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Failure Analysis of a Universal Coupling using Finite Element Method

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I. Introduction

Universal coupling is commonly used in rotating shaft that transmits rotary motion. It is a specialized rotary joint used to allow a rotating split shaft to deflect along its axis in any direction. This flexibility is achieved by constructing the joint with two U-shaped yokes (coupler) joined by a cross shaped hub (pin). One yoke is attached to the end of each portion of the split shaft and joined with the cross hub, with the U-sections oriented at 90°to each other. This arrangement allows the horizontal primary shaft to drive the inclined shaft with no undue friction or loss of speed or drive output potential. Typical applications of universal coupling include aircraft appliances, control mechanisms, electronics, instrumentation, medical and optical devices, ordnance, radio, sewing machines, textile machinery and tool drives. Fig. 1 shows a commercially available universal coupling and Fig. 2 shows CAD design of a coupling.

There are some available literature on universal coupling[3]. The novelty of the present literature is that it gives emphasis on yoke and hub separately. The main stress zone of a coupling is the yoke slot-hub interface and the hub corners. In the yoke slot-hub interface, the stress acts is circumferential. At the same time, friction at the interface generates heat. This heat generates thermal stress. So during the operation of a coupling, mainly two types of stresses works, namely circumferential stress and thermal stress. During our investigation, we applied circumferential stress at the yoke slot-hub interface to see how it affects the stress propagation in both the yoke and the hub. In addition, we applied thermal stress and increased it gradually to show how it influences generation of stresses. To show the strain rate and the displacement in the yoke, the strain contour and the displacement contour are also plotted. The simulation was carried out in SolidWorks 2010, the validity and acceptability of which is well established.

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Figure 1 : Commercially available universal coupling

Figure 2 : CAD design of a universal coupling

II. Solution Procedure

a) Formulation of the Problem

The equation of motion relating the two angular positions of the two yokes is given by,

$\tan \Upsilon_1 = \cos\beta \tan \Upsilon_2$

where, Υ_1 = angle of rotation of yoke 1

Υ_2 = angle of rotation of yoke 2

β = the angle of the yokes with respect to each other

The angles Υ_1 and Υ_2 in a rotating joint will be function of time. Differentiating the equation of motion with respect to time and using the equation of motion itself to eliminate a variable yields the relationship between the angular velocities $\omega_1=d\Upsilon_1/dt$ and $\omega_2=d\Upsilon_2/dt$

$$\omega_2=\omega_1\cos\beta/(1-\sin^2\beta\cos^2\Upsilon_1)$$

The angular velocities are not linearly related but rather are periodic with a period twice that of the rotating shafts. The angular velocity relation can again be differentiated to get the relation between the angular acceleration α_1 and α_2,

$$\alpha_2=\alpha_1\cos\beta/(1-\sin^2\beta\cos^2\Upsilon_1)\ -(\omega_1^2\cos\beta\sin^2\beta\sin2\Upsilon_1)/(1-\sin^2\beta\cos^2\Upsilon_1)^2$$

b) Solution Methodology

The CAD drawing is carried out in SolidWorks 2010. At first yoke, hub and disc are drawn in part drawing option separately. Then these three things are assembled in assembly drawing option. The main parameters used during the drawing are given below.

Parameter	Dimension (mm)
Yoke base radius	100
Disc radius	100
Yoke base thickness	50
Yoke slot radius	25
Hub ends distance	200

The simulation too is carried out in SolidWorks 2010. The main parameters and variables used during simulation are given below.

Parameter	Type/Value
Simulation	Static
Fixture used	Fixed geometry
External load	Circumferential (1 MPa)
Mesh type	Solid mesh
No. of elements (hub)	7783
No. of elements (yoke)	7314
No. of nodes (hub)	12125
No. of nodes (yoke)	12059

Fig. 3 shows SolidWorks drawing of yoke, hub and disc before being assembled. Fig. 4 shows different parts of the yoke and the hub.

