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FINITE ELEMENT ANALYSIS OF THE FLEXIBLE COUPLING WITH METALLIC MEMBRANES

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Abstract: *The paper describes the design of flexible metallic membrane couplings with reference to the influence of axial and angular misalignments on membrane stress. The finite element analysis (FEA) is developed in the paper for one membrane unit. This analysis was made in the absence and with consideration of axial deviation. The FEA study and the corresponding results are given and discussed. The final conclusions are important for future researchers for other analysis variants (the existence of angular misalignment and the case of spacer couplings with two membranes units).*
Key words: *flexible coupling, endurance limit, stress state*

1. INTRODUCTION

In order to transmit the torque between two shafts of a kinematical chain, in compensation conditions of some important joined shafts misalignments, it is necesary for coupling producers to handle some multicriteria requirements regarding size, safety in exploitation (by guaranteeing a superior mechanical strength), behaviour during shocks and vibrations, constructive simplicity and reduction of execution costs. Through their functions which compensate coaxial errors in the radial, axial and angular plans, and also damping torsional oscillations, elastic couplings determine the mechanical system efficiency improvements, as well as simplification of transmition maintenance.

It is necessary and adequate to perform some complexe researches on flexible intermediary elements from elastic coupling structure, which would lead to working optimization on a long period, with favorable results in what concerns life and safeness of the system.

The paper's objective is the analisys of the factors that influence resistance of flexible intermediary elements, the capacity of compensating the position deviations of the shafts linked through an elastic coupling, in normal loading or overloading conditons. The material properties such as elasticity modulus, ultimate shear strength, ultimate tensile strength, endurance limit and fatigue strength are used in the design of a flexible metallic membrane couplings. The flexible membranes have a spoked form, the deformation of the spokes giving to the coupling its flexibility and thus its ability to handle installation misalignments (Phillips et al., 1977).

The coupling variant without spacer allows the taking over of the axial and angular deviations. There is a coupling variant with intermediary spacer permitting also radial deformations and the taking over of the radial (parallel offset) displacements. In this idea, the coupling assumes significant misalignments.

2. LITERATURE REVIEW

Dedicated papers for flexible couplings with membranes are limited as number. The references in this paper cover a special area linked to this type of flexible couplings (Phillips et al., 1977, Dobre G. et al., 2003, Sorohan S. & Sandu M., 1997). Mancuso (1986) created the guidelines to help evaluate disc and diaphragm designs for high power rotating systems. A dedicated paper used as a basis for the considerations coming next was created by Dobre D. (2004).

3. FINITE ELEMENT ANALYSIS OF THE MEMBRANES UNIT

In order to analyze a membranes packet using Finite Element Analysis (FEA), the 3D geometrical models were first designed for each individual component of the membranes unit including the assembling pieces, after which constraints for connection of these individual parts were entered. The geometrical model of a membranes unit having two pockets each of them with 8·flexible membranes and also two guiding and control rings is presented in figure 1.

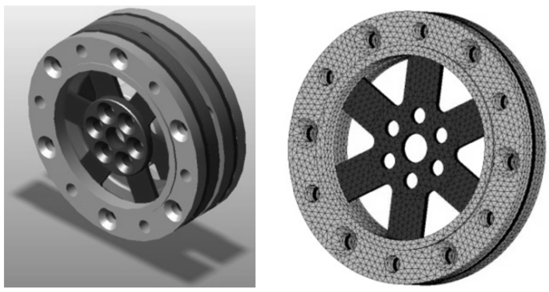

Fig. 1. Solid model of the membranes unit with two pockets and finite element mesh of the membranes unit

Once the solid model is created geometrically, the finite element model was generated with free meshing command. The solid model is not restricted by any special meshing requirements and the COSMOS Works meshing algorithms automatically generate the best-fit pattern of nodes and elements. By reasons of geometrical symmetry of the two pockets in the membranes unit, the mesh was applied only to a single elastic module. The elements of the two guiding and control rings have merged common nodes with them of the elements of the membrane in contact. The same merged common nodes exist between the elements belonging to two membranes in contact in the outer and inner part assembled by rivets (Dobre, 2004). The finite element mesh is of type 3D Tetrahedral Solid, with the maximum size of 0.5 mm on the side, resulting 135567 nodes, 88277 elements and 406429 degrees of freedom. The meshing with this element dimensions resulted after a number of analysis sets with different number of elements to ensure a sufficient convergence and accuracy of the FEA. Figure 1 shows the finite element mesh of the elastic module using a uniform distribution of the elements.

The boundary conditions for FEA at each membrane from the unit are presented in the following observations:

a) all outer holes are blocked as displacement on the direction of the membrane axis;
b) the inner assembling holes are blocked as rotation and translation on contour nodes.

