Examining Fire Pump Metz FP 24/8 on Cavitation

Assist. Prof. PhD. Stud. Eng. **Nikolett FECSER**[1], Assist. Prof. PhD. **Rajmund KUTI**[2]

[1] Széchenyi István University, Department of Mechatronics and Machine Design H-9026 1 Egyetem tér, Győr,fecser.nikolett@sze.hu

[2] Széchenyi István University, Department of Mechatronics and Machine Design, H-9026 1 Egyetem tér, Győr, kuti.rajmund@sze.hu

Abstract: *For the safe operation of pumps, it is essential to examine the operation parameters, in particular regarding fire pumps, which are occasionally used under extreme conditions. Operation deviating from the operational parameters defined by the manufacturers would damage the pumps. The majority of specialists who are experts at pump technology and fluid mechanics are familiar with cavitation and aware of its detrimental effects. Our goal is to call the attention to the proper way of the operation of centrifugal pumps, the cavitation generated during operation as a harmful phenomenon and its development examined in practice by us. Firstly, in our study we will briefly present the cavitation as a phenomenon taking place during operation and its counting method. Then we state the results of our measurements carried out during the operation of a pump built in a fire engine type Metz FP 24/8.*

Keywords*: Operation of a pump, centrifugal pump, operational parameters, cavitation, NPSH*

1. Introduction

In order to maintain an uninterrupted water supply and to achieve effective firefighting, it is vital to ensure the safe operation of fire pumps. Factors like terrain, the conditions of the places to obtain water from and the quality of water highly influence the performance of the pumps, which can change significantly and alter from the expected values. Operation not in conformity with the standards recommended by the manufacturer can result in a decline in performance or a failure of the pump. Cavitation is one of the phenomena which causes pump failure and whose development we monitored in our practical tests. Before presenting our measurements, we find it important to give a short introduction to cavitation and the mathematical basis of its calculation to help a better understanding of the topic. We believe that publishing our experience contributes to the safe operation of fire pumps.

2. Defining cavitation

The available scientific literature provides several definitions for cavitation. István Józsa claims that the physical process of cavitation is linked to the phenomenon of the boiling point, because if saturated steam pressure corresponding to the temperature develops at a given location in the flowing fluid, there the fluid turns into vapour and a bubble filled with steam evolves. The head space of the bubble is condensed of the flow travels the vapour cavity (i.e. bubble) into a location of higher pressure and the bubble implodes as a result of the thus created vacuum. This bubble implosion is called cavitation [1]. According to another definition, cavitation takes place when the gas bubbles developed in the fluid suddenly collapse. This process takes place at those locations in the pump where the pressure is subjected to the vapour-pressure of the pumped medium. Vapour-pressure of a fluid is a kind of pressure at which the fluid starts boiling or vaporising. Cavitation, which may cause even serious damage to the pump, occurs when the Net Positive Suction Head (NPSH) needed for the pump is not available [2]. Intense shock waves, various sound effects (cracking, flapping and sometimes howling sounds), changed fluid mechanics characteristics, significant decline of performance and mechanical errors belong to the detrimental effects of cavitation. Cavitation has a decisive effect on the pump's ability to suck as well. During the operation of the pump, the fluid entering from the suction pipe to the impeller has the lowest pressure here.

When cavitation occurs at this location, the flow pattern of rotating pump wheel changes along with the pump characteristic curves. [3].
Cavitation is divided into two classes:

- Physical cavitation: a smaller type of cavitation occurs under normal operational conditions in holes or due to detachments caused by collision. Its effects can be tracked down by noise and smaller erosive dissolutions. The effects are undetectable in the pump characteristic curves and do not cause reduction in transfer or a decline in efficiency.
- Mechanical cavitation: causes "detachments" in the pump characteristic curves and the operation of the pump becomes chaotic.

Cavitation can occur in the course of operating pumps used by firefighters. In the initial phase well-detectable noises develop, then continuously stronger and stronger shockwaves and vibrations are forming in the fluid and the travelling systems. Since the fluid has a minimum pressure at the leading edge of the impeller from the direction of the suction pipe, this is the location where cavitation may occur the earliest. The decrease of suction depth, applying suction pipes with a narrow diameter, resistance emerged in the suction pipe or an increase in the temperature of the fluid all contribute to the emergence of the phenomenon. [4].

