Static and Thermal Analysis on Mechanical Shaft Using Titanium Alloy

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Abstract- **A Shaft is consisted to various loads like torsion, axial load, and bending moment as well as for compressive, the loads might be uniformly distributed, and point, impact in nature and the shaft may be stationary or rotating. In this paper we use the mechanical shaft to check the bending moment, axial load, torsion and thermal transient in a shaft for calculating equivalent stress, equivalent elastic strain, directional deformation, total heat flux and directional heat flux. The shaft is connected to ball bearing at both ends, while we take titanium alloy as a material for doing analyses in mechanical Shaft. We use to design the Shaft in Catia software and the analysis parameter is done on Ansys software**

Index Terms- **Shaft, Catia, Ansys, Bending Moment, Strain, Stress**

1. INTRODUCTION

A shaft is a stationary or rotating device, it use to transfer of Power from one body to another. It is generally used for bending, torsion, tension or compression loads for isolation or combined modes. The load may be uniformly distributed, point, impact loading. The shaft structure are generally circular either solid or hollow. The shaft is a transmitting device which uses to transfer power from one body to another, and generally shafts are used for combined loads. A shaft which rotates and have steady loads should have a full reverse load, and each portion of shaft is with tension and compressive loads. The shaft should have strength, rigidity (torsion and axial), and have to maintain critical speed. The shaft design should be in these ways that the deflection which is produced by the devices should be minimum and in the tolerance limit. Lateral deflection in shaft might increase the vibration and increase of noise. In this paper we use to design the shaft in catia software of different material of shaft and the analyzing of shaft is done on Ansys software for different load condition to check the bending moment.

Notation

T- Torque
d – Diameter of shaft
J- Polar moment of inertia
M- Moment
I – Moment of inertia
σ_b – Bending moment
σ_a – Axial load
τ - Torsion
F- Force
A- Total surface Area
d_i- inner diameter
d_o- outer diameter
k -Thermal conductivity
Q_x- Heat flux

2. ANALYTICAL METHOD

In Analytical Method, we use to give the momentum to the shaft and then we use to calculate the deformation in the shaft and also to calculate the stress and strain in that particular shaft.

1. To calculate the torsion we use,

$$J = \frac{\pi(d_o - d_i)^4}{32}$$

$$\tau = \frac{T \times d}{2J}$$

2. Bending Moment

$$I = \pi(d_o - d_i)^4$$

64

$$\sigma_b = \frac{M \times d}{2I}$$

3. Axial load

$$A = \frac{\pi(d_o^2 - d_i^2)}{4}$$

$$\sigma_a = \frac{F}{A}$$

4. Heat flux (conduction)

$$Q_x = -k\frac{dT}{dx}$$

3. FINETE ELEMENT METHOD

This is a type of method used for solving problems in mathematical physics using numerical method. In these finite element method major problems used to solved using structural analysis. In this method generally consists of different complicated geometry with different material like titanium alloy and used to calculate equivalent stress, equivalent elastic strain, and directional deformation which is generally very complicated with Mathematical solution. And with the help of these we use to calculate heat flux while total and directional also.

4. DESIGN AND DATA

Mechanical shaft is used to modeled in CATIA V5 R20, the mechanical shaft have different geometry condition as it is used to assemble in CATIA with 3D model. As the shaft is at the middle of geometry and ball bearing at the both end, and the arrangement is done as the shaft have rotating moment. The shaft consists of different geometrical condition as Shaft inner diameter= 30 mm, Shaft Outer diameter is 45 mm, length of shaft = 1100mm, diameter of ball in ball bearing= 25mm, No of ball bearing= 10, centre of ball bearing from centre= 67.5 mm, inner diameter of ball bearing= 85mm, outer diameter of ball bearing= 185mm, diameter of bearing inside ball bearing= 120mm, diameter of bearing outside ball bearing= 150mm, thickness of ball bearing= 50mm, and distance between two ball bearings= 1000mm.

