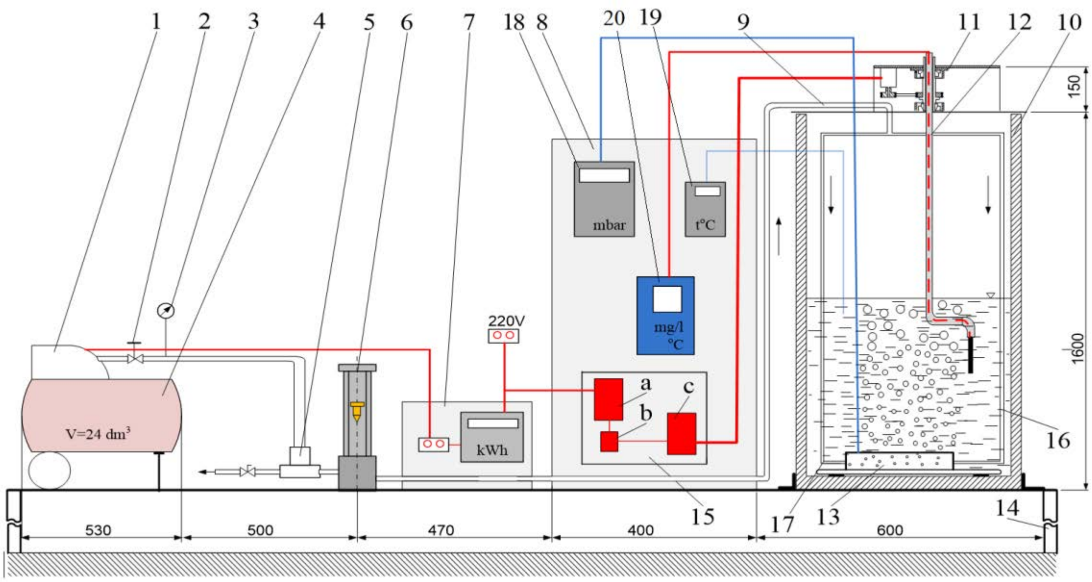

Fig. 5. Scheme of the experimental installation for researches on water oxygenation
1- electro compressor with air tank; 2- pressure reducer; 3-manometer; 4-compressed air tank V = 24 dm^3; 5- T-joint; 6- rotameter; 7- electric panel; 8-panel with measuring devices; 9-compressed air pipeline to the fine bubble generator; 10 - water tank; 11 - probe actuation mechanism; 12-oxygen probe; 13- fine bubble generator of rectangular shape; 14 - support for the installation; 15-command electronics: a - power supply, b - switch, c - control element; 16, 17- compressed air supply pipes; 18 - digital manometer; 19 - electronic thermometer; 20 - oxygen meter

The installation works as follows: compressed air from an electro compressor (1) accumulates at p = 1.5-2 bar in a 24 dm^3 tank. Subsequently, the air passes through the reducer (2) through the manometer (3) and reaches the fine bubble generator (13). The fine bubble generator (FBG.) has the shape of a parallelepiped with 37 orifices Φ 0.5 mm. During an experiment, the volumetric air flow rate is kept constant, the pressure at the entrance to the fine bubble generator and hydrostatic load. The panel (15) with the control electronics provides, via the mechanism (11), the rotation of the oxygen sensor probe into the water tank at a rate of 0.3 m / s.
In version II when the fine bubble generator is fed with a gaseous mixture of air and ozone, the ozone generator (5) appears in the operating diagram (figure 6) in addition to figure 5.

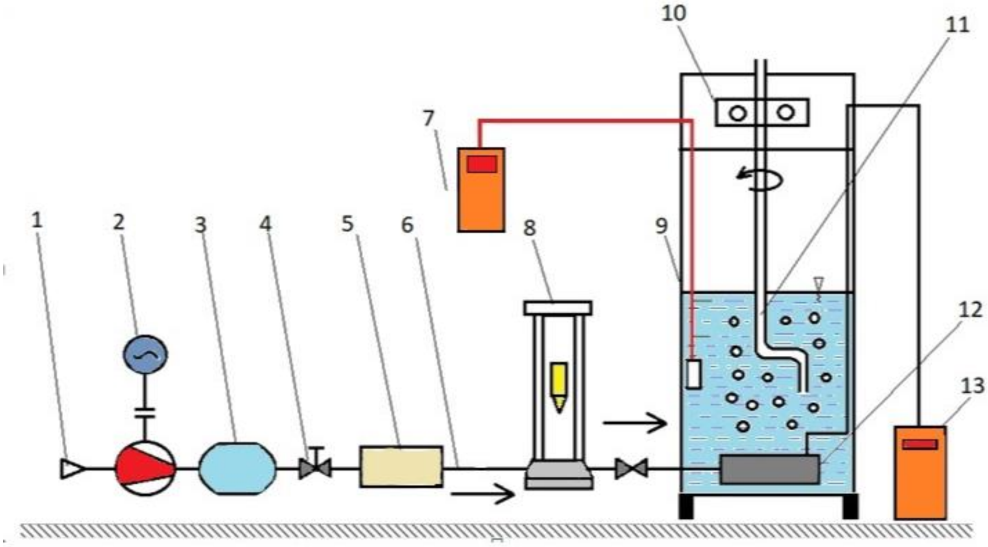

Fig. 6. Scheme of experimental installation for water ozonation
1-air filter; 2- electro compressor; 3 - compressed air tank; 4 pressure reducer; 5 - ozone generator; 6-pipe; 7- digital thermometer; 8-rotameter; 9- water tank; 10- mechanism for rotating the oxygen probe in water; 11 - oxygen meter probe; 12 - fine bubble generator; 13- digital manometer.

The experimental installation contains an ozone generator type FQM - P300 with the characteristics: power: 12W; ozone flow rate: 100-300 mg / h; voltage: 220 V / 50 Hz.
The experimental installation can be used in the case of various gases introduced into water to increase the dissolved oxygen concentration in water, such as [11]:
- Atmospheric air delivered by an electro compressor;
- Atmospheric air + oxygen from the cylinder;
- Atmospheric air + ozone provided by an ozone generator;
- Low nitrogen air supplied by oxygen concentrators.

The experimental installation is equipped with modern digital indication devices for measuring the flow rate, pressure, and temperature of the gas introduced into the water and the temperature of the water in the tank.

3.2 The methodology of measurements of the variation in dissolved oxygen concentration in water and of electricity consumption

For each measurement step the following phases are successively [12] [13] [14] [15]:
1. Perform the pressure test of the fine bubble generator;
2. Fill the tank up to H = 0.5 m with water;
3. Measure the initial concentration of dissolved oxygen in water C_0 (mg / dm^3);
4. Measure the water temperature in the tank and the air temperature;
5. Introduce the fine bubble generator and record the start time of the experiment;
6. The flow rate and compressed air pressure are measured and maintained constant by means of the control valves;
7. After 15 minutes the oxygenation of the water stops and the oxygen probe is introduced into the water;
8. Start the electro-actuator of the probe that provides a speed of 0.3 m / s; when the oxygen concentration value on the oxygen meter screen stabilizes, it means that the measurement has been completed;
9. Remove the oxygen sensor from the tank;
10. Restart the oxygenation system and note the time.

From the previous investigations [16] [17] [18] it was found that by introducing an airflow rate of 600 dm^3 / h into the water tank with hydrostatic load of H = 0.5 m in a water volume (0.5 x 0.5 x 0.5 = 0.125 m^3), the dissolved oxygen concentration in the water approaches the saturation concentration after a time τ = 2 h.
The concentration of dissolved oxygen in water was measured at equal time intervals: τ = 0 min; τ = 15 min; τ = 30 min; τ = 45 min; τ = 60 min; τ = 75 min; τ = 90 min; τ = 105 min; τ = 120 min. For the measurement of electricity consumption, a two-phase electric counter was used, indicating the meter reading at the start and end of the experiment, for each version.

4. Experimentally obtained results

* In the version I, only atmospheric air (21% O_2, 79% N_2) was introduced by means of the electro compressor; it was found that during one hour it consumed 1.041 KWh. During the two-hour experience (τ_F), the electricity consumed by the compressor was E_I=2.082kWh.
** In the version II a gaseous mixture (air + ozone) is introduced so that in the water the dissolved oxygen concentration increases from C_0 to C_5 it takes a duration of τ_{II} one hour; at this time, the power consumption of the compressor and the ozone generator was E_{II}=1.22KWh. Version II is more advantageous because $E_{II} < E_I$ and the time (τ) where C_0 increases to C_s is shorter for version II: $\tau_{II} < \tau_I$.

5. Conclusions

Experimental researches were carried out for the two versions considered:
I. Introduction of atmospheric air into the water tank;
II. Introduction of a gaseous mixture consisting of atmospheric air and ozone.
The following conclusions resulted:

• For the same initial data, when a gaseous mixture (air + ozone) is introduced into the water through the fine bubble generator, the period in which Cs is reached is reduced by half, which makes this process much more efficient.
• The power consumption (E) for version II is lower than the one in the version I: $E_{II} < E_I$, which leads to the saving of electricity.
• Ozone use is a new way to increase the dissolved oxygen concentration in water.
• Due to its properties, ozone can be a very viable alternative for air disinfection and especially for disinfection and treatment of polluted waters.
• Increasing the production capacity of the ozone generator leads to increased volumes of air or water that can be treated and also considerably reduces the time required for treatment.

Acknowledgments

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Ballast Water Treatment System with UV Filter and Advanced Oxidation Technology

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Abstract: *This article presents various methods which can be applied on a ship for treatment of ballast water and their efficiency on a variety of marine organisms, ballast water treatment system with UV filter and advanced oxidation technology and about the aquatic invasive species known to have been spread by ballast water and their environmental impact. Because of shipping industry between 3 and 5 billion tonnes of ballast water are transferred internationally annually. As a consequence of discharging untreated ballast water from ships, the risks of introducing aquatic invasive species is very high and this becomes a major threat to global biodiversity.*

Keywords: *Ballast, water, treatment, UV, ships, environment, oxidation*

1. Introduction

Ballast water means water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship.
Ballast water management means mechanical, physical, chemical and biological processes, either singularly or in combination to remove, render harmless, or avoid the uptake or discharge of harmful aquatic organisms and pathogens within ballast water and sediments.
Harmful aquatic organisms and pathogens means aquatic organisms or pathogens which, if introduced into sea, including estuaries, or into fresh water courses, may create hazards to the environment, human health property or resources, impair biological diversity or interfere with other legitimate uses of such areas [1]. When a ship does not have cargo, it fils its tanks with ballast water. Ballast water contains microorganisms, phytoplankton, zooplankton and others.
When they enter into the new marine environments, they become a threat to the local marine ecological system.
The species that survive in the new environment, may become serious pests. Estimations show that more than 3000 species are transported by ships each day and 40 recent invasions have been mediated by ballast water.

2. Ballast water quality and standards set by IMO

The regulations of discharged organism are presented in the Table 1 and the ballast water technology implementation timeline is presented in the Table 2.

Table 1: Regulations of discharged organisms according to Regulation D-2 Ballast Water Performance Standards

Organism	**Regulation of discharge ballast water**
Phytoplankton / zooplankton ≥ 50 μm	<10 viable organisms per m^3
Phytoplankton / zooplankton 10–50 μm	<10 viable organisms per mL
Toxicogenic Vibrio cholera (O1 and O139)	<1 colony forming unit per 100 mL
Escherichia coli	<250 colony forming unit per 100 mL
Intestinal enterococci	<100 colony forming unit per 100 mL

Table 2: Ballast water technology implementation timeline

	Construction year of the ship			
Ballast capacity (m^3)	**Before 2009**	**2009+**	**2009-2011**	**2012+**
<1500	Ballast water exchange or treatment until 2016	Ballast water treatment only		
	Ballast water treatment after 2016			
1500-5000	Ballast water exchange or treatment until 2014	Ballast water treatment only		
	Ballast water treatment after 2014			
>5000	Ballast water exchange or treatment until 2016		Ballast water exchange or treatment until 2016	Ballast water treatment only
	Ballast water treatment after 2016		Ballast water treatment after 2016	

Each ship will have a ballast treatment system on board that could be capable of treating the ballast water before discharging it into the marine environment (Table 3).

Table 3: List of ballast water types of treatment systems that make use of active substances and their status in the approval

Type of treatment	**Type of approval**
Filtration+Ultrasound +UV	MEPC 59 Application for Basic Approval
Filtration+Advanced electrolysis	MEPC 55 Basic Approval MEPC 59 Application for Final Approval
Coagulation+Magnetic Separation+Filtration	MEPC 57 Basic Approval
Filtration+UV	MEPC 59 Application for Final Approval MEPC 59 Application for Basic Approval
Biocide (Chlorine dioxide)	MEPC 58 Basic Approval MEPC 59 Application for Final Approval
Electrochemical oxidation+ neutralizing agent (sodiumthisulfate)	MEPC 54 Basic Approval MEPC 58 Final Approval
Filtration+UV	MEPC 57 Basic Approval MEPC 59 Application for Final Approval
Ozone	MEPC 56 Basic Approval MEPC 59 Application for Final Approval
Filtration+cavitation+ nitrogen supernaturation+ electrodialysis	MEPC 57 Basic Approval
Chemical Treatment	MEPC 54 Basic Approval
Filtration+Advanced Oxidation	MEPC 57 Basic & Final Approval

Filtration+cavitation+ ozone+sodium hypochlorite	MEPC 57 Basic Approval MEPC 59 Application for Final Approval
Hydrocyclone+ Electrolytic chlorination	MEPC 58 Basic Approval MEPC 59 Application for Final Approval
Hydrocyclone+ Filtration+Biocide (PeracleanOcean)	MEPC 57 Final Approval
Filtration+Electrolysis	MEPC 59 Application for Basic Approval
MechanicTreatment+ Ozone	MEPC 55 Basic Approval
Filtration+biocides (sodiumhypochlorite) +neutralizing agent (sodiumsulfate)	MEPC 59 Application for Final Approval MEPC 58 Basic Approval

3. Shipboard treatment of ballast water

There are more methods which can be applied on a ship for treatment of ballast water:
3.1 Filtration and cyclonic separation
3.2 Ultraviolet radiation treatment
3.3 Chemical treatment
3.4 Combined methods

3.1 Filtration and cyclonic separation

Filtration is the most frequent environmental method for the treatment of ballast water. Majority of filtration techniques are effective against sediments and many types of organisms. Cyclonic separation is accomplished using hydro cyclones.

