ISSN No.: 2455-6130
Special Issue: I, 2022, pp. 78-89

website: www.ijoetr.com

International Journal of Emerging Trends in Research

OPTIMIZATION OF POWER SCREW MATERIAL USED IN SCREW JACK

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Abstract

A screw jack is a mechanical lifting device used to apply very high magnitude of forces or lift heavy loads. In this project structural analysis of screw jack is performed in terms of total deformation, Equivalent stress and Factor of safety (FOS) using unconventional materials for the screw to find the best suitable material. Finite Element Analysis (FEA) is used for analysis of the screw jack. The materials used for power screw (Spindle) of screw jack are 20Mn2, 35Mn2 Mo28, 35Mn2 Mo48, C50 and C60. The materials used for components other than power screw are Grey Cast Iron for Cup & Frame, Phosphor Bronze for the nut & stainless steel for the handle. From the structural FEA, it is found that 35 Mn2 Mo28 material is most suitable for the screw.

Keywords: Total Deformation; Stress; FOS; Power screw; Static Structural analysis;

1. Introduction

When the tyre of an automobile vehicle fails or to perform normal repair or maintenance of vehicle, it is necessary for the driver of the vehicle to elevate the vehicle from the ground level [1]. For this reason, a jack can be very helpful. Scissor jack, Screw jack, Floor jack, Garage jack are the familiar forms of jacks which are used to lift the automobile vehicle for maintenance and repair [2]. The materials used to create the screw jack should have the capability and qualities to raise enormous weights while also preventing buckling, wear, and other issues that might occur in unexpected mishaps [3]. The standard screw jacks are still in use as it possesses many advantages like long life span, strength, packaging, mobility, cost and the prominent of them all is self-locking mechanism [3]. Screw jack utilizes power screw for its operation. To lift a vehicle, car jacks make use of mechanical advantage so that car can be elevated by manual force alone [4]. To furnish more lift over greater distance, powerful jacks work on hydraulic power [4]. A CAD model of a Screw jack was made on Solidworks as shown in Figure 1.

Fig.1: Screw jack [11]

A Power screw is a mechanical device that transforms rotational motion into linear motion while also delivering power. The translation screw is another term for the power screw. [5]. Helical motion of screw is used to transmit the power rather than holding the parts. A power screw mainly consists of three most important parts i.e., a screw, a nut and a part which holds either nut or bolt in place. Generally, there are two types of threads employed in power screw i.e., square or trapezoidal. A power screw can be used to raise a load, as in the case of a screw jack, or to acquire accurate motion in machining components, as in the case of a lead screw on a lathe, to firmly clamp the work piece, as in the case of a Vice, or to load a specimen, as in the case of a universal testing machine. Power screws function in two ways, depending on the holding configuration. [5]. In first method screw rotates in bearing, while that the nut has axial motion (e.g., lead screw of lathe). In the second method nut is stationery and screw move in axial direction (e.g., screw jack).

A screw jack is that type of jack which works by turning a leadscrew [6]. It has a wide range of uses, but it's most commonly used to lift relatively heavy loads, such as vehicles, to raise and lower aircraft's horizontal stabilizers, and to provide adjustable supports for greater loads, such as building foundations. It has a wide range of uses, but it's most commonly used to lift relatively heavy loads, such as vehicles, to raise and lower aircraft's horizontal stabilizers, and to provide adjustable supports for greater loads, such as building foundations. Design of such screw jack is based on the aspects of strength and wear consideration. Engineers, scientists, and ergonomists have recognized the traditional automotive screw jack for its efficiency over the years [6]. The screw jack is employed with self-locking characteristic of screw. This self-locking feature is required to prevent the weight from falling on its own.

