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# OPTIMIZATION OF OPERATIONAL CHARACTERISTICS OF SHOTBLASTING TURBINE

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## ABSTRACT

*A parametric study has been performed in order to optimize the operational characteristics of shotblasting turbine used for surface cleaning of metal products in foundries. The study has been focused on four main parameters: shot velocity, shot distribution, shot mass flow and turbine efficiency. Different turbine designs were experimentally studied which enabled the influence factors to be identified and then quantified by means of comparison of original and modified turbine characteristics. The step-by-step optimization was then performed which resulted in redesigned shotblasting turbine with improved operational characteristics. Up to 35 % higher maximum mass-flow rate of shot particles has been achieved and turbine efficiency has been improved by more than 6 %. Just slight reduction of shot flow velocity was observed (only 2 %), which confirms an important improvement of shotblasting potentials of new turbine.*

**Keywords:** Shotblastig, Parametric study

## 1. INTRODUCTION

Shotblasting is widely used in the metal industry for surface cleaning of different metal products. These are exposed to the flow of shot particles, and the energy of the particles' impact is used to remove rust, paint or any other deposits from the surface of the object being cleaned. Small steel spheres with a mean diameter of 1 mm are usually used as shot particles. These are accelerated within electrically-powered radial pump called shotblasting turbine. Shotblasting turbine consists of five main parts (see Fig. 1): inlet pipe, pre-rotor, guidance ring, main rotor and housing. Shot particles enter the turbine through the inlet pipe. A special pneumatic valve is used to control the mass flow of shot particles. Entering the pre-rotor shot particles change their flow direction from axial to the radial direction and fill the gap between the guidance ring and pre-rotor. The shot particles can enter the main rotor only through the opening in the guidance ring which does not rotate, thus changing the position of guidance ring opening changes the flow direction of particles leaving the turbine. In the final stage, the rotating main rotor blades accelerate the shot particles to the final velocity which can exceed 100 m/s.

The main objective of the research presented here was to increase the turbine power by 30 %, keeping the outer turbine dimensions unchanged and modifying only inner parts of the turbine. Our work was, therefore, focused on the modification of the inlet pipe and pre-rotor, while the guidance ring and the main rotor remained unchanged.

## 2. TURBINE CHARACTERISTICS

Turbine characteristics may be defined by four parameters: shot velocity, shot distribution, shot mass flow and turbine efficiency. Measuring procedures suitable to attain these parameters have been already given in [1], thus they are omitted here.

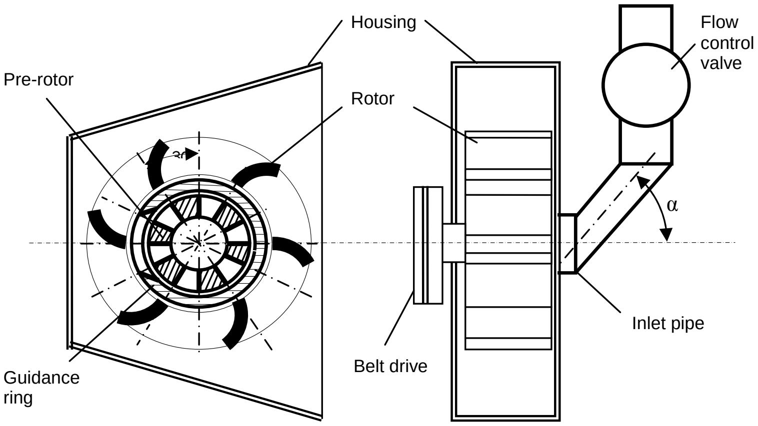


*Figure 1. Shotblasting turbine*

### 2.1. Turbine swallowing capacity

Turbine swallowing capacity can be determined by changing the flow control valve opening and measuring the power extracted by the turbine. This can simply be done by measuring the power of electric motor which propels the turbine. Characteristic change of turbine power versus valve opening is presented in Fig. 2. As we can see, the turbine power is gradually increasing with the valve opening until it reaches its maximum. Immediately after this chocking conditions occur and the mass flow and turbine power drop significantly. As we will see latter the chocking occurs within the pre-rotor, which gets filled up with the shot particles and can no more take the advantage of the inflow velocity of shot particles. In order to test the turbine prototype for any power increase, it is therefore necessary to measure its swallowing capacity and to compare the maximum power and the corresponding control valve opening with the values of the basic turbine model.