Table 4: Summary of physical separation techniques tested

Method	**Capacity**	**Marine organism tested**	**Percentage removal**
Filtration	6 ton h^{-1}	Zebra mussel	> 70%
Filtration/Cyclone	199.8 m^3 h^{-1}	Phytoplankton	30%
		Macrozooplankton	30%
		Microzooplankton	95%
		Dinoflagellates	>90%
Cyclone/UV	312-350 m^3 h^{-1}	Skeletonamacostanum,Thalassiosira sp.	Not reported
		Chaetocerosgracile	Not reported
		Copepodes	Not reported
Filtration	340 m^3 h^{-1}	Phytoplankton	30–90%
		Zooplankton	
Hydro cyclone	5.7 m3 $\min^{-1}$	Zooplankton	60%
Filtration	25-75 m^3 h^{-1} m^{-2}	Phytoplankton	50–58%
	(crumb material)	Zooplankton	70-90%
Filtration	530 m^3 h^{-1}	Phytoplanktonbloom	70% (after 24h)
Filtration	2 m^3 h^{-1}	Chlorella	93%
Filtration/UV	100–3000 m^3 h^{-1}	Artemia sp.	13.7%
		Nauplius larva of Artemia	8.3%

3.2 Ultraviolet radiation treatment

Mechanical separation methods include the use of ultraviolet radiation, heat treatment and electric pulse applications.

Table 5: Summary of mechanical separation techniques

Method	Capacity	Marine organism tested	Percentage removal
UV	Not reported	Gymnodinium sp.	<6%
		Alexandrium sp	
		Chattonella sp	<40%
UV	2 m^3 h^{-1}	Chlorella	87%
UV	0.2–1.6 m^3 h^{-1}	Various	78–100%
UV	Not reported	Phytoplankton	40–99%
		Zooplankton	
		Bacteria	
UV/hydrocyclone	312–350 m^3 h^{-1}	Phytoplankton	>85%
		Zooplankton	
		Bacteria	
UV	100–3000 m^3 h^{-1}	Artemia salina	99.5%
		Dinoflagellate Prorocentrum	84.7%
		Tetraselmis sp.	87.6%
UV/Filtration	Not reported	Phytoplankton	>70%
		Zooplankton	
		Bacteria	
Heat	50,000 of ballast water	Phytoplankton	>98%
		Zooplankton	
		Bacteria	
Heat	Various tests	Phytoplankton	>99%
		Zooplankton	
		Bacteria	
Heat	85 L $\min^{-1}$	Zooplankton	90%
		Bacteria	95%
Heat Microwave	1–2 L $\min^{-1}$	Microalgae (Nannochloropsis oculata)	Complete in activation
		Zooplankton (Artemia)	
		Oyster larvae(Crassostrea virginica)	
Heat Microwave	1–2 L $\min^{-1}$	Artemia cysts	100%
Heat Ultrasound		Artemia salina	
		Larvae stage	100%

		adults	85%
		cysts	60%
		Dunaliella tertiolecta	40%

3.3 Chemical treatment

Table 6: Summary of chemical treatment technique

Method	**Capacity**	**Marine organism tested**	**Percentage removal**
Biocides	Not reported	Three fresh water organisms	>95%
Biocides	Lab scale	Bacteria	Effective
Biocides	Lab scale	Marine organisms	Effective
Biocides	Lab scale	Microalgae	Effective
		Dinoflagellates cysts bacteria	
Biocides (Naphthoquinones)	Lab scale	Dinoflagellates cysts	>95%
Biocides	Lab scale	Living biomass	>99%
Chlorine	Not reported	Gymnodinium catenatum cysts	100%
Sodium hypochlorite	5 mgL^{-1}	Bacteria	85.2–100%
		Phytoplankton	Effective
	2 mgL^{-1}	Zooplankton (Artemiasalina)	15-100%
Chlorine	Not reported	Zooplankton,Phytoplankton,	>99%
		Bacteria	
Chlorine dioxide	Not reported	Alexandrium catenella and Gymnodinium catenatum	>97%
Chlorine dioxide	Not reported	Gymnodinium catenatum cysts	75–98%
NaOCl	Not reported	Cysts	>89%
Ozone	400 Lh^{-1}	Bacillussubtilisspores	Not effective
Ozone	400 Lh^{-1}	Dinoflagellate alga Amphidinium sp.	>98%
Ozone	Not reported	Zooplankton,Phytoplankton	99%
		Bacteria	
Ozone	Not reported	Zooplankton, Phytoplankton	90–99%
		Bacteria	
Ozone	Not reported	5 species marine organisms	>95%
Ozone		Zooplankton, Phytoplankton,	>96%
	(1.3–3.11)∗ 103 m^3	Bacteria	
Electrolytic	1200 m^3h^{-1}	Phytoplankton	>99.99%
		Mesozooplankton	>99%
Electrolysis	2.5 m^3h^{-1}	Artemia	>95%
Magnetic separator	100 m^3day^{-1}	Red phytoplankton	>92%

3.4 Combined methods

Combined methods are used for ballast water treatment.

Table 7: Summary of combined treatment techniques [2]

Method	Capacity	Marine organism tested	Comments
Filtration+UV	5.7 m^3h^{-1}	Zooplankton	Effective (undetectable level)
Filtration+UV		Zooplankton	Effective
		Phytoplankton	
		Bacteria	
Filtration+UV	304 m^3h^{-1}	Zooplankton	60%
		Phytoplankton	60%
Cyclonic separation+UV	200 m^3h^{-1}		30%
		Zooplankton	60%
		Phytoplankton	
Filtration+UV	2 m^3h^{-1}	Chlorella	>93%
Filtration+UV	312–350 m^3h^{-1}	Zooplankton	effective
Hydrocyclone+chemi caldisinfectant	530 m^3h^{-1}	Zooplankton	effective
		Phytoplankton	
		Bacteria	
UV+US	200–1600 Lh^{-1}	Artemiasalina	97–100%
UV+H2O2			94–100%

4. Ballast water treatment system with UV and advanced oxidation technology (AOT)

4.1 Description of the system

This is an integral part of the vessel's ballast water system, on the discharge side of the vessel's ballast water pumps. During ballast operation, the water is led through the filter, which removes larger particles and organisms, and then to the advanced oxidation technology reactor, where the water is treated with UV light and advanced oxidation technology. During deballast, the water is led the same way, but the filter is bypassed. The UV lamps are powered by the LDC (via LPSs, lamp power supplies). The AOT reactor has one dedicated LDC. Flow is monitored by the flow meter and regulated by the control valve. The control valve also regulates pressure during back flushing of the filter.

The advanced oxidation technology reactors are cleaned using the CIP (*cleaning-in-place*) module, which first rinse the AOT reactor with fresh water, and then circulates CIP liquid through the AOT. At the end of the process the AOT reactor and the filter (filter preservation) is filled with fresh water from the CIP. The complete system and ongoing processes are controlled and monitored from the control cabinet. Control can also be performed from remote control panels and the ship's ISCS, via the remote interface. The by-pass valve makes it possible to bypass the entire system, for example to secure ballast operation if the system is not functioning. The valve is controlled from the ISCS (integrated ship control system).

4.2 The key components of the system

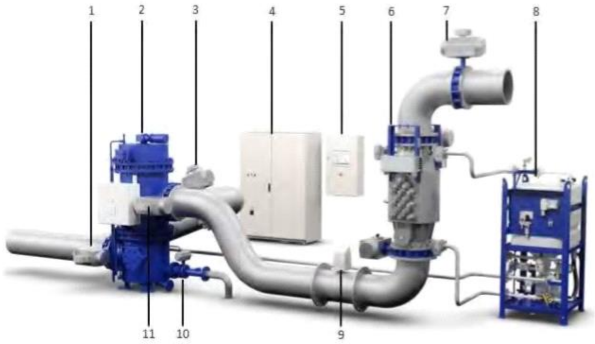

Fig. 1. Advanced oxidation technology system

Components:
1. Filter inlet valve
2. Filter
3. Filter bypass valve
4. Lamp drive cabinet (LDC)
5. Control cabinet with main control panel
6. AOT reactor
7. Control valve
8. CIP (cleaning-in-place) module
9. Flow meter
10. Backflush valve
11. Filter outlet valve

Not in illustration:
• System bypass valve
• Sampling devices, before and after treatment
• Pressure monitoring device

4.3 The main processes performed by this water ballast treatment system

4.3.1. Start-up

Ballasting and deballasting begins with a start-up phase. There must be available power for the system. If power management is integrated, this will be confirmed automatically. If power management is not integrated, this is confirmed manually.
During start-up, the UV lamps are warmed up for 90 seconds. Cooling water is pumped through the AOT reactor to secure that the UV lamps are not overheated. The flow is monitored by the flow meter to secure that there is enough flow to cool the UV lamps. If flow deviates from parameter set values, an alarm is issued and the system is shut down.

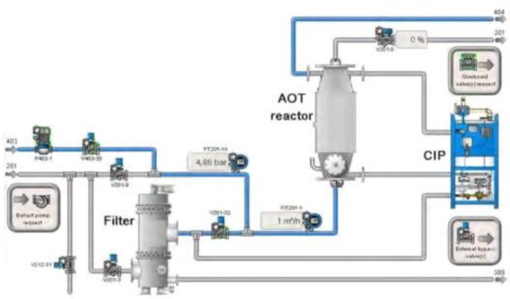

Fig. 2. Ballast and deballast start-up

4.3.2. Ballasting

After the start-up, when the lamps are ready, the operator is requested to start the ballast pump. The ballast water is pumped from the sea chest to the filter, that removes larger particles and organisms. This also reduces the amount of sediment build-up in the ballast water tanks. The organisms and sediments caught in the filter are flushed overboard via regular filter backflush operations. The water is finally led to the AOT reactor, which produces radicals and UV light that breaks down and neutralize the organisms.

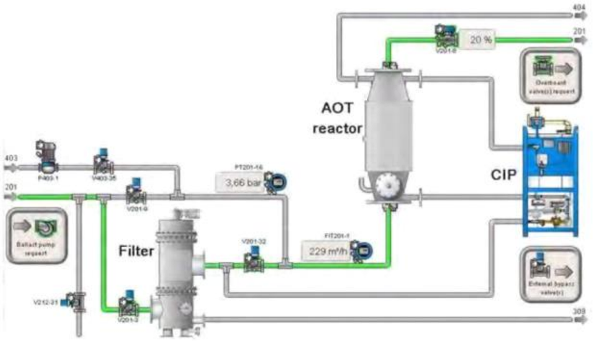

Fig. 3. Ballasting

4.3.2.1. Power optimization

It is possible to activate power optimization (parameter p237). During ballast and deballast, the lamp power is adjusted according to the value from the UV intensity sensor, which constantly measure the water transmittance. In clear water with good transmittance, the lamps are automatically dimmed, to lower the power consumption. This means that the lamps are lit to the degree needed for full treatment, but not more. The purpose is to save power by dimming the lamps to minimum power required to fully treat the water. The UV lamps are regulated individual on all AOT reactors between 50 % and 100 % of full effect.
Power optimization during special conditions.

• During start-up and the first two minutes of ballast/deballast, the UV lamps are lit to 100 % to ensure treatment before values from the UV sensor are stable.
• Pause: UV lamps are dimmed to 50 % during pause and lit to 100 % for 2 minutes when process is resumed.
• Stop: UV lamps are lit to 100 % for 10 seconds before they are stopped. This will prolong the life of the lamps.
• Low UV intensity: See Actions at low UV intensity below.
• Broken UV lamps: See Operation with broken UV lamp below.

➢ *Actions at low UV intensity*

If the UV intensity falls below minimum (defined in parameter p221) for one AOT reactor, a warning is issued, but process continues. When UV intensity falls below limit defined in the type certificate, a new warning is issued and a log is written to the event log. The operation continues but does not fulfill the type approval certificate. However, the flow is decreased so that the treatment shall correspond to the type approval requirements. The operator will have do decide to continue or stop the operation.

➢ *Operation with broken UV lamp*

If a UV lamp breaks a warning is issued and a log is written to the event log. The operation continues but does not full fill the type approval certificate. However, the flow is decreased to 80 % of current flow for all AOT reactors and the UV lamps are lit to 100 %. These actions are taken so that the treatment shall correspond to the type approval requirements.
The operator will have to choose one alternative:

• Stop the operation.
• Continue operation and not comply with type approval certificate.