There are many criteria for the choice of appropriate car jack depending on the type of vehicle and personal requirement of the vehicle owner [7]. A screw jack is made consisting of a heavy-duty vertical screw with a load table on top that screws into a threaded hole in a stationary support frame with a huge ground-level base. The handle is designed to fit into holes in a rotating collar on the screw's head. As the handle is cranked clockwise, the screw glides further out of the base, raising the weight on the load table. The screw is usually formed with Acme threads to support large load forces. Their ability to generate a great mechanical advantage i.e., a large force amplification – from a manually operated handle has increased the popularity of such screw jack. Despite the fact that the screw jack is a basic and extensively used device, it is not without risk. The screw jack generates a lot of heat, and extended lifts can lead to catastrophic overheating. The screw jack must be operated at room temperature to maintain its performance; otherwise, lubricants must be used. [8]. The dangers encountered in screw jack applications include machines or their parts falling, toppling, or sliding during the operation. [9]. These dangers can result in major and even fatal accidents. From a safety standpoint, correct size, strength, and stability are critical requirements for the construction of a screw jack.

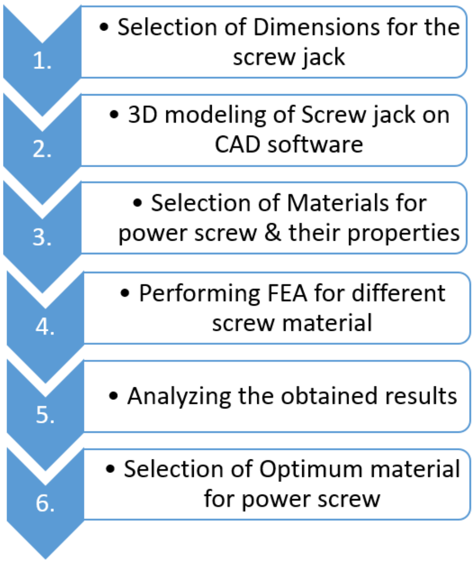
The objective of this paper is to:

- Compare the Stresses & Deformation induced in screw jack for all materials according to criteria minimum Deformation, high compressive strength & minimum induced stresses.
- Find the best alternative material for the screw of screw jack.

2. Layout analysis

The selection of screw material depends upon several factors, some of the factors being service load, minimal deformation, weight of the complete assembly, portability etc. In this paper the strength of the power screw has been compared for various materials viz., 20Mn2, 35Mn2 Mo28, 35Mn2 Mo48, C50 and C60. The Fig.2 shows the flowchart describing the process of evaluating performance of different material of power screws.

Fig.2: Methodology Flowchart



Assuming the ground clearance amount of jacking required to perform tire changing operations and other under the vehicle operations comfortably and keeping portability in mind the dimensions of the screw jack were finalized for a medium weight vehicle. Also, a trial run analysis was made to make sure that there is no failure occurring in the body of the screw jack. After finishing the dimensions of the screw jack, the next step is to create a 3D model of the screw jack on Solid works, this involves modeling of individual components and then assembling these components. The various components modelled are shown in Fig.3 to Fig.7.

Fig.3: Base

Fig.4: Power Screw

Fig.5: Nut

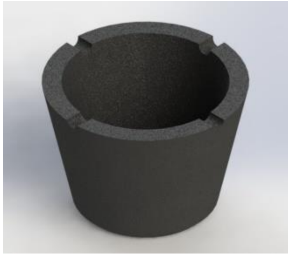


Fig.6: Cup

Fig.7: Handle

A. Material Properties

The material selected for various parts of the Screw Jack are tabulated in Table 1 & the different materials used for the screw were C50, C60, 20Mn2, *35*Mn2 Mo28 & 35 Mn2 Mo48. The mechanical properties of these materials are shown in Table 2.

Table 1: Part List & their Materials

Sr No.	Name Of Component	Material
1	Frame	Grey Cast Iron FG
2	Screw	Different Steels
3	Nut	Phosphor Bronze
4	Handle	Stainless Steel
5	Cup	Grey Cast Iron FG

Table 2: Comparison Matrix [10]

Materials	C50	C60	20 Mn2	35 Mn2 Mo28	35 Mn2 Mo48
Young's Modulus (GPa)	200	200	207	190	200
Poisson's ratio	0.25	0.25	0.29	0.27	0.29
Bulk Modulus (GPa)	13.334	13.334	164.88	137.768	158.73
Shear Modulus (GPa)		80	80.4	74.80	77.519
Tensile Yield Strength (GPa)	0.372	0.410	0.431	0.588	0.686
Tensile Ultimate Strength (GPa)	0.706	0.730	0.662	0.858	0.956

