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Heat Transfer Analysis of Ball Bearing for three different materials using ANSYS

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ABSTRACT

Engineering is the branch of applied science that calls for innovation. Mechanical engineering in particular is a symbolism for advancement in the field of manufacturing, production and designing. With progress in technologies, computer softwares for mechanical designing has reached their new heights. This project aims at using these mechanical designing softwares, namely CATIA and ANSYS to virtually create, simulate, calculate, observe and report the thermal analysis done on simple ball bearings considering three different materials. It then compares the results for the three materials and draws conclusions for the selection of appropriate material for ball bearing in terms of effectiveness and efficiency of materials.

Key words: Heat Transfer, Ball Bearings, CATIA, ANSYS, Material properties

1. INTRODUCTION

A ball bearing is essentially a rolling bearing. Fundamentally it is made up of two races - inner and outer. In between these races there are different numbers of small balls trapped. The quantity and size of these balls are dependent on the dimensions of the two races. The bearing housing is associated with the outer race whereas the shaft goes inside the inner race. This restricts any relative motion between bearing housing and outer race & shaft and inner race respectively. In order to accommodate these balls properly within the two races the radius of the races are kept slightly larger in comparison to that of the balls. However the differences are kept imperceptible to naked eyes [1]. To keep the angular separation between each ball constant, metal rings are tied around the balls. These rings are connected to each other via metal strips.

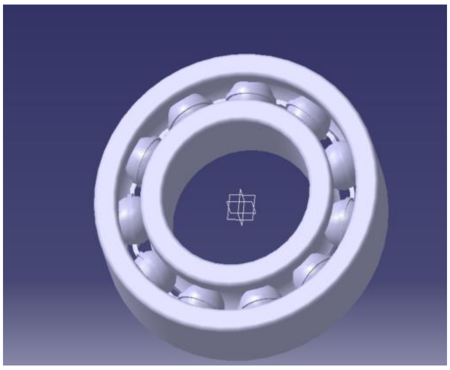

Fig. 1 CATIA V6 model of Ball Bearing

The deformation at the two surfaces result in increase in area of contact.This generates rolling friction. To counter this balls and races are made up of very hard materials. This ensures reduction in distortion and thereby helps deduct rolling friction. It is also observed to have lower friction in ball bearings when dried to that when lubricated. However, lubrication is vital as it serves like a preventive measure against rust formation. There are different varieties of ball bearings subjected to use under different kinds of applications. These include deep groove ball bearings, duplex angle contact bearings, four point contact bearings etc [1]. The greatest advantage of using ball bearing is its vast temperature range. It is readily available, replaceable and enhances performance. It also uses grease that has a higher dripping point. Pradeep K Gupta *et al* [2] conducted an experiment for the study of time varying heat generation. This study also showed the effect on the geometry of working bearing. It then followed the effects on the rheological properties of the lubricants that contributed to the increase of heat generation in bearings. Jafar Takabi, M.M. Khonsari [3] conducted experiments for thermal analysis of ball bearing with regards to variation in time. This experiment used an oil bath arrangement for lubrication. The main purpose of this arrangement was to ensure a continuous flow of oil over both ball bearing and housing. This method was incorporated for the observation of temperature transition and frictional torque. The results finally concluded how thermal boundary condition and oil viscosity change to restrict thermal failures when the ball bearing is put under varying load and speed. This provokes temperature generation, Total heat Flux and Directional heat Flux studies as necessary for thermal heat removal from bearings. Ke Yan *et al* [4] investigated the characteristics for dissipation of heat for ball bearings with deep grooves. It was done with the use of a quasi-static model. This helped to determine the oil heat flow path. It also contributed to enhancing heat distribution parameters. Fangbo Ma *et al* [5] performed analysis for thermal transition for greased ball bearings having deep grooves with changing speeds. A quasi static model was incorporated for this. It helped to understand the path for oil air flow which helps in improving the parameters for heat distribution. This improvisation favours reduction of recrystallization that helps keep oil viscosity significantly constant. Chao Jin, Youmin Hu [6] explored analytically about the drastic increase in ball bearing temperatures associated with machines. This causes thermal deformation. It also distorts the performance of machinery. P.C. Santhosh Kumar along with S.K. Lakshman Moorthy conducted an analysis on heat transfer through ball bearings using ANSYS. They concluded that stainless steel is used as conventional. Analysis shows that chrome steel has terrific physical properties and gives a high heat flux than stainless steel [7].

2. DESCRIPTION, MATERIAL PROPERTIES & METHODS

This analysis determines the thermal properties like the distribution of temperature and heat flux - total & directional for ball bearings. High carbon chromium steel (HCCS), Stainless steel (SS), and metal matrix are the three different materials considered for the ball bearings. HCCS has significantly better thermal properties in comparison to SS.

