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*Research Paper*

# STRESS DISTRIBUTION IN INTERFERENCE FITTED ASSEMBLIES WITH DIFFERENT MATERIAL

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Interference fitted assemblies find wide engineering applications such as bearing bushes, liners in cylinder blocks and cup sealing in Governor covers. The strength of any such assemblies depends on various geometric features, amount of interference and other physical conditions of the mating surfaces. This paper presents the details of analysis carried out to study the effect of different Tension rod cup material on aluminum governor cover and geometric parameters on stress distribution at the mating surface of interference fitted assemblies. This work covers, analysis based on Lame's approach and finite element method—to evaluate the principal stresses and Von Mises stresses on the performance of interference fitted assemblies. For the Finite Element Analysis (FEA), an appropriate finite element model was developed to analyses the pattern of contact stresses in interference fitted assemblies effect and under varying geometric parameters such as contact length, mating diameter and amount of interference. A comparative study of both the methods has been carried out.

Keywords: Stress distribution, Interference assemblies, Lame's approach, Finite element method

## LITERATURE REVIEW

The reliable functioning of an interference fit depends on the correct size relationship between the mating parts of the assembly. That is, mating surfaces of the parts must fit together to fulfill the purpose for which it has been designed. By varying the sizes of two mating parts, innumerable types of fits can be obtained. Depending upon the actual limits of the hole and shaft the fits are classified into clearance fits, transition fits and interference fits. Interference fitted assemblies provide intimate contact between mating parts, intended to be held permanently as a solid component. The absence of clamping makes them compact and aesthetic in appearance.

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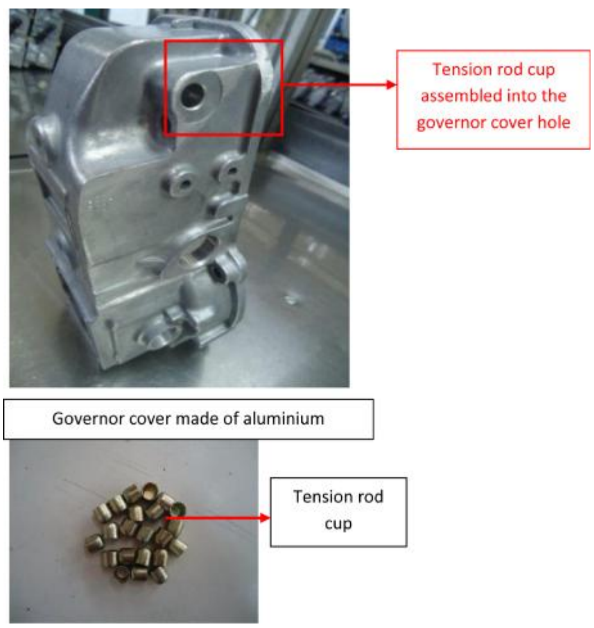
They have an excellent load bearing ability under static as well as dynamic loading conditions. These assemblies find wide engineering applications such as bearing bushes, pump impeller on shaft, small end bush in connecting rod, a crank pin in a cast iron web, liners in cylinder block, valve seats, gears, locomotive wheel on axle, stator of a fan, fitting rotors of turbines and compressors on shafts and mechanical drives and assembling of bearing races (Johnson Harold, 1981; and Firsov, 1982). Hence, it is worthwhile to study the strength of the interference fitted joints. The stress distribution at the interface of interference fitted assemblies depends on various parameters such as amount of interference, physical dimensions, material properties, diameter and contact length, geometrical inaccuracies and surface roughness of mating members. Several investigations have been carried out to study the effect of material properties, surface finish of mating surfaces and amount of interference on load bearing ability of interference fits. Also, different methods were suggested to improve the load bearing ability of the interference fits such as glow discharge treatment of sleeves, surface hardening of pins, ageing of assemblies, surface hardening of bores, oxidation of shafts, vibro strengthening and heat treatment of mating surfaces (Andreev, 1978; Dobrovenskii Yu and Manokhin, 1978; Papshev, 1980; and Ramamoorthy and Radhakrishnan, 1992).

