THE FGM ANALYSIS

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Abstract: The shafts specifically used to transmit power are made up of the single material, but in the current work it has been modified with smart material using Functionally Graded Material (FGM) of ceramic and metal combination. The direct mixture of these two materials leads to the formation of an alloy with a possibility that the shaft may undergo oxidation which results in decreasing its lifespan. In order to avoid oxidation and improve the lifespan of the shaft, direct mixing of metals are avoided and the concept of applying FGM over a standard material is used and analyzed (ANSYS) by applying external loads.

Keywords: Shaft, Functionally graded material, Oxidation, Ansys.

1. Introduction

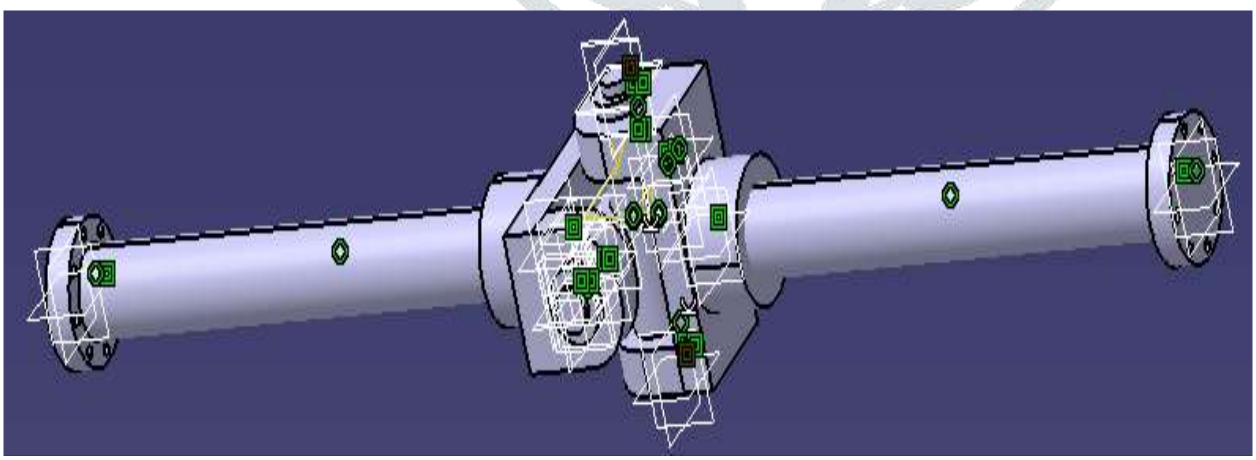
FGM stands for functionally graded material. These are the materials that are formed by adding a layer of ceramic material over standard economical materials such as steel, aluminum, copper etc. Many types of research are carried on ceramic materials by using the concept of FGM. These are produced by Electroplating, Case-hardening. The main concept of FGM is to form a ceramic layer over a ductile material, which will enhance the mechanical properties compared to other metals. If the base metal is of ductile material which contains toughness but has a very low strength and hardness. To overcome these defects of base material a layer of ceramic material is placed. As ceramic materials contain very high strength, high hardness and also very low coefficient of thermal expansion this will increase the strength of the product. In many types of research as it is not economical to fabricate ceramic product layers of ceramic is placed on a metal which minimizes the cost and maximizes the outputs. Some of the applications of FGM are in missiles at the exhaust portion, in the fields of nuclear energy, aerospace technology, Optical and electronic material. Advantages of FGM components possess good corrosion resistance and high strength along with toughness. These materials have the least coefficient of thermal expansion and its performance is independent of surrounding conditions.

2. Types of loads

The evaluation and comparison of deformation between steel shaft and FGM shaft are made by applying a load of twisting moment of magnitude 4O N-M clockwise direction at one end and 30 N-M anticlockwise at another end.

3. Design of shaft (catia model)

This is the shaft that is readily used for the analysis purpose. The shaft has a universal coupling joint as in general this type of joint is used in a regular transport system. Modelling is done using CATIA design software. Here the shaft of 40mm diameter is used and a layer of 5mm thickness ceramic material is coated on the shaft in order to assess the deformations.