2. 1. The mathematical basis of cavitation

Manometric suction head value

$$H_{sm} = \frac{p_0 - p_1}{\rho \times g} = A_0 - h_1 = H_{sg} + h'_s + h_c \quad (1)$$

Table 1: Labels

Name	Signal	Unit of Measure
Manometric suction head	H_{sm}	m
Atmosphere	p_0	bar
Pressure measured in suction pipe in front of the impeller	p_1	bar
Saturated steam pressure	p_g	bar
Amount of pressure drop	Δp	bar
Water density at 20°C 998.23 kg/m^3	ρ	kg/m^3
Gravitational acceleration 9.81 m/s^2	g	m/s^2
Height of atmospheric pressure	A_0	m
Pressure at blades entering	h_1	m
Geodetic suction depth	H_{sg}	m
Frictional and hydraulic resistance of suction pipe	h'_s	m
Geodetic suction height	h_c	m
Blade depression value	Δh	m

$$A_0 = \frac{p_0}{\rho \times g} \quad (2)$$

$$h_1 = \frac{p_1}{\rho \times g} \quad (3)$$

$$h_g = \frac{p_g}{\rho \times g} \quad (4)$$

$$h_c = \frac{{c_1}^2}{2g} \quad (5)$$

$$H_{sm} = \frac{p_0 - p_1}{\rho \times g} = A_0 - h_1 = H_{sg} + h'_s + NPSH_{pump} = \Delta h + h_c \quad (6)$$

$$NPSH_{pump} = \Delta_h + h_c \quad (7)$$

$$\Delta h = \frac{\Delta p}{\rho \times g} \quad (8)$$

$$NPSH_{system} = A_0 - H_{sg} - h'_s - h_g \quad (9)$$

The condition of a cavitation-free operation:

$$NPSH_{system} \;>>>> NPSH_{pump} \quad (10)$$

3. Introduction to Measurement

Our measurements were carried out on field and we used the Csepel-Metz TLF 24/50 type heavy-duty truck fire hose illustrated in Figure 1 into which a Metz FP 24/8 centrifugal pump was inbuilt whose drive is ensured by the engine through the driving mechanism mounted on the gear box. In our measurement we gradually increased the performance of the pump under the conditions determined by us, then we provoked cavitation and measured the change in the performance of the pump.

Fig. 1. Csepel-Metz TLF 24/50 heavy-duty truck fire hose and the inbuilt FP 24/8 type pump (Sources: Authors' photos)

3.1. The tools applied for the measurement

In accordance with the regulations applied by fire departments, standard fire-fighting equipment and pressure hoses were used during the measurement. 1 piece of suction hose "A" of d=110 mm internal diameter, 4 pcs of pressure hoses "B" of d=75 mm internal diameter, 8 pcs of pressure hoses "C" of d = 52 mm inner diameter and 4 pcs of 75/52 quadruple stands were applied during the installation. The amount of water carrying through the hoses was measured by a MOM 4233 type certified flow meter (fire hydrant pitot tube) and the amount of water exiting the nozzle was measured by CSSZ C52 type flow meter. In the case of the rest of the water streams we applied 7 pcs of standard curved hoses fitted with a manual shut-off valve and the diameters of its nozzle equals to the diameter of the nozzle of the measuring hose.

3.2. Measuring nominal fluid flow and cavitation

Regarding fire pumps, the manufacturing companies measure the flow performance of the pumps under laboratory conditions creating an optimal operational environment. The nominal fluid flow of the Metz FP 24/8 type fire pump examined by us is Q = 2400 l/p, at H_{sg} = 1.5 m suction depth. In the course of firefighter interventions the operational conditions of the pumps are not optimal in most cases, thus flow performance alters. So we found it crucial to measure the nominal fluid flow of the pump under the conditions we provided. The pump measured by us has 1 pc of intake manifold "A" of d = 110 mm inner diameter, 4 pcs discharge manifolds "B" of d=75 mm inner diameter and 1 pc of water cannon with carrying Q=1600 l/p fluid. During the measurement we used 4 pcs of fire hose "B" and 8 pcs of fire hose "C", 4 pcs of stands, 7 pcs of standard, 1 pc of fire hydrant pitot tube and 1 pc of flow meter. We stood the fire engine by a pool used for storing firefighter-water and the intake manifold of the pump got connected to the connection point built for suction by 1 piece of suction hose "A". The water level was set 1.5 m above the centre line of the pump shaft. All the four discharge manifolds of the vehicle were assembled with multiple streams, 1 pc with hose B and 2 pcs with hose, C each of d=52 mm inner diameter. A flow meter type MOM 4233was built into one of the main hoses. A flow meter type CSSZ C52 with a d = 16 mm inner diameter nozzle was connected to the first stream. The flow meter is fitted with a certified pressure gauge, which comes with a factory catalogue. The catalogue makes the mating of discharge pressure and the belonging water amount easy, which simplifies the process of our measurement and calculating with losses generated in the hoses is unnecessary. Since the fire hose nozzle jet we applied is identical with the jet mounted on the flow gauge, the amount of water discharged at each stream can be taken as equal. Figure 2 shows the arrangement we set and made the firefighting system operate, and the tools were marked by the conventional signs of the fire-station.

