PERFORMANCE ANALYSIS OF KNUCKLE JOINT MADE OF METAL AND POLYMER

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Abstract: A knuckle joint is employed to connect two rods under tensile load and permits angular misalignment of the rods. Generally knuckle joints are made of cast iron and stainless steel. But in today's scenario, advancement in modern design technology has led to the reduction of cost as well as weight of the materials. Therefore in the present study, along with afore mentioned materials, Teflon is also used to produce a knuckle joint and results are compared. The reason for polymer (Teflon) consideration is due to the fact that *Ashby charts* show similarities in properties of polymers and metals. Modeling and analysis of a knuckle joint was carried by using Finite Element Method. A knuckle joint model was designed in solid works and analyzed in ANSYS for different materials under varying tensile loads in following designs.
Design-1: Material selected for eye and fork is Cast Iron while material selected for taper pin, collar and small pin is Stainless Steel.
Design-II: Material selected for eye and fork is Teflon while material selected for taper pin, collar and small pin is Stainless Steel.
From analysis, results show that deformation and equivalent elastic strain is significantly higher in Design-II as compared to Design-I but equivalent stress shows mixed response in both designs.

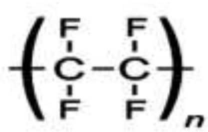
Keywords: Knuckle, Teflon, Ashby, ANSYS, Solid Work

I. INTRODUCTION

A knuckle joint is utilized to connect two rods subjected to tensile loads whereas, if the joint is directed, compressive load may be supported by rods. A knuckle joint can be easily disconnected when required. Knuckle joints have a wide variety of applications in various systems such as: Cranes, Earth movers, Robotic joints, Structural members, Bicycle chains, Tractors etc. A knuckle joint is shown in Fig. 1, in which projection in one part (single eye) enters the recess of the other part (fork) and knuckle pin passes through the eye hole as well as fork holes which may be protected by a collar and taper pin or split pin. In order to get a better joint, the sides of the eye as well as fork are machined and hole is precisely drilled. Knuckle joints can be produced by casting or forging.

Fig 1: Knuckle joint

Generally Knuckle joints are made up of cast iron and stainless steel. But with advancements in the field of polymers, Teflon can also be used for knuckle joints. Polytetrafluoroethylene (PTFE) is a synthetic fluoro polymer of tetrafluoroethylene that has numerous applications. The best known brand name of PTFE-based formulas is Teflon by Chemours, who discovered the compound in 1938 .Fig. 2 shows the chemical formula of Teflon. Because of the strength of carbon–fluorine bonds It is non-reactive and therefore often used in containers and pipe work for chemicals. In Fig. 3, Density versus strength of different material is shown in which strength of polymers is compared with metals.



