Analysis of Two-Part Shrink Disc using ANSYS

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ABSTRACT: Keyless Locking Devices (two-part shrink disc) directly connects hub and shaft by using an interference fit for transmit torque. In this research we including a design equations of torque transmission capacity as well as contact pressure which is generated by radial load for two-part shrink disc. In this research include theoretical transmitting torque is compared to catalogue value of torque transmission capacity of two-part shrink disc also research includes CAD model which is made in CREO PARAMETRIC 6.0.1.0 of two-part shrink disc then we find results obtained theoretically are further compared with the results obtained by numerical analysis which is find by ANSYS software and then we will include experimental model to check our selected two-part shrink disc is able to transmit required torque or not.

KEYWORD

Two-part shrink disc, shaft-hub keyless connection, mechanical interference fit, radial force, contact pressure, torque calculation.

1: INTRODUCTION

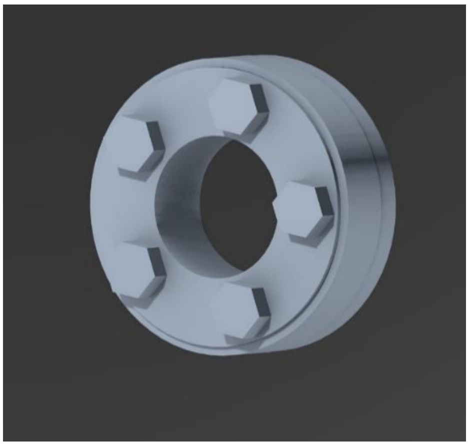
When we used keyed shaft and hub connection that time clearance in key and keyway required to fitting. This is a main disadvantage for that type of joint during shock/reversing loads is transmitted so when start up or load reversal the component is held by a key may slip Frome to shaft by the value is equal with the value of clearance in between shaft and components there is also impact load is generated this impact loads does not consider at that the design process also generate constantly continues as well as higher hammering in key and keyway corrosion also cause there by micro movement on a fit interface joint of shaft as well as component of that type of fit.

That type of problem occurs when we use key type joint so we need to solving that type of problem. That type of problems solved by ushing mechanical interference fit. Interference fit like shrink fit also called press fit which is provide us to zero clearance in the shaft and components also eliminate backlash. Advantages are this it is used all full contact area to uniform transmission torques and forces also in this type of joint will never constantly continues as well as higher hammerings in infinite number of load cycles during operations also there is more advantage like remove of key so no need of keyed and shaft notch factors. The key and shaft notch factor permit side reduction between shaft and bearing also that type of reduction reduced cost as well as complex design.

Two-part shrink disc is used as a locking keyless device works on the proven wedge principle for create a keyless. Work of two part shrink disc is connecting a hub to shaft also that type of connection same as conventional shrink/press fits. Two-part shrink disc has many advantages like it has ability to quick easy assembly and disassembly even it is also protecting Frome corrosion.[1]

Working Principle

We can see fig.1 and fig.2 over there is a two-part part1 and part 2. When we tightening screw there is develop the axial force by tightening torque which we apply on screw from this axial load inner ring is go inside to outer ring there is conical angle is provide so the radial load is apply on hub surface. So, there is generate contact pressure through radial load and then hub and shaft connect through that contact pressure.



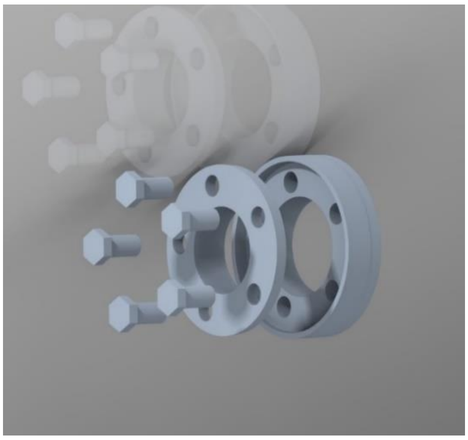
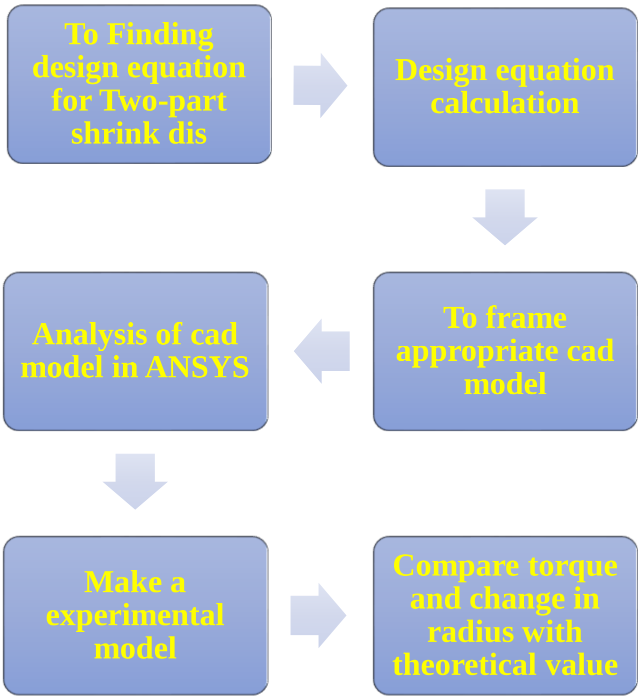