4.3.2.2. Backflush

To keep the filter clean, it is automatically backflushed. The backflush is performed during ongoing process without interrupting the ballasting process. When a ballast operation is stopped, a backflush is performed before the system comes to a full stop. The water used for backflushing is returned to the sea directly at the ballasting site.

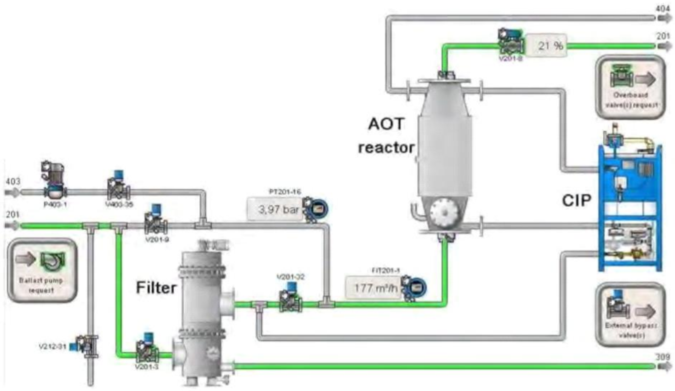

Fig. 4. Filter backflush

4.3.2.3. Ballast after-treatment (CIP)

After a ballast operation, a cleaning-in-place (CIP) process is performed to clean the AOT reactor. This process can either be performed immediately after a ballast operation or within 30 hours after. Note, that it is possible to perform new processes during these 30 hours. A CIP process takes about 25 minutes per AOT reactor, if default parameters are used.
The AOT reactors are cleaned one at a time. First, the AOT reactor is rinsed with fresh water. Then the cleaning-in-place (CIP) module circulates a biodegradable solution through the AOT reactor to remove seawater scaling. After the cleaning is finished, the AOT reactor is filled with fresh water to preserve the filter and prevent scaling, algae growth etc. Then the system continues with the same procedure for the next AOT reactor. Finally, the filter is filled with fresh water to prevent scaling and algae growth. The cleaning liquid is reused between the cleaning operations.

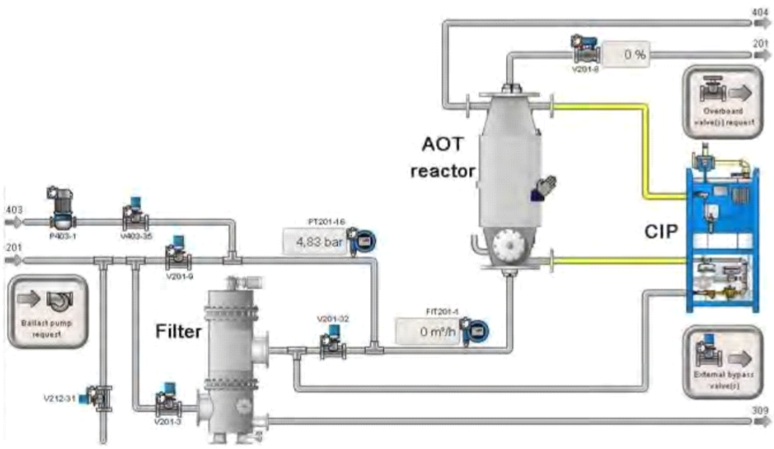

Fig. 5. CIP process

4.3.3. Deballasting

After the start-up, when the lamps are ready, the operator is requested to start the ballast pump. The water passes through the AOT reactor, but the filter is bypassed since the water has already been filtered during ballasting. The reason for treating the water a second time during deballasting is to secure that the treatment is fully effective. The minor part of the organisms, which were only injured during ballast, will be rendered totally harmless during the deballast.
The process flow and power optimization are controlled in the same way as during ballasting.

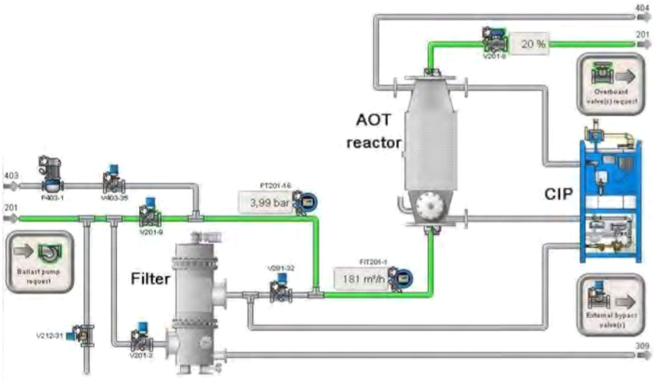

Fig. 6. Full debalastting

4.3.3.1. Deballast after-treatment (CIP)
After deballast operation, a cleaning cycle is performed to clean the AOT reactor. It is performed in the same way as described for the ballasting process. If only deballast operations has been performed since the last CIP process, the filter does not need to be filled with fresh water at the end of the cycle, since the filter has not been used.

4.3.4. Stripping with eductor
Stripping can be performed to achieve total emptying of the ballast tanks via a stripping eductor. To use ballast water treatment system during a stripping process an eductor must be installed before the system.
The water used in the stripping process, must be filtered from particles larger than approximately 5 mm. The water passes through the water ballast treatment system as a regular deballasting process (with the filter bypassed). The water is finally pumped into the sea.
Note the following:
• The eductor is not part of Alfa Laval’s scope of supply.
• Procedures to dispose of sediments from the sieve must be included in the vessel’s ballast water management plan.

4.3.5. Ballast water handling in the event of malfunction
The system is equipped with a bypass valve. The valve can be used in case of emergency to secure the ship, by allowing ballast water operations (ballast, deballast and internal transfers) without involving the ballast water treatment system. The valve is controlled by the ISCS, but all bypass valve activities are logged in the event log. Such valve is required by the International Convention for the Control and Management of Ship’s Ballast Water and Sediments 2004.
If the system malfunction in connection with general cargo operation, ballast and deballast operations should be avoided. In case untreated water is pumped to a ballast tank, this water shall be discharged on open sea (according to regulations) and exchanged for treated water. Note that full treatment requires treatment both during ballast and deballast.
The procedures concerning emergency and malfunction of the ballast water treatment system should be implemented in the ships Ballast water management plan.

4.4. System components

4.4.1. AOT reactor

The main part of this ballast water treatment system is the AOT reactor in combination with a lamp drive cabinet (LDC) giving power to the UV lamps in the AOT reactor. The LDC does not need to be placed in close relation to the AOT reactor.

4.4.1.1. AOT reactor working principle
The main treatment process take place inside the AOT reactor, where the UV light inactivates the cell DNA to prevent regrowth of organisms. The UV light also generates radicals. The radicals are extremely reactive and react instantaneously with micro organisms and other organic contaminants

destructing their membranes. The radicals are extremely short-lived and exist only for some milliseconds. This means that they will only exist inside the AOT reactor. The quantity of radicals produced in the reactor is sufficient to treat the water as it passes through the reactor.

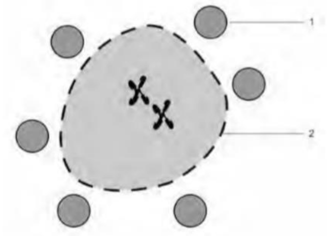

Fig. 7. AOT

Destruction of cell membranes
1. Radical
2. Cell membrane

There are no chemical substances added to the process, and there are no toxic residuals created. Since the water is not affected chemically there are no environmental impact, and the process does not influence corrosion in any way.

4.4.1.2. AOT reactor description

The AOT reactor consist of the reactor, sensors and valves for ballast water, fresh water and CIP liquid, as shown in the illustration below. The AOT reactor accommodates 16 medium-pressure UV lamps (6 kW each) powered from the lamp drive cabinet (LDC). The UV lamps are enclosed in individual quartz-glass sleeves.
The UV lamps get very warm, so they must be cooled whenever they are lit. To secure that there is water in the reactor when the lamps are lit, each reactor is equipped with a level switch. The level switch also secures that enough CIP liquid is pumped into the reactor during the CIP process. To secure that the lamps are adequately cooled by the ballast water, each AOT reactor is equipped with one temperature transmitter that shut down the reactor at 60 °C, completed with a temperature switch that automatically shuts down the reactor if the temperature reaches 65 °C.
A UV sensor monitors the UV lamp efficiency in relation to the water transmittance inside the AOT reactor. Based on this input, the power to the UV lamps are regulated between 50 and 100 % of full capacity. The UV lamps will be dimmed to lowest possible level, where they are still effective.
Note, that the lamps are always lit with full effect during start-up and the first two minutes of full ballast to secure full efficiency independent of transmittance. The lamps are also turned up to full effect for 10 seconds before stop and normal shut down. This method will prolong the UV lamp life time.
The illustration below shows the main components for the AOT reactor (Fig. 8).

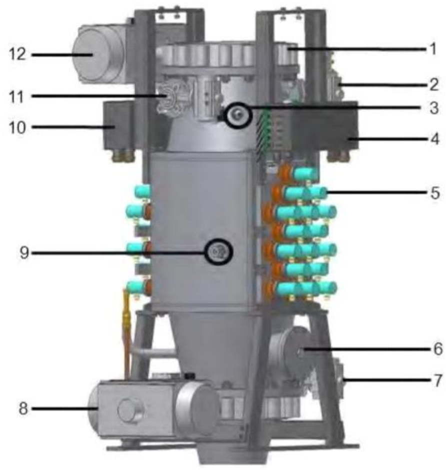

Fig. 8. AOT reactor

AOT reactor components:
1. Ballast water outlet valve
2. CIP liquid outlet valve (actuator indicated)
3. Level switch
4. Junction box
5. UV lamp cap (UV lamp and quartz sleeve inside)
6. Access hatch
7. CIP liquid / fresh water inlet valve and reactor drain valve (actuator indicated)
8. Ballast water inlet valve (actuator indicated)
9. UV sensor
10. Junction box
11. Cooling water outlet valve
12. Ballast water outlet valve actuator (actuator indicated)

4.4.2. Lamp drive cabinet (LDC)

The lamp drive cabinet gives power to the AOT.

4.4.2.1. LDC working principle

The AOT reactor is connected to a lamp drive cabinet (LDC) containing 16 lamp power supplies (LPS), each feeding one lamp with power. The LPS also monitors the function of each UV lamp and takes action if a fault occurs. Lamps on the cabinet indicates if power is on, UV lamps are lit and if the cabinet needs to be reset after a shutdown or power off.

4.4.2.2. LDC description

The LDC is equipped with a cooling system to maintain correct operating temperature in the LDC, using low-temperature cooling water. The cooling water flow is constant, but the fan is regulated based on heat inside the cabinet. When lamps are lit, the fan starts at 15 % of full effect. When the temperature reaches 40°, the fan starts to regulated between 15 % and 100 %, according to parameter settings based on input from the temperature transmitter in the LDC.
The humidity in the cabinet is monitored by a liquid sensor. If a leakage from the heat exchanger is detected, a warning is issued, the reactor is shut down and the cooling water inlet valve to the LDC is shut.
The LDC can be placed up to 150 meters (cable length) from the AOT reactor. The main breaker cut the power to the LDC and the AOT reactor.

Fig. 9. LDC

LDC components:
1. Fan
2. Heat exchanger
3. Lamp power supplies (LPS)
4. Fuses
5. Cooling water inlet and outlet
6. Main breaker
7. Status lights and reset button

4.4.3. Filter

4.4.3.1. Filter working principle

The filter is a fully automatic self-rinsing component, equipped with filter elements to remove particles and organisms from the ballast water flow. The ballast water is lead through the filter, and filtered particles are trapped in the filter. The filter control cabinet is only used for connections. The filter is entirely controlled from the ballast water control system.

4.4.3.2. Filter description

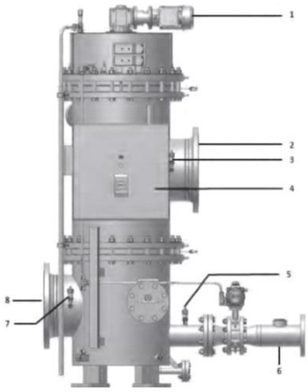

Fig. 10. Filter

Filter components:

1. Geared motor
2. Water outlet
3. Pressure transmitter, outlet
4. Filter control cabinet.
5. Pressure transmitter, backflush line
6. Backflush outlet
7. Pressure transmitter, inlet
8. Water inlet

To secure efficient filtration, the filter performs a self-rinsing backflush operation at time set intervals or when triggered by indication of dirt in the filter. Pressure drop over the filter is monitored by pressure transmitters on the filter inlet and outlet. Dirt is detected by an increased differential pressure drop caused by particles in the filter. When the differential pressure reaches a parameter set value, an automatic backflush operation starts.

The backflushing does not interrupt the filtration process, since all filter candles are not cleaned at the same time. The not cleaned filter candles continue the filtration of the ballast water. It is also possible to start backflush manually from the control system.

The filter candles are backflushed in two steps:

- **Step 1:**

The flushing arm is positioned under the first filter candle to be backflushed. The purpose of the flushing arm is to collect the backflush water and lead it, with the flushed particles, to the backflush line. From this point, this filter candle is not used for filtering. A valve on top of the filter candle is opened to lead water through the filter candle from the top downwards. The water flow through the filter candle down to the flushing arm, flushes particles from the filter candle walls and lead them to the backflush line.

