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تأثير خشونة الأسطح وسمك المحمل على التركيب التداخلي

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الملخص :

أختص هذا البحث بدراسة تأثير خشونة الأسطح للأجزاء المتداخلة وسمك المحمل على السلوك الميكانيكية الناتجة خلال عمليات التركيب والتفكيك لهذه الأجزاء, ولهذا الغرض فقد تم دراسة عملية لاحدى وعشرون عينة لقياس مقدار القوة اللازمة لتركيب وتفكيك المحمل على العمود لثلاثة أسطح مختلفة الخشونة للأعمدة مع تحديد خشونة السطح الداخلي للمحمل, وفي المرحلة الثانية تم قياس مقدار القوة اللازمة لتركيب وتفكيك المحمل على العمود لأربعة محامل مختلفة في أقطارها الخارجية مع تحديد خشونة سطح العمود والمحمل. كما تم دراسة تاثير تغير الأقطار الخارجية للمحمل عن طريق برنامج المحاكاة (ANSYS), وأظهرت نتائج المحاكاة بأن مقدار الأجهادات الناتجة بين العمود والمحمل تعتمد بشكل كبير على القطر الخارجي للمحمل, حيث بزيادة القطر الخارجي للمحمل تزداد مقدار الأجهاد بين الأجزاء المتداخلة, وكذلك اظهرت النتائج العملية للدراسة بأن القوة اللازمة لتركيب وتفكيك المحمل تقل بزيادة خشونة الأسطح المتداخلة وتقل هذه القوة عندما تكون سمك المحمل قليلة وذلك لحصول تغير في اقطار المحمل نتيجة التداخل التركيبي .

كلمات دالة: التركيب التداخلي, المحمل, العمود , خشونة الأسطح, سمك المحمل.

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Influence of Surface Roughness and Hub Thickness on Interference Fitting

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Abstract

In this study the mechanical behaviors of shaft and hub were investigated by using the experimental tests by measuring the required axial load during coupling and decoupling in interference fitting. The surface roughness of the shaft and hub thickness effects on the mechanical property of interference was studied. All tests were performed for constant interference fit classes for three different surface roughness of the shaft without changing the inner surface roughness of the hub. Also four different outer diameters of hubs with keeping constant surface roughness of the inner diameter of hub studied, thus 21 samples of interference studied.

The analysis of variance reveals in this study is that the best interference tightens condition is achieved at fine surfaces, the results also show that the hub thickness effect and increases the stresses are

usually generated immediately and reach maximum value in the inner site of hub after the assembly completed. Finite element model of shaft and hub was established, and the equivalent stress and contact stress for different hub thickness were computed after interference coupling, diameters in the thin hubs increase when coupling complete which reduces the interference between the shaft and hub.

Key words: Interference fit, Shaft, Hub, Surface roughness, Hub thickness.

1. INTRODUCTION:

Interference fit considers as a semi-permanent assembly method for mechanical parts, which is achieved by the interference after the tolerance part hub cooperate with the contained part shaft. Assemblies can transmit torque and load bearing after interference fit. Interference fit is one of the most common assembly methods in many mechanical machines, such as the fit of the gear and shaft, assembly of the roller bearing, connection of wheel and wheel cone, etc...

When the hub and shaft are assembled by shrinking or press fitting one part upon another, a contact pressure is created between the two parts in interference fit. The interference fit is achieved by the outer radius of the shaft member was larger than the inner radius of the hub by the radial interference (δ) [1].

In this assembly the tensile stresses will be induced in the outer hub and compressive stresses on the inner shaft. Due to this shrink fitting a radial pressure will be induced in the common surface due to diametrical interference. At a common diameter, inner surface of the hub will be subjected to tensile stress and outer surface of the shaft will be subjected to compressive stress due to press fit of interference fit.

The mechanical behaviors in interference fit of shaft and hub depend on axial load, hub thickness and friction of coefficient, which depend on the roughness of hub and shaft surfaces. There is related between interference fit and fretting, where fretting is very small amplitude and appears between two contact surfaces, which usually occur in approximation to the fastening contact surfaces in a vibrating environment. Fretting can cause friction and wear, loss in assembly, component bite, all these factors lead to crack, propagation, and reduction of the fatigue life of components [3]

Many research regarding focusing on interference fit for shaft and hub. For example, Yang et al. studied the effects of casing length, thickness, friction coefficients and interference on the contact pressure, and friction sheer force of the sleeve specimens [4], Croccol and Agostinis. Studied the static and dynamic strength of interference fit, and did experimental verification [5], Oswald analyzed the effect of interference assembly on the bearing life, numerical simulation of fretting contact for wheel-set [6], Yang. Studied the fretting damage of the shaft and sleeve under interference fit, and analyzed the effects of sleeve length, sleeve thickness, interference on the contact stress and shear stress. [7], Li.