In Fig. 2 showing the chemical formula of Teflon

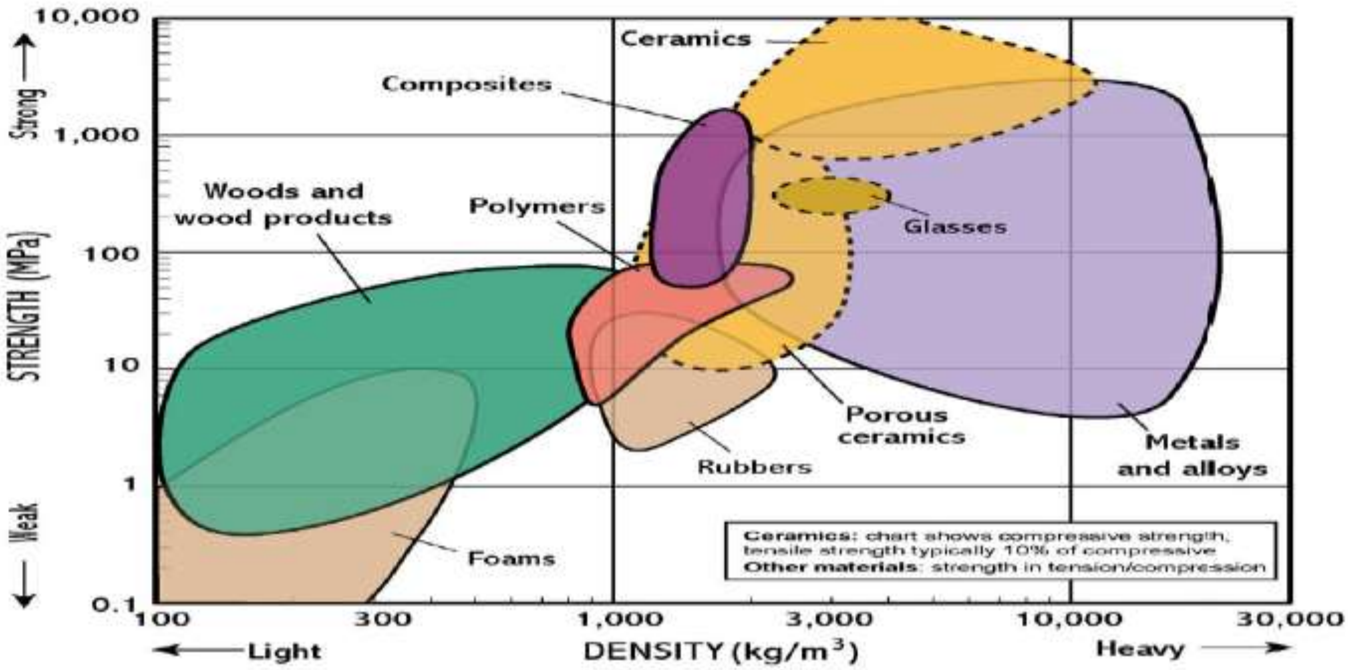


Figure 3: Ashby chart showing density versus strength of materials

S.J. Basha and H.S Vanka [1] obtained results from simulation which prove that for same loads Stresses induced in Composite material are very close to stainless steel and cast iron.F. Ausaa and F. Abusa [2] analyzed a knuckle joint made of 17HMBVA high strength low alloy steel and checked tensile, crushing and shear stresses inthe eye, in the fork end and all other parts of knuckle joint. N. Patil et al [3] performed static structural analysis of a knuckle joint using ANSYS and found maximum and minimum stresses induced. S. B. Herakal, R. Avadhani & S. C Goud [4] carried out Static Structural Analysis of Knuckle joint and concluded that induced stresses in fork are higher as compare to eye. S.Yadav et al. [5] designed a steering knuckle component and analyzed using ANSYS to study various parameters such as total deformation, directional deformation, Maximum principal stress. *G. Y. Kim, S. H. Han* and *K. H. Lee [6]* perfomed Structural Optimization of a Knuckle with steel and Aluminium. Jones [7] observed that shear failure due to torsional loading is the common failure mechanism in various engineering components. Pantazopoulos et.al [8] analysed the failure of a knuckle joint in a universal coupling system and observed that torsion is the major cause of failure. *S. Das , V. Bartaria and P. Pandey [9]* Analysed a Knuckle Joint of 30C8 Steel for Automobile Applications.

II. METHODOLOGY

A. Model design and meshing

A knuckle joint is modeled in Solid works having same dimensions but different materials for Design-I and Design-II as shown in Fig. 4.

Design-1: Material selected for eye and fork is Cast Iron while material selected for taper pin, collar and small pin is Stainless Steel.
Design-II: Material selected for eye and fork is Teflon while material selected for taper pin, collar and small pin is Stainless Steel.
After importing model from solid works in to ANSYS software, Model is meshed using tetrahedral elements in 3D domain. Meshed model is shown Fig. 5.