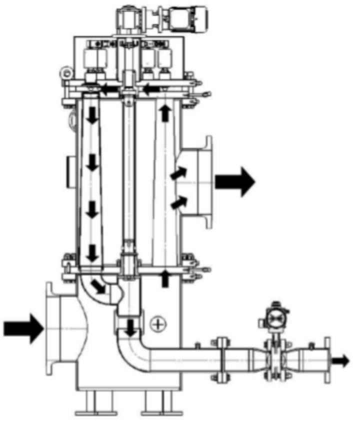

Fig. 11. Step 1

- **Step 2:**

The valve on top of the filter candle is closed to stop the axial flow to the filter element. The existing water pillar inside the candle continues the flow downwards, which creates an under pressure. This under pressure forces water to flow radial through the filter candle from the outside (filtered side) to the inside (unfiltered side), which pulls remaining particles from the mesh and downwards to the backflush line.
When the first candle is backflushed, the flushing arm change position and the process is repeated until all filter candles are rinsed.

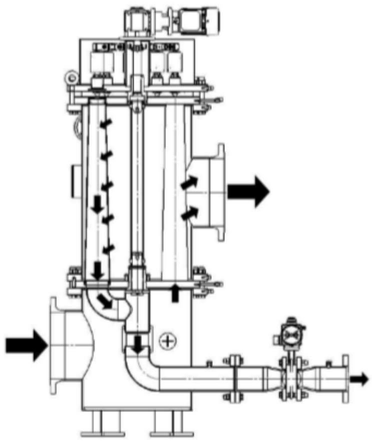

Fig. 12. Step 2

4.4.3.3. Backflushing for different dirt loads
Below, the filter pressure drop over time (pfilter) is illustrated for different dirt load situations in the filter. Different dirtload depends on the water condition, which means that "normal" condition regarding filter backflush depends on the water conditions.

- **Low dirt load**

In water with low dirt load, the backflush cycle is started by the time trigger (default: every 30 minutes). As long as the pressure is below 0.85 (0.085 MPa) bar, there is no need for the pressure triggered backflush. See examples below.

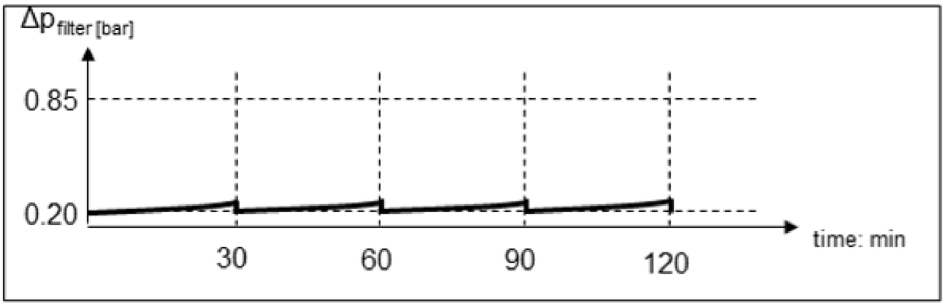

Fig. 13. Low dirt load 1

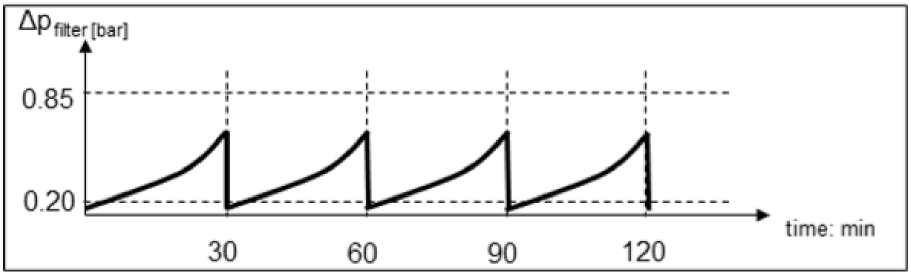

Fig. 14. Low dirt load 2

- **Medium dirt load**

In more dirty waters the backflush cycle will be triggered when pfilter reaches 0.85 bar, which indicates dirt in the filter candles.
After each backflush, the backflush timer is reset. The filter will be backflushed again after 30 minutes or when Δpfilter reaches 0.85 bar, whichever comes first.
In the example below, three backflushes are triggered due to high differential pressure over the filter. After that, there is not so much dirt build-up, so the next backflush is performed after 30 minutes.

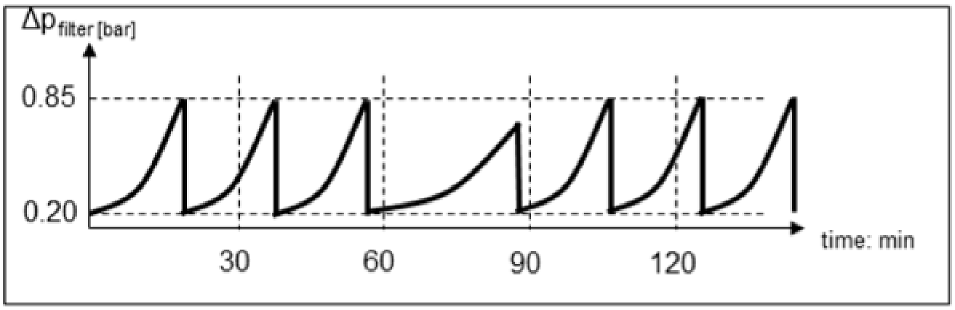

Fig. 15. Medium dirt load

- **Heavy dirt load**

In conditions with heavy dirtload, the system will perform more frequent backflushes to keep the filter clean.
Also, the 0.85 limit might be exceeded. In this case the self-rinsing cycle will run continuously until the problem is solved and the pressure has returned below 0.85 bar. It is OK that the flow momentarily fluctuates in an irregular curve, but it is important that the curve stabilizes.
In the example below, a series of backflushes are performed (approx. every 4 minute). After that the pressure rises above 0.85 where the filter is backflushed constantly. After that, the normal control is resumed, where the filter backflush is triggered by pressure (2 times) or by time (last backflush in the example.

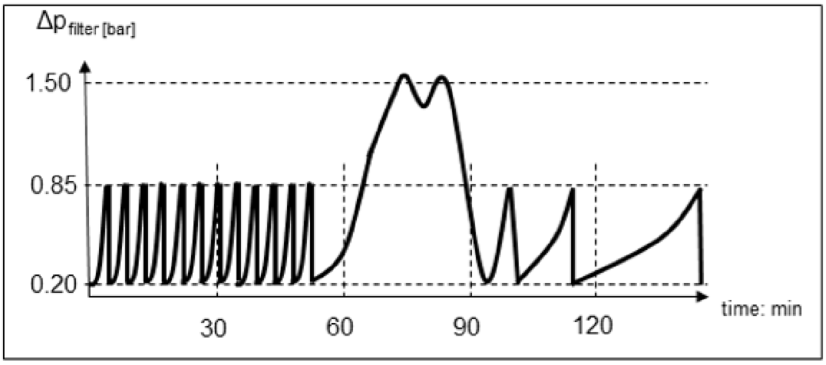

Fig. 16. Heavy dirt load

- **Long term dirt build-up**

Over time, the filter candles will undergo a long-term build-up of particles that are not removed by backflushing. One effect of this is that "normal" pressure will increase over time. Therefore, the maintenance schedule state that the candles shall be inspected and manually cleaned once a year.
The extent of the long-term dirt build-up is dependent on the water conditions. In the great majority of cases this will not cause any problems – cleaning once a year is enough. But in exceptional cases (vessels trading very muddy waters) it might be necessary to clean the filter candles more often. If the pressure triggered backflushing is performed with short intervals, we suggest that the filter candles are manually cleaned more often than once a year.

4.4.4. CIP (cleaning-in-place) module

4.4.4.1. CIP working principle

To ensure full performance in ballast water treatment system, an automatic cleaning cycle is performed after ballast and deballast operation. The purpose is to keep the quartz sleeves covering the UV lamps and the UV sensor clean, to maximize the effect of the UV lamps, and thereby treatment efficiency.
During a cleaning cycle, the CIP module rinse the reactor with fresh water and circulates a CIP liquid through the AOT reactor. The low-pH CIP liquid removes scaling, calcium chlorides, metal ion build-up and chemical fouling on the lamps' quartz glass sleeves. After finished cycle, the liquid is returned to the CIP module tank; the CIP liquid is reusable for a great number of cycles. The sequence is finalized by filling the AOT reactor with fresh water. A backflow preventer secures that no CIP liquid is mixed with the fresh water.

4.4.4.2. CIP module description

The CIP module consists of a tank where the CIP liquid is stored between usage. The pumps and valves integrated in the CIP module are controlled by the valve block.
To secure that there is enough CIP liquid for the process, the level switch in the reactor indicates when it is filled with CIP liquid. To prevent intrusion of water in the fresh water system, a backflow preventer is used in the CIP module.
The CIP module is equipped with two membrane pumps:
• Pump 1 (4) circulates the CIP liquid in the AOT reactor and fills it with fresh water.
• Pump 2 (6) drains water (sea and fresh water) overboard from the reactor, via the drain line.

Fig. 17. CIP module

CIP module components:
1. Deaeration valve
2. Valve block
3. Regulator
4. Pump (CIP liquid)
5. Backflow preventer
6. Pump (reactor drain)
7. Tank for CIP liquid

4.4.5. Control cabinet and control system

The control cabinet is used to control and monitor the entire system, via the built-in main control panel (Fig. 18). It is also used to communicate with the vessel’s systems and components, if integrated. The control cabinet functions as a single point of contact for signal cables to and from the vessel. Examples of integration: Remote interface integration and power management system (PMS). Remote interface will allow control of ballast water treatment system from the vessel’s ISCS and PMS integration will allow automatic verification that there is enough power to run an operation. If not integrated, the operator must verify this manually. Also, integration with other external components (not part of Alfa Laval’s scope of supply), such as GPS or booster pumps, are done to the control cabinet.

Fig. 18. Control cabinet with main control panel

4.4.5.1. Control system

The control system is used to set parameters, operate and monitor the ballast water treatment system. The control system continuously monitors ballast water treatment (sensors, communication and PLC status), both during operation and in standby mode. Any deviation is either communicated to the operator or handled automatically, based on parameter settings. Safety risks are always handled automatically. The control system stores all alarms and relevant events

for at least 24 months. The memory has a vast safety margin but when it is full, data will be deleted starting with the oldest logs. Logged information can be exported to a USB memory stick.
There are three alternative ways to monitor and control the system: main panel, remote control panel (optional) and remote interface (optional). If two ballast water treatment systems are installed on a vessel, two control systems are needed.

4.4.5.2. Main control panel

The main control panel in mounted in the control cabinet, and it is included in the standard installation of the system (Fig. 19). It is installed in the engine room. The main control panel handles every aspect of the control system. It allows the operator to monitor the system, to operate it manually and automatically, and to set parameters. Please note that some of the operations are password-protected.

Fig. 19. Main control panel

4.4.5.3. Remote control panel (optional)

As an option, it is possible to install one or two additional panels to be placed in locations from where ballast operations are performed. A remote control panel looks and functions in the same way as the main control panel, and it allows same operations (Fig. 20).

Fig. 20. Main control panel with four integrated remote control panels

4.4.5.4. Remote interface (optional)

As an option, the control system can be integrated with the vessel's ISCS via modbus. This allows monitoring and operation of system from the ISCS's graphical user interface (Fig. 21).
Note that Alfa Laval does not supply the graphical user interface to handle the system in the ISCS, only the means to enable the integration.

Fig. 21. Remote interface

4.4.6. Main valves

The main valves in the system are:

• Inlet valves:

The inlet valves direct the water flow from the vessel's ballast water system into the system. Different valves are used during ballast and deballast.

- System and filter inlet valve - inlet valve to ballast water treatment system during ballast. The valve directs the water flow through the system filter.
- Filter outlet valve - the valve directs the water flow from the filter to the AOT reactor during ballast.
- Inlet valve -inlet valve to the system during deballast. The valve directs the water to the ballast water treatment system, but bypass the filter, since the water was filtered during ballasting.

• Control valve - the valve has the following functions:

- automatic regulation to maintain flow during operation so it does not exceed selected certified maximum flow. Regulation is based on input from the flow meter.
- automatic regulation to maintain pressure needed to perform backflush of the filter. Regulation is based on input from the pressure transmitter.
- outlet valve from the system to the vessel's ballast water system after treatment.

• System bypass valve - makes it possible to completely bypass the system. The valve is solely operated from the ISCS, but the valve positioning is (and must be) indicated in the control system. When ballast water treatment system is bypassed, an event is written to the event log. The component is optional to be included in Alfa Laval's scope of supply.

• Cooling water inlet valve - supplies cooling water to the reactor to secure cooling of the lamps and prevent overheating during start-up.

• Check valve - ensures that there is water in the reactor at all times.

4.4.7. Flow meter

The flow meter monitors the process-flow during operation. It has two main functions:

• It monitors that the flow within the ballast water treatment system does not exceed its certified flow. If the certified flow is exceeded a warning is issued.

• Via the flow transmitter, mounted on the flow meter, it sends valuable data to the control system, where it is displayed. Example of information: Current flow and data about total amount of treated ballast water. The flow meter consists of two main parts: a flow sensor, which is a pipe with four electrodes detecting the flow. On top of the pipe, there is a terminal box, where the flow transmitter is mounted. The flow transmitter monitors the flow and transmits the information to the ballast water treatment control system.

4.4.8. Pressure monitoring device

The pressure monitoring device is a manifold that includes the following components to monitor and handle pressure in the system:

• Pressure transmitter - send current pressure information to the control system. The control system uses the information to take actions accordingly, for example issue warnings, shut down the system or adjusting the control valve to obtain optimal pressure during filter backflush.

