Research Article

Thermal Analysis of Floating Ring Mechanical Seal

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Abstract

A floating seal arrangement is preferred to counteract the effect of misalignment in any machinery. In the present study a carbon graphite mechanical seals of stationary siphon rotary joint (SRJ), used in paper industry, has been considered. To understand the uncertainties due to floating arrangement of seal rings, axisymmetric finite element analysis of SRJ assembly (rotational speed=150 rpm, steam pressure=3 bars) has been performed. Four configurations of floating seal rings have been studied. In this investigation, the heat generated at the interface is estimated and is assumed to be conducted away by both the seal and mating rings. The axisymmetric steady-state heat conduction and structural equations are solved using ANSYS software.

Keywords: Floating ring seal, Finite element analysis, Temperature rise, Heat conduction.

1. Introduction

Mechanical face seal is a component of seal joints, which is required to close the gap between the mating faces, so that the leakage of fluid (either a gas (Itzhak, 2008), (Sarkar and Hirani, 2013), (Sukhwani *et al* 2009), (Hirani and Goilkar, 2011) or liquid (Goilkar and Hirani, 2010), (H. Hirani and S.S. Goilkar, 2009), (S.S. Goilkar, and H. Hirani,2009)) from one region to other region is acceptably small under all circumstances of operation. Faces of new mechanical face seals are lapped flat.
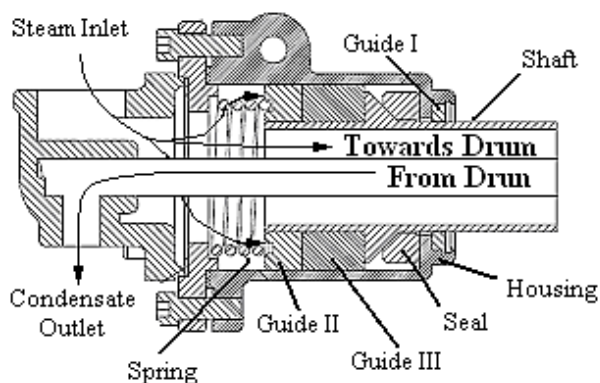

Fig. 1 Construction of Stationary siphon rotary joint

However, changes in operating conditions, particularly during start-up and shutdown, viscous heating, pressure, centrifugal effects, etc. (Doust and Parmar, 1986), (Ruan *et al*, 1997) inevitably cause the faces to deform from their initial flat state. It has well been established that face coning has a paramount effect on seal dynamics (Green and Etsion,1985), (Green and Etsion, 1985), which in turn increase temperature of the seal.

In the present work, the failure of mechanical seal due to the temperature rise between different components of stationary siphon rotary joint (SRJ) (as shown in figure 1) is studied. In this joint the steam enters from the cap provided with threaded connection for steam pipe into the housing of rotary joint. After entering into housing, the steam passes through hollow shaft made up of stainless steel (SS 304) to the drying drum. In paper industries, paper pulp is passed over the rotating drying drum. The shaft of SRJ is connected to the drum by flanged joint. The external surface of drying drum evaporates the water content of paper pulp by heating the pulp during the pass of paper pulp over it. The drying drum is therefore always kept heated with the help of high pressure and temperature of steam inside the drum. During drying process the heat of drum gets released through the paper pulp to atmosphere and therefore much amount of condensate gets collected inside the drum housing which is taken out with the help of siphon pipe system. The important components of SRJ are:

+ Primary seal (to minimize the steam leakage from joint to environment,
+ "Secondary seal"/"Guide I" (to support the radial load of shaft and seal the steam escaped from primary seal),
+ Shafts (rotary component coupled with drying drum)
+ Spring (to hold the shaft and seal surfaces together in absence of the steam pressure).
+ Stationary housing (to isolate steam from ambient environment)

