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Comparative Analysis of Sn–Pb–Sb Babbitt bearing alloys material with and without copper

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ABSTRACT

The most frequently used bearing is the deep groove ball bearing. It is found in almost all kinds of products in general mechanical engineering. Babbitts, also known as white metals, are either tin or lead-base alloys having excellent embed ability and conformability characteristics. The Babbitts, are among the most widely used materials for lubricated bearings.The development of new advanced material is an important activity for continues progress in science and technology. Considerable research and development efforts are underway towards the development of tin-based bearing alloys.

The effect of Copper in Babbitt material is considered as the Bearing Materials for comparative analysis in between the Babbitts having copper and doesn't. A Numerical analysis has been carried out for constant speed and at different bearing loads. The comparative analysis is based on the parameters like Elastic Strain, Maximum Principal Elastic Strain, Maximum Shear Elastic Strain, Equivalent Stress (MPa), Maximum Principal Stress (MPa), Maximum Shear Stress (MPa), Stress Ratio, Strain Energy (J) and Safety Factor. A structural analysis has been carried out. The design considers for the study of SKF6003 Bearings with the maximum load carrying capacity of 35MPa.

As the results it has been find out that the copper mixing of 5% in Babbitt consider for study is profitable for enhancing the material property for the bearing applications.

Key words: Babbitt, Bearing Material, Stresses, Strain, Strain Energy, Safety Factor.

1.INTRODUCTION

For having the lower frictional relative motion between two parts like shaft and housings Bearings are the essebtial elements. The function of the bearings for any mechanism is to provide minimum frictional rotational motion between the elements, support the elements at position to avoid the bending and keeping them at correct alignment, force transmission to the frame etc. The forces which acts during the motion on the bearing can be the basis for its classification and classified it as radial and thrust bearings, (Fig 1). The load is normal to the rotating shaft for radial bearing and tangential for thrust bearing [1]. Theer are some factors like more radial space, noise generation with rolling-element bearings and the sliding bearings are less expensive than ball or roller bearings for simple applications requiring minimal lubrication provision.

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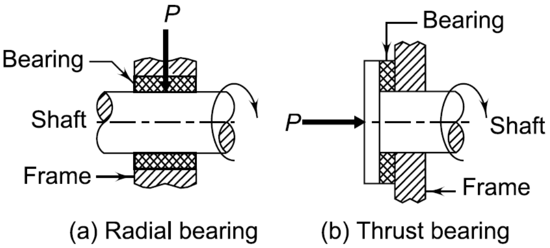


(a) Radial bearing (b) Thrust bearing

Figure: 1 Radial and Thrust Bearings [1]

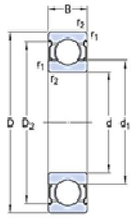
The bearing materials are the important consideration for selection of any bearing for the application. As the development of new and advanced materials are continuous process and the application for such type of material by replacing the existing materials are the key concern at present scenario for design and development of any mechanical elements.The development of new advanced material is an important activity for continues progress in science and technology. Considerable research and development efforts are underway towards the development of tin-based bearing alloys. Various researchers carried out their study in this era.***M.Y. Toumi; 2018, R.K. Upadhyay et al; 2013*** presents a study of the rolling contact fatigue damage applied to bearings [2,8]. ***Sham Kulkarni and S.B.Wadkar; 2016, V. M. Nistane, S. P. Harsha; 2016*** analysed effect of surface roughness, roughness size, speed and load on the vibration response, vibration signature of ball bearing for lifetime assessment of the ball bearing [3,4]. ***M.S. Patil et al; 2010*** presents an analytical model for ball bearing vibrations analysis [10]. Design automation and optimization techniques are also applied for the bearing design and development [5]. ***Barmanov I.S., Ortikov M.N.; 2017*** was carried out the study to reveal and study the influence of interference on the rolling elements of a ball bearing [6]. ***Dipen S. Shah and Vinod N. Patel; 2014*** studied various dynamic models for rolling bearing in existence and nonappearance of local and dispersed faults [7]. ***Tang Zhaoping and Sun Jianping; 2011*** built a 3-D model of deep groove ball bearing by using APDL language [9]. Now it can be said that various researchers carried out their study considering the various parameters like vibrations, design, interferences etc. but not sufficiently literature is available for advanced materials for bearings. The aim of the present study is to apply the advanced material for ball bearing. ***Mustafa Kamal et al; 2011*** shows the effect of copper for Babbitt material mechanical properties. For the present analysis the same material is considered for SKF6003 bearing**.**In this work the Finite element analysis of SKF6003 bearing is carried out by considering the Babbitt materials examined by ***Mustafa Kamal et al; 2011*** as the author did not carried out the further analysis for end application as ball bearing. The properties of materials are taken into considerations by the work carried out by the author for this study. Thus, the objective of the work is to deliberate the copper effects in the mechanical properties of quickly hardened Sn–Pb–Sb bearing alloy as bearing materials in the non-appearance of satisfactory lubrication.

