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Rotational Pneumatic Drive with Radial Jet Action

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Abstract: In this paper authors present a study on a rotational pneumatic drive with radial jet action. Rotational pneumatic drive with radial jet action is a special drive using power of compressed air to produce rotational motion. The rotating motion is generated by jets, generating tangential oriented forces which act on the rotor. This study presents some of the theoretical and experimental results referring the operating parameters of a jet rotation drive.

Keywords: rotation pneumatic drive, jet, radial action, jet action, rotational motion

1. Description of pneumatic drive with radial jet action

Pneumatic drive with radial jet action consists of the following parts that can be found in Fig. 1.

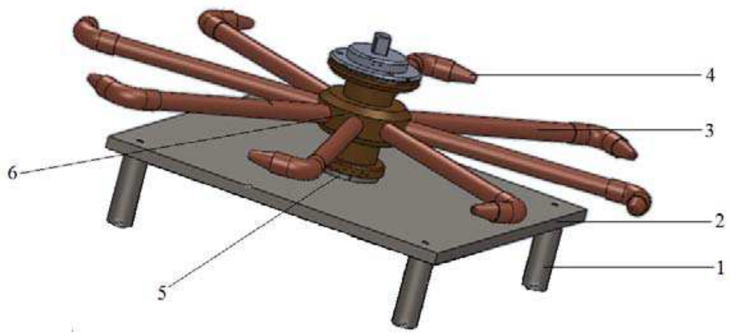

Figure 1: Pneumatic drive with radial jet action.

The feet 1 sustain the plate 2, designed to support the entire engine. In the center of the plate a large diameter threaded hole connects the compressed air network. Body supply 5 is fixed on plate 2 through screws disposed concentrically with the previous hole.

The supply body 5 is made of OL 50construction steel. Geometrically it consists of a tube ended in a shoulder where the main body 6 is fixed. At the top of the supply body another shoulder mounted by thread of the top of supply body serves to fix the top of the main body. On the cylindrical surface of the supply body are channels linking the outside and the inside of it.

The cylindrical shaped main body 6 is mounted on the supply body. It is made of bronze. On the outside of the main body are mounted the tubes 3 of the pneumatic drive that communicate with the inside of the main body through holes.

Pneumatic drive duct 3 were made of copper have a tubular shape, which are glued to the main body at one end and the other end attached to an elbow at 90°. With the elbow positioned nozzle and adjust the angle of 90° jet nozzle produced a pneumatic motor motion having a tangential direction.

The tubular nozzles 4 present variable inner diameters, where the input is greater than the output. More exactly, the inner diameter decreases parabolically. The nozzle's geometry influences mainly the characteristics of the jet propulsion.

2. The operational mode of pneumatic drive with radial jet action

On the lower support plate is mounted a device that connects the pneumatic drive to the compressed air network.

The compressed air enters the device mounted on the lower support plate in the inside of the supply body. The communication channels connect the inner and outer passages of the compressed air. Thus the compressed air passes from supply body in the main body. Due to the specific geometry of the nozzles, the outcoming compressed air is accelerated. At the leave of the nozzle results the jet propulsion force that depends mainly on the flow and density of operating air.

3. Analytical calculation of parameters pneumatic drive

The functional parameters were calculated considering the following values of the operating parameters:

- internal pressure: 5 bar;
- external pressure: 1 bar;
- temperature: 300 K;
- specific mass of O_2: 32kg/kmol;

- k = 1,4– the correction coefficient while the compressed fluid is oxygen;
- air outlet section $A = 7{,}065 \cdot 10^{-6}\ \mathrm{m}^2$.