A) Sketch of shaft in catia[12]

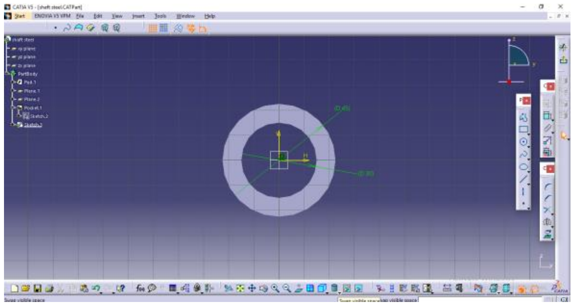

Fig 1: Sketch of shaft in catia

B) Mechanical Shaft model in catia

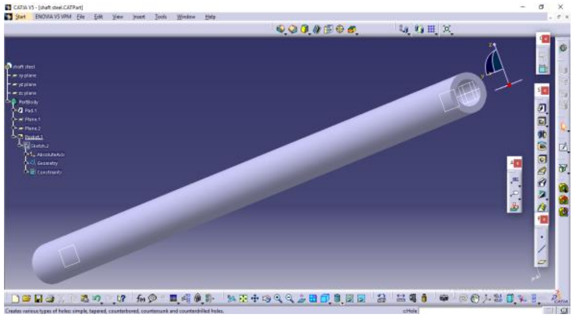

Fig 2: Model of shaft in catia

C) Ball bearing sketch in catia

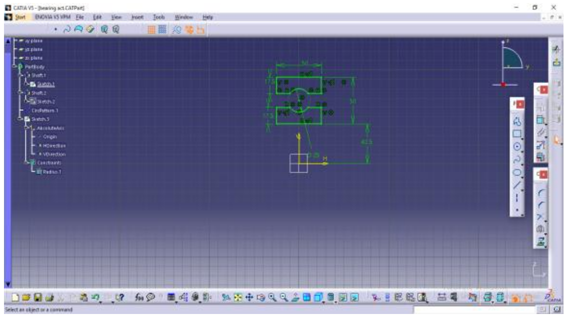

Fig 3: Sketch of ball bearing in catia

D) Ball bearing final model in catia

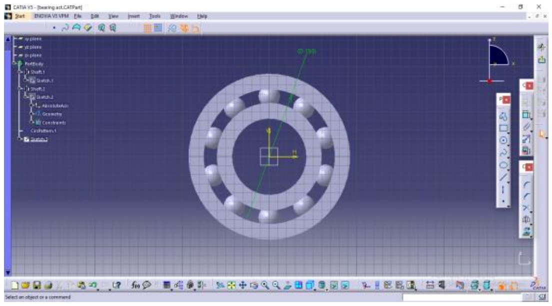

Fig 4: Model of ball bearing in catia

E) Assembly of ball bearing and shaft in catia

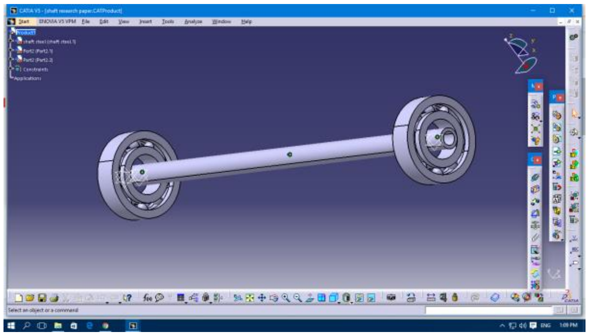

Fig 5: Assembled model of ball bearing and shaft in catia

5. ANALYTICAL RESULTS

In this analyzing of mechanical shaft we use Titanium alloy as a material for axial load, bending moment, and torsion, for checking the maximum and minimum value of Equivalent stress, equivalent elastic strain, and directional deformation. And for thermal transient we use to calculate directional flux and total heat flux for 500 watt, 600 watt, 700 watt, 800 watt, 900 watt and 1000 watt.[13]

