A NEW MODEL OF PNEUMATIC TRANSDUCER USED IN THE DRYING STAGE OF THE CERAMIC PRODUCTS OBTAINING

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Abstract
For obtaining high-quality ceramic products, the final stage of the production process, the drying, must be realised in good conditions, leading to very low final losses caused by the cracks and cleaves which occur during the burning in the oven. An important parameter of the drying process is the dimensional contraction of the bodies, during drying. For the online control of the drying process and depending on the contraction evolution, it was created a pneumatic transducer, with which can be measured the linear contraction, on a witness body, with a max error of 1%. The transducer performs a conversion linear contraction → pressure, due to the fact that the air presure is not influenced by temperature and the elastic element of the pneumatic cylinder is made from steel, with a slight variation of the elastic properties up to 150^{o}C. The measurement pressure is linearly converted in a tension which is input signal in the PLC which controlls the drying installation. In order to obtain a very low consumption of energy of the measurement system, the transducer works in a sampled operational mode, which may provide a high measurement precision.

Key words: drying, pneumatic transducer, contraction, ceramics

1. Introduction

Drying is a very important operation within the process of manufacture of ceramic products and construction materials. A high quality drying leads to very low final losses caused by the cracks and cleaves which occur during the burning in the oven, as last stage.
The drying time for the average size bricks are relatively high, 36 - 48 h. In all the drying installations it is used a drying agent obtained by mixing combustion gases and atmospheric air. The famous brands (Lingle, Ceric, Rietter, Keller, Fuschs, etc.) deliver technological installations with automatic control systems, which use process models pre-selected depending on the type of brick to be dried and the chemical, mineralogic and physic ceramic properties of the raw clayey materials.
For optimizing the drying process, it must be compensated entirely the influence of the perturbations caused by the composition and granulometry of the bodies subjected to the drying process. The online measurement of the discharged water mass and of the linear contraction of the bodies allows the achievement of high quality products, with minimum energetic consumption and an increase of the real manufacture capacity.

In figure 1 is shown the graphic of the relative variation of humidity W and contraction C of the bricks, during the the drying process.

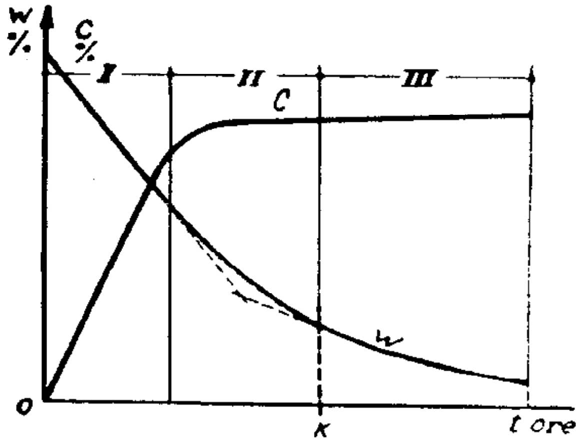

Fig. 1. The relative variation of humidity and contraction at drying of bricks

The relative linear contraction of the ceramic bodies, in the studied case of the bricks, during drying is in the range 6...12% with typical values 6...8%. The measurement of the contraction is made by measuring the variation of the distance between the two anchors introduced in the raw brick before starting the drying process. The common values of the initial distance L_0 for the mechanical measurement devices are $L_0 \in \{100, 150, 200\}$ mm.
During the drying process the body contracts itself and it is measured a closeness of the anchors with ΔL. The relative contraction coefficient ε is calculated with the relation:

$$\varepsilon = 100\frac{\Delta L}{L_0} \quad (\%) \tag{1}$$

Due to the fact that during the drying process temperature varies between 20 and 150 ºC, the anchors and the support mechanism are made of invar. The mechanical devices in use is ponderous and has no output signal for the modern automatic adjustment systems. There are also used resistive displacement transducers with temperature compensation, which are expensive and less reliable.[11]

2. Pneumatic transducer for measuring contraction

In figure 2 is shown the functional scheme of the pneumatic transducer for measuring the linear contraction of the bricks during the drying process and in figure 3, the functional scheme of the control block.

