Development and Performance Investigation of a Laboratory Screw Jack

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Abstract:  
This study is aimed at developing a screw jack that can be used for experimental demonstration to science students for better understanding of efficiency of a lifting device, mechanical advantage and relationship of effort to load during lifting. The design put into consideration of material selection, cost and easy operational use. The screw jack was put to test under various loads of; 50N, 100N, 150N, 200N and 250N and effort to lift each load, distance travelled by load and effort at different interval was recorded. Graphical relationships from the reading were established for effort vs load and efficiency vs load to show that effort increases with increase in load and efficiency of the screw jack was around >50%. The result also show efficiency and velocity ratio are not constant due to presence of friction in the system.

Keywords: Screw jack, lifting, mechanical advantage, efficiency

1. Introduction  
A screw jack is a simple device employed to raise heavy load with a relatively little effort. Example is when short lift distance is required like the car screw jack. This makes the screw jack a common mechanism for lifting/lowering heavy load (Benjamin and Modestus, 2017). The laboratory screw jack is model built to demonstrate the mechanism of a screw jack, the nut rotates in a screw thus making a connected pair in which one remains stationary while the other rotates and translates axially. Screws application can be seen in transmission of force in machines such as universal tensile testing machine, clamps, adjustable floor post or automotive jack (Ahmed, 2010). Although there are several other mechanisms like hydraulic or pneumatic also used for lifting purposes.

Significance of study  
The purpose of this study is to develop a screw jack for experimental use by engineering students or researchers. The screw jack under different loads will help demonstrate some engineering principle such mechanical advantage, velocity ratio and mechanical efficiency.

Mechanical advantage – this is calculated from the ratio of load to effort. In an ideal machine friction is considered zero and the ratio of load to ideal effort is then called ideal mechanical advantage which is always greater than the actual mechanical advantage. (Singer, 1975)

Velocity ratio – the ratio of a machine is determined by the ratio of the distanced moved by the effort to the distanced moved by the load. Ideally the velocity ratio of a machine is always constant for all load, but for real machine the velocity ratio is not always same since there is always friction present. (Singer, 1975)

Efficiency – this is defined as the ratio of useful work done by the machine to the actual work put into the machine. It can be calculated by the ratio of mechanical advantage to velocity ratio. For a simple machine, efficiency usually increases with load until it reaches a limiting value.
2. Material and Specification

There are common materials used in the design of screw jack such as; steel for the screw and cast iron, bronze or plastic for the nuts. The selection of material for the screw and nut is of great importance because of the consideration to reduce friction resistance between the screw and nut. (Nitinchandra et al., 2014) The project considered mild steel for the screw because of its high tensile strength, good amount of compression, easy machinability and local availability when compared with other types of steel and a softer material - cast iron for the nut. A material with high tensile strength, good amount of compression, local availability and less expensive were considered during the selection of material to achieve desired result.

The overall design of the screw jack comprises of the screw spindle having a square thread which is positioned in the centre of the body, the nut which rotates along the screw, load drum at the top of the screwed spindle, and threaded pulley attached to the nut for the rope winding.

![Figure1: Exploded View Showing Various Part of the Screw Jack](image)

To achieve accuracy and utmost performance of the screw jack fact like rigidity, strength and portability.

- **Screw** – the screw diameter is calculated by considering the screw under pure compression and maximum considered load ($W$). The nominal diameter ($d_n$) and pitch ($p$) for a square thread of nominal series was selected in respect to the calculated value of core diameter ($d_c$) from basic dimension for square threads according to IS: 4694-1968 (reaffirmed 1996) standard table ()

$$W = \sigma_c \times \frac{\pi}{4}(d_c)^2$$

- **Torque required to rotate the screw** – the torque to raise the screw will be determined using the coefficient of friction ($\mu$), helix angle ($\theta$) and mean diameter ($d_m$) by the expression below

$$T = W \tan(\alpha + \theta) \frac{d_m}{2}$$

From the result of the above equation the shear stress ($\tau$) can be calculated.