The value of the critical pressure is given by the following formula [3, 4]:

$$p^* = p_1 \left(\frac{2}{k+1} \right)^{\frac{k}{k-1}} = 5 \cdot \left(\frac{2}{2{,}4} \right)^{3{,}5} = 2{,}64\,\mathrm{bar}. \tag{1}$$

The temperature in the output section will reach the value [2,4]:

$$T_2 = T_1 \left(\frac{p_2}{p_1} \right)^{\frac{k-1}{k}} \cdot \left(\frac{1}{5} \right)^{0.2857} = 189\,\mathrm{K}. \tag{2}$$

The density of the working fluid in the output section is computed by:

$$\rho = \frac{p_2}{RT_2} = 2{,}036\ \frac{\mathrm{kg}}{\mathrm{m}^3}. \tag{3}$$

The outcoming velocity of the fluid in the output section is

$$w_2 = \sqrt{\frac{2k}{k-1} RT_1 \left[1 - \left(\frac{p_2}{p_1} \right)^{\frac{k-1}{k}} \right]} = 448\ \frac{\mathrm{m}}{\mathrm{s}}. \tag{4}$$

Using (4) the volumic flow for a nozzle will be:

$$m = w_2\, A = 7{,}065 \cdot 10^{-6} \cdot 448 = 3{,}165 \cdot 10^{-3}\ \frac{\mathrm{m}^3}{\mathrm{s}}. \tag{5}$$

Finally, the total volumic flow for all nozzles becomes:

$$m = 8\, A\, w_2 = 25{,}32 \cdot 10^{-2}\ \frac{\mathrm{m}^3}{\mathrm{s}}. \tag{6}$$

Using results obtained from the equations (1) to (6), the global force produced by all fluid jets can be computed with the formula below:

$$F = m\, \rho\, w_2 = 448 \cdot 2{,}036 \cdot 25{,}32 \cdot 10^{-2} = 23{,}095\ \mathrm{N}. \tag{7}$$

4. Experimental determination of parameters of the pneumatic drive

In the proposed experimental determinations, the following equipment components will be used in order to find the values of the functional parameters for pneumatic drive with radial jets (force jets, rotation and drive operating pressure):

- force sensor type 1242 Vichay Tedea-Huntleigh;
- pressure sensor type HBM P3MB of 10 bar pressure;
- data acquisition system type HBM Spider 8;
- pressure source;
- PC unit;
- tachometer type DT 1236L Lutron Electronic;
- pneumatic drive with radial jet.

The configuration of the experimental set-up is presented in *Figure 2*.

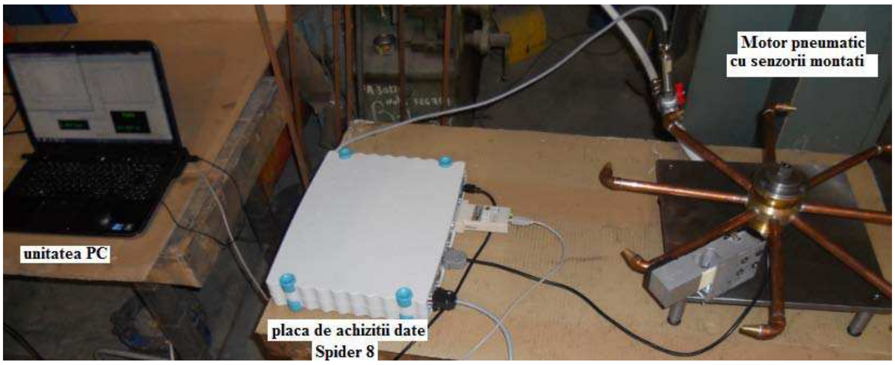

Figure 2: Configuration of experimental set-up

The experimental value of the pressure inside of the pneumatic drive is output on a screen (Fig.3).It can be observed that a pressure of is 3.941 bar is able to produce a the jet force of 24.45 N. It can be concluded that the experimental values are close to the computed values.

Figure 4 shows the measured value for rotation of pneumatic drive with radial jets.

Here it must be noticed that the pneumatic drive is equipped with 8 pipelines, and as a consequence the tachometer records eight values for one complete rotation. Knowing this the computation of the real rotation value will be done using the correction below:

$$n = \frac{n_{registered}}{N_{pipelines}} = \frac{42834}{8} = 5354 \text{ rpm} . \quad (8)$$

Figure 3: Pressure from inside of pneumatic drive and the jets force

Figure 4: Value for maximum rotation

5. The functional diagrams of radial jet engine

The dependence of the force with the rotation is shown in *Figure 5*.

It can be concluded that the variation of the force with the rotation is approximately linear.