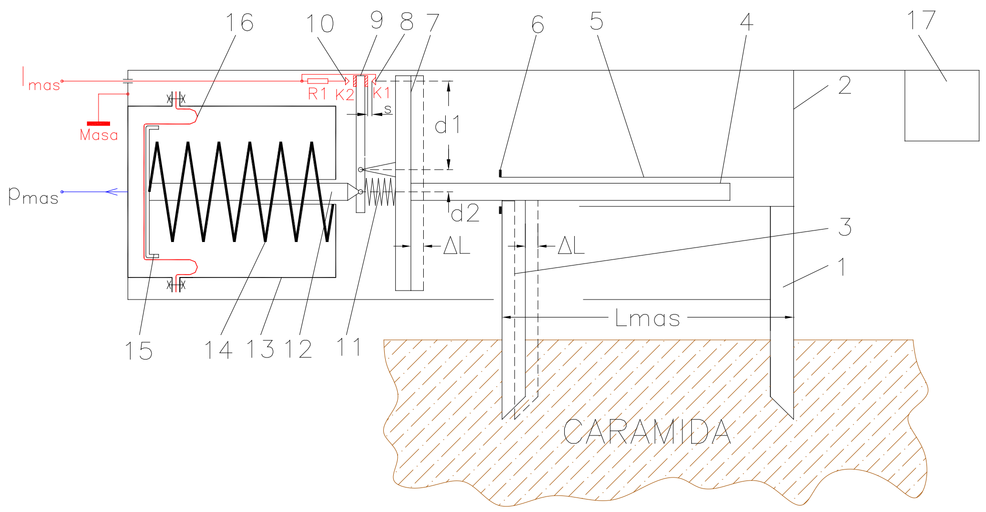

Fig. 2 Functional scheme of the pneumatic transducer for measuring contraction

The absolute contraction is represented by the variation of the distance ΔL between the anchor (1) fixed on the body (2) of the transducer and anchor (3) which is fixed on the rod (4) that slides in the guide (5) on which is the pawl (6). The rod (4) is connected to the support (7) on which is jointed a lever (9) which is pushed continuously by the spring (11) to the fix contact (8) which is at 2s distance of the fix contact (10). The lever (9) is also in contact with the rod (12) of the pneumatic cylinder with simple action (13) that has a membrane (16) which presses on the rigid centre (15) that leans on the spiral spring (14). For having the center of gravity of the device between the 2 anchors, it is mounted a load (17) for balance.
For simplifying the construction it was adopted a scheme with 2 contacts K1 and K2 serially linked to R1, with signal I_{mas} in a current intensity on a single conductor connected by means of R2 at the plus of the supply voltage stabilized U_{st}. The command signal in tension U_{cd} is compared on 2 comparators C1 and C2 with two tensions 0,25 Ust at C1 and 0,75Ust at C2.
The output signals of the comparators CS for writing and CR for deleting are applied to a bistable BIST1 whose output u_1 commands the distributor D1 through which is introduced compressed air in the cylinder (13) through the pneumatic resistance RP. For discharging the air from the cylinder (13) it is commanded through the output command signals CRp and CSp the bistable BIST2 with which is commanded the distributor D2.
The measurement pressure p_{mas} is converted in tension signal with a convertor P/U from which gets out the signal U_{mas}.

