filled with a highly conducting or insulating fluid using activecontrol, depending on the temperature gradient between the gas and the cylinder wall, which can function like diodes. The high temperature environment in compressors has also generated theneed and interest for developing lubricants for withstanding such high temperatures inside the cylinders of lubricated compressors. If external cooling is to be provided, particularlyin non lubricated cylinders, the mechanical aspect of design also becomes complex in many cases because of the complexity of the cooling passages_ Further, in multistage compressors, inter cooling becomes a necessity in many cases and in all compression systems, after cooling has to be done to meet the user's requirements. Even from the reliability point of view, high temperaturescause serious concern. For example, impact strength of a valve plate or the sealing effectiveness of a piston or packing ring depends on the temperature. Cylinder lubricants may not just lose their viscosity, but also may break up leading to deposition on valve plates and passages causing inefficient operation or even failure. Any such deposition of a lubricant, or refrigerant in refrigeration compressors, or water /liquid droplets I slugs in compressors operating at relatively low temperatures, would pose a further challenge to development of reliable wall heat transfer correlations. In addition, the lubricant may also vaporize and contaminate the discharge gas thus affecting the downstream process, unless the oil vapors are removed by using expensive filters. It is also not uncommon for cylinders and pistons to loose their concentricity because of poor lubrication, leading to operational failure and even irreparable damage to the components as a result of ceasing of the parts. Finally from a designer and developers point of view, no amount of progress in analytical modeling or experimentation would help, unless quick and easy methods are developed for accurately predicting the discharge temperature, losses attributable to suction gas heating and its impact on volumetric efficiency and power economy. However, users of such methods should also be aware of their limitations, since reliable and accurate methods with universal applicability to all types of compressors are unlikely to be developed. Hence theseanalytical methods could only be used as tools for reducing thecycle time for development and one will have to rely on testing for proving the design.

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4 RESULTS AND DISCUSSION

Heat transfer changes its direction during the cycle of crankshaft depending on the gas temperature inside the cylinder. When the gas temperature is lower than the wall temperature, heat flux is positive, which means that the heat is transferred from the wall into the gas. When the compressed gas reaches the same temperature as the wall, heat flux is zero and after that it changes direction, meaning the heat is transferred from the gas into the wall. This change of direction occurs not just during the compression, but also during expansion process (Figure 3). The negative effect of heat transfer inside the cylinder is the superheating of the sucked gas, resulting in decrease of compressor efficiency.

The simulation procedure started with the expansion process moving the piston from top dead center towards bottom dead center. When the pressure force acting on suction valve overcomes the spring force, suction process begins. Usually the suction process is ended when the piston is in its bottom dead center followed by the compression and discharge. Movement of the discharge valve is again controlled by pressure and spring force. A special care must be taken when the valves are opening and closing in numerical simulation. Keeping the mesh in the gap between the valve and the seat is fundamental for CFD simulation and therefore it is not possible to close/open valves continuously, but when the gap is less than 0.01 mm, suction or discharge process is terminated.

Numerical simulation of heat transfer requires high quality mesh, especially close to the walls, where the heat transfer coefficient is calculated. The value of y+ should be kept around 1, however, when the fluid flow is not static, it is difficult to keep the high mesh quality and not to enormously increase the computational requirements. In this simulation the value of y+ was checked on each surface during the whole simulation and the average value was mostly below ten. Also the convergence of the momentum equations, continuity equation and energy equation did not overcome the 10-4 criteria.

The analysis of Müllner and Bielmeier (2008) shows that most of the heat flows between the gas and piston (around 50 %), e.g. it is 35 % for cylinder head and less than 5 % goes into the cylinder wall. The rest of the heat is transferred in out-walls, which are walls around the valve. Similar results were obtained in this paper despite the fact that boundary conditions and settings were not described in Müllner and Bielmeier (2008). The results in Table 4 show the area integrated heat fluxes during one cycle of crankshaft.

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CFD analysis provides with more detailed flow field inside the cylinder including the velocity and temperature distribution, which helps to divide the heat flow more accurately among the surfaces. On the other hand, the computational cost is enormous, which is not convenient during the development process. Due to the complicated use of CFD, the objects of interest are simplified tools, such as the one presented in section 3.1. The results of complex analysis can be used in 0d model, which uses integral correlations to predict heat flux. However, it is distributed just according to the current heat transfer area. As the heat transfer area is the same for all the models, distribution of heat flux is consequently almost the same as well. The values used in

Good agreement was found for the piston surface, where the same trend can be observed – minor share on total heat flux during suction and compression and higher during discharge and expansion process. The heat flux through the cylinder wall is overestimated. The surface of cylinder wall does not play such an important role as it is predicted by 0d model, especially during the suction process. CFD predicts lower heat flux through the cylinder wall than 0d simulation and vice versa for cylinder head. During discharge process the heat flux from cylinder wall is higher again at the expense of the piston. All of this could be the consequence of high velocities of gas around the cylinder head and piston, which increase the heat flux on these surfaces.