1. Torsion

A) Equivalent Stress

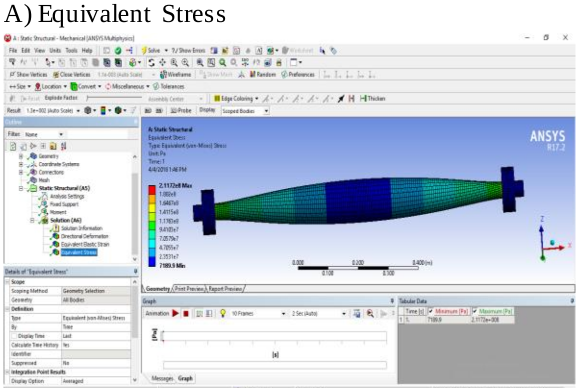

Fig 6: equivalent stress in Torsion

B) Equivalent Elastic Strain

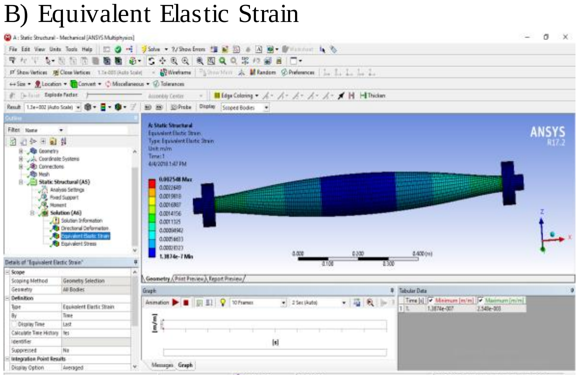

Fig 7: equivalent elastic strain in Torsion

C) Directional Deformation

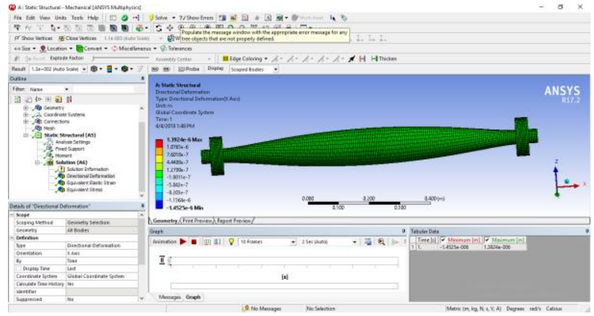

Fig 8: directional deformation in Torsion

2. Axial Load

A) Equivalent Stress

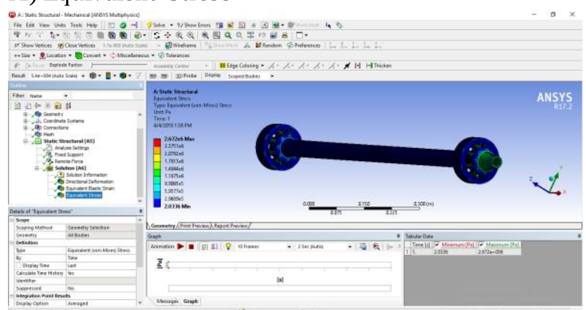

Fig 9: equivalent stress in axial load

B) Equivalent Elastic Strain

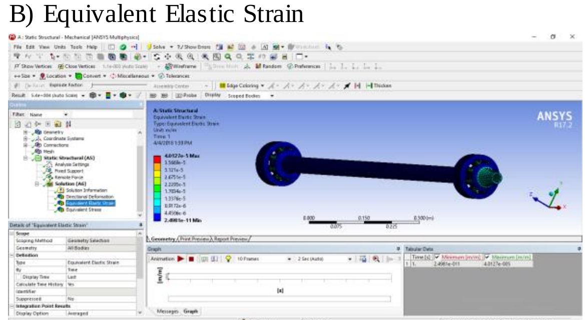

Fig 10: equivalent elastic strain in axial load

C) Directional Deformation

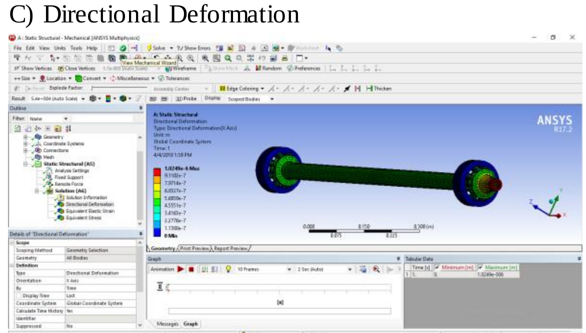

Fig 11: directional deformation in axial load

3. Bending Moment

A) Equivalent Stress

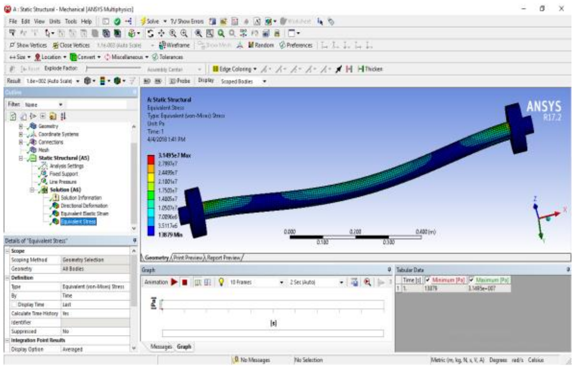

Fig 12: equivalent stress in bending moment

B) Equivalent Elastic Strain

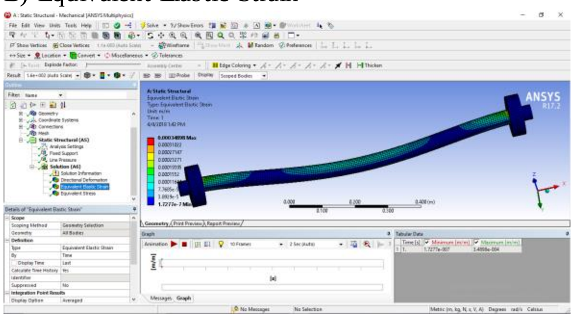

Fig 13: equivalent elastic strain in bending moment

C) Directional Deformation

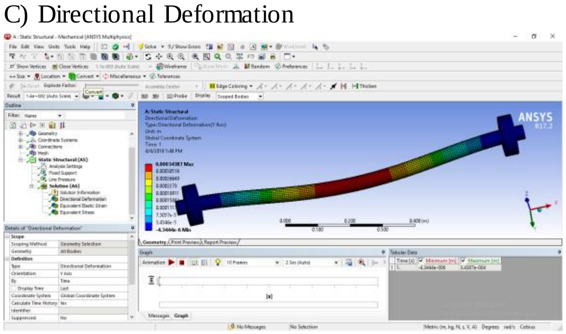

