MASTER

The Flow of Supercritical CO2 between Mechanical Seal Faces
A Study on the Effect of Mach Number and Choking on Expansion

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The Flow of Supercritical CO_2 between Mechanical Seal Faces — A Study on the Effect of Mach Number and Choking on Expansion

Master's Thesis

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Increased environmental awareness has seen increased interest in pumps, compressors and mechanical seals for (supercritical) CO_2 applications. With the current software models, calculations have been found to be compromised by incorrect assumptions and methods. This means that the results are not as accurate as Flowserve would like. With this project, these predictions are to be improved and an updated overview is given on how to seal CO_2 at supercritical pressures.

To achieve this, three steps are required. First, CO_2 properties, applications in a mechanical seal and expansion behaviour have been analysed. Then, the current software (Flowserve Seal FEA) is analysed. In this analysis of the methodology and the assumptions made, it was found that the software is not correctly handling turbulence and inertia, and that the choking conditions are severely underestimated. The last step of this research digs into the choking conditions within a mechanical seal and analyses how the prediction can be improved.

Three types of choking have been analysed for this. First, the effect of a changing area in an isentropic flow has been studied. It was found that a decreasing area, due to the radially inwards flow, causes choking pressures where phase change is prevented. However, the isentropic flow assumption is invalid when operating in the field. Therefore, the effects of friction (Fanno flow) and heat transfer (Rayleigh flow) on the choking conditions are studied. Friction from the seal faces causes the middle of a flow to accelerate towards the choking conditions at Mach 1. During this process, an entropy increase takes occurs. An entropy change also occurs when heat transfer takes place between the fluid and the seal face. However, it was found that heat transfer is limited due to the high flow velocities between the mechanical seal. Therefore it was concluded that, from a gasdynamics perspective, the Rayleigh flow effects can be neglected for the expansion between seal faces.

When combining these results, an accurate prediction of the expansion can be described. These have been plotted in a phase diagram to visualise phase change and proximity to the wet-vapour region. It is found that high pressure sealing solutions often do not encounter phase change. This is due to the high choking pressures. This means that the change in fluid properties can be compared to contemporary solutions, which implies that a similar type of seal is to be used for these conditions. With these results, an updated overview of the sealing solutions for CO_2 can be generated.

This research provides an updated overview to Flowserve on how mechanical seals for supercritical CO_2 applications should be engineered. It allows them to better advise customers with the solution they need. The conclusions in this report give Flowserve an edge over competitors when deciding what additional equipment (e.g. heaters) are required in certain areas of supercritical CO_2.