B. FEA ANALYSIS OF SCREW JACK

FEA is used for the structural analysis of Screw Jack and software used for FEA is ANSYS [12]. The following steps were carried out for performing the static structural analysis on ANSYS workbench:

Firstly, configure ANSYS workbench on 'Static Structural' mode. Export the geometry and the material files into the workspace and confirm if the geometry is being updated in the space claim. Once everything is added to the workspace then continue with opening of the mechanical workspace tab. Then continue with assigning material to the different components of the screw jack and mesh the entire assembly according to the systems computing power. Tetrahedron elements were used as these elements represent the model accurately with minimum deviation. Once meshing is done go ahead with providing boundary conditions on the screw jack assembly, apply fixed support constrain on the base face then apply a vertically downward force on the faces of the cap (P=10000N). The jack is responsible for lifting only half the load of vehicle as only two wheels are lifted from ground. After the analysis of all the unconventional materials for the power screw is completed, the equivalent stress, deformation and FOS are noted and the suitable material for the screw is selected.

3. Results and Discussion

In structural analysis, authors have analyzed all the mentioned materials (C50, C60, 20Mn2, 35 Mn2 Mo28 & 35 Mn2 Mo48) for Von-Mises Equivalent Stress, Total Deformation and Safety Factor of screw jack. The boundary conditions were considered as a fixed base support and the top surface of the cup was given the downward force of 10000 N [13]. As the screw jack is only responsible to lift half of the vehicles static load, hence the applied load is half of the both the axle loads. After analyzing the Screw Jack for every material. The obtained results were as shown below:

A. 20Mn2 Alloy Steel

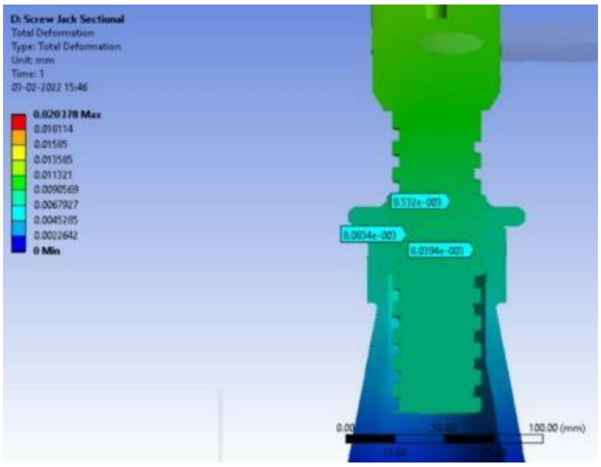


Fig.8: Total Deformation in 20Mn2 Alloy Steel

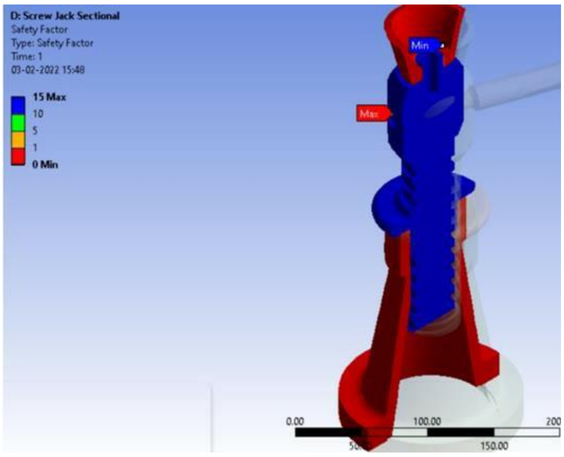


Fig.9: Factor of Safety in 20Mn2 Alloy Steel

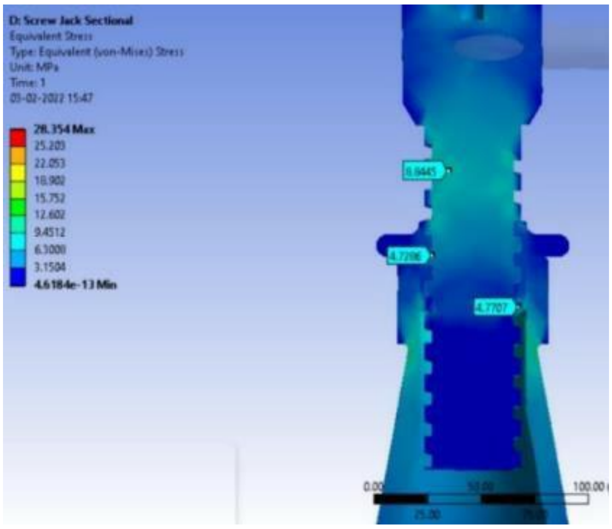


Fig.10: Equivalent Stress in 20Mn2 Alloy Steel

In the Fig. 8 to 10 with the material as 20Mn2 Alloy Steel, the maximum total deformation in the Screw Jack is 0.0853mm, the maximum equivalent Stress is 8.85 MPa & Factor of Safety is 15.

B. 35Mn2 Mo28 Alloy Steel

ISSN No.: 2455-6130
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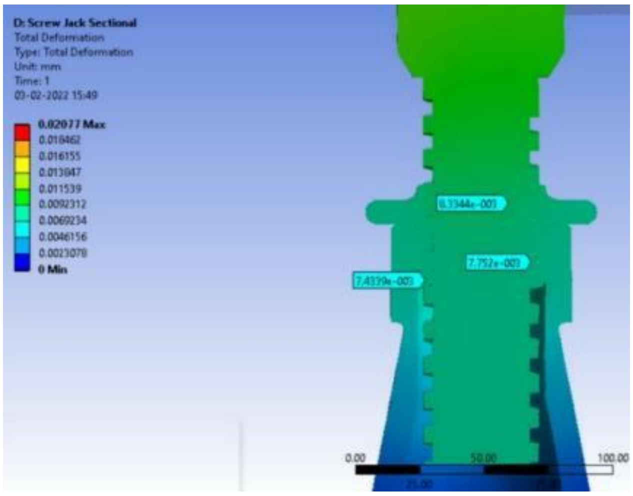