Fig 14: directional deformation in bending moment

4. Thermal transient

A) 500 watt

i) Directional heat flux

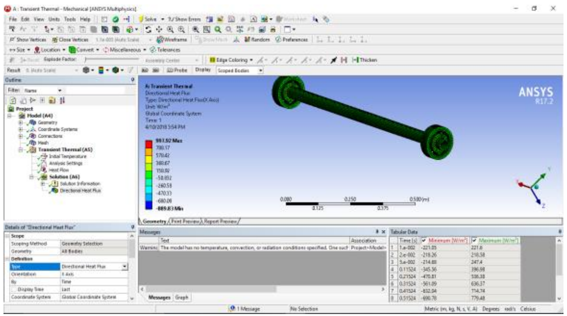

Fig 15: directional heat flux for 500 watt

ii) Total heat flux

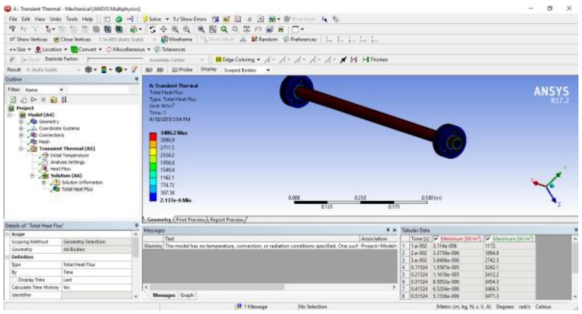

Fig 16: total heat flux for 500 watt

B) 600 watt

i) Directional heat flux

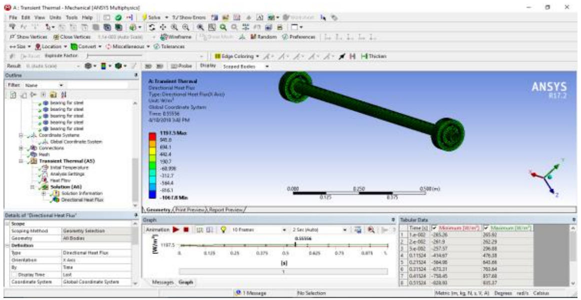

Fig 17: directional heat flux for 600 watt

ii) Total heat flux

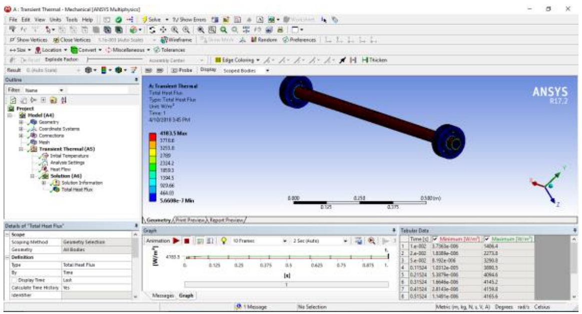

Fig 18: total heat flux for 600 watt

C) 700 watt

i) Directional heat flux

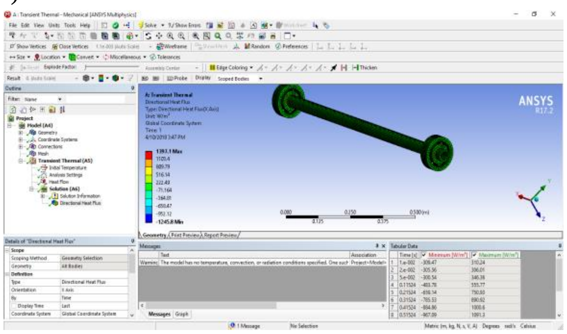

Fig 19: directional heat flux for 700 watt

ii) Total heat flux

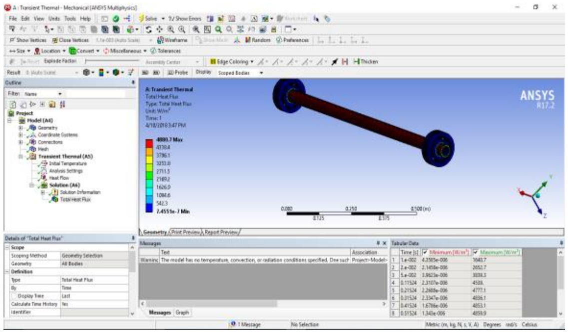

Fig 20: total heat flux for 700 watt

D) 800 watt

i) Directional heat flux

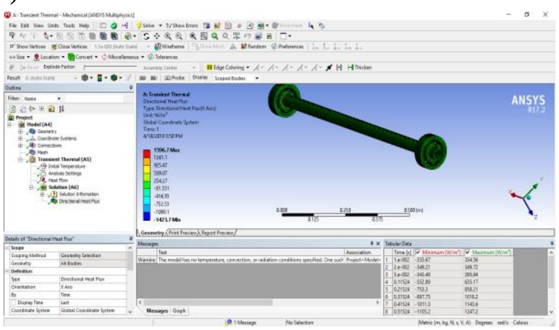

Fig 21: directional heat flux for 800 watt

ii) Total heat flux

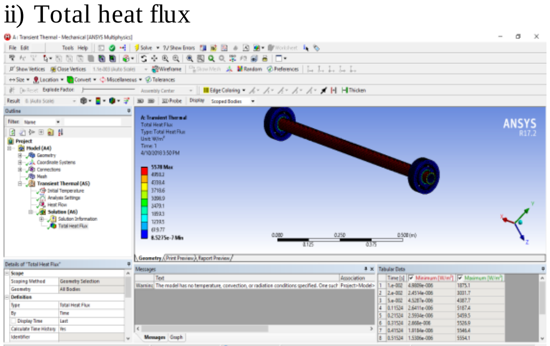

Fig 22: total heat flux for 800 watt

E) 900 watt

