Capstan Based Mechanical Power Amplifier Act as 'Mechanical Torque Booster'

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***Abstract* - This paper presents the experimental characterization of a mechanical power amplifier based on the theory of capstans. It is hypothesized that a system can be designed which would allow a rotating capstan to act as a mechanical power amplifier when a flexible member such as a cord or rope is wrapped around it. Whereas Capstans are used to lift or pull of heavy objects with mild effort in the form of winches. When a tension is applied to the end of the cord in the direction of the capstan's rotation, then friction will be transferred to the cord and the tension will effectively be amplified. Experimentation was performed to validate capstan as a mechanical torque booster for precise positioning and movement of heavy loads, by using different materials of rope viz. Woven cotton, Leather and Steel. This project determines the performance characteristics of a developed mechanical power amplifier for respective types of ropes.**

***Index Terms* – Capstan, band, amplification, load carrying capacity, torque booster.**

I. INTRODUCTION

The capstan in conventional terms is used simply whenever a user must lift or pull something which is out of their means to accomplish under their own abilities. Historically they have been used on sailing vessels when heavy sails and anchors required methods other than simple pulleys. Present day capstans are drums driven by electric or hydraulic motors whereas historical capstans were driven under human force. In both situations however the concept is the same; there is a rope wrapped about a drum which is rotated. As force is applied in the direction of rotation, friction is developed between the rope and the drum. The generated friction will then act in the same direction of pull effectively amplifying the users force. [1]

The generalized capstan equation determines the tension in the both ends of the rope. The Capstan equation is shown in following Equation1.

$$T_2 = T_1 e^{\mu\beta} \qquad (1)$$

The input tension, the smaller tension historically driven by a human, is represented by T_1 and the output tension, the greater tension used in lifting or winching, is represented by the term T_2. The variable within the exponential are μ, which is the friction coefficient between the drum and the rope and β, the angle in which the rope is in contact with the drum (in radians). [1]

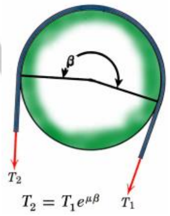

Fig.1 Capstan Friction Equation

Fig.1 summarizes the capstan equation for friction over a drum. Using this simple friction law leads us to conclude that the frictional force for a rope depends only on three things:

- The tension in the rope
- The coefficient of friction between the rope and the drum
- The total angle of contact between the rope and the drum

Generally, the usage of the capstan is to develop sufficient friction force between the rope and the drum to have the rope travel at the same rate as the drum. The friction developed in this process is able to transfer most of the needed force to the capstan driver rather than the human, allowing for heavier things to be hoisted. This concept of force transference is the underlying principle in this investigation. The goal of this study is to test the hypothesis that small scale capstan-based mechanical amplifiers might be feasible for application of accurate linear positioning and lifting of heavy loads, with reference to different materials of rope wound to the drum.

II. EXPERIMENTAL METHOD

To characterize the performance of capstan-based mechanical power amplifier, a system was constructed Fig.2 a friction band A and B was wrapped around LH drum and RH drums respectively which was driven by an electrical motor. Both ends of the band were connected to input arm and output arm. As the input arm gets the power from input shaft and band A connected to input arm which absorbs kinetic energy from the drum, multiplies it according to number of turns of wound to it and that will be deliver to band B as tension, further that is delivered to output as load, since load carrying capacity increases. This output torque was totally depends upon the coefficient of friction between drum and band, diameter of the drums and the number of wraps of the band on their respective drums.

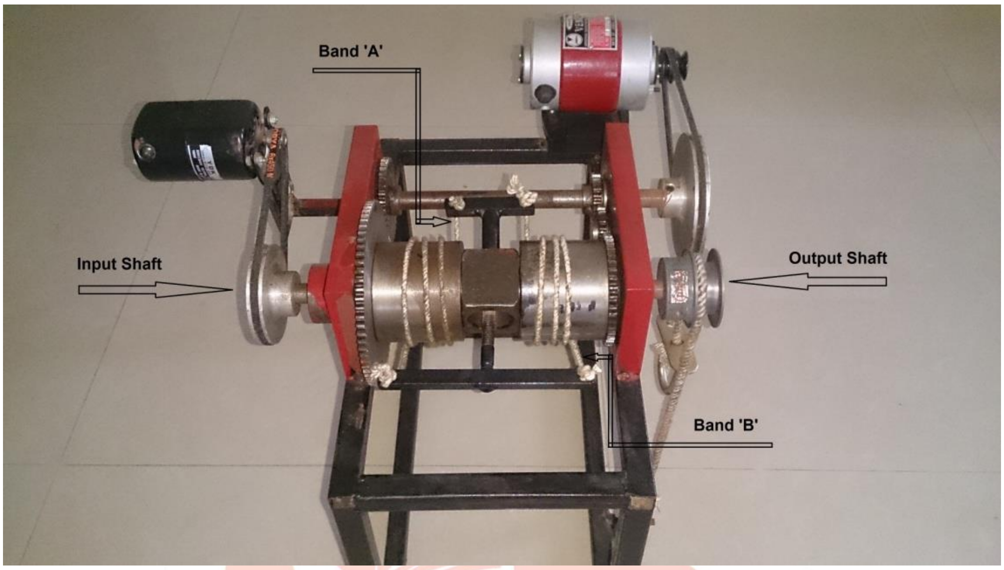

Fig.2 Capstan based Mechanical Power Amplifier System

For three types of different materials viz. Woven Cotton, Leather and Steel test were carried out to determine the performance characteristics of a developed mechanical power amplifier system.