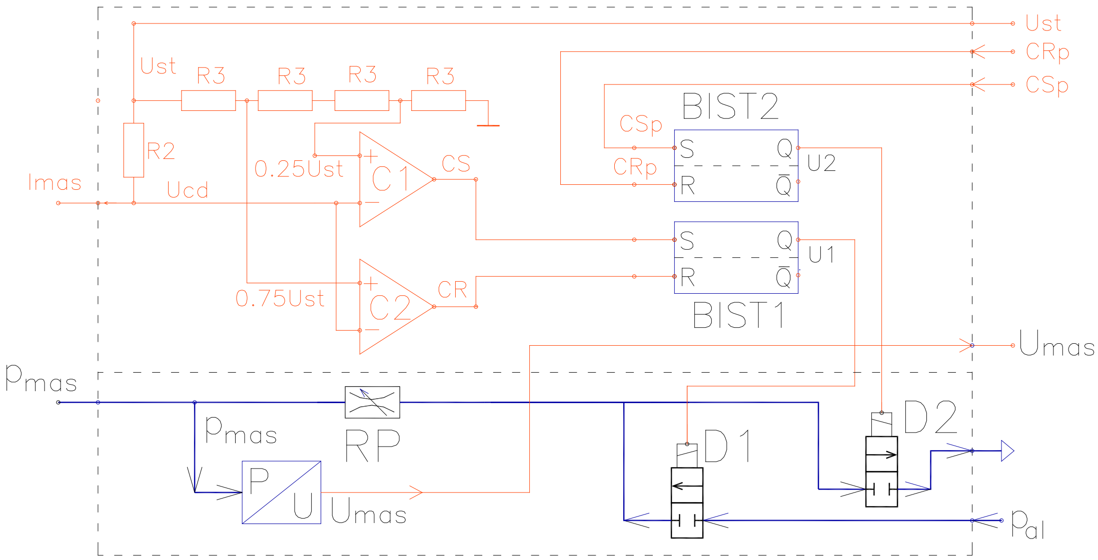

Fig. 3 The scheme of the command block

Initially in the raw brick are plunged the anchors (1) and (3) positioned at the nominal distance L_0. If in the pneumatic cylinder (13) there is no pressure, the spring (14) retracts the rod (12) of the piston and the spring (11) presses on the comparison lever (9) that will rely on the contact K1.
When the contact K1 is shut in the command block is generated a signal u_1=1 of opening the distributor D1; it starts the pressure growth p_{mas}, the rigid centre (15) compresses the spring (14) and displaces the rod (12) until it reaches the lever (9) that it will rotate around the joint until it leans on the contact K2. The command block generates a shut signal $u_1 = 0$ for D1 and p_{mas} stabilizes at a new value p_{mas0} that is the value from which is started the measurement. From the converter p/U results U_{mas0} memorized as origin for measuring contraction.
In the drying process cause of the brick contraction the anchor (3) and rod (4) will displace towards the anchor (1), the spring (11) releases and under the action of the spring (11) the comparison lever (9) rotates itself until the contact K1 shuts. It is generated the signal CS which applied at BIST1 makes that $u_1 = 1$ and D1 it opens. It starts the pressure p_{mas} growth from the cylinder which leads to the compression of the spring (14) and the displacement of the rod (12) that rotates the

lever (9) until the contact K2 shuts, which leads to the generation of a signal CR which applied at BIST1 makes u_1= 0 and shuts D1.
For a displacement with 2s between the contacts K1 and K2 the rod (12) displaces with Δh_{arc}:

$$\Delta h_{arc} = 2 \cdot s \cdot \frac{d_2}{d_1 + d_2} = \frac{2 \cdot s}{i_{pg}} \cdot \qquad (2)$$

where i_{pg} is the transfer factor of the lever 9.
The variation Δp_{mas} of the measurement pressure for a sampling step is:

$$\Delta p_{mas}[i] = \frac{\Delta h_{arc} K_{arc}}{S_{mef}} = \frac{2 \cdot s}{i_{pg}} \cdot \frac{K_{arc}}{S_{mef}} \qquad (3)$$