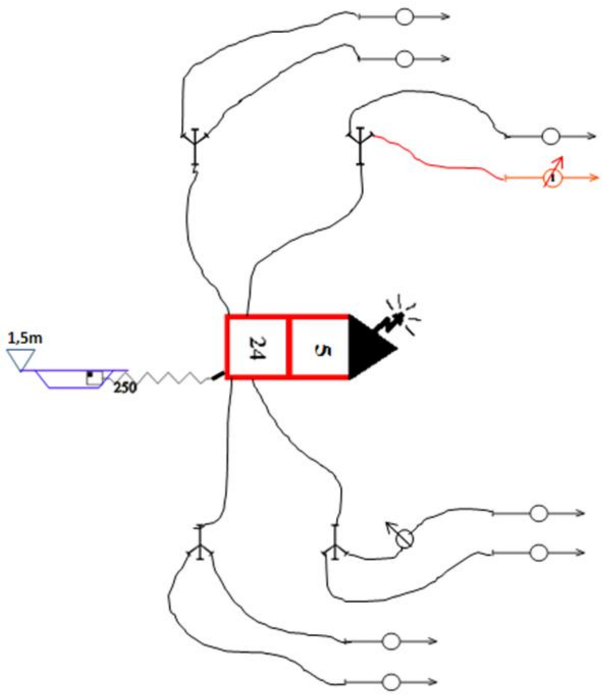

Fig. 2. The design of the firefighting system operated by the authors (Source: Illustration by the Authors)

The streams were operated at the height of the pump as shown in Figure 3.

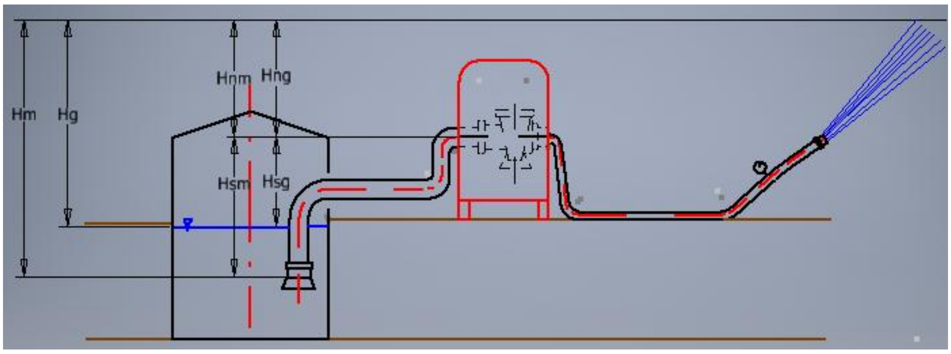

Fig. 3. Process of measurement (Source: Illustrated by the Authors)

We determined a 5 bar outlet pressure of the pump i.e. in the course of the actual firefighting the firefighters work with such pressure. First we put the stream mounted on the flow gauge into operation and gradually increased the pump performance up to 5 bar. Table 2 and Figure 4 illustrate the changes of the flow rate in the case of the first stream.