2.1 Procedure

First, a standard [9-10] 3-D model of a ball bearing is constructed using CATIA designing software (Fig 1). The designed model is then saved in .IGES format. It is the standard format for 3-D model data transference across different CAD programs. It is an ASCII text based format that saves and exports vector data.

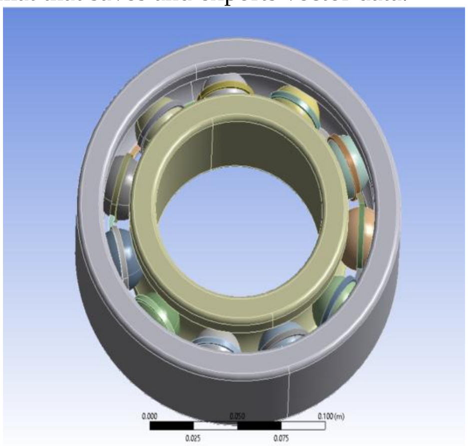

Fig. 2 Ball Bearing imported in ANSYS using IGES format

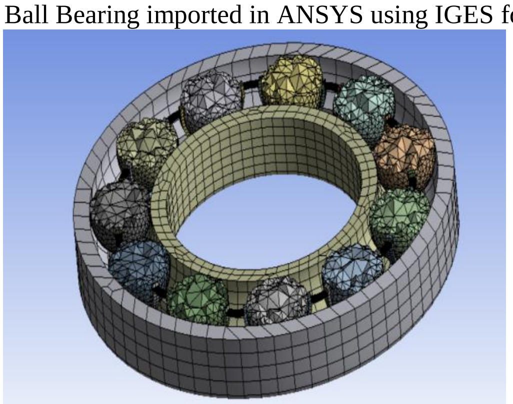

Fig. 3 Cross sectional view of Tetrahedral Meshing

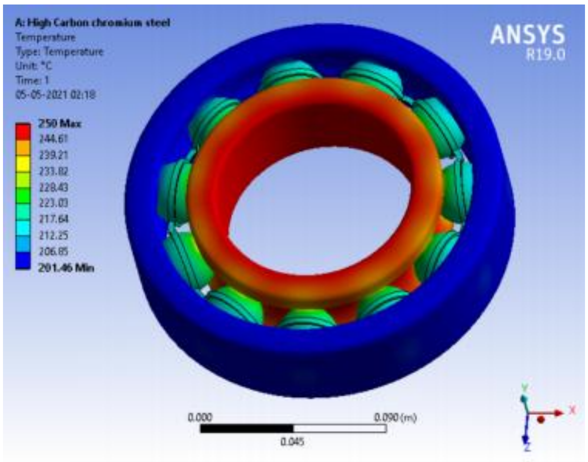

Fig. 4 Distribution of temperature - High Carbon Chromium Steel

The IGES file of the designed ball bearing is then opened into ANSYS 2019 workbench (Fig 2) which helps to virtually simulate the required thermal conditions for analysis. Here, the different properties such as Young's modulus of elasticity, thermal conductivity, density, poisson's ratio etc. (Table 1, Table 2, Table 3) for each different material for ball bearing are entered. We then create a fine-meshed structure of the imported ball bearing model using the ANSYS 2019 workbench (Fig 3).

The values for initial boundary conditions are put in for each differently selected material. Thus, calculations and computations are done.

