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Design Optimization of Air compressor Intake Valve using FEA

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Abstract: Compressors are used in various industrial applications to increase the pressure of air from the initial conditions to the discharge conditions. Proper design and material selection for compressor is essential for smooth operations and withstanding high inner pressure.

The current research is to investigate the effect of structural and thermal loads on intake valve of compressor using techniques of Finite Element Method. The design and FE simulation of valve is conducted in ANSYS software. The design of valve is then optimized using linear regression model.

The critical regions of high stresses and heat flow are determined. The stresses and deformation obtained on compressor intake valve is well within the safe limit.

Key Words: *Compressor, FEA, Stress*

1. INTRODUCTION

An air compressor is a device that converts power (usually from an electric motor, a diesel engine or a gasoline engine) into kinetic energy by compressing and pressurizing air, which, on command, can be released in quick bursts. There are numerous methods of air compression, divided into either positive-displacement or negative-displacement types [1].

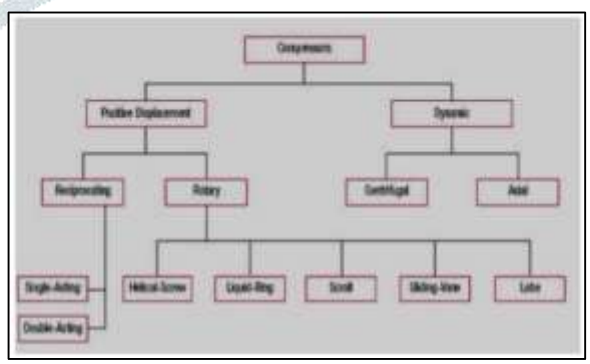

Figure 1: Types of Compressors

Compressors are used to increase the pressure of air from the initial conditions (air intake) to the discharge conditions (air discharge). Compressors may be used as vacuum pumps. A vacuum pump has an intake that is below atmospheric pressure and usually compresses to no higher than atmospheric pressure. The degree of vacuum attainable is dependent upon the type of system, leakage into the system, and limitations of the equipment.

2. LITERATURE REVIEW

Kanwar JS Gill et al. [2] studied "designing and fabrication of intercooler and control of three phase digitalized reciprocating air compressor test rig with automatic control drive unit, international conference of advance research and innovation. The air compressor test rig is designed to study the characteristics of a two stage reciprocating air compressor and the compressed airflow through flow arrangement. This unit is self-contained and fully instrumented with mild steel frame-mounted on raised foundation, with intercooler, air stabilizing tank and air receivers. The compressor is driven by an AC Moor. To provide adequate cooling to the system is the function of the intercooler and is supplied with pressure and temperature measuring instruments at the inlet and outlet. With the introduction of intercooler the volumetric efficiency has been increased to 100 %. In order to measure the air flow rate air stabilizing tank should stabilize the flow of air which is mandatory in this work. Actual volume of free air delivered by this compressor is 0.020 m3/sec with a work done of 77 N-m was the result obtained during test. Moreover it was also found that the capacity to deliver air is about 1.02 kg/minute of this compressor, when the isothermal efficiency of the compressor is 45 %. If an intercooler is specially designed it has capacity of 2.049 kilojoules/kg of heat rejection" [2].

Vijaykumar F Pipalia et al. [3] have conducted investigation on reciprocating air compressor using experimental techniques. The effect of heating in efficiency of compressor was investigated and use of coolant, water cooling is also investigated for double cylinder reciprocating compressor systems.

Ravur et al. [4] have presented studies on use of different types of coolants and efficiency of compressor. The research findings have shown that lower efficiency of compressor can be attributed to various factors like "location, elevation, length of pipe lines, inter cooler performance, even atmosphere conditions" [4].

Tyagi et al. [5] have conducted experimental investigation on air compressor intercooler. The use of shell tube heat exchanger is emphasized as intercooler. The shell and tube heat exchanger is suited for two different compressor stages. The heat exchanger design is based on heat transfer area and pressure drop. The "modeling of heat exchanger which is based on the minimization of heat transfer area and a flow chart is provided showing the designing procedure involved" [5].