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Often misalignment between contacting mechanical pair reduces the seal life to 20-25% therefore to overcome the misalignments in SRJ, floating ring mechanical seal is provided. To understand the uncertainties due to floating arrangement of seal rings, finite element analysis of SRJ assembly was performed. A typical operating condition of 150 rpm as rotational speed and 3 bars as steam pressure was considered for analysis. A 3-D solid model of assembly is shown in figure 2.
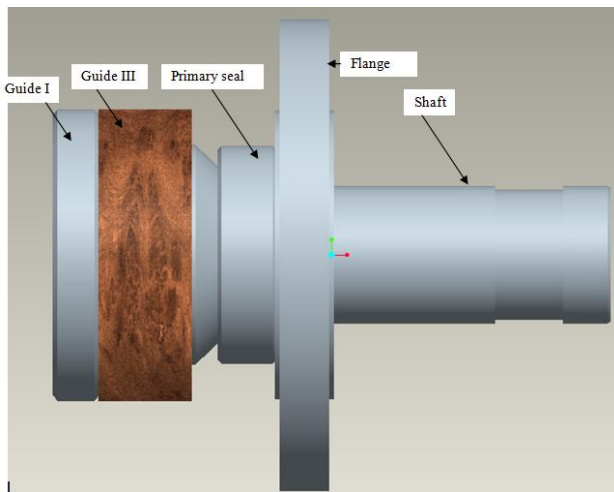

Fig. 2 Three dimensional SRJ assembly

In idle conditions, Guide I should not rotate relative to Guide III. Similarly primary ring should not rotate relative to shaft. But in almost every experiment, performed on existing SRJ assembly relative motions between guide I & Guide III, Guide III & shaft, shaft & primary seal, and primary seal & flange were observed. One advantage of such floating arrangements of Guides I & III, and primary seal is to spread the wear over all five surfaces (one surface of Guide I, two surfaces of Guide III, and two surfaces of primary seal). Unfortunately coefficient of frictions between various surfaces do not remain same. Coefficient of friction between carbon-graphite and antimony-impregnated-carbon-graphite is high (~ 0.5), carbon-graphite and SS is approximately 0.25, while antimony impregnated primary and cast iron flange it is approximately 0.15. Therefore, variation in relative motion from one assembly to other assembly changes the heat generation rate. To understand this phenomenon thermal analysis using ANSYS (finite element software) (Hirani, 2009), (Burla, 2004) was performed for the following four cases and analysis results are presented.

+ Case I: Relative rotation between Guide III & shaft, and Primary seal & flange
+ Case II: Relative rotation between Guide III & shaft, and Primary seal & shaft
+ Case III: Relative rotation between Guide III & Guide I, and Primary seal & flange
+ Case IV: Relative rotation between Guide III & Guide I, and Primary seal & shaft

2. Finite Element Analysis of floating Seal Rings

For the present work, an axisymmetric model of SRJ assembly (with casing) shown in figure 3 is considered. In this figure A1 stands for stainless steel shaft, A2 represents antimony impregnated carbon graphite guide I, A3 shows cross section of carbon graphite guide III, A4 stands for antimony impregnated carbon graphite primary seal, A5 and A6 represent cast iron flange and housing respectively. These all areas (A1 to A6) are axisymmetric about Y-axis. Coupled structural thermal field analysis using element: PLANE223 was considered for finite element analysis. The temperature rise estimated for all the four different arrangements has been discussed in the next section.
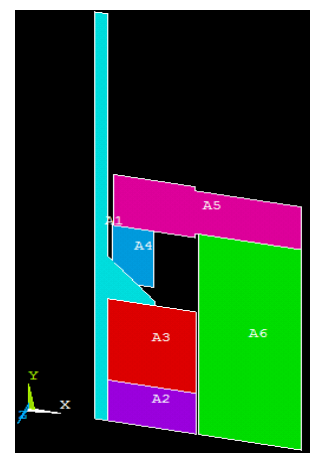