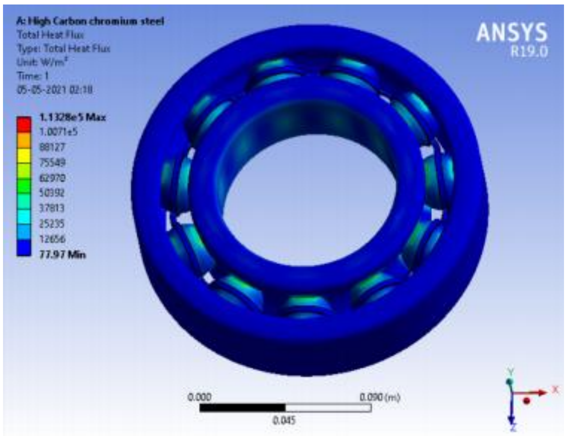

Fig. 5 Heat Flux (total) - High Carbon Chromium Steel

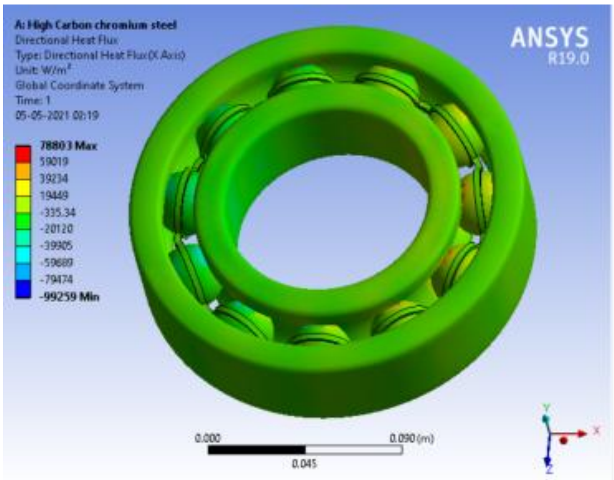

Fig. 6 Heat Flux (Directional) - High Carbon Chromium Steel

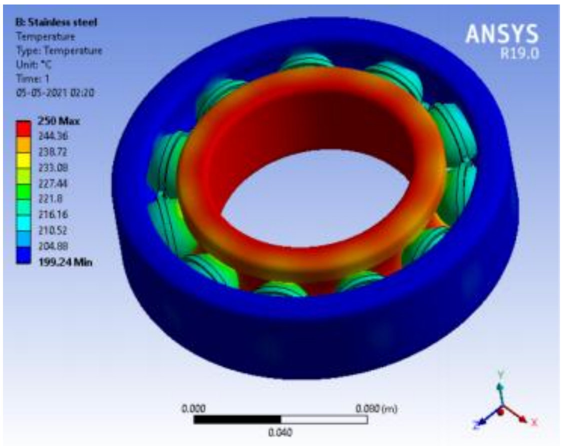

Fig. 7 Distribution of temperature - Stainless Steel

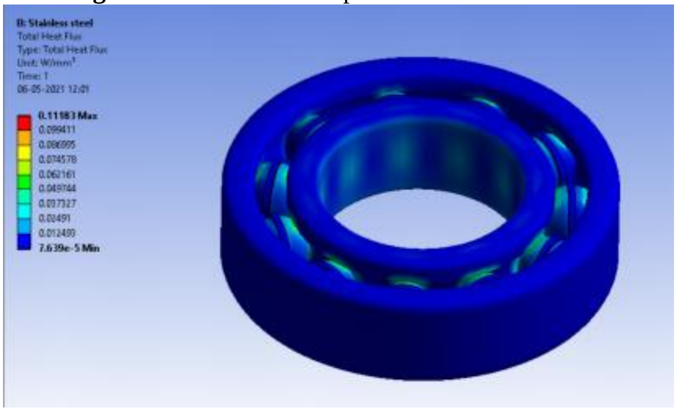

Fig. 8 Heat Flux (total) - Stainless Steel

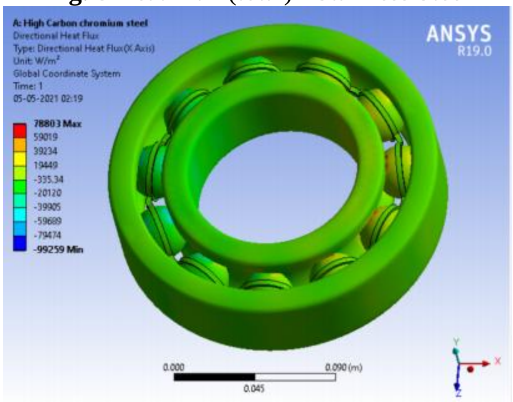

Fig. 9 Heat Flux (Directional) - Stainless Steel

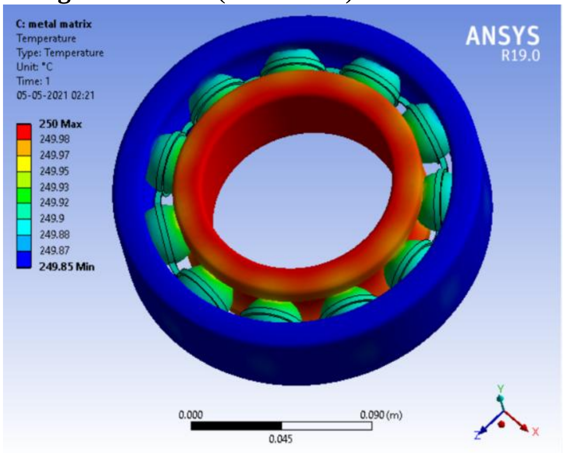

Fig. 10 Distribution of temperature - Metal Matrix

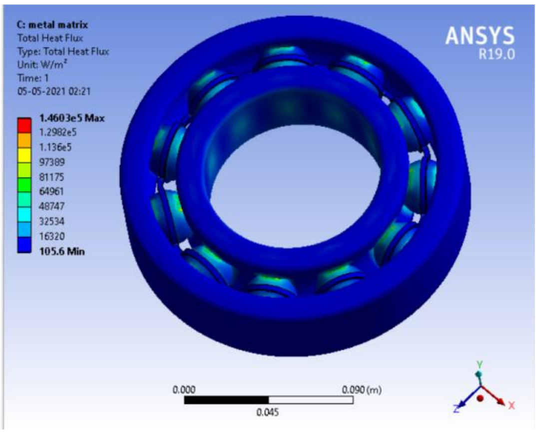

Fig. 11 Heat Flux (total) - Metal Matrix

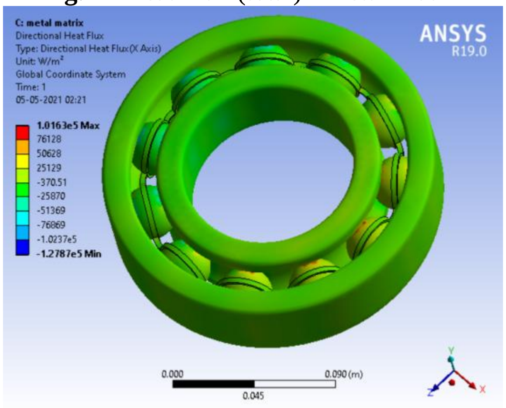

Fig. 12 Heat Flux (Directional) - Metal Matrix

Table -1 Properties of High Carbon Chromium Steel

Thermal Conductivity	16W/m-C
Specific Heat	490J/kg-C
Poisson ratio	0.28
Young's modulus	2.2E+011 Pa
Density	7600kg/m³

Table -2 Properties of Matrix Metal

Thermal Conductivity	6700 W/m-C
Specific Heat	0.53 J/kg-C
Poisson ratio	0.342
Young's modulus	1.14+E011 Pa
Density	4433 kg/m³

Table -3 Properties of Stainless Steel

Thermal Conductivity	15.1 W/m-C
Specific Heat	480 J/kg-C
Poisson ratio	0.3
Young's modulus	22E+05 Pa
Density	4433 kg/m³

3. RESULTS

Table 4: Result Comparison for Different Materials Used

Materials	**Temperature Drop from 250**	**Total Heat Flux w/m²**	**Directional Heat flux w/m²**
High carbon Chromium Steel	201.46	1.13e5	78803
Stainless Steel	199.24	1.11e5	78803
Matrix Metal	249.85	1.46e5	1.016e5

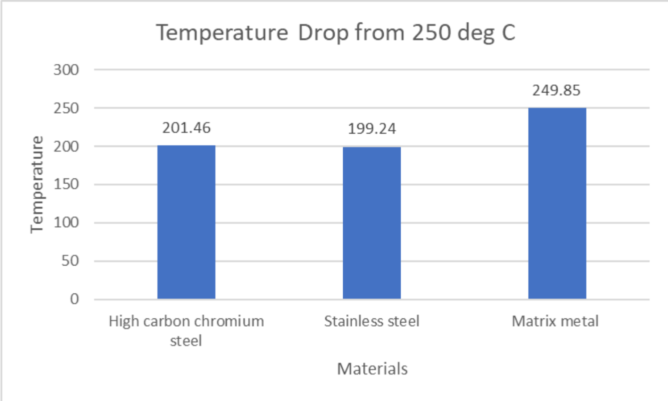

Fig. 13 Temperature Drop Graph from Initial 250 Degree Celsius

After careful input of different material properties (Table 1, Table 2, Table 3) such as Young's Modulus, density, thermal conductivity, specific heat and poisson's ratio results for respective metals are obtained.

First, Properties of high carbon chromium steel, stainless steel & matrix metal are input [11-13]. The results for the same are obtained in Fig 4-6, Fig 7-9 and Fig 10-12 respectively. These results for respective metals are regarding temperature distribution across ball bearing for respective metal, total heat flux and directional heat flux respectively.

The compared results for temperature drop from an initial temperature of 250 Degree Celsius to respective final temperatures for different considered metals are summarised in Table 4. Fig 13 shows graphical representation for deduction in temperature using different materials for ball bearing from an initial temperature of 250 Degree Celsius.

4. CONCLUSIONS

This conclusion is in coherence to the fact that the temperature drop between HCCS and SS is very close. However, the material and thermal properties for high carbon chromium steel surpasses that of stainless steel [8, 11-13]. Therefore, from the above analysis and results on heat transfer for different materials of ball bearings considered, we may conclude that the use of stainless steel is conventional but the choice of high carbon chromium steel (HCCS) is the most effective & efficient one for the production of ball bearings.

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