The main features used during drawing are extrude, extrude cut, mirror and mate. For simplicity, details description of the drawing has been avoided.

Figure 3(a) : Yoke of a universal coupling

III. Results and Discussion

In our specimen, the material considered is Al 1060 alloy. Modulus of elasticity of the material is E=69 GPa and Poisson's ratio is ν =0.33. The simulation has been carried out in room temperature, which is considered to be 25 °C. To find out the most critical condition in terms of stress and strain, the clearance between the hub and the slot of yoke is kept zero.

Fig. 5 shows the generation of strain across the yoke. It is found to be maximum along the edge of the yoke extension. Besides there is also an abrupt rise of strain at the extension-base intersection. The maximum value of strain is found to be $6.2\text{x}10^{-5}$ and the minimum value is found to be $1.93\text{x}10^{-8}$. The value of strain around the slot is found to be almost $3\text{x}10^{-5}$.

Fig. 6 is a demonstration of displacement, takes place during the operation of a universal coupling. The displacement is found to be maximum at the free end of the yoke extension. It is in conformity with the physical condition because the extension works as a cantilever and a cantilever with a load at the free end displays maximum displacement at that end. On the other hand the displacement is negligible at the base. It is also valid because the base is considered to be rigidly fixed. The maximum value of the displacement is found to be almost 0.02mm.

Fig. 7 shows the demonstration of von Mises stress generated in the yoke. Like the generation of strain, maximum stress is found along the edge and at the extension-base intersection of the yoke. The maximum value is found to be 6.03 MPa and the minimum value is found to be almost 0.00099 MPa. Stress around the slot is about 3 MPa, which is half of the maximum stress. So in terms of von Misesstress, the most critical zone of a yoke is the base-extension intersection and the edge of the yoke extension having the maximum probability to fail. But under the given load at room temperature, the yoke would not fail because the maximum stress is 6.03 MPa which is much smaller than the yield strength of Al 1060 alloy, which again is 27.57 MPa.

Fig. 8 shows relationship between temperature at the slot of the yoke and generation of maximum stress in the yoke. With increase of temperature in the slot surface, stress increases across the yoke. The relationship is linear in nature. That means the more friction between the hub and the slot of the yoke, the more temperature rise will be, hence the more stress generation will be. The friction can be reduced significantly using bearing and lubricant. From the figure it is evident that under given loading and restrained condition, the yoke material will fail if the operating as well as yoke temperature rises as much as 315K (42 ^{0}C).