Table 2: The flow rate changes of the first stream

Pressure [bar]	Flow rate [l/min]
0	92
0.5	131
1	164
1.5	198
2	231
2.5	257
3	283
3.5	306
4	328
4.5	347
5	366

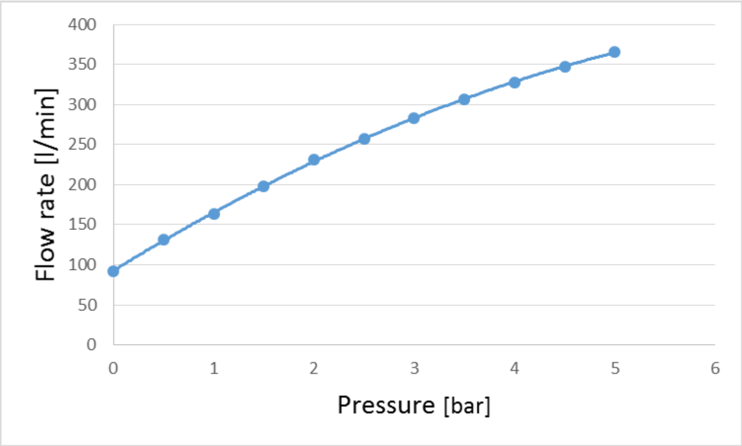

Fig. 4. The flow rate changes of the first stream (Source: Illustrated by the Authors)

Reaching the 5 bar outlet pressure, we also measured an approximately 5 bar pressure at the nozzle. Next, opening the closing devices slowly, we put the streams into operation one by one. The outlet pressure of the pump and the streams started to decrease continuously. After putting the 8th stream into operation, the pressure of the discharged water at the nozzle was 3 bar with 283 l/p water output set in the catalogue, which meant 2264 l/p water output totally calculated with the 8 operating streams.
Our next task was to increase water flow up to reaching 5 bar pressure, then the appearance of cavitation. Finishing the measurement, the pump was kept operating 8 streams. The refilling of the water storage tank was continuous in order to keep the 1.5 m suction depth. First, we decreased the revolution of the pump until it reached 1 bar discharge pressure to be able to draw a precise operational diagram, then we started to increase the revolution. Water flow was measured continuously and its measurements are recorded in the following table. Before reaching 4 bar pressure, the pump started to produce a rattling noise and suction pressure dropped below 0.06 bar. We continued to increase the revolution and the discharge pressure reached 4 bar. The pump grew louder and louder emitting crackling sounds and the discharge pressure dropped below 2 bar, then after a short period of time it started to decrease, then dropped back again. By that time cavitation had appeared. Discharge pressure reached 4 bar at the water flow meter for a short

period of time and the water quantity belonging to this value was 328 l/p in the catalogue and operating with 8 streams, the performance of the pump was 2624 l/p. To avoid damages, we started to decrease pump rev and finally stopped it. Figure 5 shows the values measured at the pump and the nozzle at the time of cavitation [6].

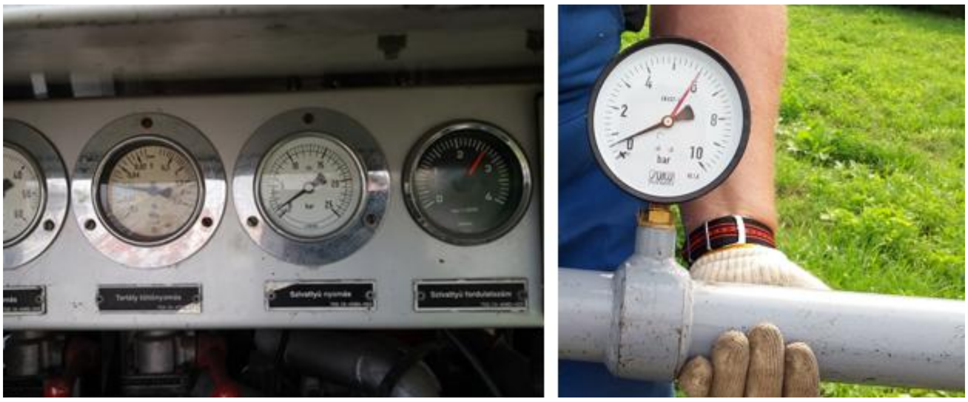

Fig. 5. The measured values on the Metz FP 24/8 type fire pump and the pitot tube at the moment of the cavitation (Source: Authors' captures)

Table 3 is a demonstration of measurement results of operating 8 hose streams.

Table 3: Measurement results

Pressure [bar]	Elevation head [m]	Flow rate [l/min]
0	160	0
1	150	500
1.5	135	1312
2	115	1848
3	100	2264
4	75	2624
1.6	40	2650

Based on the measured values the characteristic curve of the operational process can be drawn. The following diagram illustrates the characteristic curve of a pump type FP 24/8. The appearance of cavitation in the pump was by a loud noise, there was a sudden drop in the pressure, due to which the characteristic curve broke down.