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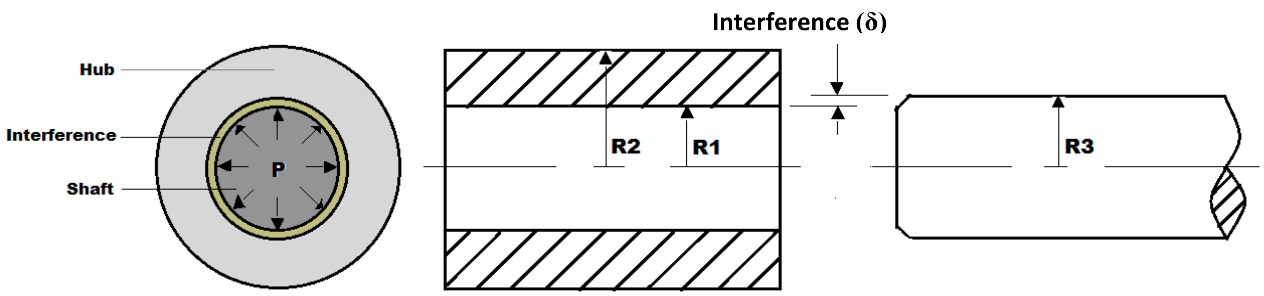
analyzed the elastic-plastic problem of interference fit shaft hub [8]. While W.C. Emmens. Studied the influence of surface roughness on friction, it is proposed that under deform condition the friction control by lubricant through a micro channel in the surface roughness [9]. Also, Fred B. studied the effect of hoop stresses in reducing cylindrical roller bearing fatigue life was determined for various classes of inner ring interference fit [10]

. The aim of this research is to investigate the effects of surface roughness on the resulting interference fitting of shaft and hub under the effect of axial force during coupling and decoupling. To achieve such objective, the research should have completed an experimental design of interference that allows considering a different surface roughness and the hub thickness between the shaft and hub.

2. Test Specimens Dimension and Material:

Interference geometrical dimensions of the specimen are shown in figure 1, consisted of shaft 30 mm length and 22.05 mm diameter fitted with a hub, the hub 25 mm length and 22 mm inner diameter. The hub degree which is the outside diameter of hub (30 mm, 35 mm and 40 mm) without changing the inner diameter to study the influence of hub degree with interference fit magnitude (0.05mm)to coupling and decoupling.



C	Si	Mn	Cr	Mo	Ni	Others
0.46	max.0.40	0.65	max.0.40	max.0.10	max.0.40	(Cr+Mo+Ni)max. 0.63

Figure 1: Coupling diagram of shaft and hub

The same material CK45 material used in manufacturing both hub and shaft by turning, table 1 shows the chemical composition of CK 45 (Steel CK45 (Mat.No. 1.1191, DIN Ck45, AISI 1045)in weight %.

Table1: Chemical Composition of CK 45 material

3. Definitions of Interference Engagement Tightening

Generally in interference fit is a semi- permanent assembly method for mechanical parts; the assembly rigidity depends on the interference contribution [5], which can be evaluated from equation (1)

$$F = \mu p A \quad (1)$$

Where **F** interference contribution force, μ static friction coefficient between the shaft and the hub, $p$the contact pressure between the shaft and inner diameter of the hub can be calculated from equation(2).[11]

$$p = \frac{E\,\delta({R_2}^2 - {R_1}^2)}{2R_1{R_2}^2} \quad (2)$$

Where p contact pressure, E elasticity modulus of shaft and hub, δ the interference between shaft and hub and R_2outer radius of the hub and R_1inner radius of hole.

4. Experiment Procedure

The work planned and carried out in such a way to provide detailed information on the effect of surface roughness on interference fitting behavior, the first independent variable are three different surface roughness of a shaft made by turning have been investigated ($\mu_1 = 0.46$,$\mu_2 = 1.2$ and $\mu_3 = 1.86$), there is a big range among the chosen coefficients of friction to reach effective results, the roughness made by changing cutting speed and depth of cut, while the roughness of the inner surface of hub keep constant by made it using drilling technique. The second independent variable is hub thickness, three different hub thickness studied in coupling and decoupling of shaft and hub by using

Universal Testing Machine, this machine was used for measuring axial force and progress of fitting of shaft in the same time.