Figure 1 3D model of two-part shrink disc

Figure 2 assembly's

2: METHODOLOGY



3: DESIGN EQUATIONS OF TWO-PART SHRINK DISC

This chapter derive design equations for torque transmission capacity of Two part shrink disc. Two part shrink discs provide a high-ratio conversion of screw tightening loads convert into radial contact pressures when the tapered collars are pulled together through tightening of the integrated locking screws of two part shrink disc and also, how the tightening torque is converted into radial load and contact pressure is briefly explained. Based on contact pressure, the value of torque which is transmit by an interference fit of two part shrink disc is also explained.

3.1: EQUATION OF RADIAL FORCE

The equation of Radial load or Radial force generated by tightening locking screws which is found by using the concept of raising or lowering load by using power screws concept.[2]

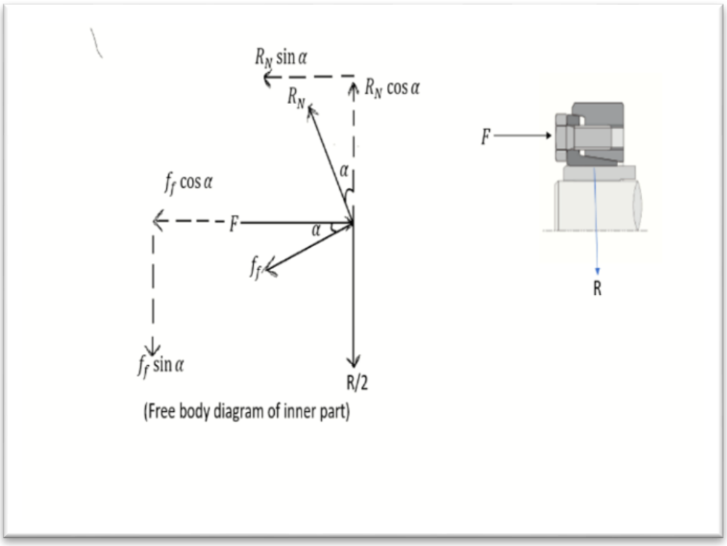


Figure 3 free body diagram

Consider horizontal component of force:

$$F = R_N \sin\alpha + f_f \cos\alpha$$

$$F = R_N \sin\alpha + \mu R_N \cos\alpha$$

$$F = R_N[\sin\alpha + \mu \cos\alpha]$$

$$R_N = \frac{F}{[\sin\alpha + \mu \cos\alpha]}$$

Consider vertical component of force:

$$R/2 = R_N \cos\alpha - f_f \sin\alpha$$

$$R/2 = R_N \cos\alpha - \mu R_N \sin\alpha$$

$$R = 2R_N[\cos\alpha - \mu \sin\alpha]$$

Value of R_N of equation A substitute to equation B:

$$R = 2\frac{F[\cos\alpha - \mu \sin\alpha]}{[\sin\alpha + \mu \cos\alpha]}$$

3.2: Tightening(clamping) Torque of screw

There is a linear relation into torque and tension. Before permanent stretch is induced within the elastic range. Some researchers have found out that there are some variables are affecting this relation. Components materials, components temperature, installation rate, helix angle of thread, friction coefficients, etc. are that type of variable. Reduced difficulty on the number of factors, one method is to depended on actual results of test. This are, to perform test setup in the work conditions of measure the persuading torque and tension of result record. That can be done by simple, piezoelectric load cells, electric strain gages, or calibrated hydraulic pressure sensors. Then the data is collected and drawing on a chart. The curve slop is used to find a factor of correlation. Torque to tension relation formula can be find by this method.[3]

$$T_s = KFd_s$$

T_s is tightening torque of screw

K is Torque co-efficient (standard value is 0.10)

F is clamping load or axial force

d_s is nominal diameter of screw

3.3: Contact pressure:

Due to radial load, Contact pressure is generated. This contact pressure depends on the contact area. The equation of contact pressure is given by equation,

$$contact\ pressure = \frac{radial\ load}{area\ of\ contact}$$

$$= \frac{R}{\pi dL}$$

$$P = \frac{2F[\cos\alpha - \mu\sin\alpha]}{[\sin\alpha + \mu\cos\alpha]\pi dL}$$