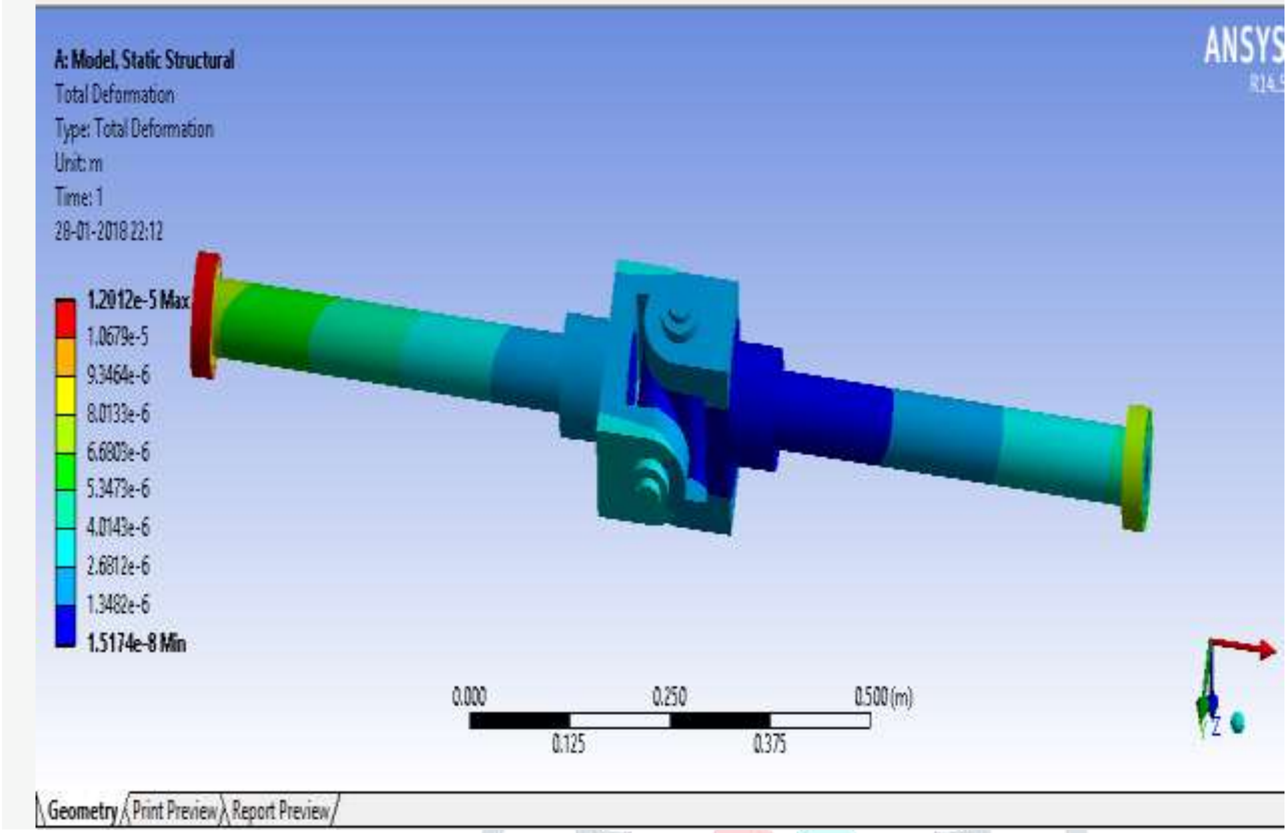
4. ANALYSIS

4.1 Analysis of steel shaft

Properties of structural steel

1. Density = 8000 kg/m3
2. Compressive strength = 250 Mpa
3. Modulus of elasticity =200 Gpa