2. RESEARCH METHODOLOGY

For the present analysis the finite element analysis has been applied. The method is based on the formulations of a simultaneous set of algebraic equations relating forces to corresponding displacements at discrete preselected points (called *nodes*) on the structure. These governing algebraic equations, also referred to as force–displacement relations, are expressed in matrix notation.

Geometry

For the analysis SKF6003 bearing has been considered the dimensions of it is shown in figure 2. Geometry has been build using solid works as the tool and imported in Ansys workbench (Figure 3).



d		17	mm
D		35	mm
B		10	mm
d_1	≈	23	mm
D_2	=	31.2	mm
$r_{1,2}$	min.	0.3	mm

Figure: 2 Dimensioning of Ball Bearing Considered for the Study

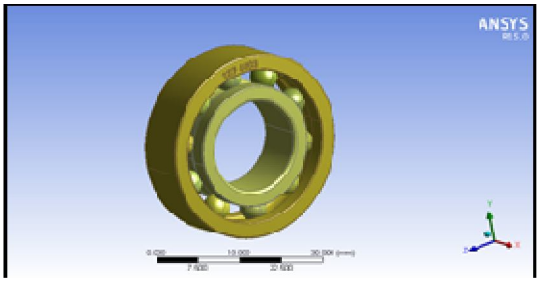


Figure: 3 Geometry of the Ball Bearing consider for the study

Meshing

Meshing is the process of discretization. 30636 nodes and 15022 Elements has been generated during the meshing process. Figure 4 shows the meshed view of ball bearing.

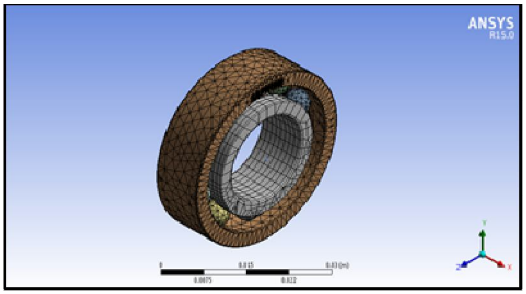


Figure 4 Meshed Model

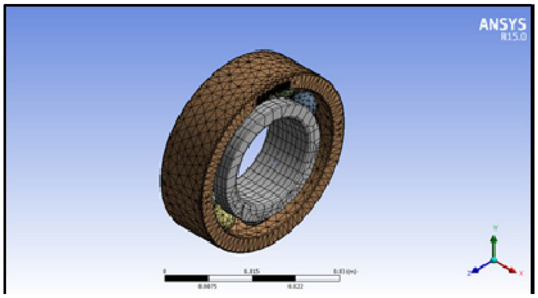


Figure 5 Boundary Conditions applied

Boundary Conditions

Figure 5 shows the applied load and direction of rotation along with the revolution per-minute in a ball bearing. The rotational velocity of shaft has been considered as 100 rpm. The pressure is applied on the inner surface of the bearing.