3.4: Torque Transmitting Capacity

The amount value of torque which is transmitted by an interference fit can also be approximate with an analysis of friction on the interface and the force of frictions are the friction coefficient product and there is normal direction force acting on the interface region. The normal direction force also can be described through the pressure product P and the area of surface A of interface region. That's why, the force of friction or friction force F_f is,

$$F_f = \mu \times N$$

$$= \mu \times (P \times A)$$

$$= \mu \times (P \times \pi d_w l)$$

Where, d_w = shaft diameter

This force of friction is generating with an arm of moment of $\frac{d_w}{2}$ to deliver the capacity of torque of joint, so

$$T = F_f \times \frac{d_w}{2}$$

$$= \mu \times (P \times \pi d_w l) \times \frac{d_w}{2}$$

$$= \frac{\pi}{2} \times \mu P l d_w^2$$

3.5: Change in radius

From the theory of compound cylinder pressure vessel which is based on Lame's Equation,

We are finding two equation

Increase radius of inner radius of outer cylinder, [4]

$$\delta_o = \frac{Pr_2}{E}\left[\frac{r_3^2 + r_2^2}{[r_3^2 - r_2^2}+ \vartheta\right]$$

Decrees outer radius of inner cylinder,

$$\delta_i = -\frac{Pr_2}{E}\left[\frac{r_2^2 + r_1^2}{[r_2^2 - r_1^2} - \vartheta\right]$$

4: THEOCRATICAL TORQUE TRANSMISSION CALCULATION

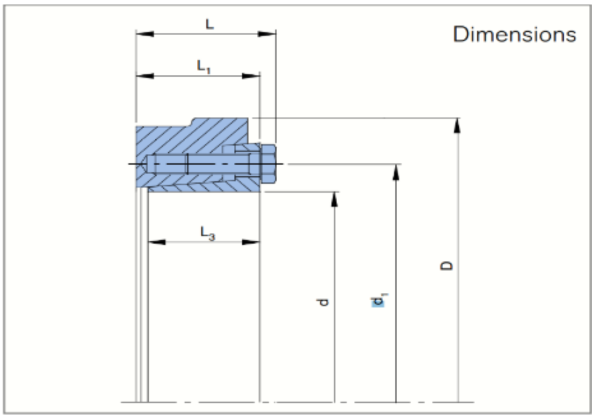


Figure 4 cross section of two part shrink disc

Table 1 dimensions of two-part shrink disc

Shrink disc dimension							Transmissible Torque	screw	
d mm	D mm	dw mm	d1 mm	L mm	L1 mm	L3 mm	T Nm	T Nm	Size
24	50	19 20 22	36	22	18	15	160 210 280	12	M6

4.1: Tightening Torque of screw

$$T_s = KFd_s$$

$$F = \frac{T_s}{Kd_s} \quad = 20000\ N$$

4.2: Contact Pressure

$$P = \frac{2F[\cos\alpha - \mu \sin\alpha]}{[\sin\alpha + \mu\cos\alpha]\pi d L} = 184.75\ N/mm^2 \cong 185\ N/mm^2$$

4.3: Torque Transmitting Capacity

Now,

for $dw = 19$ mm

$T = \frac{dw^2}{2}$ μ P π I = 188.734 Nm

for dw = 20

$T = \frac{dw^2}{2}$ μ P π I = 209.124 Nm

for dw = 22

$T = \frac{dw^2}{2}$ μ P π I = 253.040 Nm1

4.4: CHANGE IN RADIUS

For shaft-Hub pair:

Increase inner radius of hub,

$$\delta_o = \frac{P r_2}{E}\left[\frac{r_3^2 + r_2^2}{r_3^2 - r_2^2} + \vartheta\right] = 0.0160750 \text{ mm}$$

Decrease the radius of shaft,

$$\delta_i = -\frac{P r_2}{E}\left[\frac{r_2^2 + r_1^2}{r_2^2 - r_1^2} - \vartheta\right] = -0.00710789 \text{ mm}$$

For outer part-inner part of shrink disc pair:

Increase the radius outer part of shrink disc,

For contact pressure between outer ring-inner ring pair,

$$R_N = \frac{F}{[\sin\alpha + \mu\cos\alpha]} = 91161.4 \text{ N}$$

Contact pressure,

$$P = \frac{2R_N \cos\alpha}{\pi d L} = 213.14\ N/mm^2 \cong 213\ N/mm^2$$

$$\delta_o = \frac{P r_2}{E}\left[\frac{r_3^2 + r_2^2}{r_3^2 - r_2^2} + \vartheta\right] = 0.0322826 \text{ mm}$$

5: RESULT AND DISCUSSION

For the validation of theoretical results with numerical result, Equivalent elastic strain is required because we find change in radius from strain value for compare with theoretical values of change in radius of component of two part shrink disc. The results of the Equivalent elastic strain for all the components is shown in below figure also describe the direct deformation.