• Pressure gauge - analogue displayed of current pressure.
• Needle valve - enables connection of external instruments for calibration.
• Safety valve - relief of over pressure.

4.4.9. Sampling devices

The two sampling devices make it possible to take water samples to test the water. One sampling device is installed before the water is treated and one after the water is treated. This enables comparative tests of treated and untreated water. The component is optional to be included in Alfa Laval's scope of supply [3].

5. Conclusion

Because of regulations and for protection of the environment, ship owners must comply with Ballast water management convention.
Here there are some criteria's for choosing the best technology for ballast water treatment system:

- safety of the crew and passengers;
- effectiveness in removing target organisms;
- ease to operate treatment equipment;
- amount of interference with normal ship operations and travel time;
- structural integrity of the ship;
- size and expense of treatment equipment;
- mount of potential damage of the environment;
- ease of port authorities to monitor for compliance with regulations.

While several ballast water treatment technologies have been certified according to the IMO guidelines, further evaluation is necessary with regards to new marine organisms with emphasis on higher organisms, development of new processes at lab, pilot and full scale, as well as studying the environmental implications of these technologies. One of the most common methods of treating ballast water is mid-ocean water exchange. By exchanging of port ballast water in the open ocean is thought to eliminate species residing in the ballast by exposing them to different salinity and causing mortality due to osmosis [9]. This has an efficiency of 97% to 99%. The probability of organisms surviving ballast water exchange depends on waters of origin and location. In the absence of large salinity differences between receiving waters and discharge waters, organisms may be able to survive (Table 8) [10].

Table 8: Aquatic Invasive Species Known to Have Been Spread by Ballast Water [4],[5]

Species Name	**Native from**	**Introduced to**	**Environmental Impact**
European green crab *Carcinus Maenus*	➢ European Atlantic coast	➢ S Australia ➢ South Africa ➢ United States ➢ Japan	Resistant to predation due to hard shell. Competes with and displaces native crabs and becomes a dominant species in invaded areas. Consumes and depletes wide range of prey species. Alters inter-tidal rocky shore ecosystem.
Zebra mussel Dreissena polymorpha	➢ E of Europe ➢ Black Sea	➢ W and N Europe ➢ Ireland ➢ Baltic Sea ➢ E of North America	Fouls all available hard surfaces in mass numbers. Displaces native aquatic life. Alters habitat, ecosystem and food web. Causes severe fouling problems on infrastructure and vessels.

			Blocks water intake pipes, sluices, and irrigation ditches.
Chinese mitten crab Eiocheir sinensis	➢ N of Asia	➢ W Europe ➢ Baltic Sea ➢ W coast North America	Burrows into river banks and dykes causing erosion and siltation. Preys on native fish and invertebrate species, causing local extinctions during population outbreaks. Interferes with fishing activities.

Table 9: Probability of organism to survive and reproduce in freshwater (FW), brackish water (BW), and saline water (SW)

Receiving Waters	Discharged Ballast		
	FW	**BW**	**SW**
FW	High	Medium	Low
BW	Medium	High	High
SW	Low	High	High

The article shows that one of the most efficient and modern ballast water treatment system is with UV and advanced oxidation technology (AOT.), because it has a large spectrum of species that he is eliminating and is not harmful to the environment [6], [7], [8].
Because of the amount of ships in the world, management of ballast water requires significant attention globally, as it becomes more susceptible to invasive species [9], [10].

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Determination of the Calorific Power of Densified Solid Biofuels

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Abstract: *The present research addresses a current topic in the field of energy production from renewable sources, with the evaluation of the energy potential of biomass, by increasing the calorific power and efficiency of the use of wood in combustion. The current research should start from the determination of the calorific power, continue with the determination of the influence of humidity, and finally go on to evaluate the efficiency of the use of wood biomass by increasing the calorific power, by the dry heat treatment in oxygenated environment. In the production of pellets from biomass the costs and the impact on the environment must be taken into account, following the improvement of the composition of the pellets, in order to increase the quality and to reduce the production costs (of the energy consumed) and the increase of the calorific power by identifying some solutions for using the some residues from agriculture.*

Keywords: *Biomass, densification, calorific power*

1. Introduction

The evolution of the sector of production of densified solid biofuels has been growing rapidly in recent years. The solid biofuels market tends to evolve from a local market to an increasingly globalized one. In the created situation, an important role belongs to the knowledge of the factors that influence the quality of solid biofuels, the norms regarding quality control, quality assurance and the specification of the finished product.
In the world the interest for the use of biomass in the form of densified biofuels (pellets, briquettes) has increased, their market is constantly rising. Obviously, this interest is motivated by several factors, of which energy security is placed first.
In recent years, awareness of the possibilities of reducing the consumption of fossil fuels has increased, by replacing them with biofuels from vegetable biomass resulting from agricultural, forestry and industrial activities. [1]
From an energy point of view, the term "biomass" refers to organic matter that can be converted into energy. The main categories of biomass that can be used for this purpose are wood matter, vegetable residues from agriculture and animal residues from animal husbandry, as well as crops and plantations dedicated to energy recovery. In addition, the municipal waste (residues from the cleaning of the trees, maintenance of the parks, etc.), the household waste or some residues from the food industry are considered.
Wood biomass (also called lignocellulosic biomass) consists mainly of lignin (20-25%) and carbohydrates (60-80%). Most of the carbohydrates present in the biomass are poly / oligosaccharide compounds, such as cellulose, hemicellulose, starch and inulin. In addition, small amounts of monosaccharides such as glucose and fructose may be encountered. Although biomass is the most abundant resource on the planet, the use of energy contained in it has a rather low efficiency. This disadvantage is a result, first of all, of the form and state in which this energy source is used, as well as the low efficiency of the classical means of obtaining thermal energy (stoves, fireplaces, ovens, etc.). In this situation, the manufacture of high quality biomass fuels is gaining new strengths, being a current problem for the energy sector.
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2. Densification of biomass

Densification of biomass leads to increased energy efficiency. This is a process that involves two stages:
- pressure compaction of wood material for volume reduction and material agglomeration;
- The lignin contained in the wood is activated by this pressure and glues the wood chips without the need for an additional gluing agent. [2]

The compaction methods have as a common element the pressing operation, through which the thickening of the particles from the primary material is produced, resulting in an increase of the density of the finished product (tablets, pellets, briquettes, etc.).
The operations of agglomeration of biomass particles, depending on the pressure they are subjected to in the working process and the equipment used are described in table 1.

Table 1: Characterization of agglomeration operations

Name of the process	Characteristics
Compression	The method of agglomeration under high pressure by means of pairs of rollers with smooth or profiled surface, which rotate into each other in the feeding area. The material is passed through the space between the rollers and after pressing it increases its density.
Briquetting	Method of agglomeration under pressure of up to 300 MPa, with or without binders, of powdered or granulated materials, in lighters with characteristic geometric shapes, at pressures depending on the characteristics of the raw material and those imposed on the finished product.
Compression as tablets	High pressure agglomeration operation 50… 200 MPa, in individual molds, placed on a rotating disc, from unpolluted powder materials, obtaining tablets.
Pelletizing	Medium pressure agglomeration operation, in ring or flat molds, periodically the material being forced to pass through the holes of the mold, at the exit of the nozzle being cut. Pellets of cylindrical shape, with the determined length, are obtained.
Extrusion	The method of agglomeration at low and medium pressure, in which the material mixed with liquid binders is brought by kneading in a plastic state, after which it is forced to pass through the holes of a mold.

The pellets are produced by chopping sawdust, chippings, furrows, tree shells, fodder, etc. and pressing of the material obtained through a mold. The heat resulting from friction is sufficient for softening the lignin. By cooling, the lignin becomes rigid and binds the material.
The pellets have a cylindrical or spherical shape with a diameter of less than 25 mm (fig. 1 a).
The briquettes (fig. 1 b) are usually rectangular or cylindrical in shape and are obtained by pressing together the sawdust, chippings, furrows or tree shells in a piston or screw press. Because in the manufacture of pellets recyclable raw materials are used, they are of an ecological nature, so we can consider them fuels with clean combustion and an alternative of heating with a stable cost.
They are much cheaper than natural gas and the calorific power is almost double that of wood: 1 kg pellets can produce 4.7 kW or 17 MJ / kg.


a


b

Fig. 1.
a-Pellets b-Briquettes

The main advantages of wood biomass densification are:
• Increased density of compressed material (from 80-150 kg / m^3 for straw or 200 kg / m^3 for wood sawdust up to 600-700 kg / m^3 for final products);
• Higher caloric power and a homogeneous structure of compressed products;
• Low moisture content (less than 10%).
The raw material used for the production of pellets and briquettes must meet certain physical characteristics, important during the densification process:

• Material fluidity and adhesive capacities (different additives can be used as well lubricants or binders, for granting the respective characteristics);
• Predetermined dimensions of the particles of the raw material (a very fine crumb thereof it can lead to increased cohesion properties, causing a reduced flow of material);
• Material hardness (too much hardness of the particles creates difficulties in the densification process). [9]

2.1 Biomass pelletizing. Description of the pelletizing process

Pellets, also called "liquid wood", are fibrous products obtained from chips, sawdust, chop from vegetable debris or dedicated energy crops, pressed under high pressure. The characteristic of the pellet is that it has a much lower humidity than firewood, which gives a much higher thermal efficiency.
Pelletizing is a mechanical pressing of the material at much smaller dimensions and with much higher density. Pellets are solid fuels with low moisture content, obtained from sawdust, wood chips, or even tree bark, wood dust from industrial wood processing plants, as well as from unused trees from logging. The resins and binders naturally occurring in sawdust have the role of keeping the pellets compact and therefore they do not contain additives. Wood pellets are environmentally friendly, economical and CO_2-neutral fuels, mostly produced from sawdust and wood scraps, compressed at high pressure without additives for bonding. They are cylindrical in shape, usually measuring between 6-10 mm in diameter and 10-30 mm in length. [6]
The combustion is adjustable, making it possible to reduce the emission of harmful substances. The process of producing pellets involves subjecting the biomass to high pressures and forcing it to pass through the cylindrical holes of a mold. When exposed to appropriate conditions, the biomass "fuses" into a solid mass. This process is called extrusion. Certain types of biomass (mainly wood) naturally form good quality pellets, while other types of biomass (feed, herbaceous biomass, etc.) may require additives to serve as "binders" that keep the pellets bound. The stages of the pellet production process are: humidity control, extrusion, cooling and packing / storage. The material subjected to the pelletizing process must meet two essential conditions: the size of the chips between 30-50 mm and the maximum humidity 15%. In this regard, a pellet manufacturing line will include equipment for drying the raw material, chopping and pelleting.

2.2 Equipment for biomass pelletizing

The usual system for making pellets is the extrusion of the chopped material through a mold provided with a series of holes.
In general, pellet presses are the main equipment in a pellet production line. The technical characteristics of a pellet press greatly influence the quality and productivity. These characteristics are generally the size of the mold, the speed of the mold and the distance between the working elements.
The material, with the help of rollers, is pressed through the mold, thus forming the pellets. On the outside of the mold a knife cuts the pellets to the desired length. After extrusion the pellets reach the temperature of 90-100˚C and are transported to the refrigerator, where their temperature drops to 25˚C. It fixes lignin and strengthens the product, helping to maintain its quality in storage and transport. Finally, they are sieved so that the residual debris is separated and reused in the process. Dust-free pellets are ready for storage, transported to packing equipment and stored.

A pelletizing equipment, fig. 2 is composed of:
- helical feed system with dosing role of the compaction material;
- funnel for directing the compaction material;
- pellet press;
- drive gear motor;
- order cabinet.

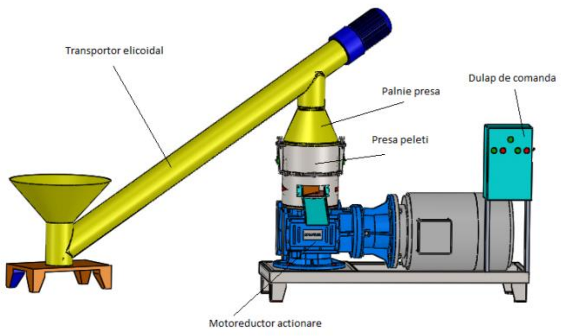

Fig. 2. Press pellets with feed and dosing with helical conveyor [5]

The most common devices used for pelletizing are those with mold and one or more pressing rollers. These are available in two constructive variants:
- with fixed mold and movable rollers
- with rotary mold and fixed rollers (with rotation movement only around its own axis).

3. Determination of the calorific power of densified biomass samples (pellets and briquettes)

The calorific power of biomass is correlated with its chemical composition. Thus, the calorific power increases as the lignin content increases. Cellulose has a lower calorific power than lignin due to the high degree of oxidation. The hydrocarbon content also increases the calorific power of the biomass. The calorific power can be calculated according to the chemical composition. Van Loo S and J. Koppejan propose in the paper Handbook of Biomass Combustion and Co-firing, Twente University Press, 2002, the following calculation formulas for calorific power, [3]:

$$Q = 88.9\,(LC) + 16821.8\ [kJ/kg] \quad (1)$$

in which LC is the lignin content related to the dry and ash-free state.

$$Q = 196\,Cf + 14119\ [kJ/kg] \quad (2)$$

where: Cf is the fixed carbon content of the biomass.

$$Q = 33500\,C + 14300\,H - 15400\,O - 14500\,N\ [kJ/kg] \quad (3)$$

in which:
- C is the carbon content [%], H is the hydrogen content [%]
- O is the oxygen content (%) and N is the nitrogen content [%].