i) Directional heat flux

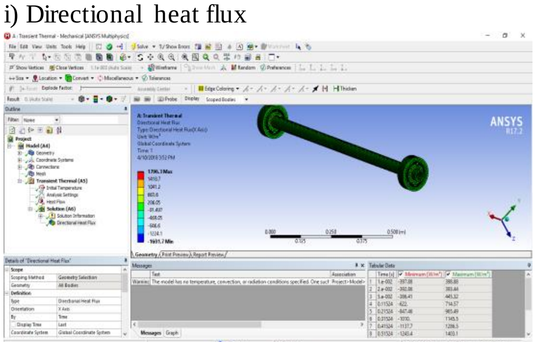

Fig 23: directional heat flux for 900 watt

ii) Total heat flux

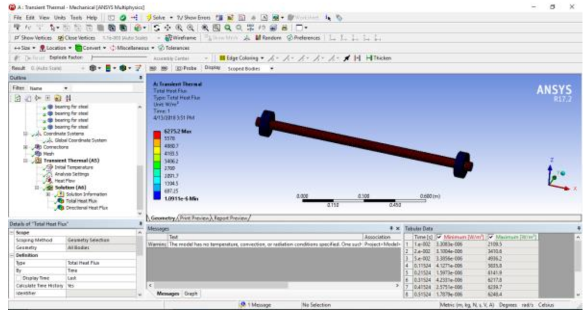

Fig 24: total heat flux for 900 watt

F) 1000 watt

i) Directional heat flux

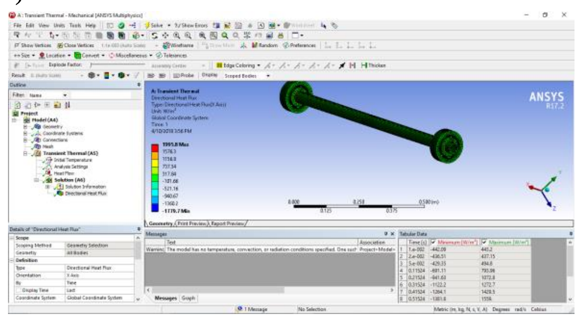

Fig 25: directional heat flux for 1000 watt

ii) Total heat flux

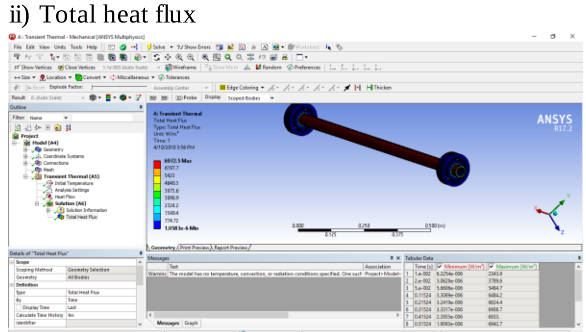

Fig 26: total heat flux for 1000 watt

6. CONCLUSION

A mechanical Shaft has two ball bearings which are attached at the end of shaft, while modeling is done in Catia V5 R20 and the analysis is in Ansys 17.2. In which we use to check the Torsion, Bending moment, and Axial load to calculate the equivalent stress, equivalent elastic strain, direction deformation, thermal transient heat flux is used to calculate directional heat flux and total heat flux for the material Titanium alloy for 500 watt, 600 watt, 700 watt, 800 watt, 900 watt and 1000 watt, which we use for analyzing the result.