In this work, an attempt has been made to study the effect of Tension rod cup made of different materials on aluminium Governor cover, influence critical geometric features such as length of contact, mating diameter and amount of interference on stress distribution at the interface of Tension rod cup and Governor cover hole of the interference fitted assembly. This analysis is done for selection of material for tension rod cup for better interference with aluminium Governor cover. As soon in Figure 1.

Figure 1: Governor Cover and Tension Rod Cup




## GEOMETRIC MODELING

The size of pin and the bush are selected in such a way as to cover the actual dimensional ranges in many practical applications and details are given in Figure 2. For the analysis, different combinations of pin of aluminium, brass and steel are considered. Tension rod cup is assembled into Governor cover hole.

X cover Hole and Cup dimension

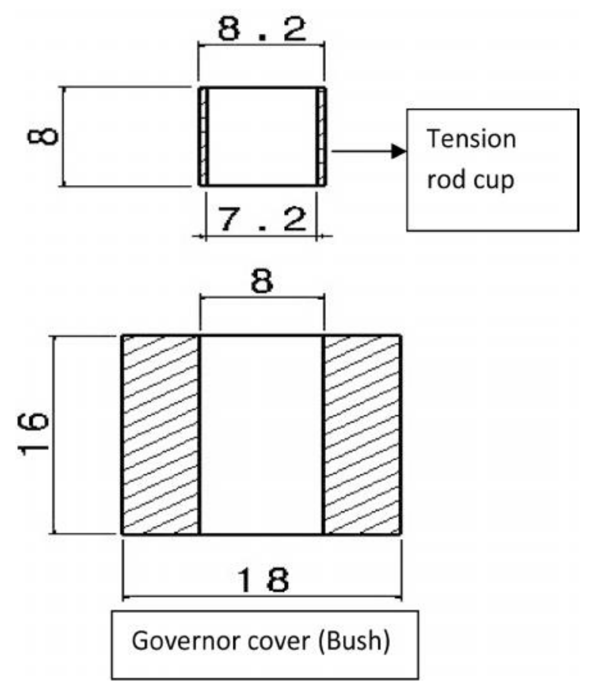
Hole ID Ø8H8(+0.022)

Seal Cup OD Ø8.2h11(–0.09)

Minimum interference – 0.088

Maximum interference – 0.2

Figure 2: Dimension of Pin and Bush




Selection of materials in the present study is based on: (i) mechanical properties such as high resistance to wear and corrosion and strength, (ii) commonly used bearing/bushing material, (iii) stress withstanding capacity (steel, brass and aluminium can be used as high, medium and low withstanding stress applications respectively), (iv) weight of the material. Based on the requirement like light, medium and heavy the appropriate material is chosen, and (v) cost and availability of the material. Further, the selection of material combination is decided based on the strength of materials. Hence, aluminium, brass and steel are considered based on their relatively low, medium and high strength in terms of hardness and modulus of elasticity. Accordingly, when the assembly involves only steel parts (pin and bush) it gives high strength combination. On the other hand when the assembly involves only aluminium parts (pin and bush) a low strength combination is obtained. In order to get a medium strength, hybrid assembly using two different metals is adopted.

## METHODOLOGY

### Analysis based on Lame's criterion

The stress distribution at the joint surface of an interference fitted assembly can be assessed on the basis of Lame's equation. The contact stress at the interface of joint is given by

$$\pm_1 = \frac{¢}{2b\left[\frac{1-¥_p}{E_p} + \frac{1}{E_b}\left(\frac{c^2+b^2}{c^2-b^2} + ¥_b\right)\right]} \quad ...(1)$$

where, $\pm_1$ is Lame's stress in Nmm$^{-2}$, ¢ is the absolute interference, $b$ is the mating radius ($d/2$), $c$ is the outside radius ($D/2$) of bush, $¥_p$, $¥_b$, $E_p$ and $E_b$ are the Poisson's ratio and modulus of elasticity of pin and bush respectively. The contact stress at the interface of joints for a pair of pin and bush made of same material is given by

$$\pm_1 = \frac{E¢}{4b}\left[1-\left(\frac{b}{c}\right)^2\right] \quad ...(2)$$

and $\pm_r = -\pm_1$, where $\pm_r$ is the radial stress at the mating surface (Rothbart Harold, 1964).