Tillman D.A established in the work Biomass Cofring: the technology, the experience, the combustion consequences, Biomass Bioenergy 2000, the following formula for calculating the heat power, [4]:

$$Q = 349.1\,C + 1178.3\,H + 100.5\,S - 15.1\,N - 103.4\,O - 21.4\,A\ [kJ/kg] \quad (4)$$

in which C, H, S, N, O, A are the carbon, hydrogen, sulfur, nitrogen, oxygen and ash contents relative to the anhydrous state, expressed as a percentage.
Table 2 shows the calorific power values for the main solid biomass fuels, [4].

Table 2: The calorific power of the main solid biomass fuels, [4]

No. crt.	Fuel type	Calorific power of dry substance [MJ/kg]
1.	Wheat straw	18.3
2.	Barley straw	18.0
3.	Rice straw	15.2

3.	Corn cobs (stems)	16.2
5.	Cobs	17.4
6.	Stems of sunflower (sticks)	21.8
7.	Peel sunflower seeds	16.2
8.	Soybean spices	18.1
9.	Ropes of vines (humidity 7%)	16.5
10.	Fruit tree branches (7% humidity)	15.2
11.	Lamppost stems	18.4
12.	Fire wood	15.5
13.	Wood pellets or sawdust briquettes	17.1
13.	Charcoal	31.8
15.	Vegetable waste (stems, leaves, shells)	12.6

From the analysis of the data presented in table 2, it is found that the highest calorific power is obtained for the sunflower stems. The calorific power of solid biomass fuels is much lower than the conventional fuels (average calorific power of diesel fuel 42.34 [MJ / kg].

3.1 Determination of the lower calorific power of densified biofuels by means of the bomb calorimeter

The principle and method of determining the calorific power with the help of the bomb calorimeter is to determine the amount of heat released by burning a known quantity of fuel (approximately 0.5 g) and giving it to the calorimetric system comprising a known quantity of water (2700 ml at the temperature of 22 ... 25°C), whose temperature is recorded. The combustion of the samples takes place in a vessel made of stainless steel, which is inaccessible to the acids resulting from the combustion of the fuel, capable of withstanding the high pressures developed during the explosive combustion of the investigated fuel.
The sample of material for determining the calorific power is placed in the cradle and weighed. Attach a cotton thread (fig. 3) to the center of the ignition wire and insert it with the other end into the sample, to propagate the combustion inside it. Insert the nacelle in its support into the bomb calorimeter and seal it tightly (fig. 4). The pump is then filled with oxygen at a pressure of 20-30 bar through the oxygen station, connected to an oxygen cylinder. The ignition adapter (fig.5) is attached to the bulb and then inserted into the calorimeter's inner vessel. Pour about 2 liters of demineralized water into the calorimeter tank, following the level indicator.

Fig. 3. Binding the cotton thread to the tungsten filament of the device

Fig. 4. Oxygen pressurization of the combustion vessel

To prepare the measurement, enter the measured weight of the sample, the type of operation to be performed (calibration or actual measurement), the type of the bomb calorimeter and the correction values for the heat generated by the combustion of the cotton yarn (the default value is entered in the measurement menu, 50 J) or from other sources.
When everything is ready, the calorimeter cover is closed (Fig. 6) and the unit starts the measurement operation. First the inner vessel is filled with water, then the combustion is carried out, the final step being to equalize the temperatures of the inner and outer vessels, by transferring heat from the inner vessel to the outer one. When this has happened, the measurement process is complete and the measured calorific power is displayed.

Fig. 5. Inserting the bomb calorimeter into the calorimeter

Fig. 6. Closing the calorimeter lid to start burning the biofuel sample

Fig. 7. The bomb calorimeter cooler

The device calculates the calorific power according to the following hypotheses:
- the temperature of the fuel and of the combustion products is 25 °C;
- the water contained in the fuel and the water formed by the combustion of hydrogen are in liquid state at the end of the process (the device measures the higher calorific power);
- atmospheric nitrogen was not oxidized;
- the gaseous products of the combustion are: O_2, N_2, CO_2 and SO_2;
- ash can form.

These elements are part of both the main constituents of wood, namely: [6]:
- cellulose: 50 - 55%
- lignin: 20 - 30%
- hemicellulose: 25 - 30%

as well as from secondary ones, such as:
- resins: 1 - 5%
- mineral substances: 0.2 - 1.2%
- tannin, coloring matter, etc.

In addition to the main constituents, listed, which are organic in nature, the wood composition also includes mineral substances that, as a result of burning, form ash.
The mineral substances, representing 0.2 - 1.2% by weight of dry wood are, [6]:
- potassium: 10 - 25%;
- sodium: 1 - 5%;
- calcium: 20 - 45%;
- magnesium: 3 - 15%;
- manganese oxide: 1 - 8%;
- iron oxide: 1 - 4%;
- silicon dioxide: 1 - 3%;
- phosphoric acid: 2 - 10%

The ash composition of different wood species is almost homogeneous and is characterized on average by the following data: 35% CaO, 16% Na_2O + K_2O, 7% MgO, 5% MnO, 3% Fe_2O_3, 3% Al_2O_3, 20% CO_2, 5% SO_3, 4% P_2O_5, 2% SiO_2, [6].

3.2 INOE 2000-IHP test results

The tests were carried out on 2 types of pellets made on 2 types of pellet presses, these being realized within a project developed by INOE 2000-IHP in collaboration with 2 companies S.C. TECHNICAL ECO CDI S.R.L. Bucharest and S.C. ROLIX IMPEX SERIES SRL Bucharest. Following the tests for determining the lower calorific power for densified biofuels obtained from different types of biomass, the following values were obtained:
- In softwood pellets made with the TECHNICAL ECO press, the average lower calorific power was 18.477 MJ / kg, for an average humidity of 7.62%;
- In softwood pellets made with ROLIX press, the average lower calorific power was 17, 873 MJ / kg, for an average humidity of 8.64%;

The results of the determinations, presented in table 3, represent the average of the instantaneous calorific powers measured in 29 points, for each 5 samples from the pellets obtained with the two presses.

Table 3: The results of the tests regarding the lower calorific power of the biofuels densified pellets / briquettes

Test	Test no.	Determination		
		Average humidity, (U), [%]	**Lower calorific power (q_i), [MJ/kg]**	**Unburned combustible substance, (S_{cn}) [g/kg]**
Softwood pellets (Tehnic Eco)	1	7.62	18.654	5.15
	2		18.347	4.35
	3		18.516	3.55
	4		18.432	3.82
	5		18.440	3.01
	Average		**18.477**	**3.97**
Softwood pellets (Rolix)	1	8.64	17.869	8.51
	2		17.821	8.95
	3		17.592	9.71
	4		18.045	8.80
	5		18.043	7.25
	Average		**17.873**	**8.64**

NOTE: Moisture is the average humidity of the samples.

4. Conclusions

• Densified biofuels (pellets, briquettes) are obtained from recyclable raw materials, they are ecological in nature, so they can be considered clean burning fuels;
• Densification (pelleting, briquetting) represents the most efficient method of increasing the energy density and the calorific power of the biomass; the calorific value of pellets and briquettes is almost double that of wood (1 kg pellets can produce 4.7 kW or 17 MJ / kg);
• Lower calorific power of the pellets tested: 18.477 MJ / kg (softwood pellets obtained with TECHNICAL ECO press), respectively 17.873 MJ / kg (softwood pellets obtained with ROLIX press), allows them to be classified in EN plus A1 class (16500 ≤ Q ≤ 19000 kJ / kg);
• Pellet presses with a flat mold with which the pellets tested were produced in order to determine the lower calorific power (presses designed and manufactured by IHP in collaboration with the companies TEHNIC ECO and ROLIX, partners in the project "Eco-innovative technologies for biomass waste recovery", under Operational Program Competitiveness 2014-2020) meet the technical-functional parameters imposed for this type of equipment; the pellets meet the quality criteria of the standards in force regarding the physical-mechanical properties (diameter, length, bulk density, mechanical strength);

• The humidity significantly influences the lower calorific power and the quantity of the combustible substance found in the densified biofuels; for the same type of biomass, the difference of 1.02% humidity determines the decrease of the lower calorific value by 0.60 MJ / kg and the increase of the quantity of the fuel substance burned by 4.67 g / kg.

Acknowledgments

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From Classical Systems Thinking to Modern Dynamic Systems Theory: Beyond the Definitions and Conceptual Delimitations

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Abstract: *The present paper presents practically an introduction to the Modern Dynamic Systems Theory and the analysis of dynamic systems behaviour, exposing a series of information that is accessible to any reader without requiring any particular notions. The study undertaken as a mixture of theory and practical examples of definitions is dedicated to familiarizing the reader with the diversity of fundamental concepts and developmental stages specific to the General (classical) Systems Theory and to review the definitions and characteristics of the existing systems in the specialized literature.*

Keywords: *Systems Thinking, Systems Theory, Dynamic Systems Theory, conceptual delimitations.*

1. Introduction

Systems Theory is still a very current field of science; in this area, many articles have been published in the specialized magazines and many books in prestigious publishers. For this reason, however advanced the modern means of information (documentation, analysis and interpretation) may be, it is practically impossible to keep up-to-date information in this area, to select and write this information in a form easily accessible to the general public.

To write about a very topical field, such as Systems Thinking, Systems Theory or, as the case may be, Modern Dynamic Systems Theory, is, from this point of view, a great risk, because, by its dynamic nature, information is usually at least partially outdated at the time of publication. Aware of this shortcoming, we tried to arouse the interest of the general public for a current field of science through this paper, by synthetically exposing, at a theoretical level, what we have perceived to be systems, in general, and dynamic systems so far, in particular.

Without constituting a popularization study, the present material sets out besides a series of theoretical statements, which are still taught in some Romanian technical faculties, with reference to Systems Thinking and Systems Theory and their characteristics, and a series examples that come to illustrate the theory.

The Systems Theory, together with its consequences, is reflected in the current technical sciences, as a new point of view, as a new integrative approach. Until recently, some researchers believed that the secrets of nature are in the microcosm and have gone on to discover elementary particles of matter (energy and information carriers), while others have searched in the macrocosm, in the world of galaxies, black holes and other formations in the huge universe, both of them leaving the environmental world we still live in, because they have considered that are at the top of modern research, disregarding the research of those dealing with the environmental world research.

The present paper presents practically an introduction to the Modern Dynamic Systems Theory and the analysis of their behaviour, exposing a series of information that is accessible to any reader without requiring any particular notions regarding the dynamic systems. The study undertaken as a mixture of theory and practical examples is dedicated to familiarizing the reader with the diversity of fundamental concepts and developmental stages specific to the Systems Thinking and Modern Dynamic Systems Theory, relative to the existing systems in literature. Also, we found interesting here, as a natural place, to present even a non-exhaustive classification of the systems, respectively of the models, depending on their linearity, the relation to the time variable, the number of input-output variables or the behaviour in time (evolution). The problems associated with different types of systems and the necessity of studying dynamic systems, as well as the implications of dynamic behaviour analysis, are also reviewed in virtue of systems dynamics.

2. Systems Thinking vs. Modern Dynamic Systems Theory - the current state of knowledge

2.1 Background & conceptual approaches

Since ancient times, from the Babylonians, natural and social phenomena have been present in the daily scientific activities of researchers, engineers and mathematicians alike [1, 2], and as the human society has evolved, especially from a technical and scientific point of view, their importance in the complex system of human civilization has continuously increased [3, 4].
In this sense, the new information and communication technologies, which are in the process of developing, through the contribution of knowledge, have led to overcoming and dismantling the separating barriers - the time and space are no longer insurmountable obstacles to communication and relationship - as references to the Super Smart Society [5-7], composed by Information, Knowledge and Consciousness Society (see Fig. 1) [8-10].

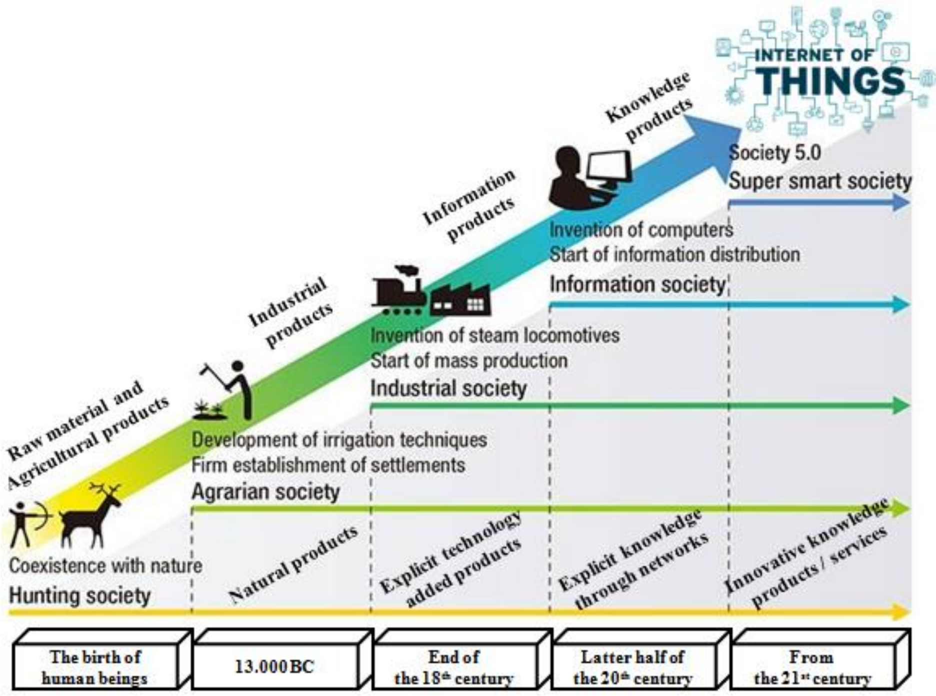

Fig. 1. Evolution of societies from the Hunting Society to Super Smart Society [10]

The study of natural and social phenomena has gradually led scientists to create mathematical representations (e.g. models) that embody their main features and characteristics in an abstract formulation. Long-term surveys have shown that both natural phenomena and social phenomena are evolutionary phenomena, with their own specific dynamics [3, 4]. The consecrated fundamental methods of research in the field of natural and technical sciences are therefore observations and measurements, concepts that are at the core of natural and technical sciences (see Fig. 2) [11-13].