Material

For the present study the two different material i.e. Sn–30%Pb–10%Sb and Sn–25%Pb–10%Sb–5%Cu considered for the study. The property of materials is as

Table 1 Material Considered for the study [***Mustafa Kamal et al; 2011***]

Composition	**Young`s modulus**	**Shear's modulus**	**Bulk modulus**	**Poisson's Ratio**
1.Sn–30%+pb-10%+Sb	13	4.72	17.9	0.379
2.Sn–25%+Pb-10%+Sb-10%+ Cu	22.7	8.27	30.1	0.374

3.RESULTS AND DISCUSSION

The study has been carried out for two different material i.e. Babbitts having Copper and the same which does not have copper. For assessing the effect of copper, the analysis has been carried for three different pressure i.e. 33MPa, 34MPa and 35MPa. The Elastic Strain, Equivalent Stress (MPa) and Strain Energy (J) have been considered for comparative analysis. The following results have been obtained.

Results for Babbitt having Sn–30%Pb–10%Sb material at different Load Condition

Figures 6,7 and 8 shows Equivalent Elastic Strain, Equivalent Stress, and Strain Energy for Babbitt having Sn–30%Pb–10%Sb material at 33,34 and 35 MPa Load.

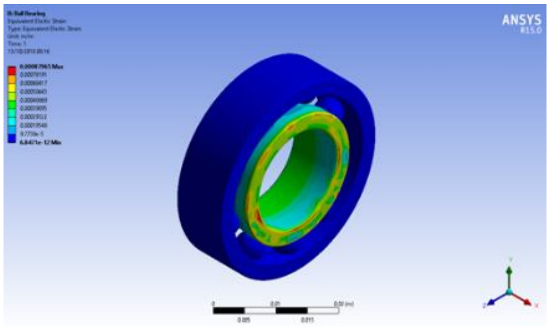


Figure: 6 (a) Equivalent Elastic Strain

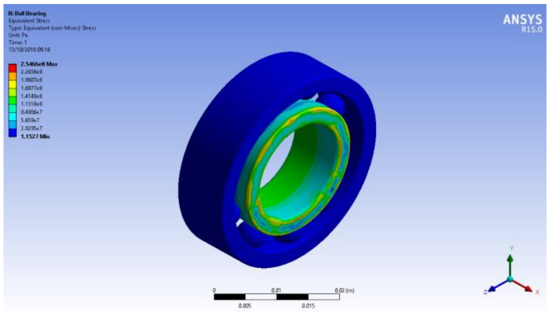


Figure:6(b) Equivalent Elastic Stress

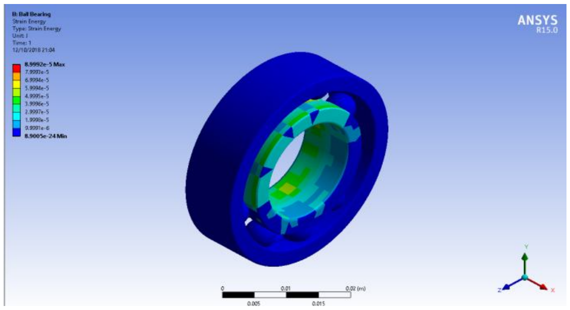


Figure:6(c) Strain Energy for Babbitt having Sn–30%Pb–10%Sb material at 33MPa Load