- **Nut** – the height of the nut ($h$) is calculated by considering the bearing pressure on the material used for the nut while the diameter of the nut is determined by considering the crushing strength.

- **Buckling of the screw** ($W_{cr}$) is also checked when the lift is at maximum. The buckling or critical load result is more than the load at which the screw is designed, therefore there will be no chance of buckling.

$$W_{cr} = \frac{2}{3}d_c^2 \times \sigma_y[1 - \frac{\pi^2}{4}
 \frac{k}{h}^2]$$

Where, $k$ is the radius of gyration ($0.25d_c$) and $C_i$ is end fixity of coefficient as given by (Khrumi and Gupta, 2005). Other design consideration includes the height of the body, diameter of the base and diameter of the top cup, development of parts and testing.

The screw jack was put to several testing conditions using various numbers of weights at different intervals. The following instruments were used during the evaluation; Metre rule, Vernier calliper and weights of different measures (2.5N, 4N, 10N, 20N, 50N and 100N). Below are the procedures taken during the testing exercise.

- The screw must be first stabilized by placing it on a flat surface and then the cord wrapped around the load drum then passed over the effort pulley and tied to the load hanger
- Weights were carefully added on the load drum, after these small weights were added to the effort hanger. This was continuously done respectively till there was a movement in the load drum
- The initial reading was recorded. That is the effort used, the distance moved by the load (measurement of the screw thread pitch) and distance moved by the effort.
- Thereafter, the load was gradually increased on the load drum.
- Likewise, effort was also increased on the effort hanger till movement was observed again
Thus, second readings were taken. This procedure was applied several times by increasing the loads on the load drum and adding more effort till there was significant movement of the load.

Precautions taken:
- Rope should not be overlap
- Load should be applied on the effort hanger gently
- Oiling should be done properly
- Carefully measure effort arm and pitch or screw

![Figure 2: Loaded Screw Jack in Operation](image)

3. Results

The procedure above was recorded 5 times to get good accuracy, which will be used to determine efficiency of the screw jack and also to show the relationship effort against load.

| S/N | Load (N) | Effort (N) | Distance Move by Load (Y)(mm) | Distance Moved by Effort (X)(mm) | Mechanical Advantage $\frac{Load}{Effort}$ | Velocity Ratio $\frac{X}{Y}$ | Efficiency $\frac{MA}{VR}$ |
|-----|----------|------------|-----------------------------|----------------------------------|---------------------------------|---------------------------|---------------------------|
| 1   | 50       | 13.5       | 40                          | 372                              | 3.7                             | 9.3                       | 0.42                      |
| 2   | 100      | 21.0       | 42                          | 400                              | 4.8                             | 9.5                       | 0.50                      |
| 3   | 150      | 28.2       | 43                          | 443                              | 5.3                             | 10.3                      | 0.51                      |
| 4   | 200      | 35.0       | 44                          | 469                              | 5.7                             | 10.6                      | 0.54                      |
| 5   | 250      | 41.6       | 46                          | 482                              | 6.0                             | 10.5                      | 0.56                      |

Table 1: Result Obtained at Different Loads

Table 1 shows that efficiency is not constant and it increases as the effort and load on screw jack increases, because there is less in frictional force. It is evident that increase in load also result in increase in effort but a lesser value than the load as seen in graphical expression in Figure 3. The graphical expression in Figure 4 below shows the relationship between load and efficiency, as load increases the efficiency also increases.

![Figure 3: Graphical Relationship of Effort Vs Load](image)
4. Conclusion

It can be concluded that a successful attempt to develop a screw jack that can be used for demonstration in the laboratory for student learning was achieved. The design is done using existing screw design calculation and standard tables. The entire design mainly aimed at showing the possibility of little effort overcoming heavy load which was achieved. This will help for easy understanding of basic engineering principles like law of machine, velocity ratio, mechanical advantage and efficiency.

5. References

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