EXPERIMENTAL STUDY OF THE NOVEL HINGE VANE MICRO COMPRESSOR

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Summary

Many different types of compressors are used in the industry to meet the need for compressed air. Research on different types of compressors is still ongoing. Vane compressors from the body are more preferred than the less number of parts, high efficiency, and simplicity. The design, manufacture, assembly, and optimization of a vane micro-compressor from a body with a unique structure by this connection joint assembly method was studied.

KEYWORDS: micro-compressor, unique valve design, optimization, vane compressor

Introduction

Today, there are hundreds of types of pumps that are frequently used in our lives and in almost every branch of industry. Sliding vane-rotary compressors are one of the most used types (Okur et al., 2011:1031-1033). There are many kinds of research about building upon the spring-loaded rolling piston compressors to build it more efficient, easy to maintain, and manufacture it cheaper (Bianchi et al.,2015:95-107; Bianchi et al.,2018:1038-1048; Al-Hawaj, 2009:1555-1562; Ma et al.,2016:1-5; Ooi et al.,2006:1-4; Milovanov et al.,1992:1352-1358). Rather than the spring-loaded rolling piston compressors, there are also many papers to build different compressors.

Piston, gear, screw, and vane pumps, which are among the volumetric pumps in the industry, find more usage areas, and in some applications diaphragm, bellows, lobe, flexible element pumps, and air bells are also used (Volk,2014:12-39). Piston pumps have high suction and pumping capabilities, and their flow rates are proportional to the number of cycles. However, since they have crank connecting rods and valve mechanisms, their manufacturing, repair, and maintenance are difficult (Bloch et al.,1996:107-158). Although gear pumps have a simple structure, they break down easily when they are not manufactured precisely. Screw pumps have found wide use in various industries where viscous and heavy liquids are sucked and pumped, as the fluid flow between volumetric pumps takes place along the rotation axis. Due to the low part inertia forces, some steam and gas turbines can be operated above 10000 RPM (El-Sayed,2017:1059-1070). However, the need to produce longer for high tolerances and high pressures is a disadvantage.

Vane pumps, which are one of the pumps used frequently in the industry, are divided into two main groups as rotating vane and body-to-vane. It has high suction and compression capabilities, and its flow rates vary in proportion to the number of cycles. Since they are manufactured in smaller sizes than centrifugal pumps for the same flow and head, they are more economical than similar ones. They are one of the ideal pumps that can be used for sucking and pumping all kinds of clean liquids, and they must be manufactured precisely (Ma et al.,2015:81-92; Facci et al.,2015, 243-254).

There are 3 main elements in the cooling system: compressor, evaporator, and condenser. In the cooling system, various equipment such as a valve or capillary pipe, thermostat, dryer filter, liquid trap, manometer, and thermometer are used to control the coolant flow. Finally, there are refrigerants and oils (Kim et al.,2002:54-60).

The function of the cooling compressor in the system is to remove the heat-laden refrigerant from the evaporator and the cooler from there, and thus to provide space for the unloaded heat from the back and to ensure the continuity of the flow, to increase the pressure of the vapor refrigerant to the level opposite to the condensing temperature in the condenser.

In this study, a two-stage micro-compressor with a unique hinge vane system and manufacturing method with a vane from the body has been designed and the pressure characteristic at different speeds has been created. It is aimed to determine the performance values of the compressor by comparing the results obtained in different volumes with the new stages added modularly due to the ease of manufacture.

Material and Method

Vane-body compressors; consist of body, rotor, eccentric shaft, vane, and side covers. Fig. 1 shows the structure of the compressor with fins from the body and the force on the vane. As seen in the figure, the rotor rotating on the eccentric shaft moves inside the body. The body chamber is divided into two volumes using the vane bedded on the body. While one side of these volumes is sucking, the other side is performing the pressing process. Friction forces occur on the vane surface due to this pressure difference.