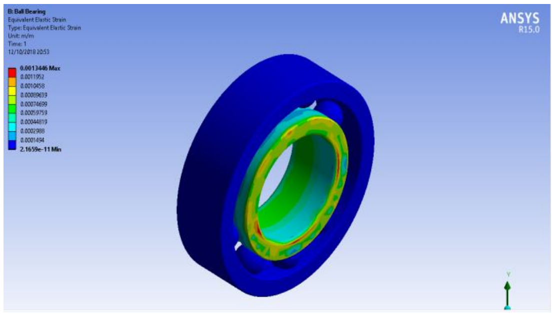


Figure 7 (a) Equivalent Elastic Strain

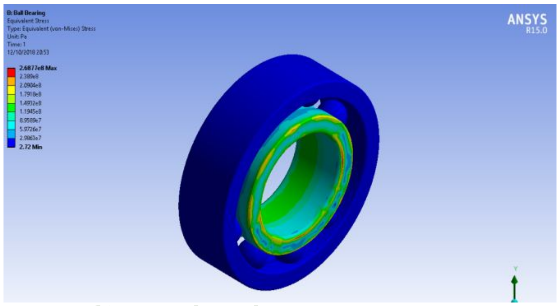


Figure:7(b) Equivalent Elastic Stress

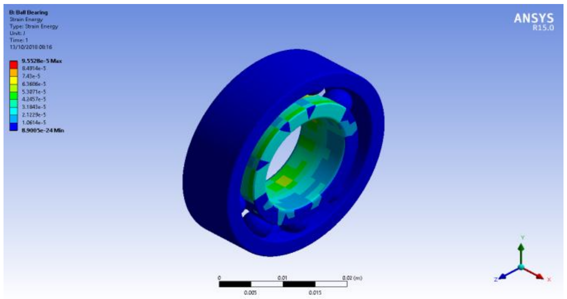


Figure:7(c) Strain Energy for Babbitt having Sn–30%Pb–10%Sb material at 34 Mpa Load

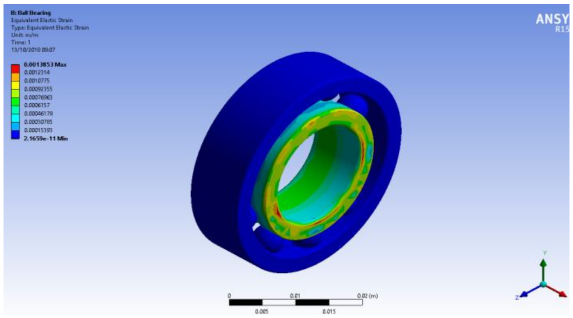


Figure 8 (a) Equivalent Elastic Strain

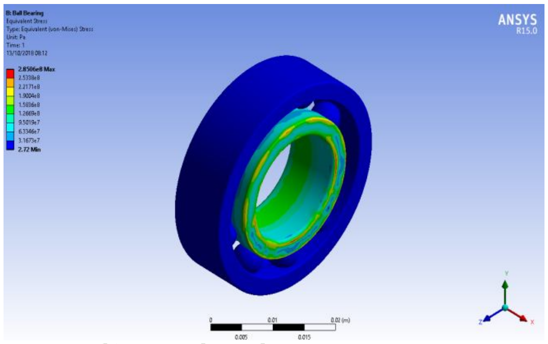


Figure: 8(b) Equivalent Elastic Stress

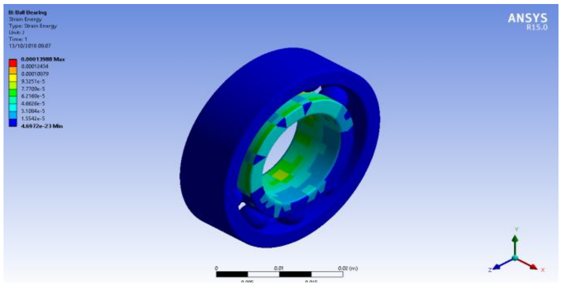


Figure:8(c) Strain Energy for Babbitt having Sn–30%Pb–10%Sb material at 35MPa Load

Results for Babbitt having Sn–25%Pb–10%Sb–5%Cu material at different Load Condition

Figure 9,10 and 11 shows the Equivalent Elastic Strain, Equivalent Stress and Strain Energy for Babbitt having Sn–25%Pb–10%Sb–5%Cu material at 33, 34 and 35 MPa Load.