Fig. 3 Axisymmetric Model of SRJ Assembly

3. Results and Discussion

The temperature distribution for the case-I has been shown in figure 4. The minimum and maximum temperatures estimated for this are 108^0C and 139^0C, respectively. For the case II (figure 5) the minimum and maximum temperatures are: 106^0C and 139^0C, respectively. The estimated values of maximum temperature under Cases III & IV are on higher side. The maximum values of the Case III and Case IV is 185^0C as shown in figures 6 and 7 respectively.
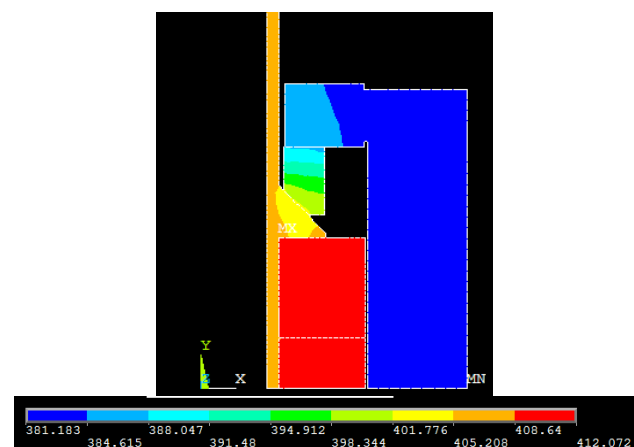

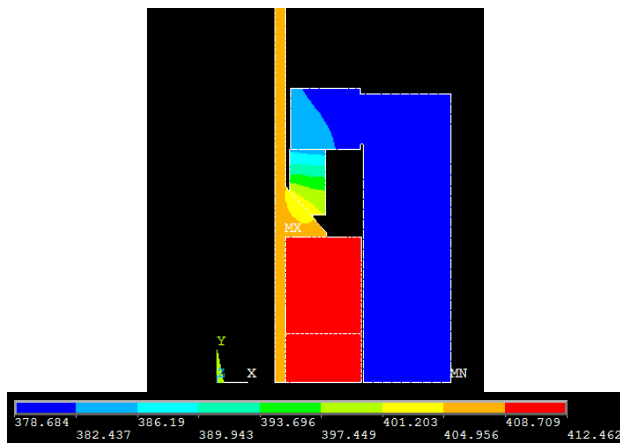**Fig. 4** Temperature (in Kelvin) profile (Case I)

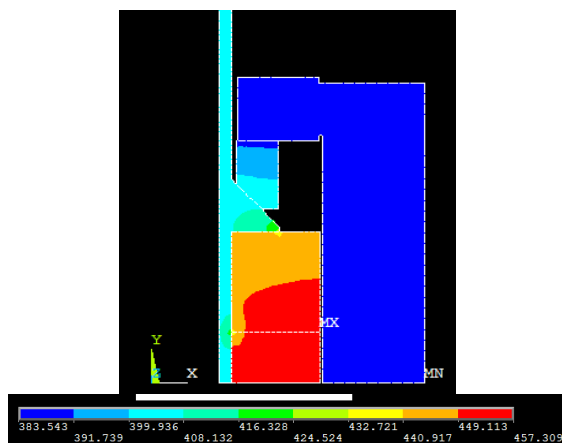**Fig. 5** Temperature (in Kelvin) profile (Case II)

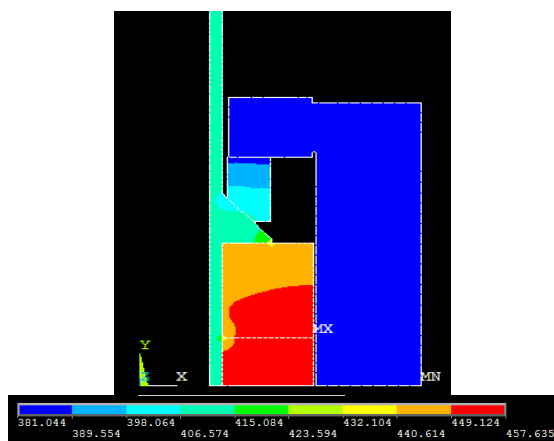**Fig. 6** Temperature (in Kelvin) profile (Case III)

Fig. 7 Temperature (in Kelvin) profile (Case IV)

Conclusion

Floating arrangement of seal rings causes variation in the maximum operating temperature ranging 139°C to 184°C. Guide III, due to its low thermal inertia, is sensitive to the formation of cracks at relatively high temperature and results in premature failure of seal rings. Therefore there is a need to design proper arrangements for floating seal rings.

If operating conditions such as Case III or Case IV remain for some time, the crack formation tendency of carbon graphite material (Guide III) increases which results premature failure of seal rings.

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