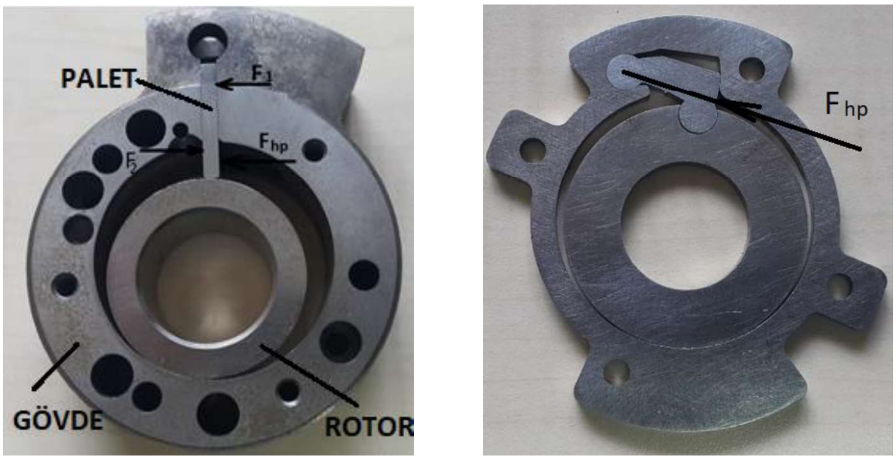

Fig. 2. Classical and Novel vane Designed Compressor Body, Rotor, and Palet
Source: Compiled by the author

As seen in Fig. 1, it has been designed in such a way that the pressure friction on the vane surface is gathered only at the hinge center. While designing vane compressors from the body, the sweeping volume determined at the end of the calculations is manufactured in a single body by casting. This requires making separate casting molds for each different compressor volume. With the new design, it is possible to manufacture compressors in different volumes with a single unit volume by using the method of adding units one after another, thanks to a single unit produced in thin plates. Fig. 3 shows different body components making up the compressor.

Fig. 3. Manufactured and Assembled Parts of the Compressor
Source: Compiled by the author

If the rotor and the vane have the same thickness as the body, because the rotor and the vane will get stuck due to the cover, it will not work. In this parameter, the effect of friction and gas leakage on efficiency in the most optimal conditions was examined by examining the operation of the rotor and the vane with different thicknesses. In this optimization, the effect of friction on efficiency has been greater. While this study was carried out, as can be seen in Figure 2, different vanes, rotors, and body thicknesses were produced in more than one thickness, and experimenting in different combinations with each other gave us a workforce advantage. Because in a normal vane compressor, it is necessary to constantly remove chips from the rotor and vane to perform these experiments. If the clearance amount is increased while changing tolerances, gas leakage increases but friction decreases. Conversely, if the amount of space is reduced, gas leakage decreases but friction increases. As a result, the most optimal value is a 0,02 mm gap. If a gap above this value is given, the effect of gas leakage on efficiency compared to friction is less when it is above this value. On the contrary, if a gap below this value is given, the effect of gas leakage on efficiency compared to friction is greater when it is above this value. Fig. 33 shows Suction- Discharge phase concerning the rotor angles of the compressor.