Fig.11: Total Deformation in 35Mn2 Mo28 Alloy Steel

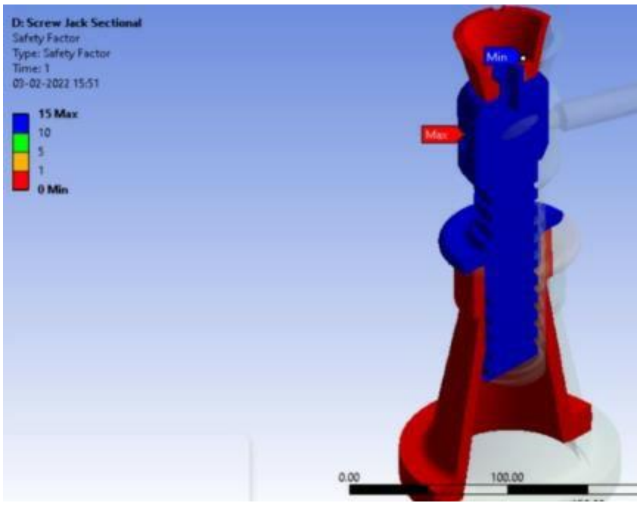

Fig.12: Factor of Safety in 35Mn2 Mo28 Alloy Steel

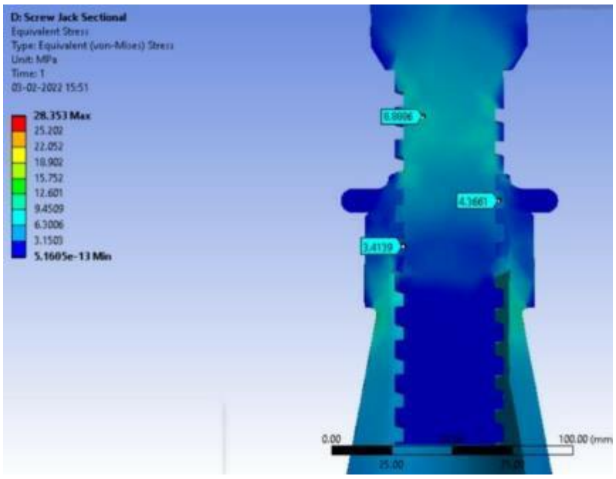

Fig.13: Equivalent Stress in 35Mn2 Mo28 Alloy Steel

For the material 35 Mn2 Mo28 Alloy Steel, the maximum total deformation in the Screw Jack is 0.0834 mm, the maximum equivalent Stress is 8.83 MPa& the Factor of Safety is 15 (Fig.11 to 13).

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C. 5Mn2 Mo48 Alloy Steel

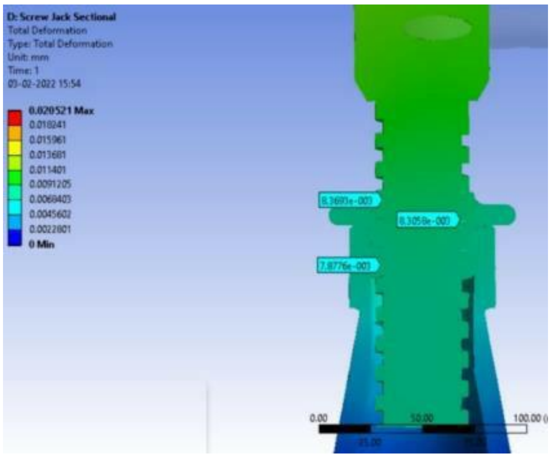

Fig.14: Total Deformation in 35Mn2 Mo48 Alloy Steel

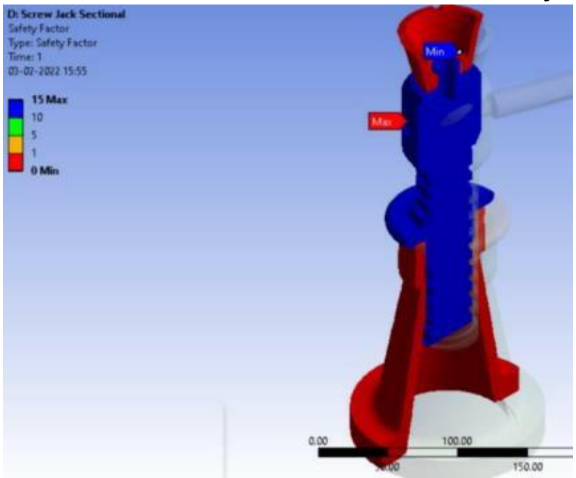

Fig.15: Factor of Safety in 35Mn2 Mo48 Alloy Steel

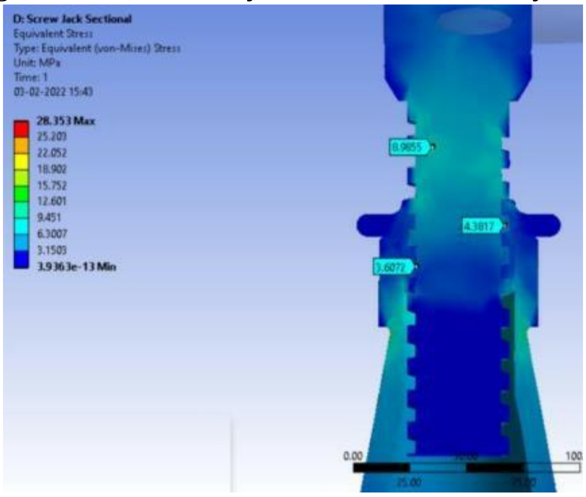

Fig.16: Equivalent Stress in 35Mn2 Mo48 Alloy Steel

For the material 35 Mn2 Mo 48 Alloy Steel, as shown in Fig.14 to 16, the maximum total deformation in the Screw Jack is 0.0836 mm, the maximum equivalent Stress is 9.214 MPa & the Factor of Safety is 15.