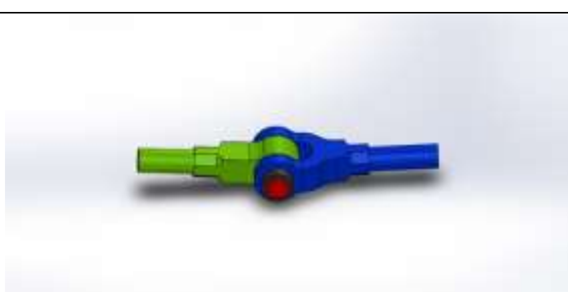


Fig 4: 3D View of knuckle joint

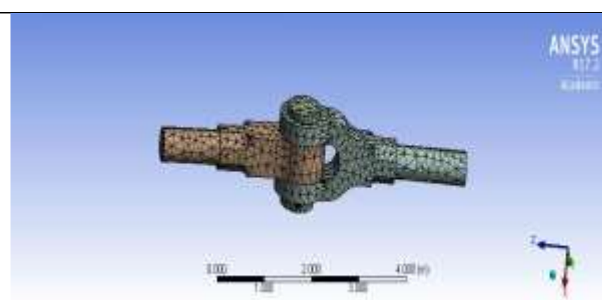


Fig 5: Meshing of knuckle joint

B. Input Data and Boundary conditions

Properties of stainless steel, cast iron and Teflon are mentioned in Table 1.

Table 1: Mechanical Properties of used material

Mechanical property	Stainless Steel	Cast Iron	Teflon
Density (Kg/m^3)	7850	7200	2100
Coefficient of Thermal Expansion (1/ºC)	1.7e-005	1.7e-005	6e-005
Specific Heat (J/kg/ºC)	480	490	970
Thermal Conductivity (W/mºC)	15.1	53.3	0.240 - 4.07
Compressive Yield Strength (MPa)	207	970	15
Tensile Yield Strength (MPa)	207	190	15
Ultimate Tensile Strength (MPa)	586	276	20
Reference Temperature (^{O} C)	22	22	22
Young's Modulus (Pa)	1.93e+011	1e+006	1e+006
Poisson's Ratio	0.31	0.23	0.23
Bulk Modulus (Pa)	1.693e+011	6.1728e+005	6.1728e+005
Shear Modulus (Pa)	7.366e+010	4.065e+005	4.065e+005

Four varying tensile loads are specified at eye and fork rods as mentioned in Table 2 for Design-I and Design-II.

Table 2: Tensile load applied in the experiments

Experiment	Tensile load applied (N)
1	100
2	105
3	110
4	115

III. RESULTS AND DISCUSSIONS

The simulation has been carried out under different loads (Table 2) for Design-I and Design-II (aforementioned) in ANSYS. Results from ANSYS on total deformation, equivalent stress (von mises) and equivalent elastic strain are observed and analyzed as shown in Fig. 6 and 7.