4. RESULTS. DISCUSSION

The analysis was made for the nominal torque T = 50 N·m. In all situations the centrifugal loading is taken into account using a rotation speed of 4500 rpm. For the calculus of the membranes unit, the following situations were analyzed:

- the coupling without misalignment (the coupled shafts are perfectly aligned): $\Delta a = 0$, $\Delta\alpha = 0°$;
- the coupling allows axial misalignment (maximum value of $\Delta a = 0.3$ mm);
- the coupling compensates angular misalignment of the value $\Delta\alpha = 1/4°$.

The results obtained from FEA are given in the table 1: the values of the extreme principal stresses σ_1 and σ_3, the equivalent stresses calculated using the von Mises theory and the resulting maximum displacement.

Parameter / Misalignment	Principal stresses		Equivalent stress	Maximum displacement
	$\sigma_{1\ max}$ [N/mm^2]	$\sigma_{3\ min}$ [N/mm^2]	$\sigma_{eq\ max}$ [N/mm^2]	u_{res} [μm]
$\Delta a = 0$; $\Delta\alpha = 0$	156	-112.7	136.6	13.16
$\Delta a = 0.3$ mm	512.4	-312.9	437.6	306.8

Tab. 1. Results obtained by FEA

In the case where the flexible coupling does not have to assume misalignment of the coupled shafts, the stresses caused by the torque transmission, centrifugal loading and the disks' circumference displacement do not have dangerous values at any node of the structure. Therefore the coupling has normally infinite life in this operating case. This is illustrated in figure 2 for the equivalent stress calculated using the von Mises theory and in the figure 3 for the principal stress σ_3.

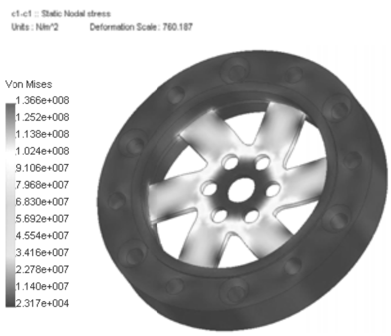

Fig. 2. Equivalent (von Mises) stress of the membranes unit without deviations

Because only the stresses of membranes are significant, it can be noted that the maximum stress is adjacent to the root at the trailing edge in the areas where the spokes are joined to the inner part of the membrane disks (Dobre G. et al., 2003).

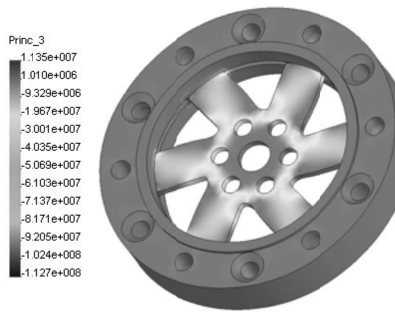

Fig. 3. Principal stress σ_3 of the membranes unit without deviations

Also, the membrane stresses are influenced by the misalignment and the method of attachment to the adjacent components (Mancuso, 1986).

In the case where an axial misalignment is initiated, $\Delta a = 0.3$ mm, the membranes on the left hand side of the pack in figure 4 have to stretch more than those on the right hand side, and therefore the induced tension will vary from membrane to membrane, and the stresses produced only reach high values locally, in the fixing area of the membranes unit with the guiding and control rings of the elastic element. This can be remedied by increasing the radius of the adjacent components in these areas, which leads to the reduction of the stress concentrations (both at the inner and outer diameters) which appear in the absence of the fillets (Dobre, 2004).

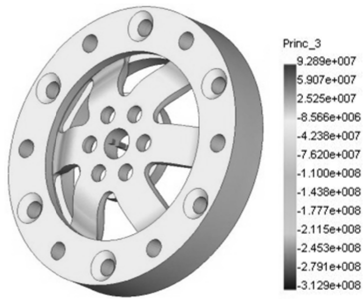

Fig. 4. Principal stress σ_3 of the membranes unit with axial deviation ($\Delta a = 0.3$ mm) on inner side of membranes unit

The introduction of angular misalignment $\Delta\alpha_1 = 1/4°$ and $\Delta\alpha_2 = 1/2°$ produce, in the same manner, local stresses over the admissible limit, in the same areas, the sections from the root of the spokes still remaining at lower values than those considered to be dangerous.

5. CONCLUSION

Among the many types of flexible couplings, the spoked metallic membrane type is particularly suited for high speed and high power applications. The flexible metallic membrane couplings rely on the flexure of membrane to accommodate misalignment and axial displacement of shaft ends while transmitting torque.

The stress state for a membranes unit may be described with accuracy using FEA meshing and boundary conditions in concordance with the solid model. The areas of maximum equivalent stress are placed on fillet root of the membrane spokes in the cases of alignment and misalignment of the two shafts. The extreme equivalent stress values increase with the axial and angular misalignments at the limit of the recommended admissible safety factor values.

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