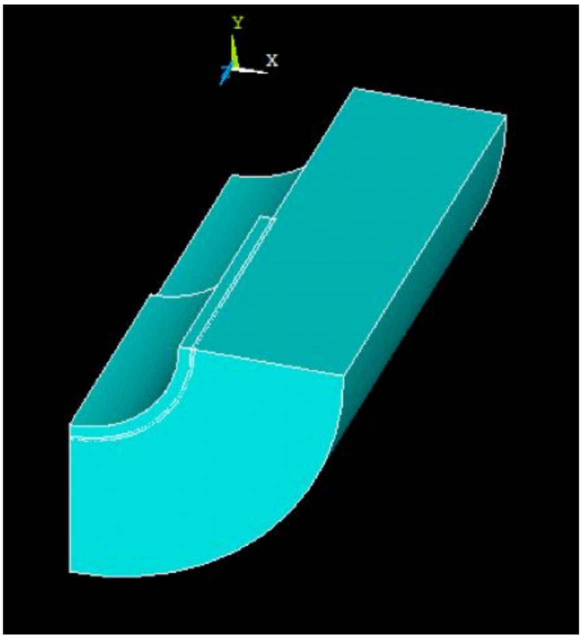
## ANALYSIS BASED ON FEM

To investigate the stresses produced at the interface of a joint finite element analysis has been used. The model considered for the analysis is symmetric in respect of geometry and loading, a 2-D axisymmetric model was analyzed using 'ansys' finite element analysis package. The geometric features of the pairs used in the analysis are shown in Figure 1.

Stress distribution at the contact surface is of main concern and the analysis was carried out on the assumption that the materials are homogeneous and isotropic in nature.

The pin and bush were modeled using eight noded quadrilateral solid elements and contact between the pin and bush was modeled using contact pair elements. The appropriate material properties such as modulus of elasticity and Poisson's ratio, were incorporated in the analysis. To take the benefit of the symmetry of the problem one half of the model was considered. Figure 2 shows the arrangement of a finite element model used in the analysis of stress. Finite element grids at the joint surface are supposed to be in a node to node contact state. With respect to symmetry of loading, the displacement was given to nodes of the elements in radial direction in such a manner that they end up with the required interference along the whole length of the bush at the contact zone and appropriate boundary conditions were applied against axial movement and contact stress due to interference is obtained. The results presented in this paper refer to the condition of static structural analysis. The various parameters considered in the analysis are material, length of contact (*l*), mating diameter (*d*), outside diameter of bush (*D*) and amount of interference (¢) on stress distribution at the interface of pin and bush of the interference fitted assembly.

Figure 3: Arrangement of Finite Element Model




## RESULTS AND DISCUSSION

### Stress Distribution Pattern

Figure 4 shows the fringe pattern of first principal stress ($\pm_1$) and Von-Mises stress ($\pm_v$) distribution in a brass pin-brass bush with 0.008 and 0.2 interference. Similar stress distributions were observed in cases of pairs made of different materials also, with only the magnitudes of the stresses varying. The stress pattern shows that stresses are symmetrically distributed along the contact length and

Figure 4: Stress Distribution in Pin and Bush (a) First Principal, and (b) Von-Mises