5. Results and Discussions

5.1 Different Coefficient of Friction

Applied force on shaft versus engaged length in coupling results are given in figure 2, for 3 different coefficients of friction.

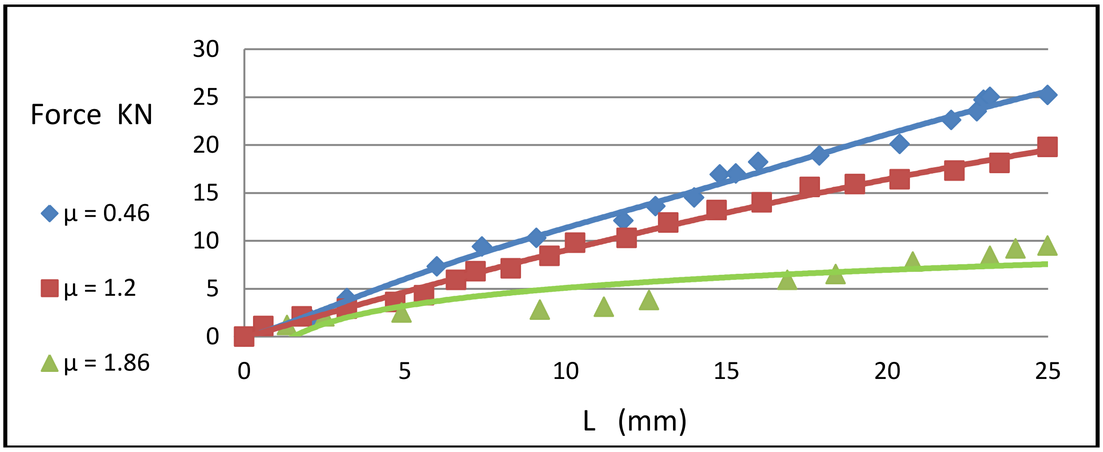


Figure2: Coupling different coefficient of friction

As seen in figure 2, shaft with $\mu = 0.46$ the load is gradually increasing and the force becomes 25.2 KN, hence coupling engaged. The engaged force decrease by increasing the coefficient of friction, the second shaft with $\mu = 1.2$ required 19.8 KN to engage all the hub, while the third shaft with $\mu = 1.86$ required 9.5 KN. Comparing the results of different coefficient of friction.

Figure 2 shows that the surface roughness of the shaft is proportional directly to the required force to achieve engagement; the performance of a shaft and hub is improved and become more strength when the contact is smoother face.

Figure 3 compares decoupling engage for the same three different coefficients of frictions, for the shaft with $\mu = 0.46$ the force increase and when reach 30.4 KN, decoupling of hub be clear. For shaft with $\mu = 1.2$ the decoupling force equal to 21.4 KN, and four shafts with $\mu = 1.86$ the force reaches 10.5 KN, then the decoupling start to be clear