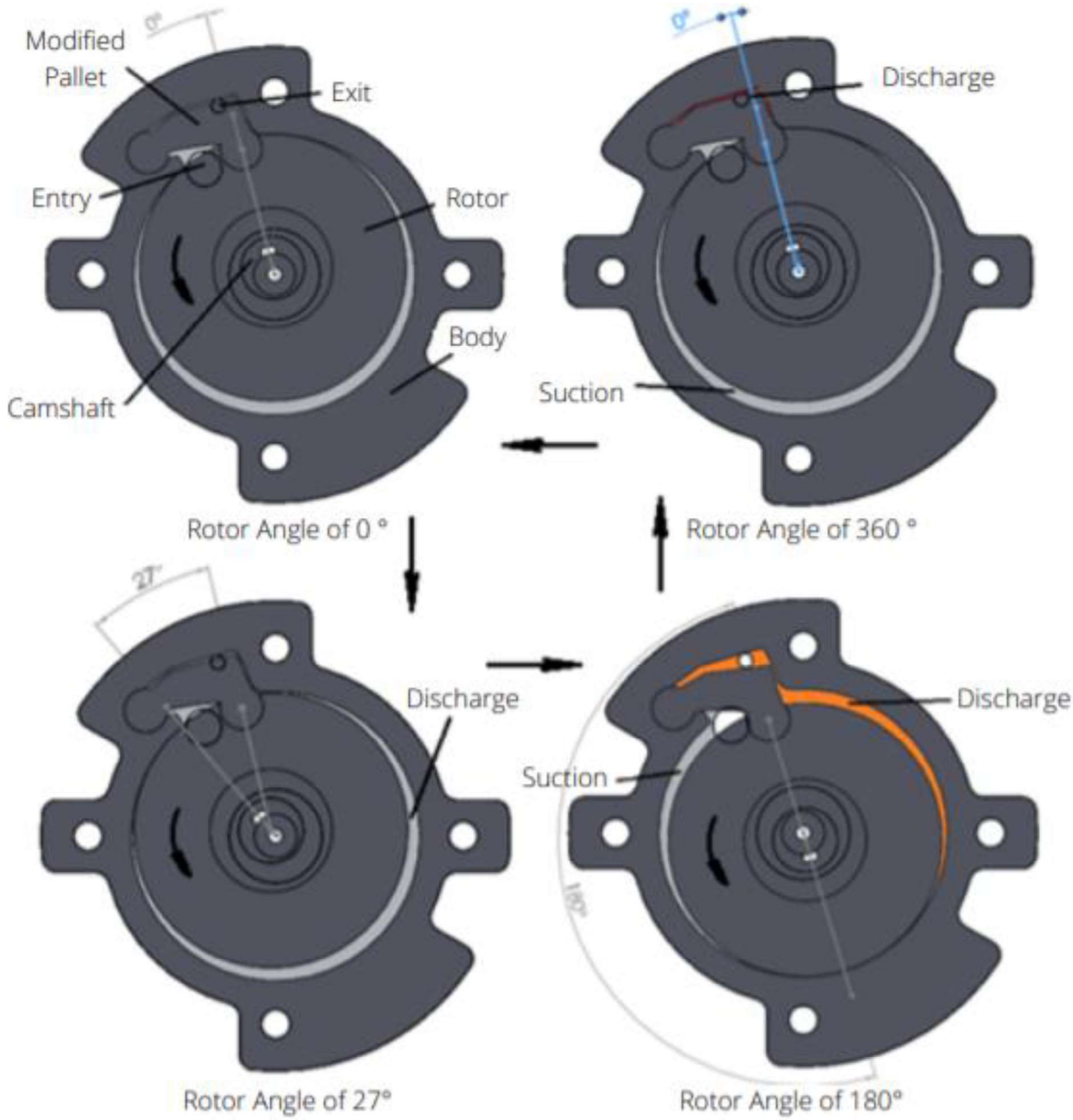

Fig. 4. *Suction- Discharge phase concerning the rotor angles*
Source: Compiled by the author

Experiments

The experiment setup consists of the electric motor, electronic barometer, oil supply system, rpm indicator, and timer. Experiments performed after prototype production was repeated at different RPM values. In the experiments, pressure-time, pressure-power, pressure-ampere, pressure-volt, and pressure-pressure increase graphs were obtained and evaluated.

The environment temperature, hydraulic oil density, hydraulic oil temperature is taken as the same for every RPM value to be sure that the compressor does not get affected by the environment. Also, it is assumed that the wear between the plates is minimal that can be negligible.

The first parameter is pressure-time graphs with different RPM values. The experimental results are given in

Fig. **5**.