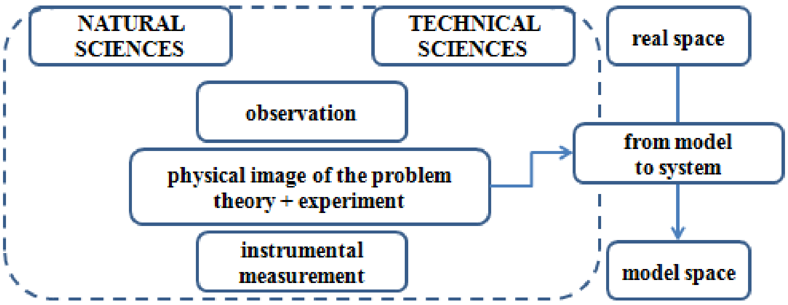

Fig. 2. Observation and instrumental measurement in relation to natural and technical sciences [4]

Starting from the identified observations, the researcher builds, first of all, a physical image of the problem that he analyzes and only then formulates a theory, that is, a concept about the aspect of the analyzed environment, which can take any form, based on the different scientific approaches of the actual system under consideration (see Fig. 3).

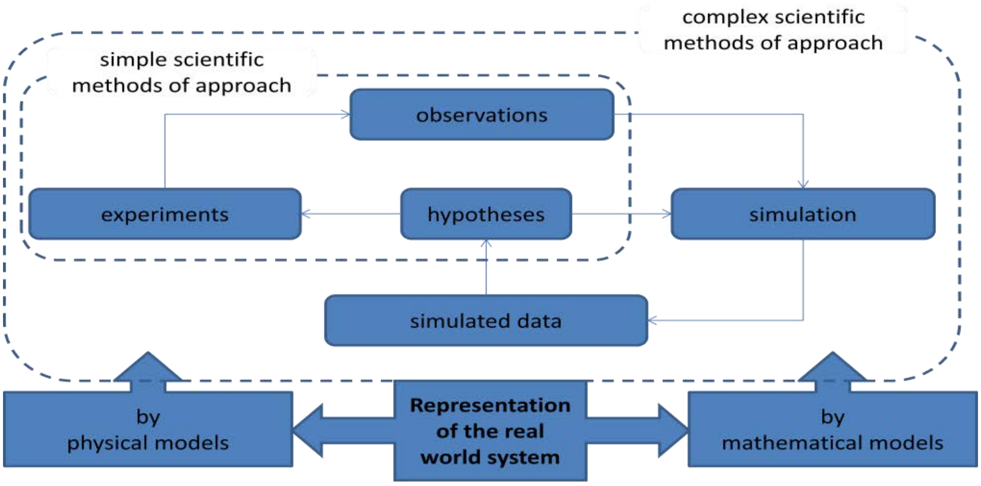

Fig. 3. Different types of scientific approaches of the real world system

Further, based on thoughtful and judiciously constructed experiments, results are obtained that can confirm the theory, determine its changes or reject it, as a result of the thinking and action plan, both defined based on inter- and transdisciplinary approaches (Fig. 4), specific to our days [13]. Based on the above arguments it can be stated that, within the vast field of research specific to the natural and technical sciences, observations and measurements (experiments) are fundamental elements, which come in the natural complement of the General Systems Theory (GST) [14, 15].

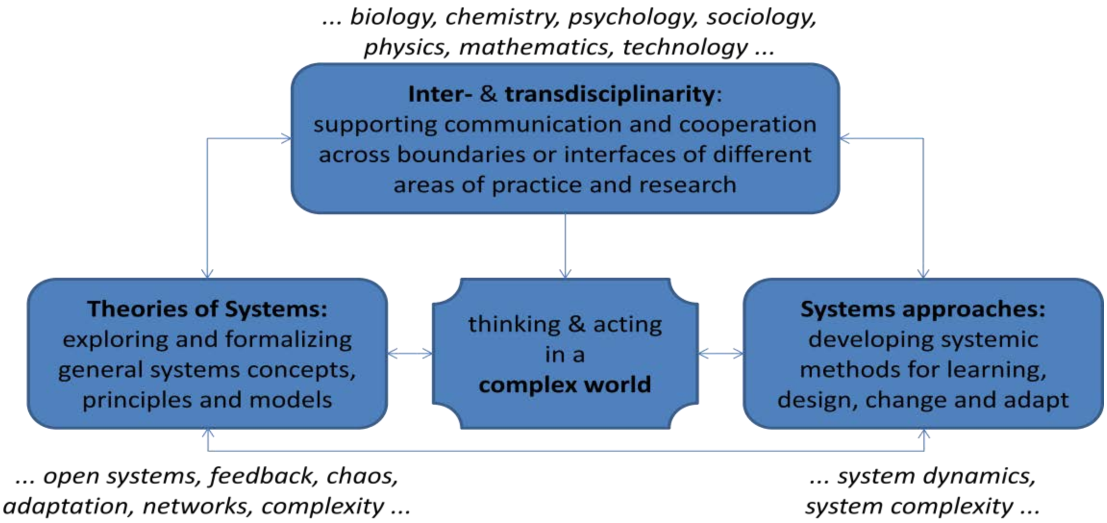

Fig. 4. Different types of scientific approaches of the real world system in relation to "Theories of Systems"

The General Systems Theory of as a field of research, by itself, follows the study of the properties of various types of systems [16], or "systemic approach" [17-20], as well as the enunciation of sets of principles [21-23], independent of domain, substance, type or time [11, 24].
By the emergence of the General Systems Theory, which includes Systems Theory (both classical and modern, respectively post-modern), the ways of designing and developing the modelling of the environment or of the various structures considered have been opened. The General Systems Theory is also the result of the symbiosis between applied mathematics and systems science, known in the literature as "Systemology" (as presented in Fig. 5).

Its origins, as a mathematical theory (see Fig. 5), are especially situated in complexity theory, thus, through the multidisciplinary vision and the use of mathematical language, complexity theory constitutes the matrix of GTS evolution. As an interdisciplinary epistemological model GTS represents a "*set of concepts, knowledge, methods and principles of independent applications, necessary and useful for the study of the structure, properties and characteristics of systems with variable degree of complexity*" [12].

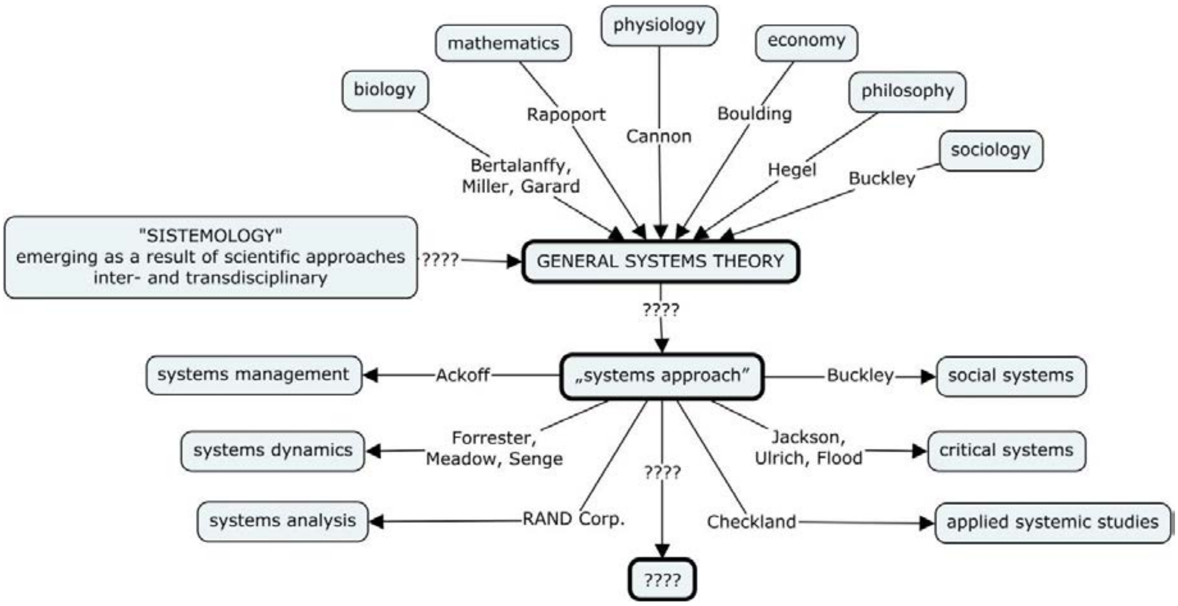

Fig. 5. The position of "Systemology" in relation to "General Systems Theory"

The GTS concept used in different scientific environments, such as computer science, physics, electrotechnics, pedagogy, chemistry, geography, biology, mathematics, physiology, sociology, psychology, ethnology, ecology, computer science and so on, has undergone a well-defined development, through the scientific approaches of the numerous promoters, some of them being reviewed in Fig. 6.

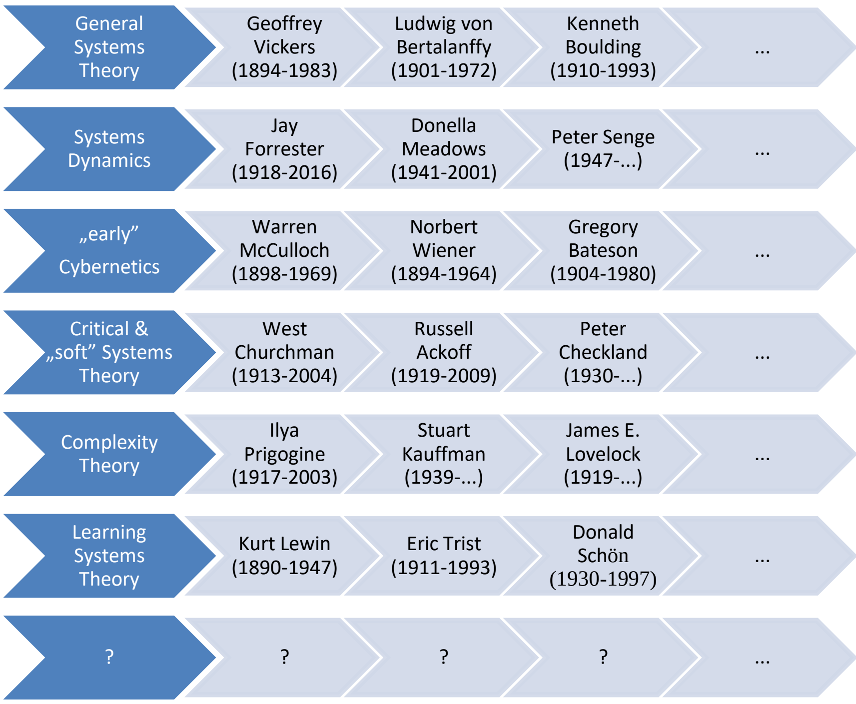

Fig. 6. General Systems Theory in relation to the "promoters of Systemology"

Having the abstract system as object of study, separated from its concrete physical nature, the GTS, which interlocks, at times, with the Complexity Theory and also has links with the Chaos Theory, the Adaptability Theory etc., is a "field of study that harmoniously combines the phenomenological aspects of real systems, as well as the mathematical elements needed to describe the behavior and dynamic interaction of systems" (see Fig. 7).

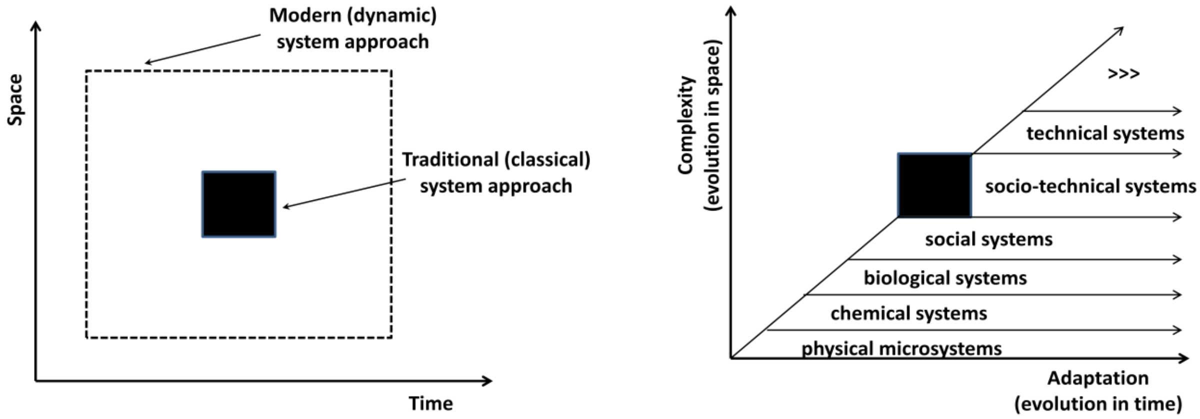

Fig. 7. "Systemic approach" - schematic representation and in relation to various "systems"

In the previous context, the Systems Thinking is by itself a part of GST, which study systems derived from their concrete forms; the extraction is done by retaining the essential components, the defining ones, from each type of system. Thus, in the GST one starts from the conception that a system is "a complex of interacting elements"; the system is highlighted by its internal structure and connections (as in Fig. 8), which constitute a delimited unit with respect to the environment.