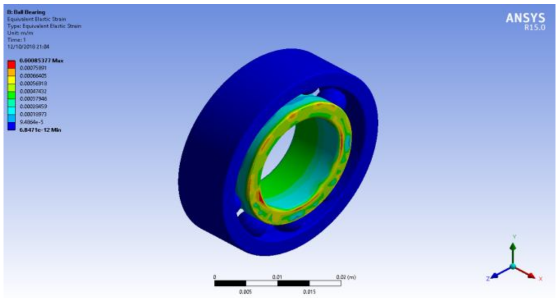


Figure:9(a) Equivalent Elastic Strain

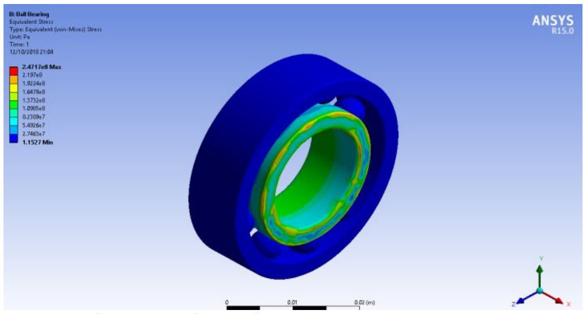


Figure:9(b) Equivalent Elastic Stress

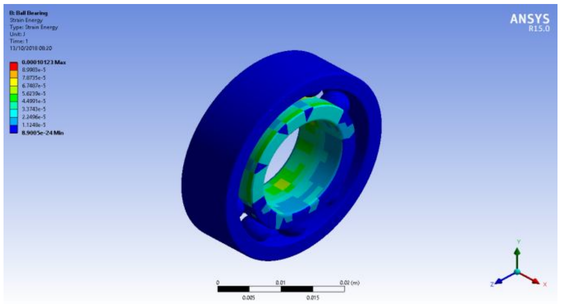


Figure:9(c) Strain Energy for Babbitt having Sn–25%Pb–10%Sb–5%Cu material at 33MPa Load

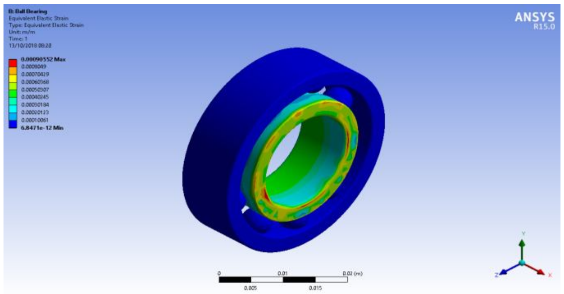


Figure:10(a) Equivalent Elastic Strain

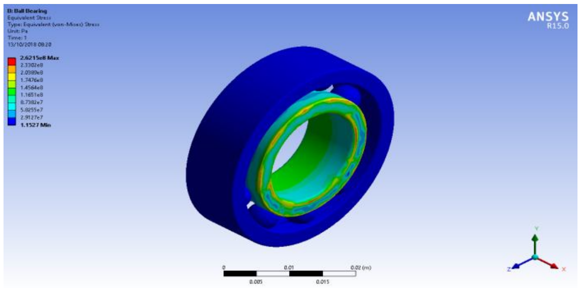


Figure:10(b) Equivalent Elastic Stress

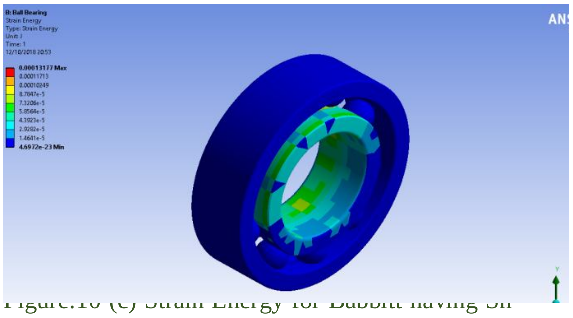


Figure:10 (c) Strain Energy for Babbitt having Sn–25%Pb–10%Sb–5%Cu material at 34MPa Load.