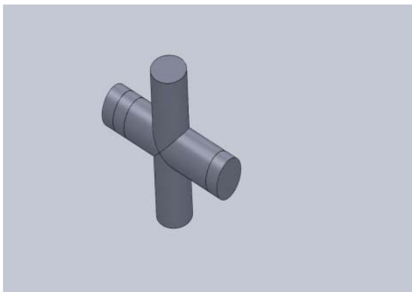

Figure 3(b): Hub of a universal coupling

Figure 3(c) : Disc of a universal coupling

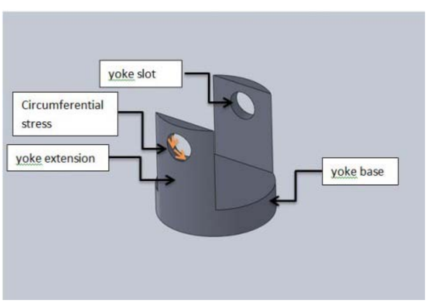

Figure 4(a) : Different parts of a yoke

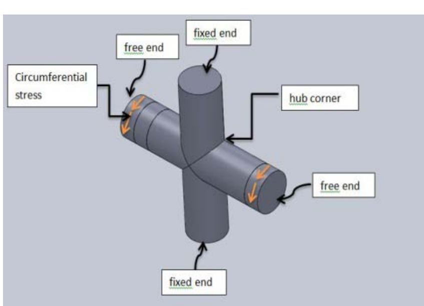

Figure 4(b) : Different parts of a hub

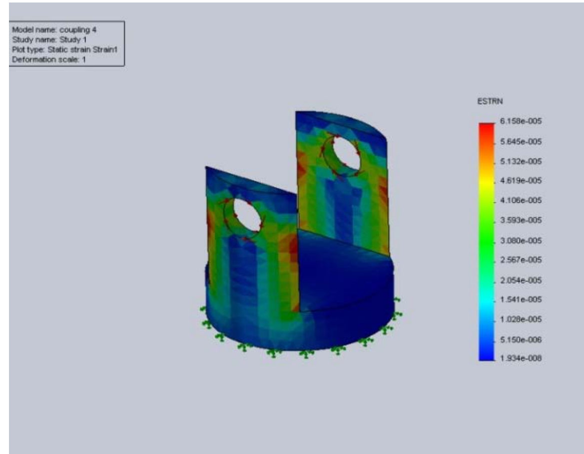

Figure 5 : Strain plot of yoke

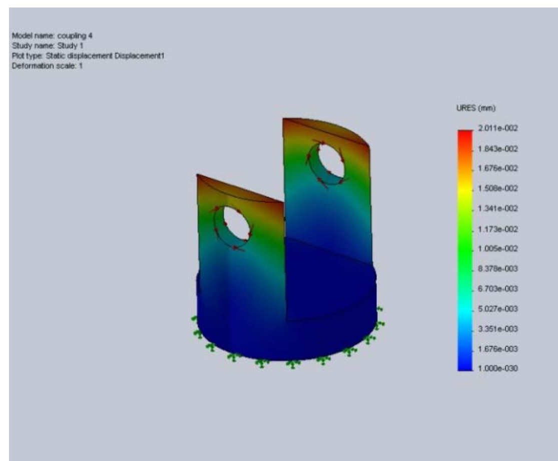

Figure 6 : Displacement plot of yoke

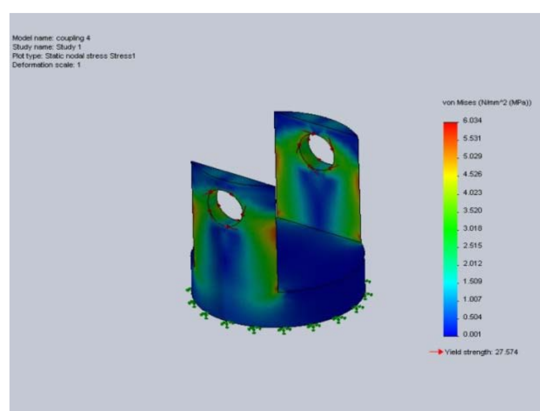

Figure 7 : Stress plot of yoke

Fig. 9 is a demonstration of relationship between strain rate and temperature. With the increase of temperature, as usual strain increases. The relationship is linear.

In Fig. 10, a relationship between temperature rise and displacement in the yoke has been showed. The relationship is not linear. The displacement at temperature 300K and 305K is almost the same, then there is an abrupt rise in displacement. The relationship is linear in the temperature range between 305K and 320K.

Fig. 11 shows the distribution of von Mises stress in the hub. At the two free ends of the hub, circumferential pressure is applied at the slot-hub interface. The other two ends are assumed to be fixed. From the figure it is evident that, for the same loading condition as like in the yoke, generation of