Wadbudhe et. al. [6] have presented research on design of 2 stage reciprocating air compressor used for various industrial applications like transmission pipelines, petrochemical plants, refineries. The failures occurring in reciprocating compressors due to high pressure ratio is investigated. The research findings have shown that unexpected failures can occur in compressors which make it imperative to design compressor parts with recommended clearances.

3. OBECTIVE

The current research is to investigate the effect of structural and thermal loads on intake valve of compressor using techniques of Finite Element Method. The design and FE simulation of valve is conducted in ANSYS software. The design of valve is then optimized using linear regression model.

4. METHODOLOGY

The intake valve design is developed in ANSYS design modeler. The tools used for modeling are sketch and revolve using the dimensions in literature [7]. The developed model of intake valve is shown in figure 2 below.

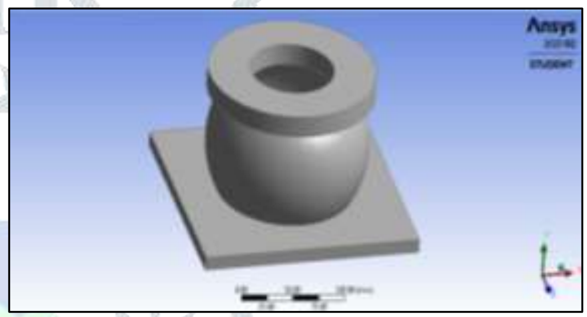

Figure 2: CAD design of intake valve

The model of intake valve is discretized with adaptive size function and fast transition. The model is discretized with tetrahedral elements and span angle center is set to coarse. The inflation is set to normal with growth rate set to 1.2.

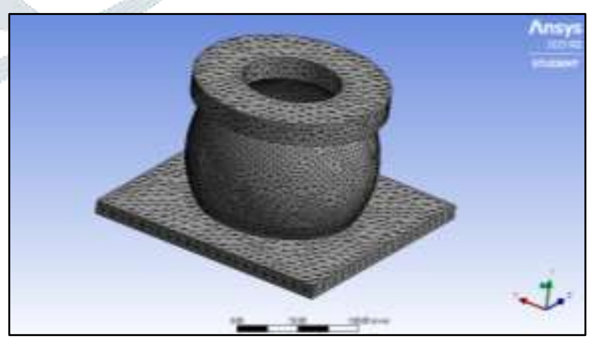

Figure 3: Meshed of intake valve

The loads and boundary condition are applied on intake valve. These conditions include fixed support at the bottom plate and pressure on inner face of intake valve. The applied loads and boundary is shown in figure 4 below.

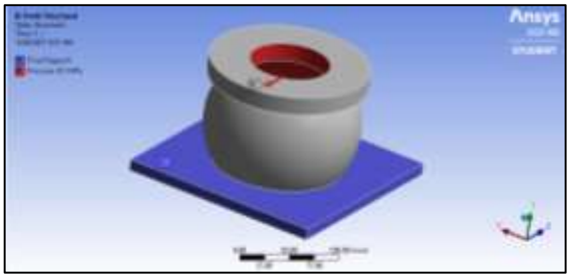

Figure 4: Applied loads on intake valve

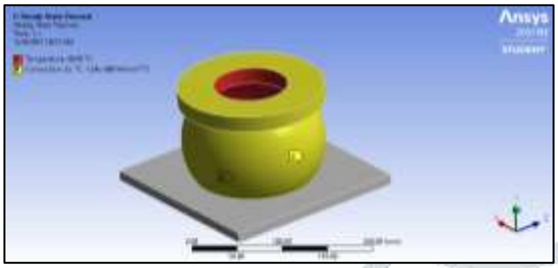

Figure 5: Applied thermal loads on intake valve

The simulation solver is run for above mentioned loading conditions. The nodal calculations are made for stresses and deformation and these results are interpolated for entire element edge length.