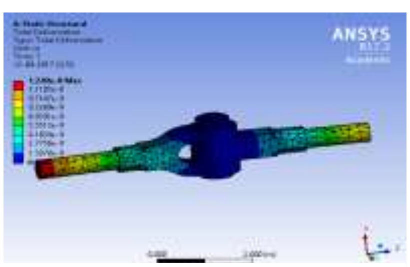


Figure 6a: Analysis of Total Deformation

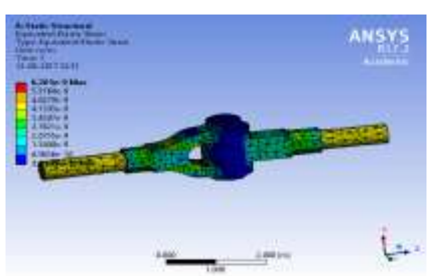


Figure 6b: Analysis of Equivalent Elastic strain

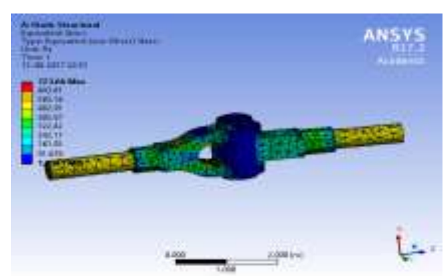


Figure 6c: Analysis of Equivalent Stress

Figure 6: Analysis of Design-I in ANSYS

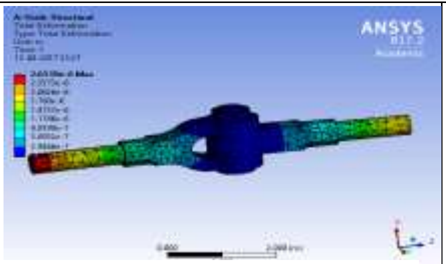


Figure 7a: Analysis of Total Deformation

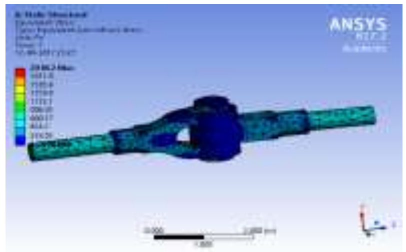


Figure 7b: Analysis of Equivalent Stress

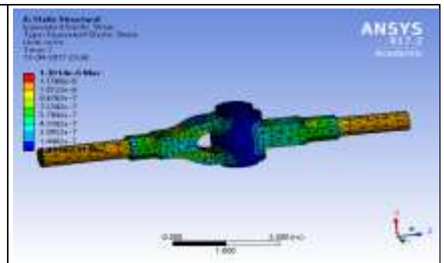


Figure 7c: Analysis of Eq. Elastic Strain

Figure 7: Analysis of Design-II in ANSYS

Comparative results of Design-I and Design-II are shown in Fig. 8, 9 and 10 respectively. In Fig. 8, it can be seen that deformation is higher in Design-II as compare to Design-I and this difference is increasing with load.

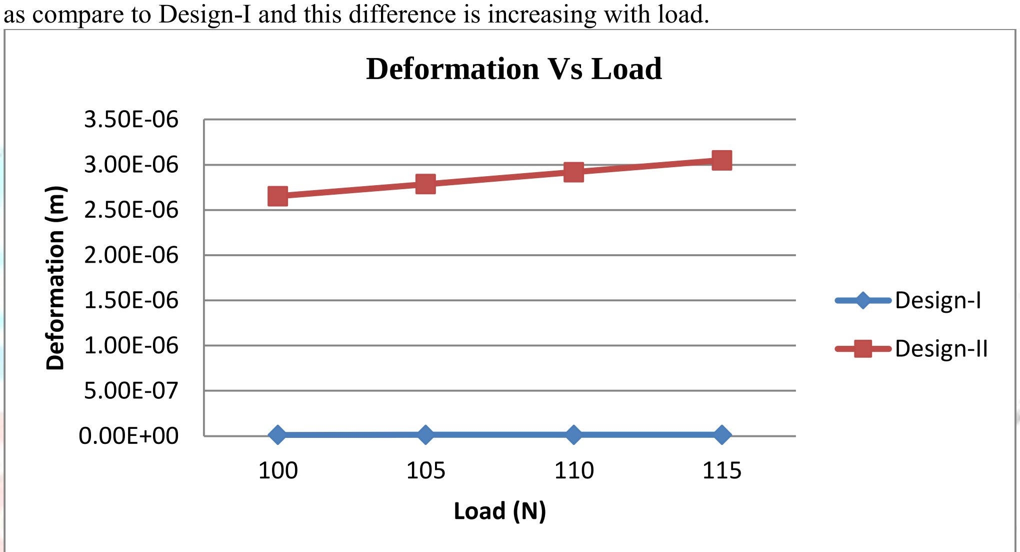


Figure 8: Load versus Deformation in Knuckle joint for Design-I and Design-II

In Fig. 9, it can be realized that equivalent elastic strain is following the same trend as deformation because strain is directly proportional to deformation.