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D. C50 Alloy Steel

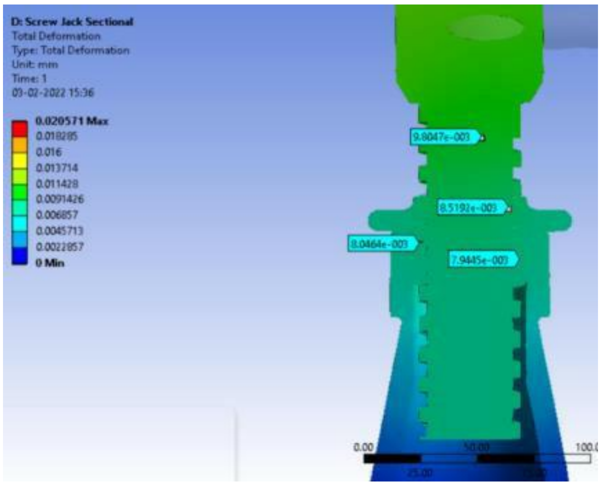

Fig.17: Total Deformation in C50 Alloy Steel

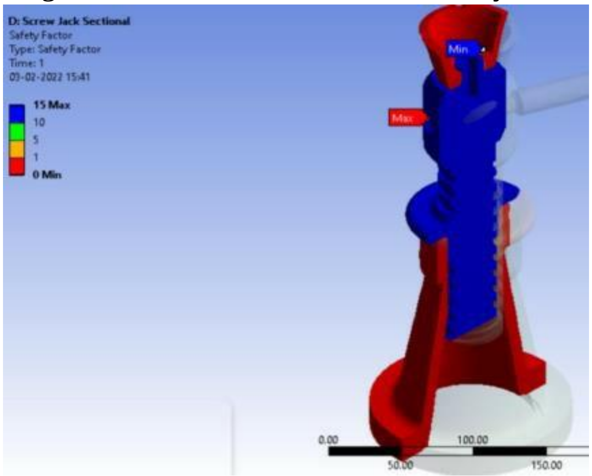

Fig.18: Factor of Safety in C50 Alloy Steel

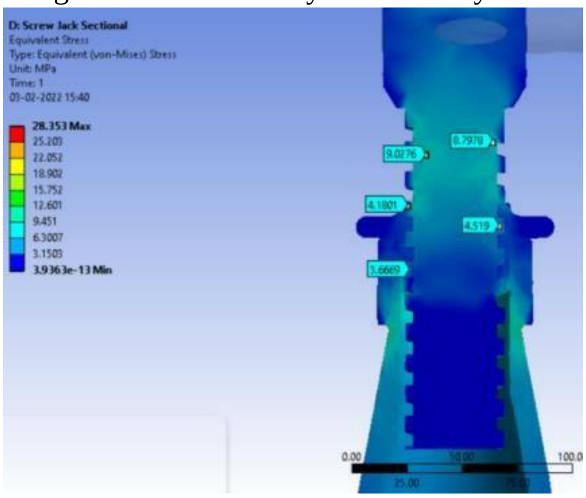

Fig.19: Equivalent Stress in C50 Alloy Steel

For the material C50 Alloy Steel, as shown in Fig.17 to 19, the maximum total deformation in the Screw Jack is 0.098 mm, the maximum equivalent Stress is 9.027 MPa & the Factor of Safety is 15.