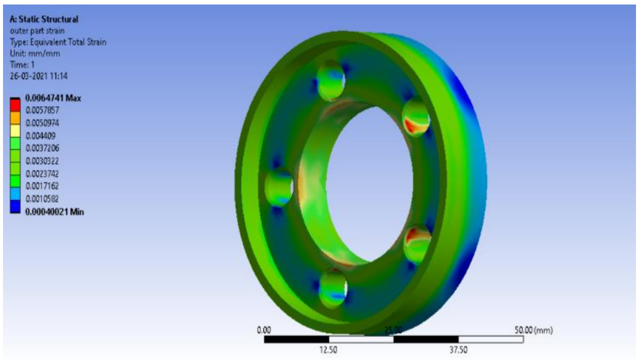


Figure 5 outer part strain

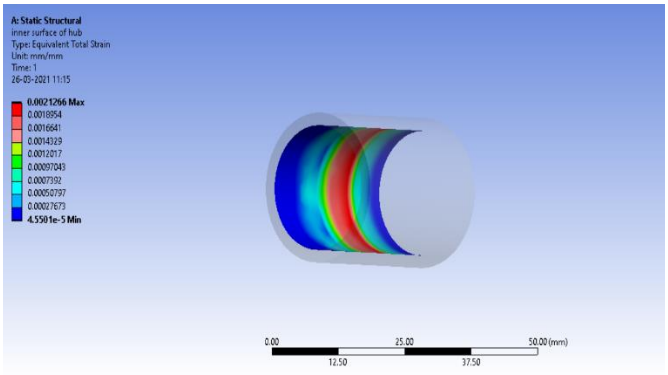


Figure 6 hub strain

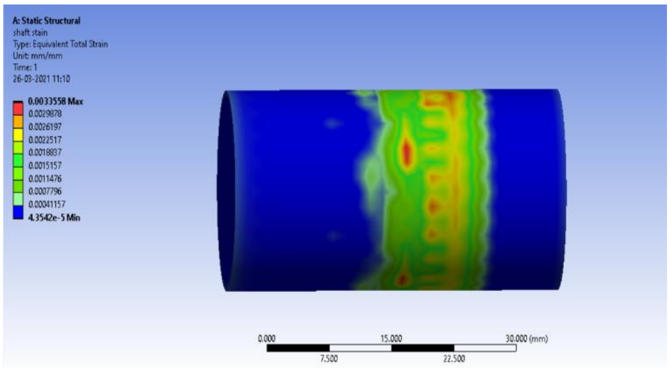


Figure 7 shaft strain

Change in radius from numerical results:

For the validation of numerical results with theoretical results, we need to calculate the change in radius of components as we considered in the theoretical results. From the results of equivalent elastic strain, value of change in radius can be easily calculated. Calculation for the change in radius of each component is described below.

Change in radius of outer part:

We know, $Strain = \frac{change\ in\ radius}{orignal\ radius}$

$\therefore$ Change in radius = Strain × original radius

Change in radius of outer part = 0.0024248 × 13.56

$= 0.03288029\ mm$

Change in radius of hub:

We know, $Strain = \frac{change\ in\ radius}{orignal\ radius}$

$\therefore$ Change in radius = Strain × original radius

Change in radius of hub = 0.0016641 × 10

$= 0.016641\ mm$

Change in radius of shaft:

We know, $Strain = \frac{change\ in\ radius}{orignal\ radius}$

$\therefore$ Change in radius = Strain × original radius

Change in radius of shaft = 0.0007796 × 10

$= 0.007796\ mm$

Table 2 comparison of theoretical and analytical change in radius from strain

Sr No.	Components	Theoretical change in radius value mm	Analytical change in radius value From Strain mm	% deviation in calculation %
1	Outer part of shrink disc	0.0322826	0.03288029	1.85
2	Hub	0.016057	0.016641	3.3
3	Shaft	0.00710789	0.007796	9.6

Table 3 comparison of theoretical and analytical change in radius from deformation

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3	Shaft	0.00710789	0.007796	9.6

6: CONCLUSION

The theoretical change in radius shown in table 2 was exact match with analytical change in radius value which was found by using total equivalent strain value from ANSYS. So, we have concluded that our calculation is true. Also, for more validation we have used direction deformation in radial direction shown in table 3 which was found from ANSYS for compare with change in radius value of components was also match. ANSYS gave us better and accurate result than theoretical result.

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