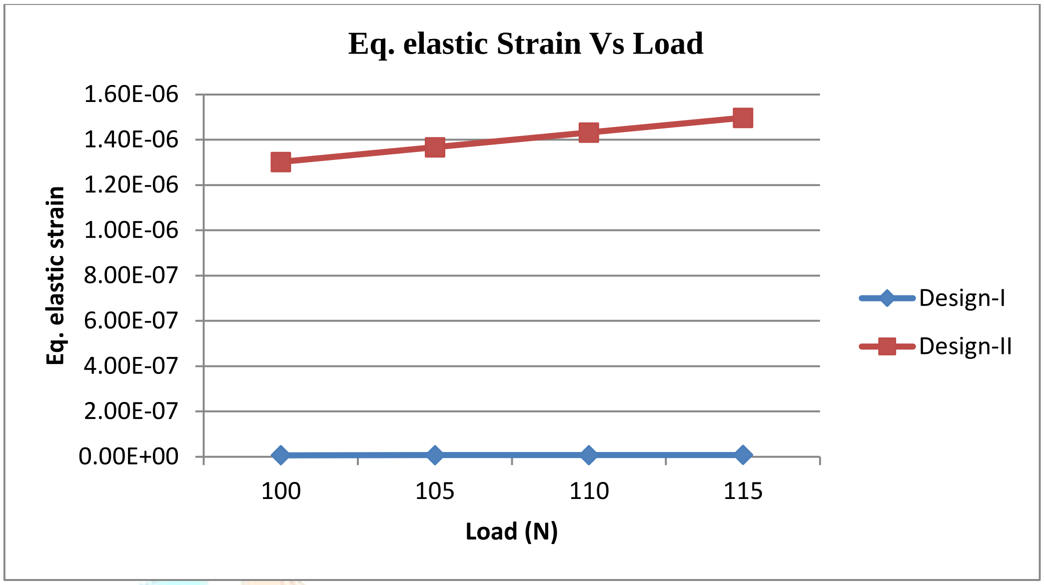


Figure 9: Load versus equivalent elastic strain in Knuckle joint for Design-I and Design-II

Fig. 10, demonstrates the behavior of equivalent stress with respect to load. Although load applied and dimensions are same in both the designs but stresses induced are different. This variation can be pertained to equivalent elastic strain and deformation.

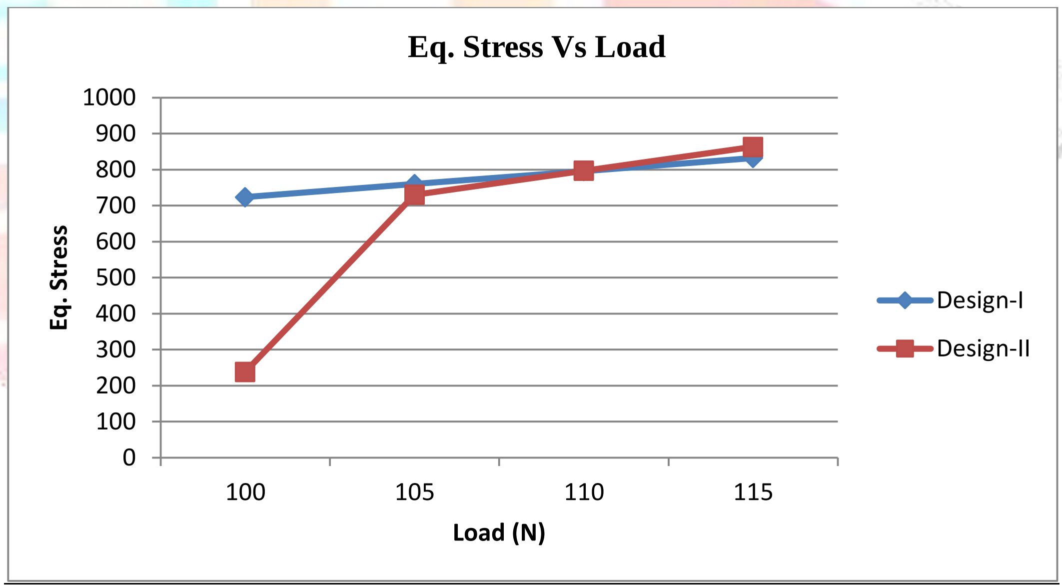


Figure 10 : Load versus equivalent elastic stress (von-mises) in Knuckle joint for Design-I and Design-II

IV. CONCLUSIONS

From the results and discussions, it is found that performance of Design-I (eye and fork made of Cast Iron) is comparatively better than Design-II (eye and fork made of Teflon). But parts made out of polymers are economical to produce, and facilitate overall systems cost reductions by eliminating secondary operations for parts, such as machining. Therefore Design-I can be proposed for light applications.

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