**(a) Principal Stress**

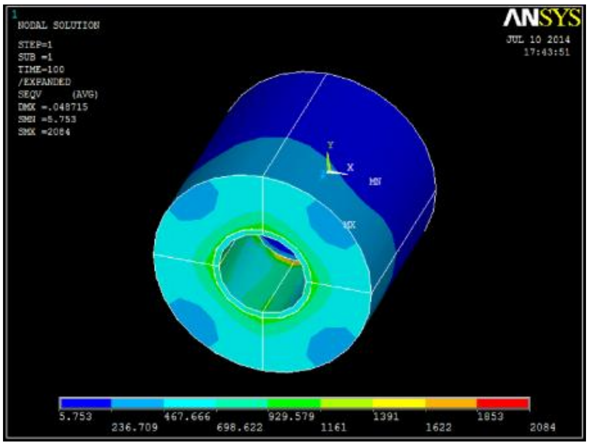
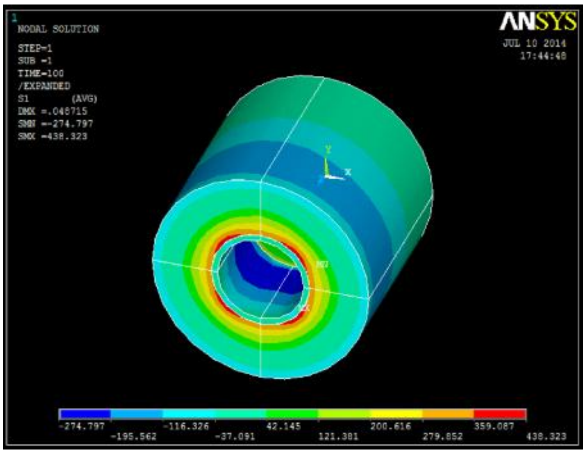


Figure 4 (Cont.)

**(b) Von-Mises Stress**

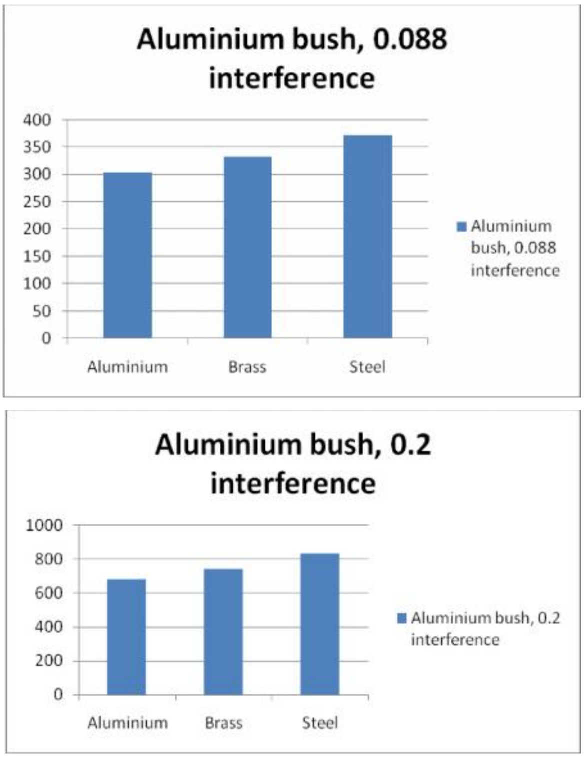



maximum stress intensity is observed at both the edges of the joint. The stresses gave rise to set of fringes which originate at points of maximum stress and vary with the magnitude of the displacement. Fringes are bands of constant stress and each fringe represents a relative stress with respect to neighboring fringe. Stress gradient is maximum at the interface of the joint and gradually decreases along the thickness of pin and bush.