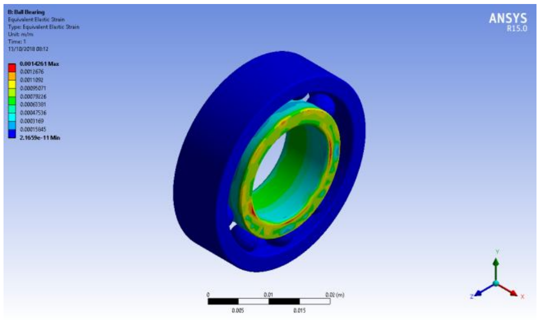


Figure:11(a) Equivalent Elastic Strain

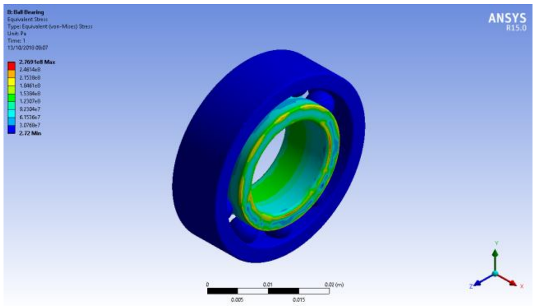


Figure: 11(b) Eqyivalent Elastic Stress

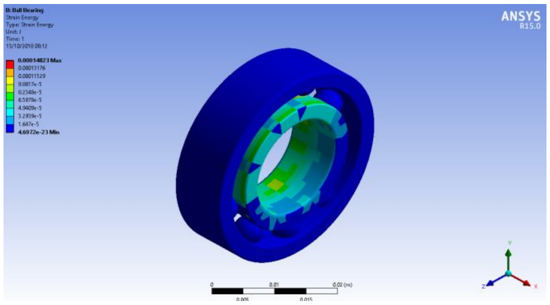
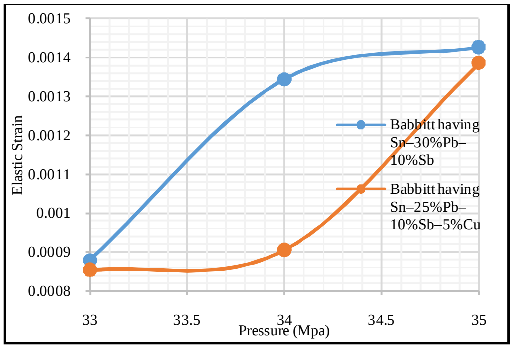
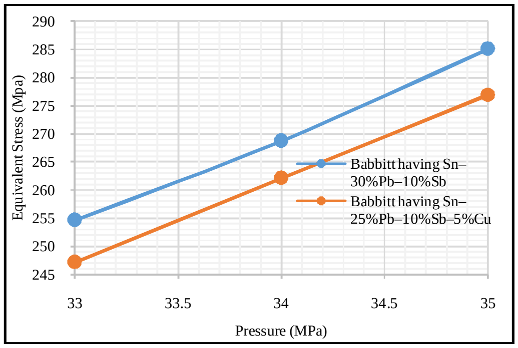


Figure:11(c) Strain Energy for Babbitt having Sn–25%Pb–10%Sb–5%Cu material at 35MPa Load

In the present comparative analysis figure 12 shows the variation of Elastic Strain, for both the material i.e. Sn–30%Pb–10%Sb and Sn–25%Pb–10%Sb–5%Cu material at three different loads i.e. 33MPa, 34 MPa and 35 MPa respectively. ***Elastic strain*** is the consideration of basic importance to the engineer. Elastic strain is the strain within the elastic limits it means body regain its original shape after removing the load. It is obvious from the results that Babbitt's without copper has more elastic strain compare then Babbitts having copper. Elastic Strain should be low as much it is possible. After 34MPa load, the increment in Elastic Strain is more compare then the load 33 to 34 MPa in Babbitt's having copper but it is opposite in Babbitt's which does not contain copper. The material which does not contain copper has more increment in the range 33 to 34Mpa load compare then 34 to 35 MPa Load. The ***maximum principal elastic strain*** shows the same nature as Elastic Strain. Maximum Principal Strain Theory (Saint Venant's Theory) stated that the failure or yielding occurs at a point in a member when the maximum principal (or normal) strain in a bi-axial stress system reaches the limiting value of strain (*i.e.* strain at yield point). Thus, having less maximum principal strain is beneficial for the machine component.