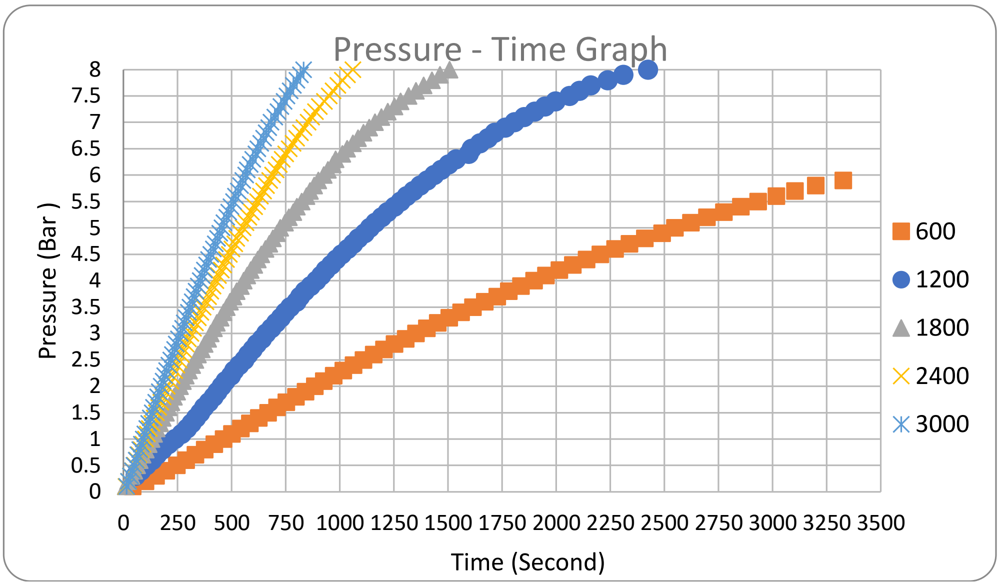

Fig. 5. Pressure (Bar) - Time (Second) Graph
Source: Compiled by the author

For the experiments 8 bars are selected for the limit for the applications, to analyze the characteristic of the compressor. The experiments show that at 600 RPM the compressor cannot exceed the 6 bars. Also, at 600 RPM to reach 6 bars take 55 minutes. The longer waiting time does not affect the pressure at this point. The compressor has a different characteristic at 1200 RPM than 600 RPM. At 1200 RPM, the compressor able to reach the 8 bars in 40 minutes. In this case, the time spend to reach the maximum level is 27% reduced concerning 600 RPM. For the 1800 RPM, it can be seen from the graph that the compressor reaches 8 bars within 1507 seconds which is under 26 minutes. The reaching maximum pressure time is 57.4% lower than the 600 RPM, and 37.8% is lower than 1200 RPM. From the graph, it seems that the slope of the pressure line is increased, which means the compressor works more efficiently at 1800 RPM than 1200 RPM or 600 RPM. In 2400 RPM, the compressor can create pressure of 8 ATMs at lower than 17 minutes. At 2400 RPM, the compressor reaches the maximum of 8 ATMs within 18 minutes. It shows that it takes a 29% shorter time than at 1800RPM. Lastly, at 3000 RPM, the compressor has able to reach at 8 ATMs less than 14 minutes, which is 21% faster than the 2400 RPM. As it seems from the graph, reaching the 8 ATM-related with the RPM value.

The second parameter is pressure-time difference graphs at the different RPM values. The results are given in Fig. 6. This graph shows the time difference between the unit pressure increase which is 0.1 bar.

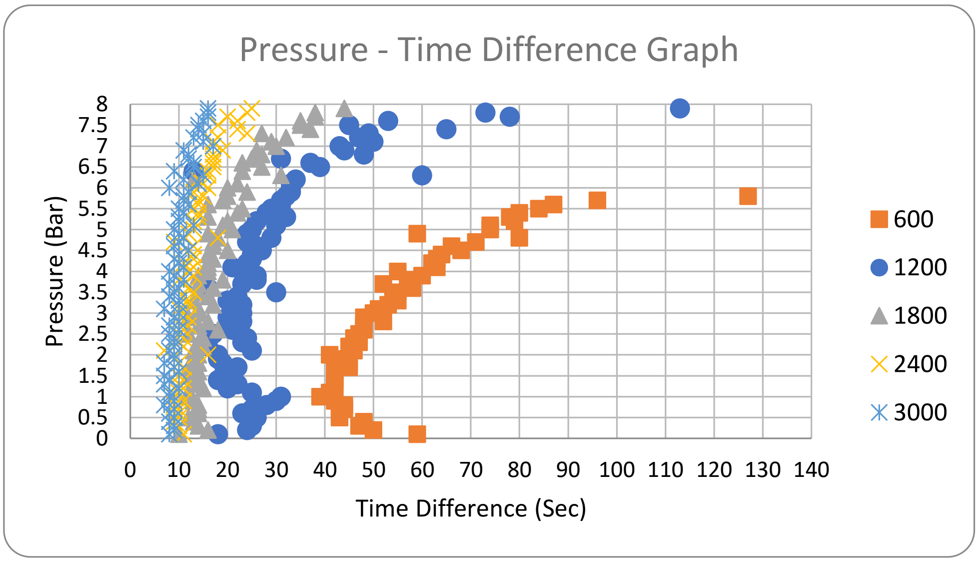

Fig. 6. Pressure - Time Difference Graph
Source: Compiled by the author

The points on the graph show that the compressor at 600 RPM does not work efficiently and even at the beginning of the experiment, it takes to build up pressure 0.1 bar takes 59 seconds. Also, it can be seen that the shape of the points on the graph for 600 RPM looks like a quarter circle which is expected. As the experiment continues from 600 RPM to 3000 RPM it can be seen that the quarter-circle shape becomes more like a line. This implies that even after 1200 RPM, the compressor can build higher pressure.