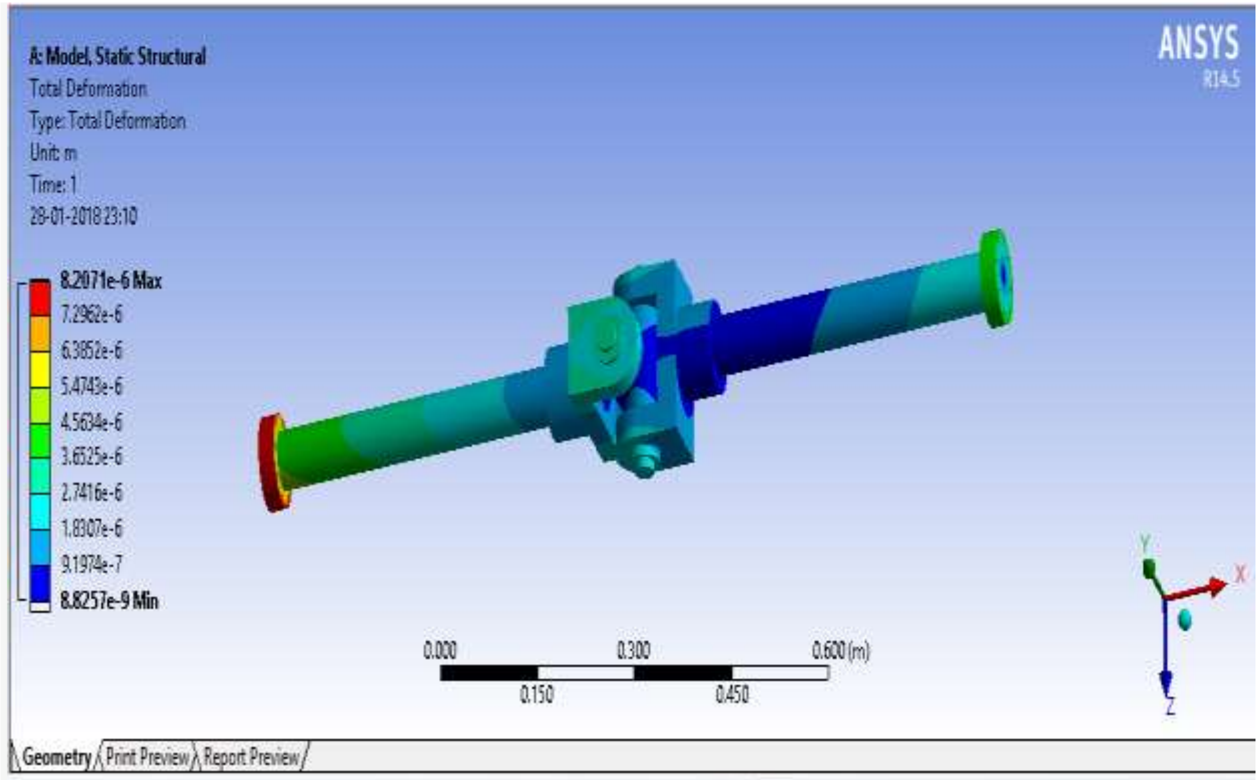
4. Poisson's ratio = 0.3



S.No	Type of deformation	Magnitude of deformation
1	Minimum deformation	$1.517*10^{-8}$ mts
2	Maximum deformation	$1.201*10^{-5}$mts