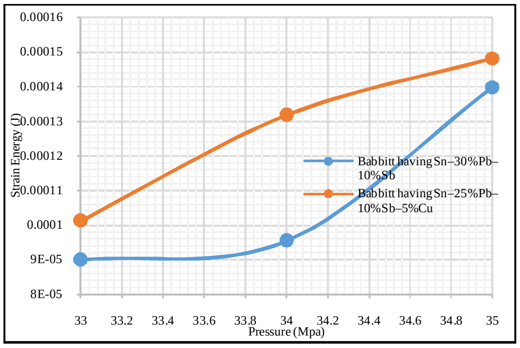
Graph: 1 Elastic Strain Variation at different load



Graph:2 Equivalent Stress Variation at different load

There are number of machine components, which are subjected to several types of loads simultaneously. When the component is subjected to several types of loads, combined stresses are induced. The Bearing members are subjected to combined stresses due to simultaneous action of either tensile or compressive stresses combined with shear stresses. There are direct tensile or compressive stresses due to the external force and shear stress due to torsion, which acts normal to direct tensile or compressive stresses. The maximum principal stresses, due to the combination of tensile or compressive stresses with shear stresses are generated. Figure 13 shows the Equivalent Stress Variation at different load. It has been observed that the equivalent stress increases as the load increases in both the material. The equivalent stress generation in less in the material having copper but high in the material which doesn't have copper. The maximum principal stress theory states that the failure of the mechanical component subjected to bi-axial or tri-axial stresses occurs when the maximum principal stress reaches the yield or ultimate strength of the material. The theory considers only the maximum of principal stresses and disregards the influence of the other principal stresses. It predicts the failure of ductile material under pure shear case.

Internal work stored in an elastic body is the internal energy of deformation or **the elastic strain energy**. It is often convenient to use the quantity, called strain energy per unit volume or strain energy density. Resilience is a material's capacity to absorb energy when it is deformed elastically and then, upon unloading, to release this energy. The modulus of resilience, Ur, is the strain energy per unit volume required to stress a material from an unloaded state to the point of yielding. When loads are applied to a machine element, it will deform. In the process, the external work done by the loads will be converted into internal work (called strain energy), provided that no energy is lost in the form of heat. This strain energy is stored in the body. The strain energy is a nonlinear (quadratic) function of load or deformation. The Babbitt material having copper shows high elastic energy material storing capacity compare then the material which doesn't have copper.



Graph:3 Strain Energy Distribution at different load

The strain energy gives indirectly the measure of modules of toughness. Which is the ability to absorb energy up to fracture. High energy absorbing capability shows high toughness. The toughness of a material is connected to its ductility in addition to its ultimate strength and that the ability of bearing to endure an impact Load be contingent upon the toughness of the bearing material. Thus, the material having copper shows more toughness. Figure 4.61 shows the Strain Energy Distribution at different load for both the material.

4. CONCLUSIONS

The bearing material plays a key role in the complete performance of a bearing system. Affected by the bearing materials, there are many serious limitations, such as the Friction, load-carrying capacity without breaking, load distribution and power loss. Various materials at different conditions have been investigated by many researchers as given in Literature Review, there is need of investigation of different composite materials and it has not been addressed thoroughly because of their inherent geometric and dynamic complexity.

The two different materials suggested by ***Mustafa Kamal et al; 2011*** has been considered for the comparative analysis. The analysis has been carried out for three different pressure i.e. 33,34 and 35 MPa but at constant RPM value. The parameters considered for the studies are Elastic Strain, Equivalent Stress (MPa), Strain Energy (J). The following Observations have been obtained.

1.Babbitts without copper has more elastic strain compare then Babbitts having copper. Elastic Strain should be low as much it is possible.

2.It has been observed that the equivalent stress increases as the load increases in both the material. The equivalent stress generation in less in the material having copper but high in the material which doesn't have copper.

3. The Babbitt material having copper shows high elastic energy material storing capacity compare then the material which doesn't have copper.

As per the above discussion it can be concluded that Babbitt having composition Sn–25%Pb–10%Sb–5%Cu is more advisable to use compare then Sn–30%Pb–10%Sb.

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