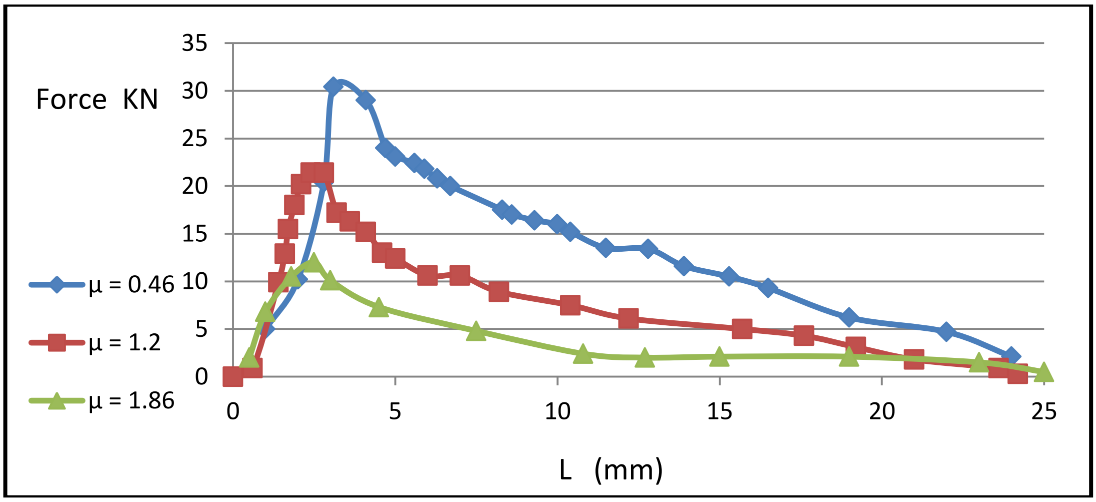


Figure 3: Decoupling different coefficient of friction

5.2Coupling and Decoupling for Different Hub Thickness

The behavior of interference fitting during coupling for different hub thickness studied. The axial load versus engaged length curves coupling under different hub thickness are shown in Fig. 4. Increasing the outer diameter of hub and keeping the inner diameter of hub constant lead to increase contact stress between the hub and the shaft during coupling.

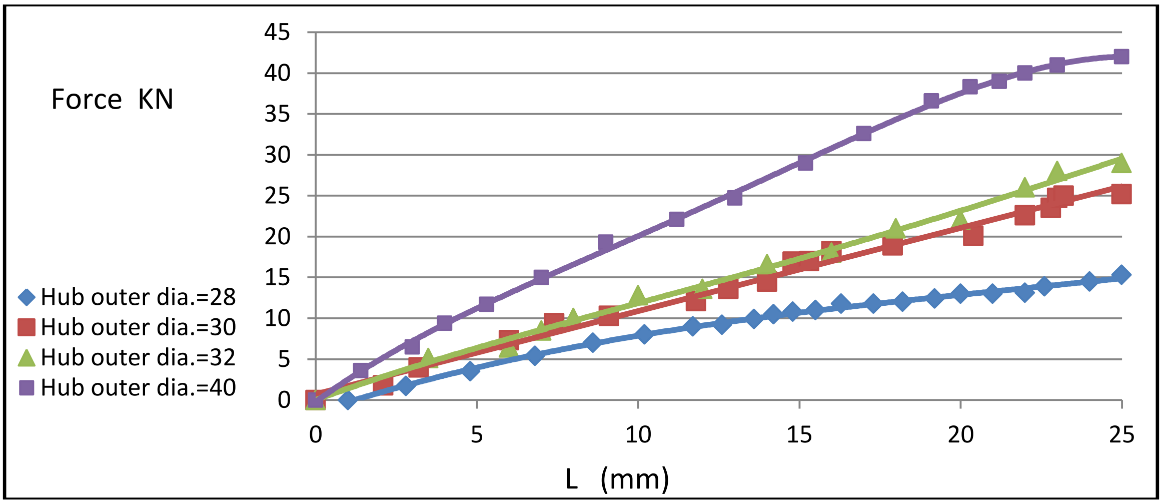


Figure 4: Coupling different hub thickness

A series of experimental tests for a different hub thickness with constant coefficient of friction for both shaft and hub are carried out to investigate the effect of hub thickness towards the performance of interference engaged at four different hub outer diameter (28, 30, 32 and 40) mm respectively.

From the results shown in Figure 4 in coupling, the first hub test (Hub outer diameter = 28mm) the force reached 15.3 KN to engage all hubs with shaft. The second hub test (Hub outer thickness=30mm) required 25.2 KN, in the third hub test (Hub outer diameter = 32mm) the engagement completed by applying 29 KN, while the last hub test (Hub outer diameter = 40mm) the force reached 42.1 KN.

The decoupling behavior of hub thickness seen in Figure5, for the hub outer thickness equal 28mm the force increase and reach 12.4 KN the decoupling between shaft and hub appear and then decrease to be close to zero, the same behavior seen for another three hub thicknesses sample. For the hub outer thickness equal 30mm the applied force increase to 15.7 KN. For the hub outer thickness equal 32mm the applied decoupling force reached to 29.8 KN. For the last hub outer thickness equal 40mm the applied decoupling force reached to maximum value 49.8 KN and then decrease approach to zero.