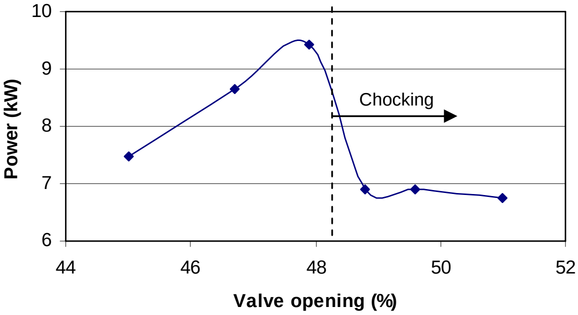


*Figure 2. Turbine swallowing capacity*

## 3. INLET PIPE MODIFICATION

Inlet pipe fills the pre-rotor with shot particles. As already mentioned the pre-rotor may use some of the kinetic energy of incoming shot particles if the inflow conditions are optimal. One of the parameters which dictate inflow condition is flow angle. Thus the first modification of the inlet pipe design was targeting the optimal inflow angle, by changing the steepness of inlet pipe. Three different angles α (see Fig. 1) were tested $30^0$, $45^0$ and $60^0$, however, no improvement of maximum turbine power was achieved, moreover, some maximum power reduction was observed at the $60^0$ steepness.

Sand and similar materials like shot particles can be very effectively transported pneumatically by air stream. The improvement of the turbine swallowing capacity when supported by air stream was, therefore, studied in the next step. Since the shotblasting turbine already operates as a radial fan, it was possible to achieve the effect of pneumatic convoying simply by making a supporting air opening in the inlet pipe. Test showed (Fig. 3) improvement in the turbine swallowing capacity by up to 10 %. This was achieved using the supporting air opening which size was approximately 6 % of the inlet pipe cross section.

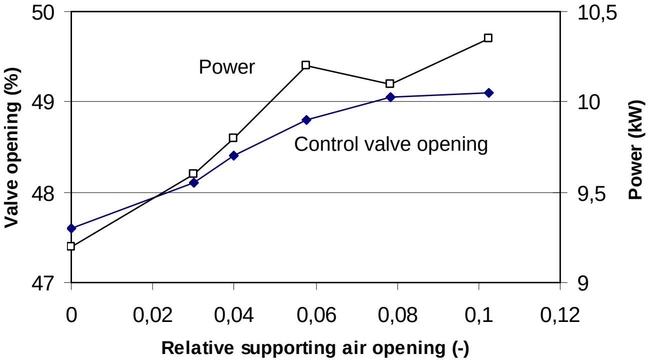
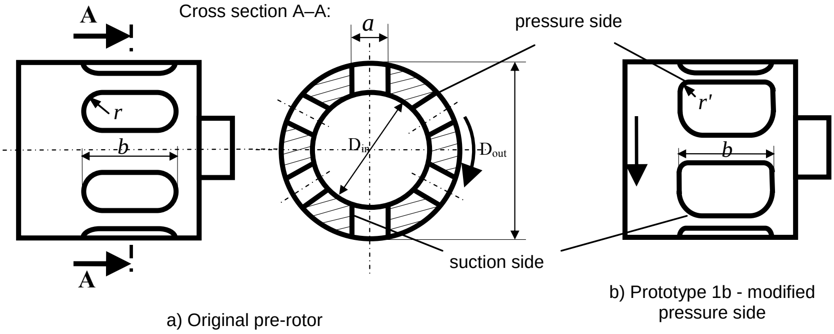


*Figure 3. Influence of the supporting air on turbine swallowing capacity*

## 4. PRE-ROTOR MODIFICATION

Original pre-rotor is shown in Fig.4. It has a cylindrical bowl shape with circumferential openings which act as blades, grabbing the shot particles at the inner side and transporting them in the radial direction to the outer side. The flow through the pre-rotor is dictated by the size of these openings and their shape. Since it was assumed that chocking started in the inflow section of pre-rotor, our first modifications of pre-rotor were focused on the size of openings, however, even 25 % increase of the opening cross-section by elongating the opening width *a* (Fig. 4a) did not resulted any increase in flow (turbine power). Reshaping of the opening was, therefore our next try. Pressure side of the opening was modified first by the reduction of side radius (Fig. 4b). This measure increases the pressure side of the opening which acts on the particles. Correspondingly the flow (turbine power) was increased (Fig. 5). Our next effort was then focused on modification of suction side of the pre-rotor opening. It was gradually reduced (Fig. 5 - prototypes c and d) and this resulted in increased flow and turbine power. Modification of inclination of pressure side of the opening (Fig. 5 - prototypes e and f) brought further increase of mass flow and turbine power. As can be seen from Fig. 5 the turbine power was increased by 25 % using pre-rotor modifications.

