ADVANCED INVESTIGATION METHOD FOR STUFFING BOX PACKINGS FUNCTIONING

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ABSTRACT
The paper presents a new method used for the analysis of stuffing box functioning based on finite element analysis, emphasizing the advantages offered. These advantages mainly referring to the stress relaxation phenomenon, the thermal fields distribution and the maintenance conditions.

KEYWORDS: stuffing box, finite element analysis.

1. Generalities
The stuffing box seal for shafts is one of the possible solutions for two environments separation.

The stuffing box functioning is based on the effect of transformation (due to the special properties of the gasket material) of axial the pressure, from the tightening lid, in the radial pressure, on the shaft.

The main drawback of these seals, [1], is the wide contact area between the gasket and the shaft, figure 1, generating, this way, high losses of power because of the friction involved.

There is large variety of materials especially designed for their gaskets, this way the tribological behaviour of the seal is improved. The design of the seal’s shape is another way for optimizing his functional parameters.

In the functioning of these seals are involved a large number of processes linked to the gasket material (with visco-elastic behaviour), to the sealed environment and to the tribological behaviour of the components. Because of that the modeling of stuffing box seal can’t be done based only on some theoretical consideration, the designing of these seals needing some experimental investigation of their functioning too.

2. Methods used in stuffing box functioning analysis
These methods can be classified in three groups: first of them presuming the gasket material as a elastic, isotropic body and neglecting the thermal processes [2,3], second taking into account the visco-elastic behaviour of the gasket material [4] and last ones obtaining the appropriate equations based on experimental determinations [5].

In first group, [2], applying the Hooke’s law into a convenient cylindrical reference system, figure 2, the equation (1) is obtained.

\[
\varepsilon_{r,\varphi,z} = \frac{1}{E} \left[ \sigma_{r,\varphi,z} - \nu(\sigma_{\varphi,z,r} + \sigma_{z,r,\varphi}) \right]
\]

were: E is the Young’s modulus and \( \nu \) is the Poisson’s coefficient.

Assuming the shaft perfectly rigid:

\[
\varepsilon_r = \epsilon_{\varphi} = 0
\]

and then:

\[
\sigma_r = k\sigma_z \quad \text{were} \quad k = \frac{\nu}{1 - \nu}
\]
Equation (3) represent the transformation law of axial pressure into radial pressure.

Due to friction between shaft-gasket and gasket-seal box, the repartition of radial pressure is nonlinear on the contact area length:

\[ p_Z = p_0 e^{-\frac{[\mu_1 + \mu_2] L - z}{S}} \]  

(4)

were: \( p_Z \) - radial pressure at z-point; \( p_0 \) - radial pressure next the tightening lid; \( \mu_{1,2} \) - friction coefficients on both side of the gasket; \( L, S \) - geometrical dimensions of the gasket.

The second group methods [4] use non-linear rheological model for stress relaxation modeling:

\[ \dot{\sigma} = -\left(\frac{E_1}{\lambda}(\sigma - E_2) + (E_1 + (dE_2/\partial \varepsilon))\right) \]  

(5)

were \( E_{1,2} \) - Young modulus for the elastic components of the model, \( \lambda \) - damper's constant.

Based on this model the stress relaxation curves can be drawn, both in case of one tightening and in case of multiple over-tightenings.

The third group methods are based on a set of experimental measurements on a real seal, working in a real environment. In this way [5], the axial pressure variation law is established:

\[ p_Z = p_0 e^{-V k z} \]  

(6)

where \( V \) is an experimental determinate coefficient, depending on gasket material, shaft ruggedness, gasket dimensions and thermal regime.

The rheological behaviour of the gasket is established based on Burgers model:

\[ \dot{\sigma}_L = -\left(\frac{E_1}{\lambda_2}(\sigma_L - E_\varepsilon) \right) \]  

(7)

were \( E_{1,\varepsilon} \) - Young modulus for the elastic components of the model, \( \lambda_2 \) - damper's constant.

3. Advanced method for investigation of stuffing box functioning

This method, based on the finite element analyze, starting from some experimental acquired data (referring to the gasket material, shaft material and working regime) allow obtaining accurate results.

The model used, [6], for gasket material rheological behaviour is a generalized one, figure 3, allowing a high degree of integration.
4. Conclusions

The classic methods used for functioning analyze and designing of stuffing box seals, present some limitations because of the initial assumptions. These assumptions are necessary because, due to the large number of variables involved (linked to the rheological behaviour of the material, the tribological and thermal processes in the gasket), is very difficult to solve the appropriate obtained equations.

This way, certain aspects in stuffing box functioning are skipped throughout the designing process. That makes necessary some expensive optimizing processes after the seal construction.

The maintenance procedures are based on experimental results obtained after a testing period with full working seal.

The finite element analysis based method can supply, starting with seal's components characteristics (experimentally acquired), valuable information on stresses distribution in the gasket and on stress relaxation during the functioning of the seal, allowing this way to define the optimal maintenance procedures.

The results obtained referring to the thermal behaviour allow to design an appropriate cooling system for maintain the seal's temperature in the gasket material's optimal domain.

The procedures and the testing rigs used for establishing the initial parameters for the finite elements analyze are the common ones.

REFERENCES