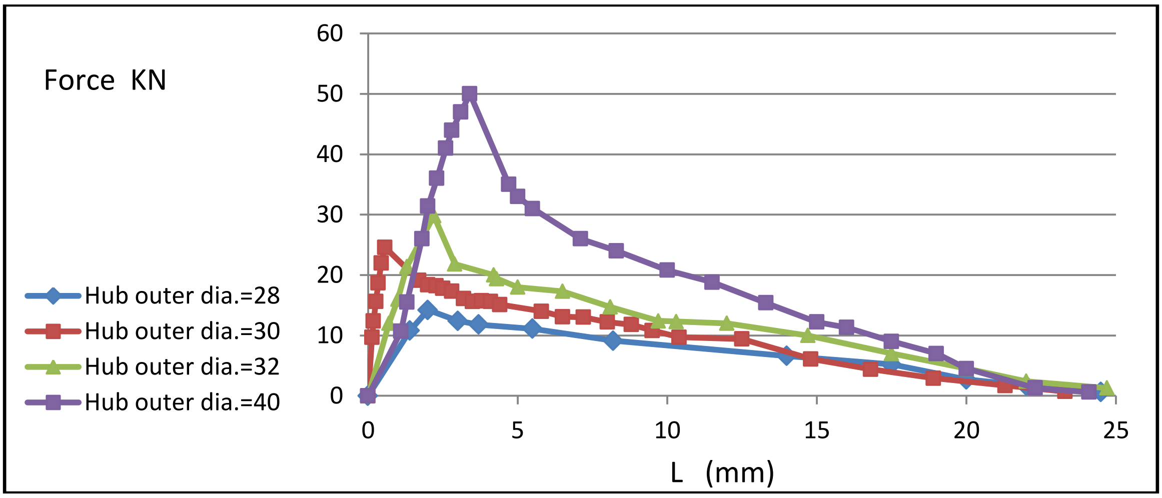


Figure5: Decoupling different hub thickness

5.3 Finite Element Model

Finite element analyses used to compute the equivalent stresses in hub after coupling process complete as shown in Figure.6. Because of the symmetry model of the geometry we take 1/2 of the original structure of the hub and shaft to build the finite element model with the medium smoothing size of meshing element. The hub constraint on the XY, YZ and XZ planes during the coupling step. In order to analyze hub thickness effects on interference fitting, the same surface roughness and interference magnitude 0.05 mm used in the finite element models.

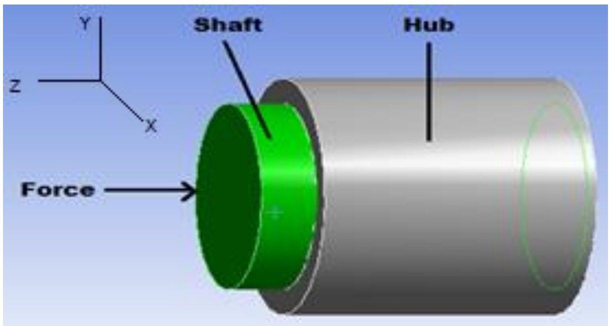


Figure 6: Schematic diagram of the interference fit

- **Interference Fit Analyses Results Using ANSYS for Different Hub Thickness**

Figures (7, 8, 9 and 10) show the von Mises stress of the hub after coupling assembly. The maximum equivalent stresses on the inner surface of the hub with outer diameter 40 reach 19.04 MPa as shown in figure 7. The second hub with outer diameter 32 the maximum equivalent stress reach 12.84 MPa as shown in figure 8, while hub with outer diameter 30 mm the maximum equivalent stress reach 8.58 MPa. As shown in figure 9, and maximum equivalent stresses of the hub with outer diameter 28 reach 8.13 MPa as shown in figure 10.