4.2 Analysis of FGM (alumina coated) shaft
Properties of alumina

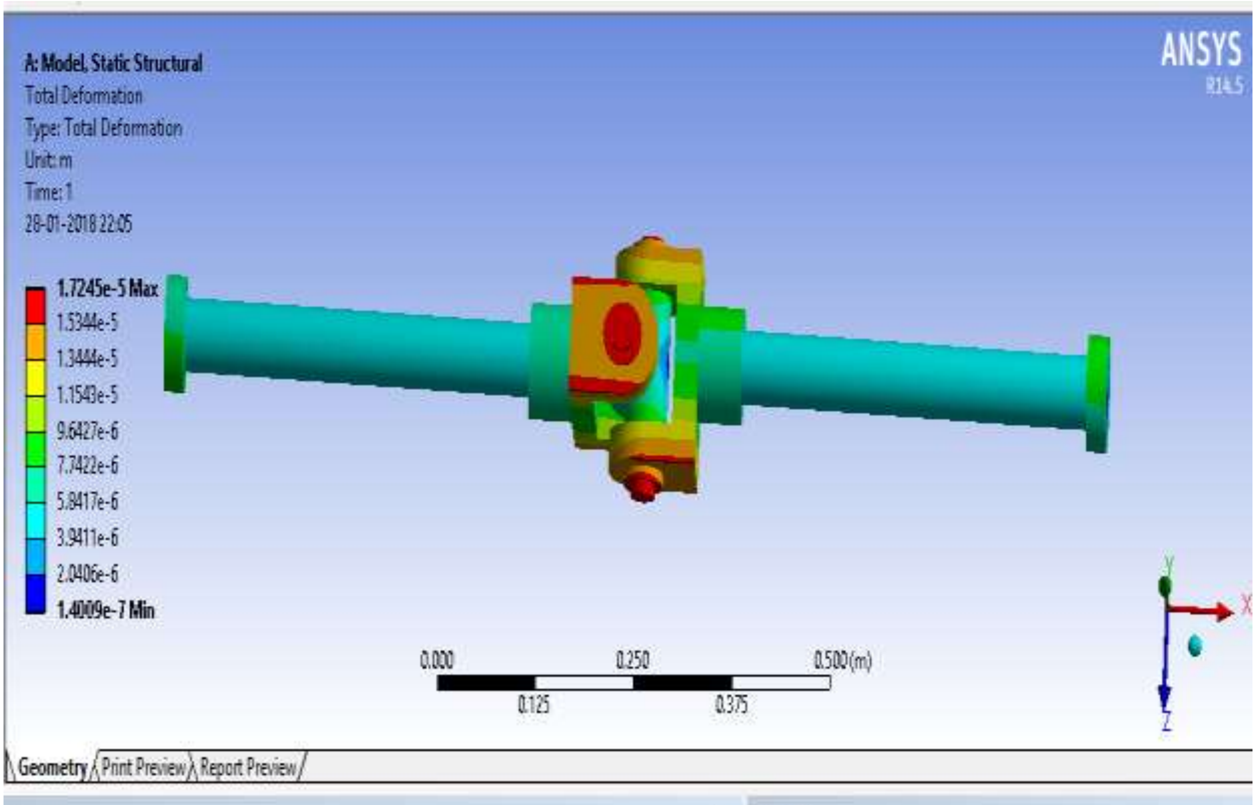
1. Density =3,980 kg/m3
2. Compressive strength = 690 Mpa
3. Modulus of elasticity =300 Gpa
4. Poisson's ratio = 0.21



S.No	Type of deformation	Magnitude of deformation
1	Minimum deformation	$8.82*10^{-9}$ mts
2	Maximum deformation	$8.20*10^{-6}$mts

4.3 Analysis of FGM (chromium carbide coated) shaft
Properties of chromium carbide

1. Density =6700 kg/m3
2. Compressive strength = 4.13 Gpa
3. Modulus of elasticity =304 Gpa
4. Poisson's ratio = 0.3



S.No	Type of deformation	Magnitude of deformation
1	Minimum deformation	$1.40*10^{-7}$ mts
2	Maximum deformation	$1.72*10^{-5}$mts