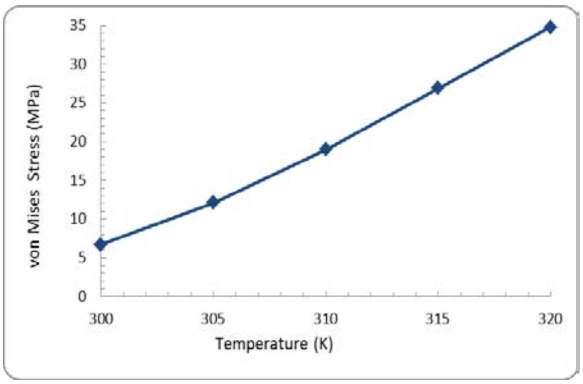

Figure 8 : Stress- Temperature relation(load constant)

stress in the hub is larger. In case of yoke, the maximum stress generation is 6.03 MPa, where as in case of hub it is 7.577 MPa, which is about 20.4% larger than the previous one. That means between the yoke and the hub, the hub will fail first, provided that both of them are facing same loading conditions. The extreme failure regions are found at the corners of the hub.

IV. Conclusions

Stress and strain generated in a universal coupling is discussed elaborately. Attention is mainly given to the yoke slot and the hub because they are the main frictional zones. Effect of thermal stress has also been demonstrated in case of the yoke. It is showed that friction can cause significant thermal effect which eventually can increase the stress intensity of the yoke. For example, if the temperature at the slot of the yoke increases up to 315K (42^{o}C), the material may yield, because the generated stress will cross the yield strength of Al 1060 alloy.

References Références Referencias

1. Russel J., Cohn R. Centrifugal Governor. 2012.
2. Timoshenko SP, Goodier JN. Theory of Elasticity, 3rd edition, *New York:McGraw Hill*, 1979.
3. Krauthamer J. Universal Swivel Coupling or Joint. NY. 1948.

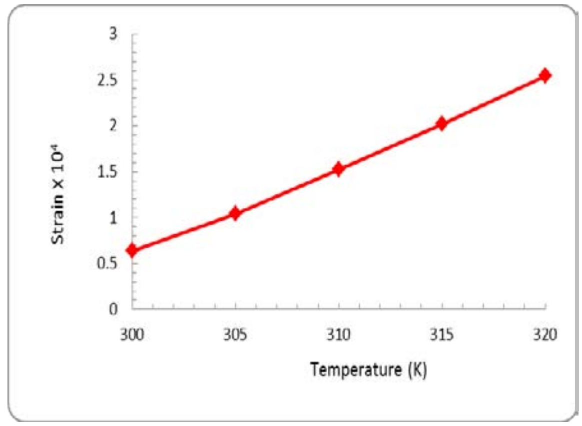

Figure 9 : Strain-Temperature relation (load constant)

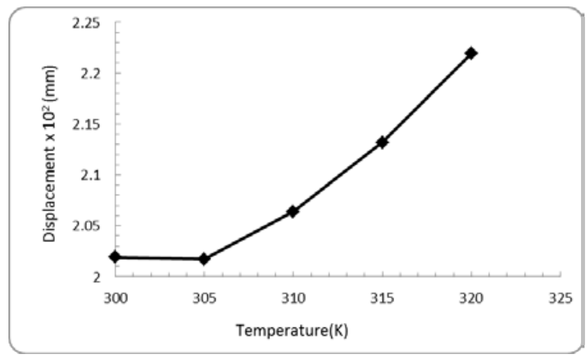

Figure 10 : Displacement-Temperature relation (load constant)

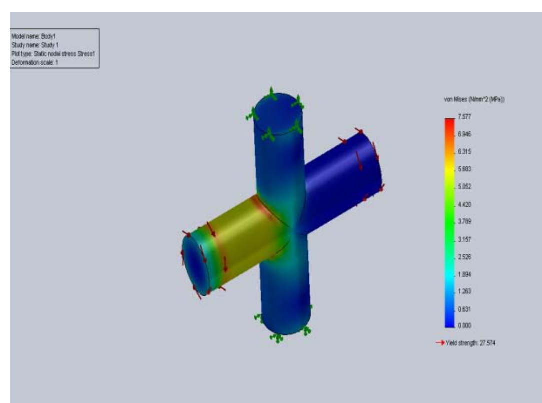

Figure 11 : Stress plot in the hub