Because the value of variation $\Delta L[i]$ of the absolute contraction for sampling is:

$$\Delta L[i] = \frac{2 \cdot s}{i_{pg}} = const. \qquad (4)$$

It results that:

$$\Delta p_{mas}[i] = \frac{\Delta h_{arc} K_{arc}}{S_{mef}} = \Delta L \cdot \frac{K_{arc}}{S_{mef}} = const. \qquad (5)$$

If it adopts constructively the value L_0 = 100 mm and the max. contraction is $\varepsilon_{max} \leq 10\%$, it results that the max. value of the displacement to be measured is ΔL_{max} = 10 mm.
For being efficient in controlling the drying process it is required that the device to belong to the CP1 class of precision, meaning that the sampling error $\Delta L[i]$ is:

$$\Delta L[i] = \Delta L_{max} \cdot \varepsilon_{est} = 10\,mm \cdot 0.01 = 0.1\,mm \qquad (6)$$

For s = 0,25 mm it results that the transfer factor i_{pg} must have the value:

$$i_{pg} = \frac{2 \cdot s}{\Delta L[i]} = \frac{2 \cdot 0{,}25}{0{,}1} = 5 \qquad (7)$$

For the measurement accuracy and for decreasing the weight of the pneumatic cylinder it is limited the total variation of the measurement pressure at Δp_{max} = 0,4 bar, which leads to:

$$\frac{K_{arc}}{S_{mef}} = \frac{\Delta p_{max}}{\Delta L_{max}} = \frac{4000\,Pa}{0{,}01 \cdot m} = 4 \cdot 10^5 \, \frac{N/m}{m^2} \qquad (8)$$

With the relation (8) may be dimensioned the pneumatic cylinder in constructive correlation with the assembly of the measurement device.[11]
The transition from 20 to 150 ºC may generate dilatations of the cylinder (13), of the rigid centre (14), as well as modifications of the elastic characteristic of the spring (14). These may influence the precision in measuring the contraction of the brick, during the drying process. The material from which will be made the cylinder, the rigid centre and the spring is superinvar type (58% Fe + 42% Ni) which has a dilatation coefficient of $\alpha_1 = 4 \cdot 10^{-6}$ until 300 ºC and it maintains its elastic characteristic until 150 ºC.
Therefore the effective average dyameter of the goffered membrane will have the real value of :

$$D_{mef}(T) = D_{mef0} \cdot (1 + \alpha_1 \Delta T) \qquad (9)$$

where: $\Delta T = T_{mas} - 20$ is the temperature difference
The error ε_D caused by the temperature variation will have the value:

$$\varepsilon_D = \left(\frac{D_{mef}(T)_{max}}{D_{mef0}} \right)^2 - 1 = (1 + \alpha_1 \Delta T_{max})^2 - 1 = (1 + 4E^{-6} \cdot 130)^2 - 1 = 4{,}027E^{-5} \qquad (10)$$

From the relation (10) it results that the error ε_D caused by the thermal dilatation of the pneumatic cylinder is very low and it may be ignored in the measurement of the contraction.

3. Conclusions

For measuring an important parameter of the drying process of the raw ceramic products, the linear contraction, parameter that must be measured in an environment with a relatively high temperature 120..150 ºC, it is proposed the use of an unconventional pneumatic transducer by means of which may be performed precise measurements, which has a plain structure and is much cheaper than the similar electronic variants.
The pneumatic transducer for measuring online the contraction of the raw bricks during drying has more precision at measurement, more than 1% for an initial distance between the measurement anchors of 100 mm.
It is conceived for a safe and easy use, it couples with the outside by means of a pneumatic pipe made of teflon with the dyameter of 4 mm and an electric conductor of 1 mm^2 has at wires a PLC compatible electric signal.
Were used the concepts specific for low cost automatisation – which led to the achievement of a plain and precise device, much more cheaper than other variants in use.
The metallic materials used for the pneumatic cylinder, spring and membrane have the dilatation coefficients very small which ensures a very slight variation of the effective average dyameter of the goffered membranes below $4 \cdot 10^{-5}$, which leads to a very high measurement precision.

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