The volumic flow variation with the force is shown in Figure 6 which lets us conclude that there is a parabolic dependence.

As shown in (Figure 8), the variation of flow with rotation is also parabolic.

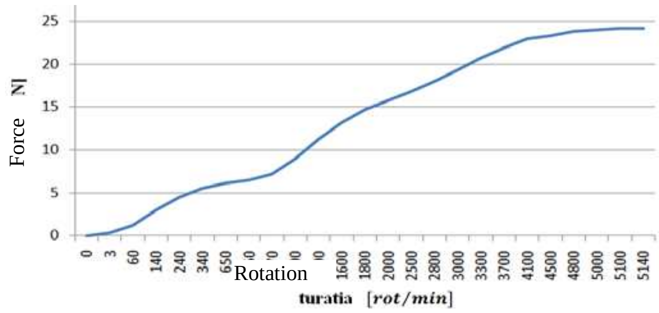

Figure 5: Variation of force with rotation

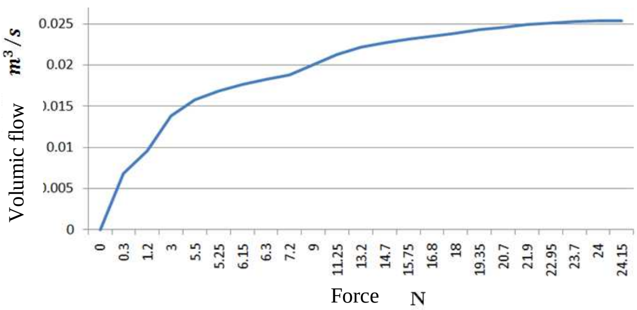

Figure 6: Variation of flow with force

The variation of the force with the pressure is also linear (*Figure 7*):

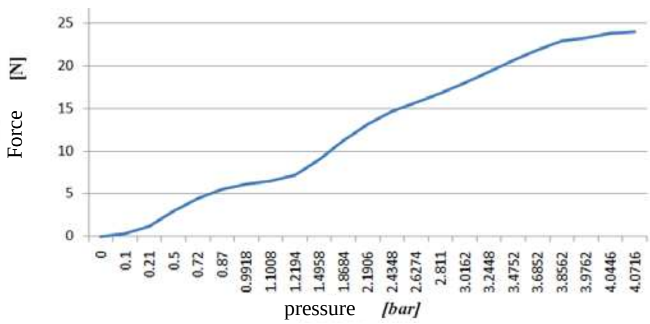

Figure 7: Variation of force with pressure

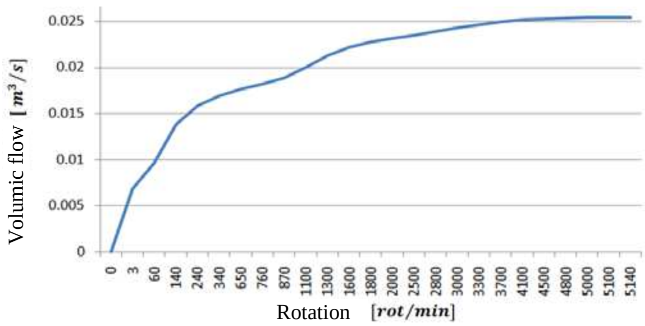

Figure 8: Variation of flow with rotation

6. The estimation of the error given by the formula of the force created by the fluid jet

Comparing the final result of force value given by the formulas (1 to (7) with the measured value, the occurred error percentage is:

$$\varepsilon[\%] = \frac{F_{measured} - F_{computed}}{F_{computed}} \cdot 100 = \frac{24{,}45 - 23{,}095}{24{,}45} \cdot 100 = 5{,}54\ \% . \qquad (9)$$

Result (9) allows to conclude that the theoretical model is appropriate.

7. Conclusion

A new type of fluid jet driven pneumatic rotary motor was conceived and realized. The technical peculiarities of this can be summarized as follows:

- Drive power is directly proportional to the length and diameter of the motor arm and motor rotation value;
- The variation of force with rotation is linear;
- The variation of flow with force is parabolic;
- The variation of force with pressure is linear;
- The variation of flow with rotation is parabolic.

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