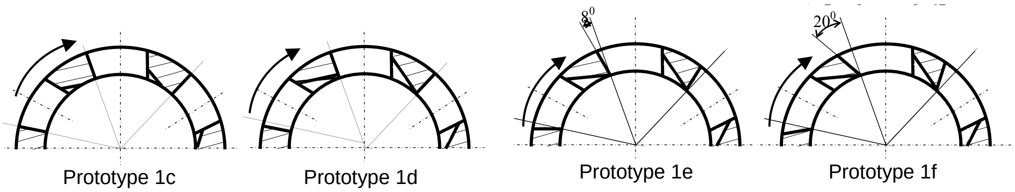


a) Original pre-rotor

b) Prototype 1b - modified pressure side

*Figure 4. Original and modified pre-rotor*

Further improvements are possible, as some tests showed, with increasing pre-rotor mean diameter, however, this would be possible only with the reconstruction of guidance ring and main rotor, which had to remain unchanged in order to keep the turbine dimensions constant.



a) Suction side modification

b) Pressure side inclination modification

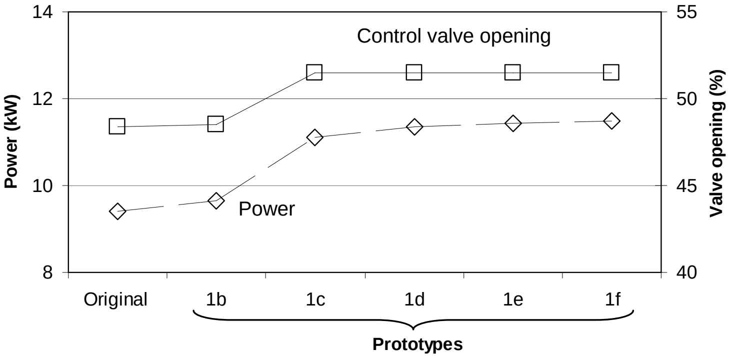


*Figure 5. Influence of the pre-rotor modification on turbine swallowing capacity*

## 5. PROTOTYPE TURBINE TESTING

As shown in previous two chapters, turbine swallowing capacity can be increased by simple modifications of the inlet pipe and pre-rotor. In order to study the influence of these modifications on turbine characteristics, a new prototype turbine was built. A 45 degrees inclination inlet pipe was used with 6 circumferentially distributed holes for supporting air placed immediately after control valve. Pre-rotor was built according to prototype 1d geometry, while guidance ring and main rotor remained unchanged. Shot velocity, shot distribution, shot mass flow and turbine efficiency were then measured and compared with the results obtained by the original turbine. Results are presented in Table 1.

*Table 1: Comparison of turbine parameters*

| | Original turbine | Prototype turbine | Index |
|---|---|---|---|
| Electric power (kW) | 9,40 | 11,50 | 122 |
| Mass flow (kg/s) | 2,870 | 3,865 | 135 |
| Spread angle ($^0$) | 50 | 54 | 108 |
| Mean shot velocity (m/s) | 68,5 | 67,3 | 98 |
| Turbine efficiency (%) | 71,6 | 76,1 | 106 |

## 6. CONCLUSIONS

Development of shotblasting turbine with improved characteristic was presented. Modifications were performed on the inlet pipe and pre-rotor, while the guidance ring and main rotor remained unchanged. Comparison of operational characteristics shows (Table 1) substantial improvement of mass flow (+35 %) and efficiency (+6 %), while shot velocity reduces just slightly (- 2%). It can, therefore be concluded, that new turbine promises more efficient shotblasting process with shorter exposure times and lower energy consumption.

## 7. REFERENCES

[1] A. Hribernik, B. Ačko, G. Bombek, Study of shotblasting turbine's efficiency, The 11th International Research/Expert Conference TMT 2007, Hammamet, Tunisia, 5-9 September, 2007