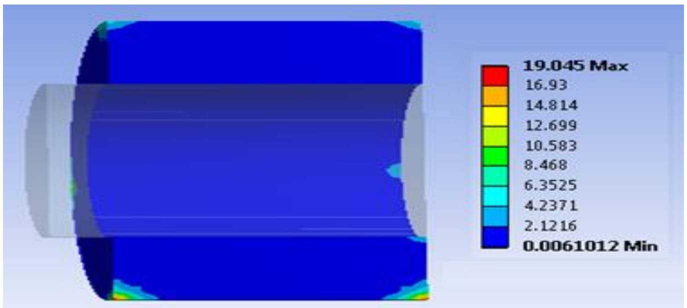


Figure 7: Equivalent stresses after coupling for hub with outer diameter 40 mm

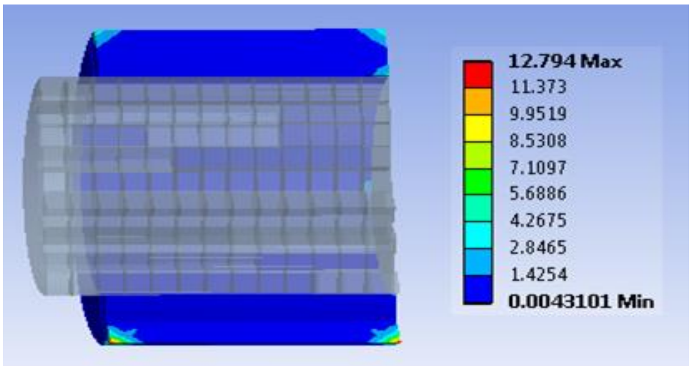


Figure 8: Equivalent stresses after coupling for hub with outer diameter 32 mm

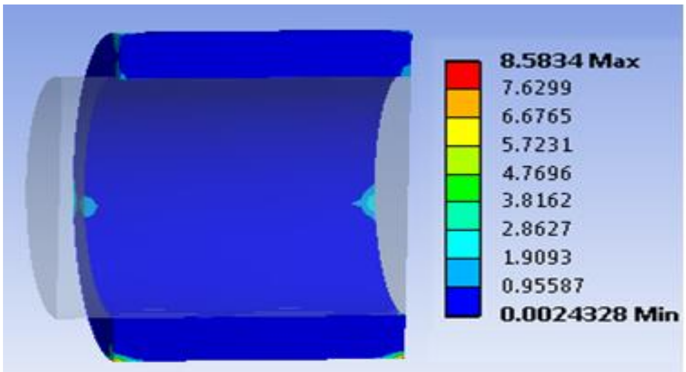


Figure 9:Equivalent stresses after coupling for hub with outer diameter 30 mm

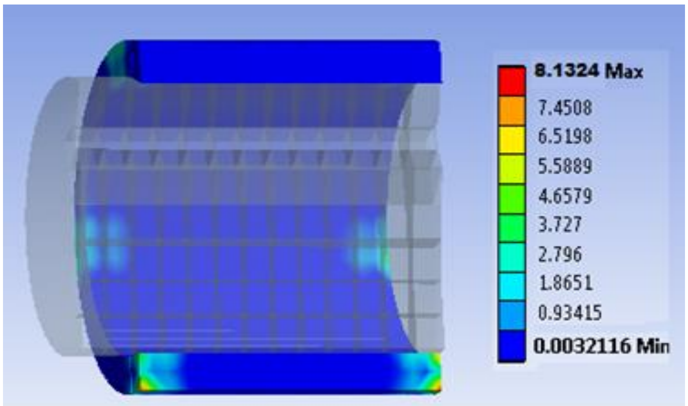


Figure 10: Equivalent stresses after coupling for hub with outer diameter 28 mm

From the results the greater of the hub thickness is, the greater the equivalent contact stress is, because the outer diameter of thin hub increase as a result from its axial deformation and reach a maximum deformation when coupling complete, which reduces the interference between the shaft and hub.

Table 2: Maximum Equivalent stresses for different hubs.

Inner diameter of hub (mm)	Outer diameter of hub (mm)	Maximum Equivalent stress (MPa)
22	28	8.1324
22	30	8.5834
22	32	12.7940
22	40	19.0450

- **Conclusions**

By using the strategy of Interference fit of solid shaft in hub we found that the value of surface roughness has the effect on interference during coupling and decoupling. Smoother surface finishes create greater contact stresses between the shaft and hub, this kind of smooth surfaces are process original manufactures, while the course surface are appearing in maintenance interference when turning used to produce the shaft or hub. By using fine surface roughness of shaft and hub we can find suitable values for allowance or decrease it which will help to design reliable interference,

The discussion of the results in this investigation can be concluded with the following points:

1- The maximum stress effect of the shaft appears on the inner surface of the hub under axial load during end of coupling, this behavior fixed for all coefficient of friction and hub thickness , so the performance of interference improve.

2- The axial load for decoupling reach to maximize value at beginning of decoupling, also this behavior constant for all coefficient of friction values.

3- The coupling and decoupling load increase by increasing the hub thickness, the equivalent stress and contact stress of shaft and hub increase with increasing the hub thickness.

4- The embedment magnitude of contact surfaces increase by increasing the coefficient of friction, which is related to coupling load.

5- Equivalent stresses decrease by decreasing the hub thickness after coupling complete, which reduces the interference effect.

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