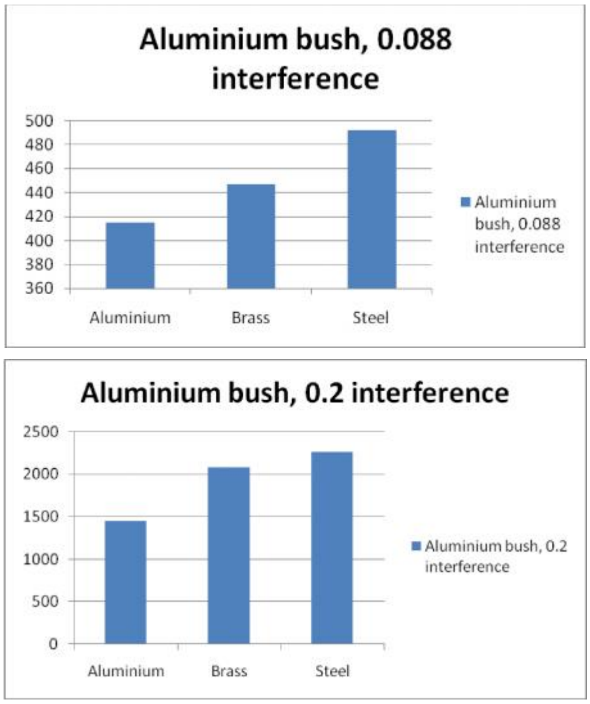
## COMPARISON OF RESULTS

The stresses produced from finite element analysis differ slightly from that obtained through Lame's approach. Stresses produced in case of finite element analysis are about more than the value obtained through Lame's approach. Because, interference fit problems are studied with Lame's approach, which is primarily applied in the elastic range. However, there is a deviation from this and practically, the mating surface of pin contracts (plastically deformed) due to pressure exerted by the inner surface of the bush and inner surface of the bush expands (plastically deformed) as a result of pressure generated by pin. This results in

Figure 5: Variation of Stresses ($N/mm^2$) with Different Pin Materials (a) Lame's Approach, and (b) FEA




**(a)**

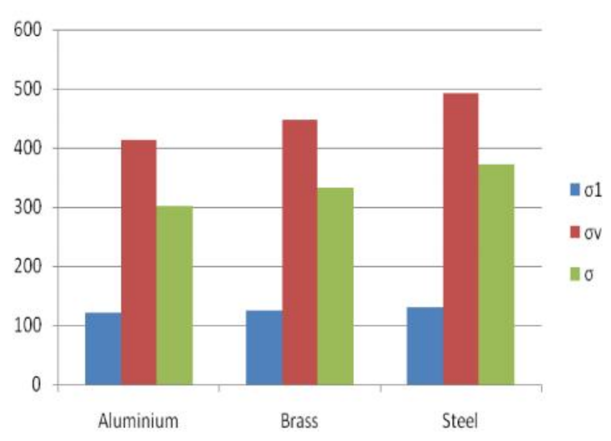



**(b)**

strain hardening at the interface of both pin and bush. Hence, stresses obtained from FEA is larger than Lame's approach and the trend of contact stress variation satisfactorily agrees with the Lame's approach. Figure 5 shows the variation of contact stress with respect to different pin materials. The variation corresponding to Lame's equation and finite element analysis for the cases with different pin materials at 0.088mm interference are clearly indicated. Figure 6 shows the comparison of stress variation corresponding to Lame's equation and finite element analysis with different bush materials. The trend of the variation of contact stresses agrees satisfactorily with the results obtained through Lame's approach. It is seen that a pair with different pin and bush materials produces a stronger assembly than the one with a pair made of same material having lower hardness.

It is observed that a pair (pin/bush) made of different materials can withstand higher stresses because ductile materials become stronger when they are deformed plastically by cold working. Cold working results in strain hardening which in turn increases the hardness and strength, and reduces ductility (Vanvlack Lawrence, 1989). Hence, the enhanced hardness and strength of the pin/bush result in greater resistance to plastic deformation at the contact surfaces of the interference fitted assemblies.

Figure 6: Comparison of Stress (N/mm²) Variation with Different Pin Materials (a) Aluminium, (b) Brass, and (c) Steel




## CONCLUSION

From the study following conclusions may be drawn:

- Assemblies with steel pin-aluminium bush can withstand higher stresses than the brass pin and aluminium pin.
- Assemblies with pin and bush made of different materials produce a stronger assembly than the one with a pair made of same material having lower hardness. Hence, wherever interference fit with higher stresses is required, it is desirable to carry out the assembly of pin and bush made of different materials.
- A change in contact length of the bush, does not affect the stress distribution at the interface of the joint (i.e., stress concentration is almost constant along the contact length).
- The outer diameter of the bush has significant influence on stress distribution at the joint surface of bush. Because, stress concentration decreases with increase in outer diameter of the bush.
- Stresses produced along the contact zone based on FEA differ slightly and the trend of variation of contact stresses agrees satisfactorily with the results obtained through Lame's approach.

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