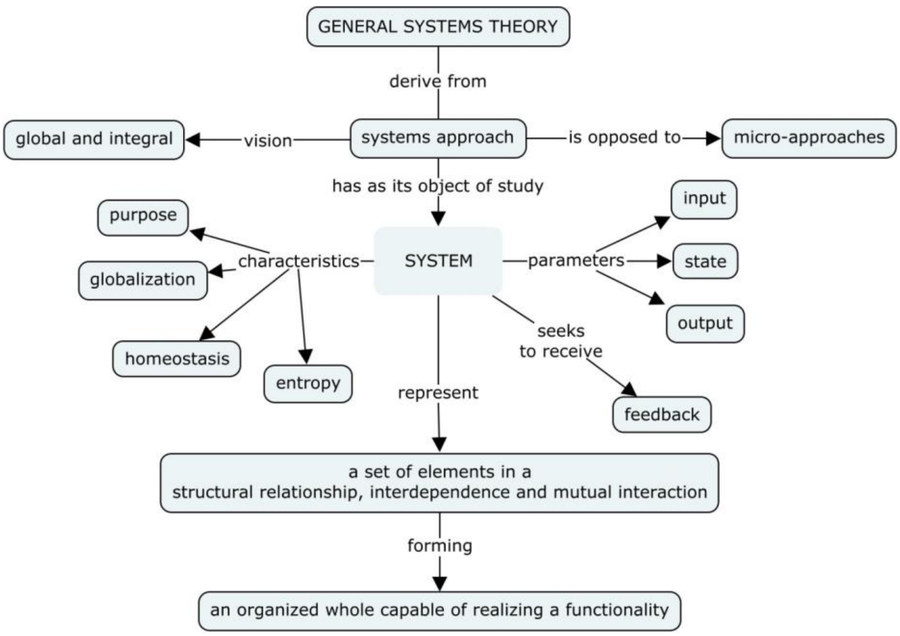

Fig. 8. The "system" as an object of study of the "General Systems Theory"

The systems behavior depends not only on the properties of its elements, but especially on the interactions between them. Similar concepts, appearing simultaneously and autonomously, in various scientific fields have led from the concept of *static system* to that of *dynamic system*, respectively from the formulation of laws governing the whole set of systems to the discovery of isomorphisms between various systems existing in nature and technique. Modern Dynamic Systems Theory introduces, a logical, so-called systemic scientific way of thinking, based on the *principle of causality*, which allows the inter- and transdisciplinary approach of the surrounding reality, respectively the "*compact sets of entities that interact and be like one*".

2.2 A few system approaches & definitions

One of the major breakthroughs in understanding the complexity of the world is the field of Modern Dynamic Systems Theory (MDST). The field studies systems from the perspective of the whole system, its various subsystems and the recurring patterns in the relationships between the subsystems. MDST has greatly influenced how we understand, change and adapt our organization system, based on different systems approaches [27].

The systems approach has a few caracerisics ...

- considers two basic components: elements and processes. Elements are measurable things that can be linked together. They are also called objects, events, patterns, or structures. Processes change elements from one form to another. They may also be called activities, relations or functions. In a system the elements or processes are grouped in order to reduce the complexity of the system for conceptual or applied purposes.
- distinguishes itself from the more traditional analytic approach by emphasizing the interactions and connectedness of the different components of a system.
- emerged as scientists and philosophers identified common themes in the approach to managing and organizing complex systems.

Four major concepts underlie the systems approach:

- *specialization*: a system is divided into smaller components allowing more specialized concentration on each component;
- *grouping*: to avoid generating greater complexity with increasing specialization, it becomes necessary to group related disciplines or sub-disciplines;
- *coordination*: as the components and subcomponents of a system are grouped, it is necessary to coordinate the interactions among groups;
- *emergent properties*: dividing a system into subsystems (groups of component parts within the system), requires recognizing and understanding the "emergent properties" of a system; that is, recognizing why the system as a whole is greater than the sum of its parts.

An extremely important notion, for the following approaches, which subscribes to the GST, is the notion of *system*. As it was natural, the notion of system appeared and developed over time, as a result of highlighting common features and behaviors for a number of processes and phenomena in different fields, which allowed their identification, analysis and treatment, from a structural-functional point of view, and not only, in a unitary way, from a emergence perspective (see Fig. 9).

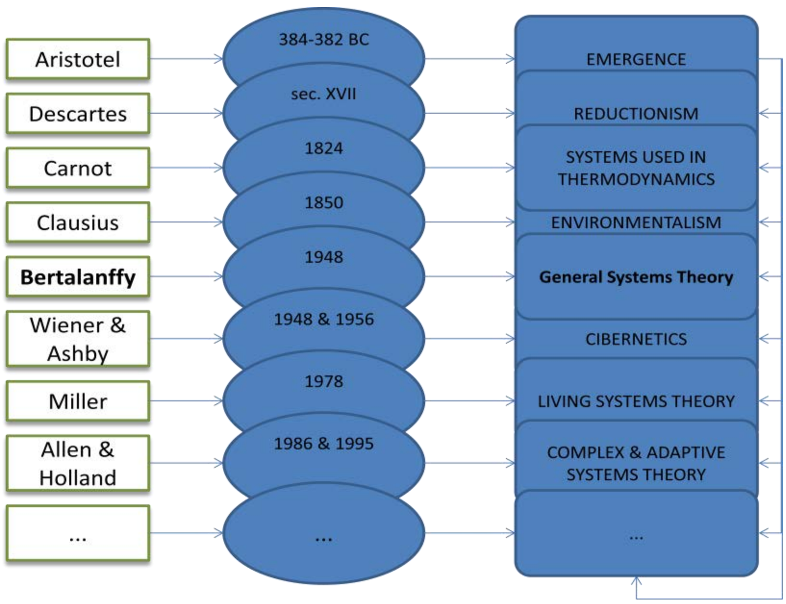

Fig. 9. The "system preoccupation" starting from the definition of the "emergency"

The system, at least from a strictly conceptual point of view, appeared in an embryonic form, for the first time, in ancient Greek philosophy, thus, stating that "*the whole is more than the sum of the component parts*", Aristotle was the one who gave a first definition of the system.

In the specialized literature there are various definitions of the concept of system, some reflecting the tendency to define the system in a broader generality, others the tendency to particularize to a certain domain of knowledge. The system can be defined as "*any set organized by resources or procedures in interaction or interdependence, real or abstract, for the realization of a set of specific functions*" [12], respectively in [13] as a "*set of elements that work and interact with each other and with the outside according to certain rules. and laws, in order to achieve a meaning or purpose*".

By focusing on the entire system, we can attempt to identify solutions that address as many problems as possible in the system. The positive effect of those solutions leverages improvement throughout the system. In that case, a system is defined as ...

- "(...) a collection of elements or components that are organized for a common purpose; the word sometimes describes the organization or plan itself and sometimes describes the parts in the system."
- "(...) an organized, purposeful structure that consists of interrelated and interdependent elements (components, entities, factors, members, parts etc.); these elements continually influence one another (directly or indirectly) to maintain their activity and the existence of the system, in order to achieve the goal of the system."
- "(...) a set of things working together as parts of a mechanism or an interconnecting network; a complex whole."
- "(...) a collection of parts which interact with each other to function as a whole. Therefore, systems have a purpose as a whole and the whole is not the pure sum of the parts of the system. From systems we have also the concept of synergy, that is the mutual interaction of the parts is more worth than the sum of the individual parts."
- "(...) an entity that maintains its existence through the mutual interaction of its parts."
- "(...) any set (group) of interdependent or temporally interacting parts; parts are generally systems themselves and are composed of other parts, just as systems are generally parts or components of other systems."
- "(...) a combination of components (elements) that act together to perform a certain objective; it contains of interacting components connected together in such a way that the variation in one component affect the other components."

All systems have (a) inputs, outputs and feedback mechanisms, (b) maintain an internal steady-state (called homeostasis) despite a changing external environment, (c) display properties that are different than the whole (called emergent properties) but are not possessed by any of the individual elements, and (d) have boundaries that are usually defined by the system observer.

The system concept is known to us and we frequently use it in everyday life. We often talk about economic, political, social, philosophical, and technological systems. We are also familiar with particular systems, such as the monetary system, computer systems, communications systems, etc. [4]. In the literature, there are several definitions for the concept of system, some reflecting the tendency of defining the system in a general scope, others the tendency to customize for a certain area of knowledge. The notion of system therefore has a broad scope, being frequently encountered in science and technology in all fields of human thinking and action, but it is almost always associated with a specification attribute. For example, phrases such as "automatic system", "transmission system", "information system", "signaling system", "production system", "social system" [1, 4] are used as special terms, in the same way as in the context of dynamic system.

A dynamic(al) system is defined as ...

- "(...) a concept in mathematics where a fixed rule describes the time dependence of a point in a geometrical space; the mathematical models used to describe the swinging of a clock pendulum, the flow of water in a pipe, or the number of fish each spring in a lake are examples of dynamical systems."
- "(...) a state determined by a collection of real numbers. Small changes in the state of the system correspond to small changes in the numbers. The numbers are also the coordinates of a geometrical space - a manifold."
- "(...) a system that have a response that is not instantaneously proportional to the input or disturbance and that may continue after the input is held constant, so the system is not in a equilibrium state."

- "(...) a system for which the present output depends on the current and the previous input, and can respond to input signals, disturbance signals, or initial conditions."
- "(...) a system whose state evolves with time over a state space according to a fixed rule."
- "(...) a system or process in which motion occurs, or includes active forces, as opposed to static conditions with no motion."

Considering the definitions from above, in the analysis of any system it must be taken into account that it cannot be separated from the environment to which it belongs as a subsystem, and that one system only functions as a subsystem within another more complex system [28]. The detachment of a system from its environment can only be realized as an abstraction technique, the existence of a system itself takes place through a permanent exchange of substance, energy and information, which takes the form of the inputs and outputs of the system.
Knowing a system based on the methodology of system analysis, means and involves, first of all, the study of system inputs and outputs, as well as the concrete ways in which inputs are transformed into outputs, in other words the functionality of the system [28]. The inputs and outputs of a system, analyzed as causal relationships between subsystems, form the structural-functional connections between them, and the study of these connections is of interest for identifying the behavior that the system presents over time.
As we have already mentioned, systems theory operates with the concept of abstract system, in the form of a mathematical model, which allows the description of the characteristics and behavior of systems. Below we highlight some basic features of the systems, respectively:

- the structural-unitary character reflects the property of a system to be represented as a connection of subsystems whose action is oriented towards a certain meaning (purpose);
- the causal-dynamic character reflects the property of a system to evolve in time under the action of internal and external factors, respecting the principle of causality (according to which, any effect is the result of a cause, the effect is delayed to the cause and, in addition, identical causes generates the same effects under the same conditions);
- the informational character reflects the property of a system to receive, process, store / store and transmit information.

In the sense of systems theory, information means any factor that contributes qualitatively and / or quantitatively to the description of the behavior of a system. In technical systems, the physical quantities used as a support for the transmission and storage of information are called signals.
The variables associated with a system, regardless of its nature, have two essential properties, namely the mediation of the input-output transfer (I→O), which thus becomes an input-state-output transfer (I→S→O), respectively of accumulation in a concentrated (synthetic) form of all the useful information regarding the previous evolution of the system, that is to say of the past history of the system, being of three types:

- input variables - independent system sizes (so of type cause), which influence from outside the system status and evolution;
- state variables - quantities dependent on the input quantities (thus effect type), having the role of characterizing and describing the current state of the system;
- output variables - sizes dependent on the state and / or input (so effect type) sizes, having the role of transmitting information about the current state of the system (especially to neighboring systems); some output sizes may be state sizes at the same time.

A system interacts with neighboring systems only through input and output sizes. Output sizes of a system are input sizes for neighboring systems. Output sizes of technical systems are measurable, while status sizes are not always accessible for measurement.

3. Conclusions

According to Systems Thinking, the structure of a system, regardless of its form of representation, is characterized by the elements of the system, the properties and the relationships between them. Classic systems theory (General Systems Theory, GST) operates with type I-O systems, while modern and post-modern systems theory (MDST) operate with type I-S-O systems. An abstract system (model) of type I-S-E and an abstract system (model) of type I-E can be associated to a physical or a real system, often subjected to disturbances or excitations.

It should be noted, however, that the system response is not uniquely determined by excitation. For example, the current charged by a capacitor depends both on the value of the voltage applied to the terminals, but also on the electrical charge existing in its dielectric when the voltage is applied. It turns out that the system also depends on a third size, called its state when the excitation is applied. The knowledge of the general and specific properties of the systems is particularly useful in the investigation, analysis, modeling and design phases of the systems.

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