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E. C60 Alloy Steel

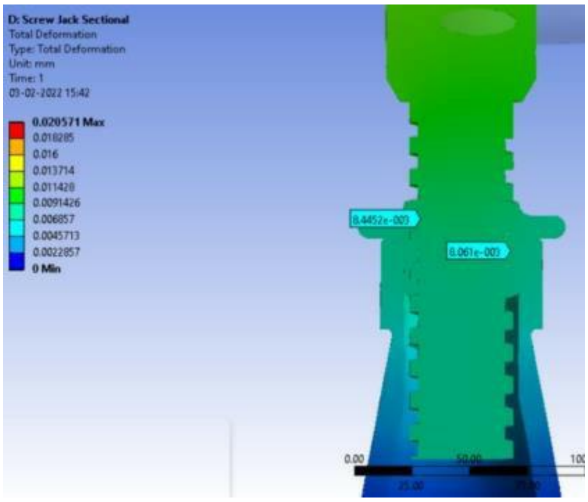

Fig.20: Equivalent Stress in C60 Alloy Steel

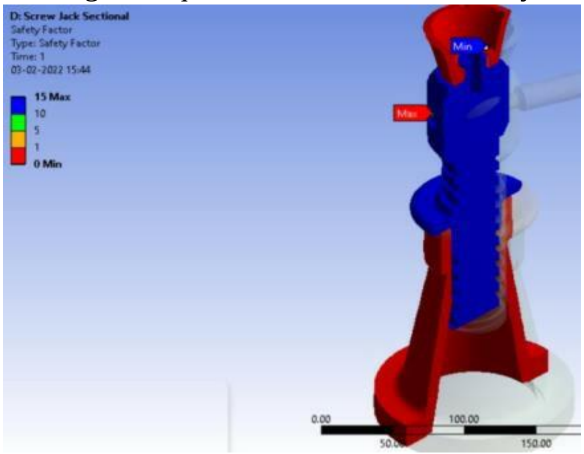

Fig.21: Factor of Safety in C60 Alloy Steel

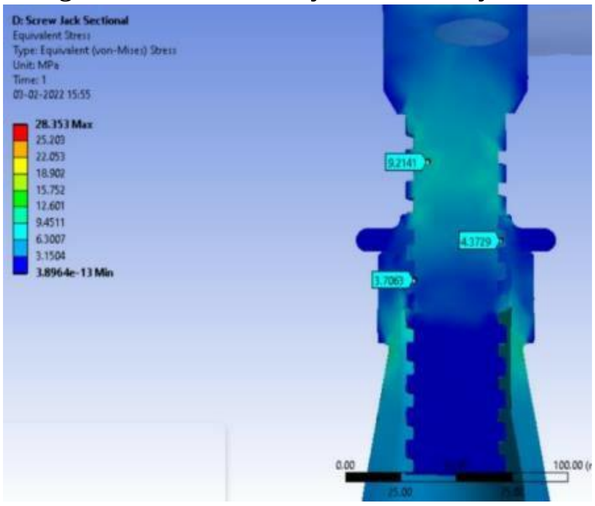

Fig.22: Equivalent Stress in C60 Alloy Steel

For the material C60 Alloy Steel, as shown in Fig.20 to 22 the maximum total deformation in the Screw Jack is 0.8443 mm, the maximum equivalent Stress is 8.985 MPa & the Factor of Safety is 15.

Table 3: Comparison Matrix

Material Grade of Alloy Steel	Total Deformation (mm)	Equivalent Stress (MPa)	FOS
20 Mn2	0.0853	8.85	15
35 Mn2 Mo 28	**0.0834**	**8.83**	**15**
35 Mn2 Mo 48	0.0836	9.214	15
C50	0.0980	9.027	15
C60	0.8443	8.985	15

As the total deformation for 35Mn2Mo28 is 0.0834 mm & the equivalent stress is 8.83 MPa is minimum as compared to other materials used for screw as tabulated in Table 3. Therefore, 35Mn2Mo28 proves to be an optimum material for the power screw.

4. Conclusions

In this paper, unconventional alloy materials (20Mn2, 35Mn2Mo28 & 35Mn2Mo48) for power screw were compared against their conventional carbon steel (C50 & C60). As evident from the results, the total deformation and factor of safety are nearly same which leads to equivalent stress being the deciding factor for selection of an alternative material. Hence the material 35 Mn2 Mo28 stands as the optimal material as its equivalent stress & the total deformation is the minimum amongst the other conventional and unconventional alloys.

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