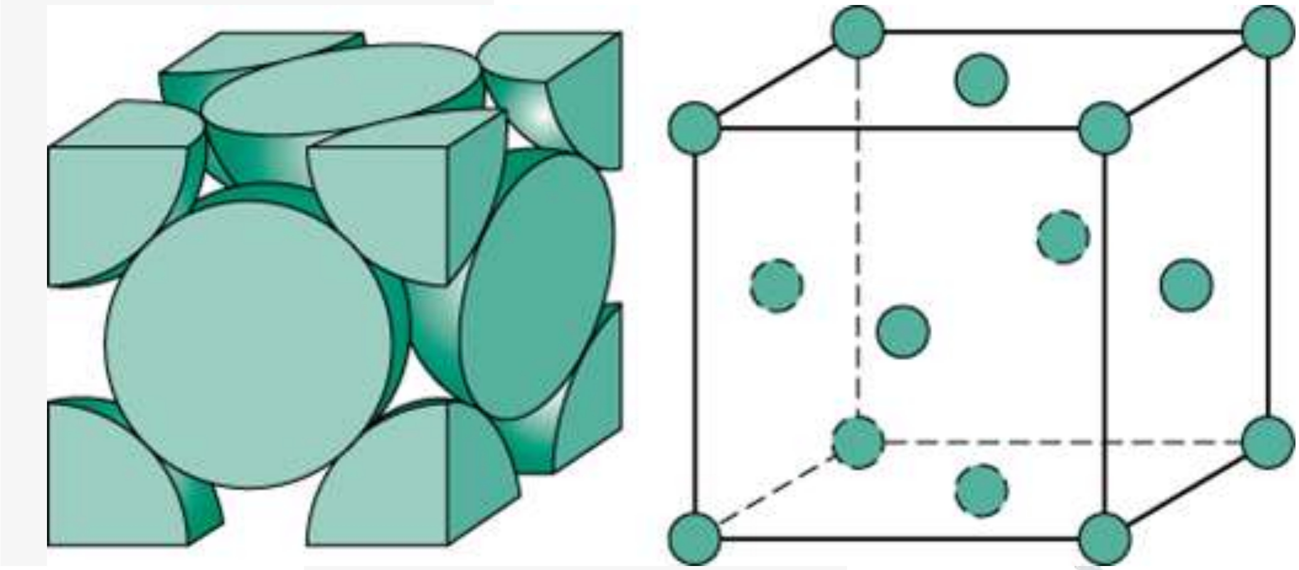
5. Comparison

S.No	Type of deformation	Deformation in steel shaft	Deformation in steel + alumina shaft	Deformation in steel + chromium carbide shaft
1	Minimum deformation	$1.517*10^{-8}$ mts	$8.82*10^{-9}$ mts	$1.40*10^{-7}$ mts
2	Maximum deformation	$1.201*10^{-5}$mts	$8.20*10^{-6}$mts	$1.72*10^{-5}$mts

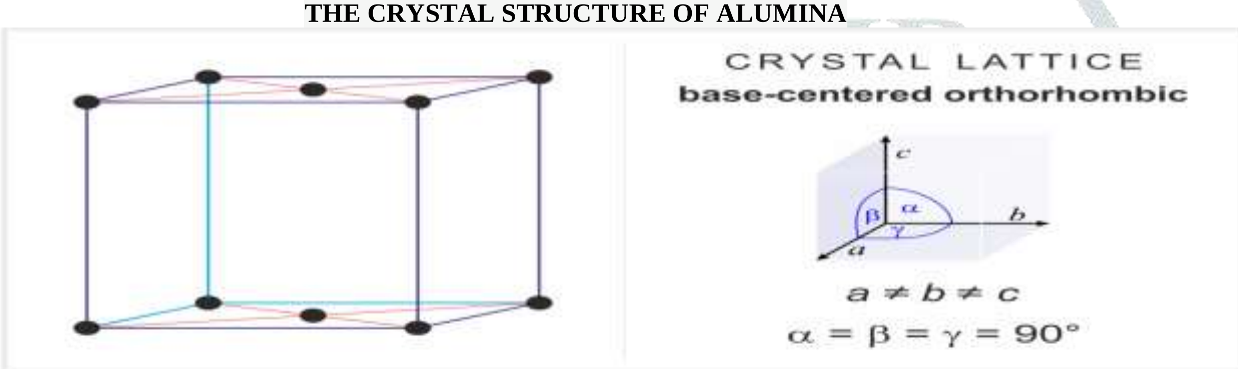
As it is clear from the above comparison, the shaft of FGM which has base metal as Structural Steel and coating material as alumina possess low deflection when compared to remaining shafts. This is because the hardness and strength of alumina is combined with toughness of steel resulting in lesser deformation. In case of Structural Steel shaft the metal only possess high toughness but low hardness and strength hence on comparison with FGM of (alumina + steel) has high deflection. In case of FGM (chromium carbide + steel) the density of chromium carbide is the dominating factor of it that its own weight is the initiative of its deformation hence the FGM of chromium carbide coated on Structural Steel has higher deformation.

The crystallographic theory

The ceramic material alumina that gave the best result of all the above cases is of FCC structure. That has total number of atoms in its crystal structure is 4 . This indicates the atoms are closely packed since the lattice length is $5.057A^0$ and the volume is 129.32 A^0 . Where as the chromium carbide is of Orthorhombic structure contains 4 atoms whose lattice length is uneven the resultant volume is 144.08 A^0 . Therefore the atoms are closely packed in alumina compared to chromium carbide . Hence from crystallographic analysis we can also say that the alumina has more hardness than that off chromium carbide



THE CRYSTAL STRUCTURE OF ALUMINA



THE CRYSTAL STRUCTURE OF CHROMIUM CARBIDE

5. Conclusion

On comparison of shafts of FGM over standard shaft found best results under application of loads, We can conclude that the FGM components gives lesser deformation than normal material. But the proper combination of ceramic and metal should be done to enhance results .After doing this analysis we can conclude that there will be an FGM that will give better performance than the metal

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