A) Static structural Analysis for Titanium alloy (Maximum)

Load	Equivalent Stress	Equivalent Elastic Strain	Directional deformation
Torsion	2.1172×10^{8}	0.002548	1.3924×10^{-6}
Axial load	2.672×10^{6}	4.0127×10^{-5}	1.0249×10^{-6}
Bending Moment	3.1495×10^{7}	0.00034898	0.00034387

B) Static structural Analysis for Titanium alloy (Minimum)

Load	Equivalent Stress	Equivalent Elastic Strain	Directional deformation
Torsion	7189.9	1.3874×10^{-7}	-1.4525×10^{-6}
Axial load	2.0336	2.4981×10^{-11}	0
Bending Moment	13879	1.7277×10^{-7}	-4.3444×10^{-6}

C) Thermal transient analysis for Titanium alloy

Power (in watt)	Directional heat flux		Total heat flux	
	Maximum	Minimum	Maximum	Minimum
500 watt	997.92	-889.83	3.486.2	2.137×10^{-6}
600 watt	1197.5	-1067.8	4183.5	5.6608×10^{-7}
700 watt	1397.1	-1245.8	4880.7	7.4551×10^{-7}
800 watt	1596.7	-1423.7	5578	8.5275×10^{-7}
900 watt	1796.3	-1601.7	6275.2	1.0911×10^{-6}
1000 watt	1995.8	-1779.7	6972.5	1.0583×10^{-6}

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