The comparison of results from the 0d model and the CFD analysis shows that one integral correlation for all surfaces inside the cylinder is not sufficient to properly describe distribution of heat flux. The same idea of using different correlation for each process of compressor was already applied by Disconzi et al. (2012), therefore it seems reasonable to use different correlation for each surface inside the cylinder as well. Usually there are three main surfaces, as it is displayed in the

Models mentioned in section 2.1 show important differences, as it was mentioned in Tuhovcak et al. (2015) and finding correct one is a difficult task. However, some correlations show better agreement with numerical simulations than others for particular surface. Therefore, the combination of well-known correlations could help to achieve higher accuracy in heat flux predictions for simplified models used for compressors.

The comparison is divided according to heat transfer areas – head, piston and wall and shows area integrated heat fluxes. Integral correlations offer only one calculation of heat transfer coefficient for all surfaces, therefore the curve produced by each correlation is the same for head, piston and wall. On the other hand, the results from numerical analysis show area integrated heat fluxes at each surface calculated from local heat transfer coefficient. Discontinuities occurring at curves from CFD are the consequence of remeshing and interpolation results from previous time step on new mesh.Even with more iteration within one time step they did not disappear. Most of the models underestimate the heat fluxes, especially during the suction phase and at cylinder head. The same problem occurs for the piston surface, only the model of Annand predicted results in reasonable agreement with CFD simulation. For the surface of cylinder wall, only the model of Disconzi shows a sufficient accuracy. The model of Adair predicts much lower heat flux for all surfaces, especially during the suction and discharge phase.

Comparison of heat flow for particular empirical correlations and numerical simulation As it was mentioned before a combination of known models could help to increase the accuracy of heat flux prediction in simplified tools. Each process and surface would have its own correlation, based on the comparison with CFD numerical simulation. The combination of models based on presented results can be found in Table 7. On the left side there is a ratio of heat flux predicted by correlations and CFD. On the right side there are models which showed best agreement with CFD simulation. In most of the cases the models of Annand and Disconzi appear, however there is also contribution of Adair and Woschni. The results show a big difference between integral correlations and numerical model for heat transfer prediction in CFD. More investigation is necessary, especially in CFD, to perform simulation with higher accuracy. It must be pointed out, that all of the presented models were developed either for combustion engines (Woschni, Annand) or for refrigeration compressor (Disconzi, Adair). The compressor used in this paper was working with air, which could have influenced the results. Another important thing is the CFD simulation, particularly the simulation of heat transfer, which is very demanding on mesh quality close to heat transfer surface.

5.CONCLUSION

Two Stage Reciprocating Air Compressor is gone through different intercooling processes, it can be concluded that more the surface area of intercooling more will be depression in temperature of air which will directly result in improving the efficiency of the Air Compressor. From all the results of intercooling processes, it can be concluded that the radiator intercooling with increase in size of intercooler results in better volumetric efficiency as compared to other type of intercooling. In operation of Two Stages Reciprocating Air Compressor it is possible that when costs of different parameters are considered, the method adopted by us can be used for improvement in its overall efficiency. Energy cost of a compressor is approximately 75% of its life cycle costs. Performance monitoring is a valuable tool to detect performance degradation of compressor during operation. It helps to keep the energy cost in check. Even though in large reciprocating compressors online performance monitoring systems have been installed, in medium and small capacity industrial compressors installation of on line systems is not economical. In medium and small capacity compressors, performance should be monitored periodically using off-line monitoring methods. Various parameters that are indicators of the performance of air compressors are defined. It is not necessary to monitor all these parameters at regular intervals; instead it is enough to monitor vital parameter called specific power consumption periodically. If the specific power consumption valve decreases below the bench mark limit diagnostic parameters needs to be measured. Diagnostic parameters help to identify the power loss making components and airflow capacity loss making components. Various measuring techniques that are suitable for offline measurement of FAD of a reciprocating compressor, Electrical power consumption, Mechanical power consumption, Indicated power consumption and leakage rate are discussed. In this paper we have studied about Two Stage Reciprocating Air Compressor and one of its main component which is used in air compression system i.e. intercooler. Also, we have used very simple and time efficient algorithms for designing of intercooler for Air Compressor.

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