Comparison of Classic and Finned Piston Reciprocating Linear Air Compressor Using COMSOL Multiphyics®

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Abstract

Introduction: Positive displacement machines like reciprocating compressors are one of the most important machines used throughout the industry. The current work is dedicated to develop a detailed CFD model for such machines. In general, a cycle of operation of a high speed positive displacement compressor (Figure 1) can be described as a number of complicated phenomena, interacting and taking place in a short period of time. One of the applications of such machines is compressed air energy storage (CAES). In this application, a compressor is used to compress the air during the off-pick electricity demand time, and store it in a reservoir, and during the pick time, the reverse mode (expander) can extract the stored energy to feed the grid. The closer the compression/expansion to isothermal process, the more efficient it is. So, the idea is to keep the air close to ambient temperature by increasing the heat transfer rate through increasing the heat transfer surface by introducing a "finned piston" (Figure 2).

Use of COMSOL Multiphysics®: An analytical model is already developed for a classic piston based on mass and energy balance [1], and is extended to the finned piston [2,3]. The limitation of such a model is that it considers a uniform distribution of parameters (e.g. pressure, temperature…) through a chamber (lumped methodology). However it is of great interest to study the distribution of properties as well as local phenomena's (vortexes, turbulences) that occur in such a system. This is the reason that COMSOL Multiphysics® is employed: first to verify the analytical results and second to provide an insight to detailed modeling of the system in desired areas.

For in order to compare the finned to a classic piston, the same dead volume and displacement volume is set for both of them. The principle of the model is the same for both cases. Moving mesh is used to describe the compression chamber changing volume over time. Heat transfer and fluid flow is modeled accurately as well as inlet and outlet valves.

Results: The results confirm very well that the temperature rise in finned piston is much less (Figure 3) resulting in reduced work required (Figure 4). The results are also compatible with analytical model.

Conclusion: Finite element model developed in this work helps to understand detailed

distribution of pressure and temperature at all points of the control volume. In addition it provides a visual insight to the behavior of the system. This model has been used as verification for a detailed analytical model verified experimentally in turn in some other published works. This is the main particularity of this work since it provides the opportunity to understand the analytical background of such a study.

Figures used in the abstract

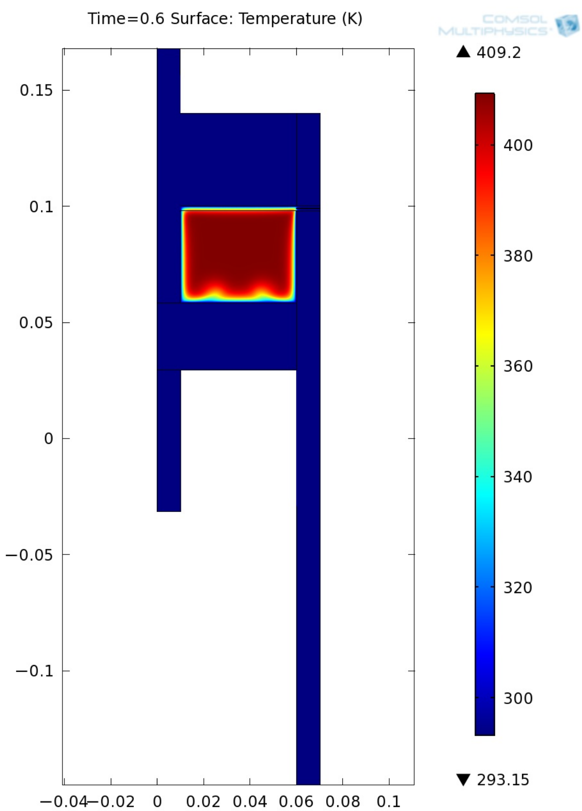

Figure 1: Classic compressor temperature distribution

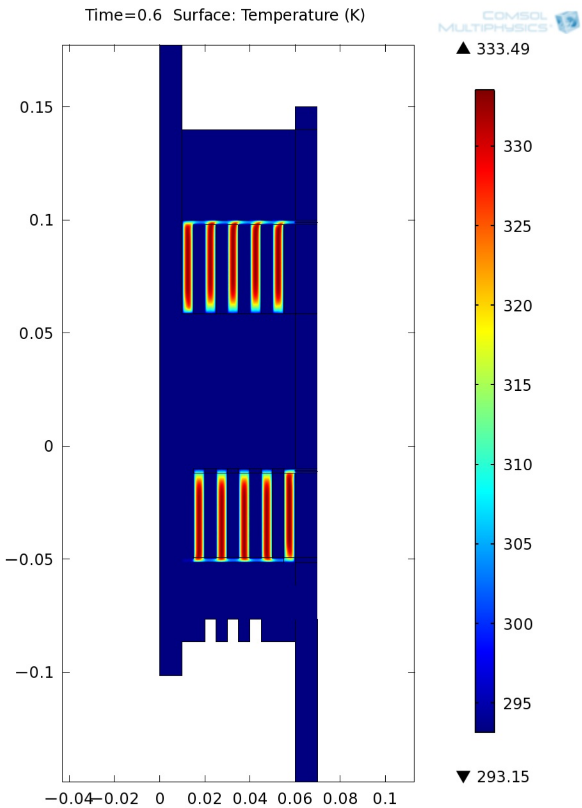

Figure 2: Finned compressor temperature distribution

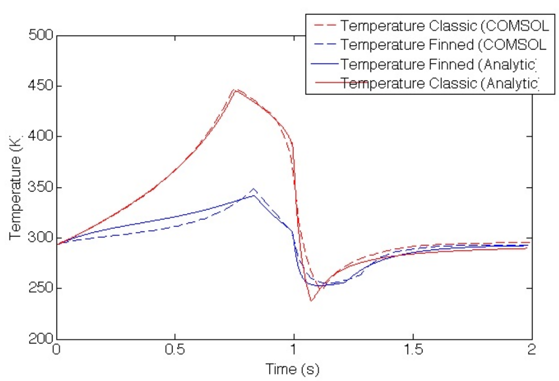

Figure 3: Analytical and COMSOL temperature comparison between classic and finned piston

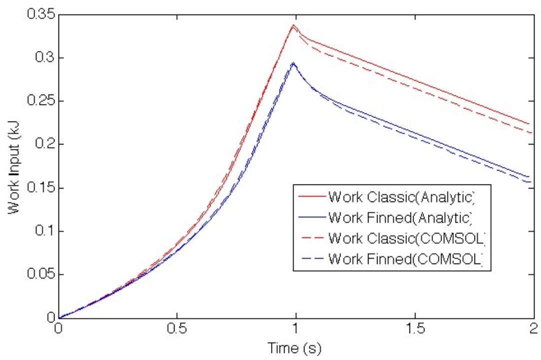

Figure 4: Analytical and COMSOL work comparison between classic and finned piston