The third and last parameter is pressure-power at different RPM values. The results are given in Fig. 6

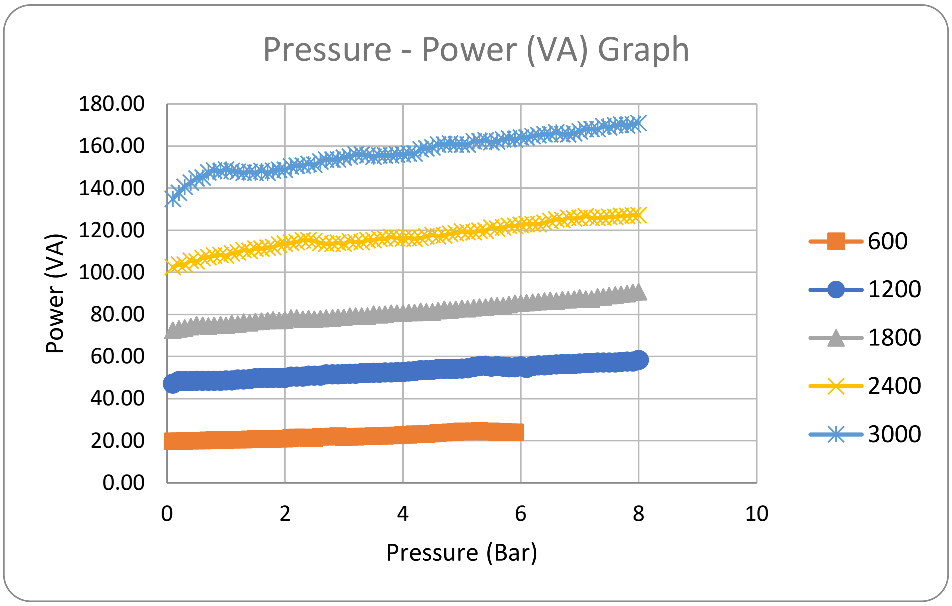

Fig. 7

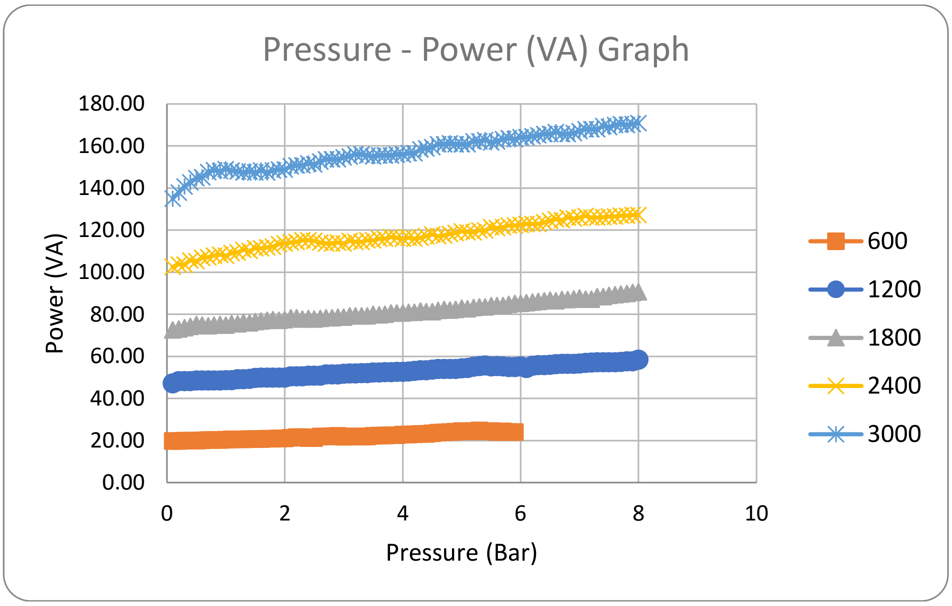

Fig. 7. *Pressure - Power Graph*
Source: Compiled by the author

To see the given total power to the compressor, these values are taken from the motor controller itself. These values differentiate depending on the RPM values. As we provide more power to the compressor, the compressor reaches the limit pressure quicker, which is expected.

Conclusion

1. Additive manufacturing and assembly technique create flexibility to build different compressors with identical parts. Later, it can be investigated to build different volumed compressors. Also, when designing a micro compressor, even small tolerances play an important role. When the manufacturing defects occur, the whole part could be scrap. However, thanks to the additive assembly and manufacturing technique, the only defective part can be changed.

2. At small speeds,1200RPM or lower, the compressor the ability to build up pressure is limited.
3. At the higher RPM speeds achieved, the higher-pressure value can be expected, which is limited by the material specifications.
4. For future scientific experiments, the maximum pressure for different RPM values can be determined.

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