5. RESULTS AND DISCUSSION

The results of FE simulation are obtained for compressor intake valve. The equivalent stress and deformation value is obtained for the valve as shown in figure 5 and figure 6 below.

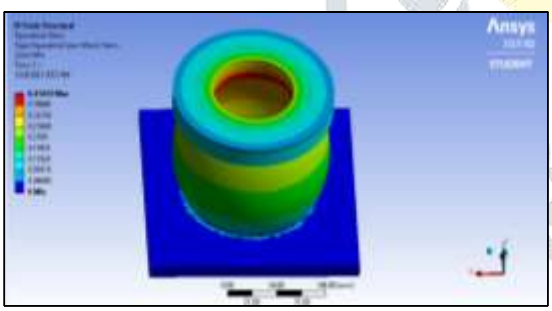

Figure 5: Equivalent stress on intake valve

The equivalent stress is maximum at the inner regions of intake valve with magnitude of more than .36MPa. The equivalent stress reduces on moving towards the base of intake valve and is minimum at the base of the valve.

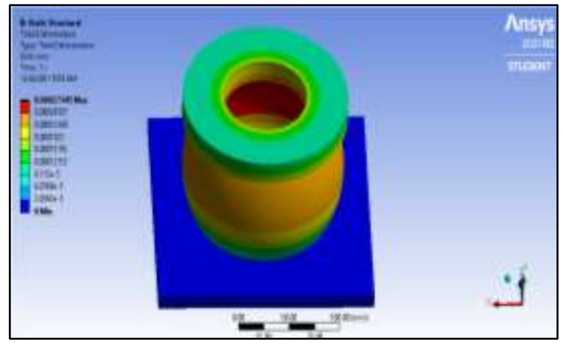

Figure 6: Total deformation on intake valve

The deformation plot is obtained for the intake valve as shown in figure 6 above. The plot shows maximum deformation at the inner surface of the intake valve with magnitude of .00024mm. The bottom of rectangular support region of intake valve has minimum deformation. The results of thermal analysis are obtained which shows regions of high temperature and heat flux.

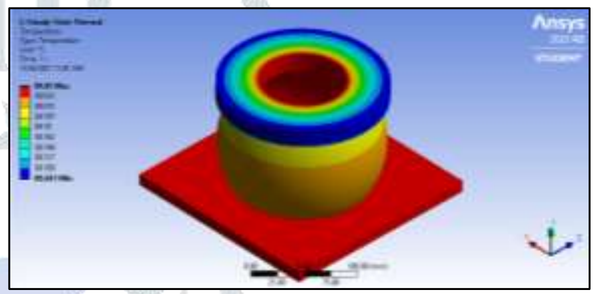

Figure 7: Total temperature plot on intake valve

The temperature plot is generated for intake valve as shown in figure 7 above. The plot shows maximum temperature at the inner regions of intake valve with magnitude of more than 89.8^0 C.

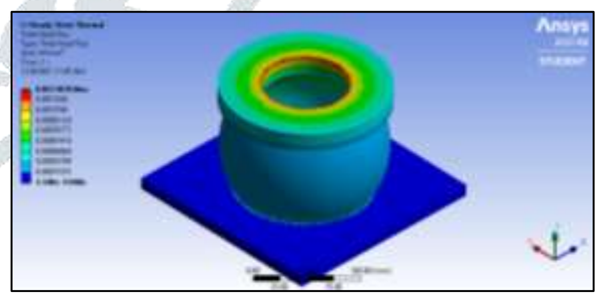

Figure 8: Total heat flux plot on intake valve

The heat flux plot is generated for the intake valve as shown in figure 8 above. The plot shows maximum heat flux at the top most regions due to high thermal gradient. The maximum heat flux plot is of .00138 W/mm^2 magnitude and it reduces on moving away from the center.

6. CONCLUSION

The use of computer simulation packages can significantly reduce time and cost in determining the strength of compressor intake valve. The FEA is a viable tool in determining the strength of compressor intake valve. The critical regions of high stresses and heat flow are determined. The stresses and deformation obtained on compressor intake valve is well within the safe limit.

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