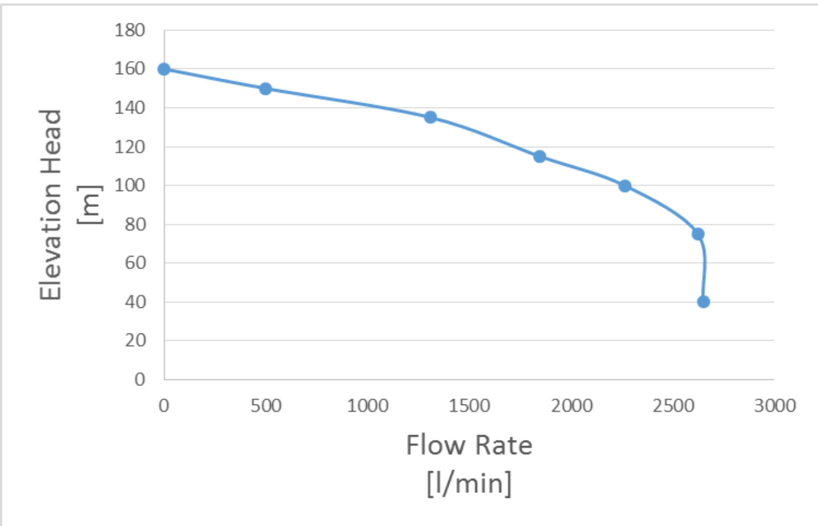

Fig. 6. Characteristic curve of a FP 24/8 type pump (source: Authors' design)

In order to justify cavitation we made calculations as can be seen below.

$$NPSH_{pump} = \Delta_h + h_c = 15.252\,m \tag{11}$$

$$NPSH_{system} = A_0 - H_{sg} - h'_s - h_g = 5.857m \tag{12}$$

$$NPSH_{system} <<< NPSH_{pump} \tag{13}$$

Our calculation shows that cavitation was generated in the system. We concluded that due to the appearance of cavitation it is not possible to achieve 5 bar pressure with operating 8 streams and applying feeding with suction. If the usage of 8 streams is inevitable during the firefighting activity, along with the pump type Metz FP 24/8 another pump is needed to be inserted into the system and connected in series to reach the required pressure and water quantity regarding all the streams [7].

4. Conclusion

During the course of our research, in order to examine cavitation, we used a Csepel-Metz TLF 24/50 heavy-duty truck fire hose, into which a Metz FP 24/8 type centrifugal pump is built. We conducted measurements in field creating a realistic firefighting environment. The scientific examination of cavitation assists manufacturers and users to avoid this undesirable phenomenon, which can lead to the failure of the pump. Its possible solution is to determine the NPSH parameter and to take it into account when you are choosing and installing the pump and during its operation. We find on field measurements essential, the results of which improve the practical usage of pumps in general. Moreover, these measurements are of high importance in the case of the pumps used for firefighting purposes, where cavitation occurs suddenly and can even negatively influence the success of the fire extinguishing activity and an incidental failure of the pump can result in unexpected costs.

References

[1] Cs. Fáy, Á. Troskolanski, J. Varga, "Szivattyúüzemi kézikönyv", Műszaki Könyvkiadó, Budapest, 1966, pp.11-45;
[2] I. Józsa, "Örvényszivattyúk a gyakorlatban", Invest-Marketing Bt., Budapest, 2013, pp. 108-196;
[3] M. Pázmándy, "A tűzoltás vízellátása", Zrínyi Nyomda, Budapest, 1974, pp. 164-176;
[4] F. Szlivka, "Vízgazdálkodás gépei", 2002, pp. 63-75. Downloaded from: http://www.ontozesmuzeum.hu/1.%20ViZGAZD%20aramlastani%20alapok%20tartalomjegyzekkel.pdf;
[5] B. Író, "A hő- és áramlástan gépei tárgyhoz kapcsolódó szivattyúüzemi mérések lebonyolításához mérési útmutató", Győr, Széchenyi István Egyetem, 2015, pp. 3-19;
[6] METZ FP 24/8 Feuerlöschpumpe Catalogue;
[7] N. Fecser, "Examining the characteristics of Pedrollo_CP130 centrifugal pump in simulated service conditions", *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*, 2017:(2), pp. 40-49.