Table 1 Properties of the Test Apparatus

Band Material	Leather
Capstan Material	EN 24
Input Motor Speed	850 RPM
Drive Motor Speed	2800 Rpm

Table 2 Properties of the Test Apparatus

Band Material	Woven Cotton
Capstan Material	EN 24
Input Motor Speed	850 RPM
Drive Motor Speed	1300 Rpm

Table 3 Properties of the Test Apparatus

Band Material	Steel
Capstan Material	EN 24
Input Motor Speed	850 RPM
Drive Motor Speed	2100 Rpm

For respective running condition of mechanism, loading is done at output pulley weighing pan from 100gm to1000 gm. And output speed was collected at same time to plot performance characteristic curve.

III. RESULT AND DISCUSSION

According to observation data produced by test shows, as there is increase in a load, power amplification factor gets increases. Since gives the greater load carrying capacity.

Performance Characteristic Curve For:

Band Material – Leather

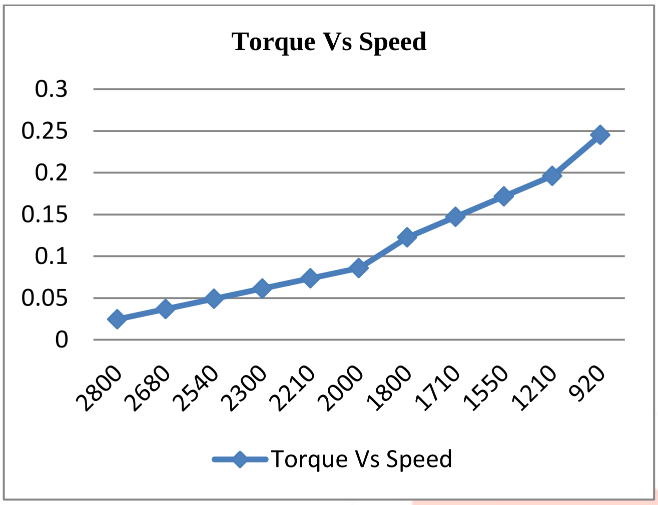

Fig.3 Torque Vs Speed

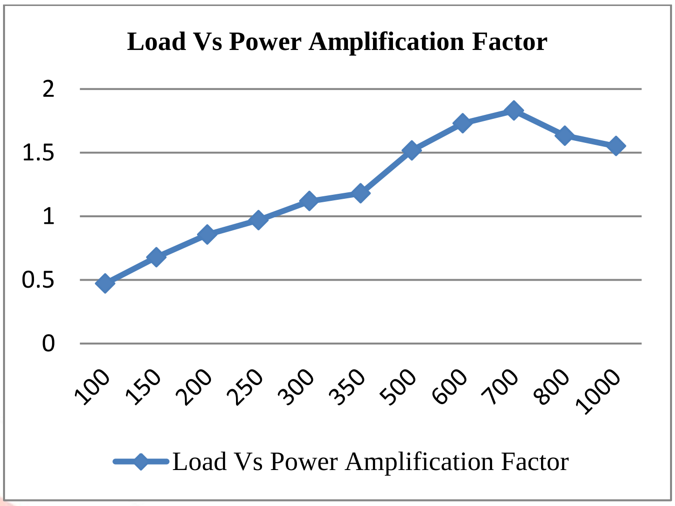

Fig.4 Load Vs Power Amplification Factor

Figure 3shows as there is application of load, speed at output get reduces which cause increase in output torque and figure 4 shows that there is an increase in power amplification factor with increase in load.

Performance Characteristic Curve For:

Band Material – Woven Cotton

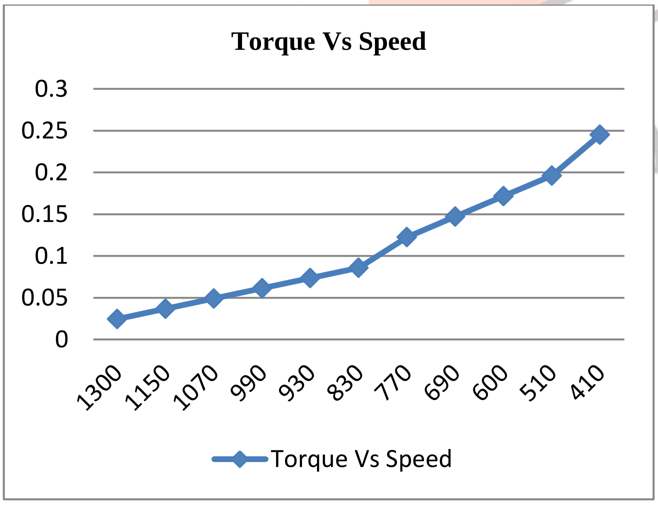

Fig.5 Torque Vs Speed

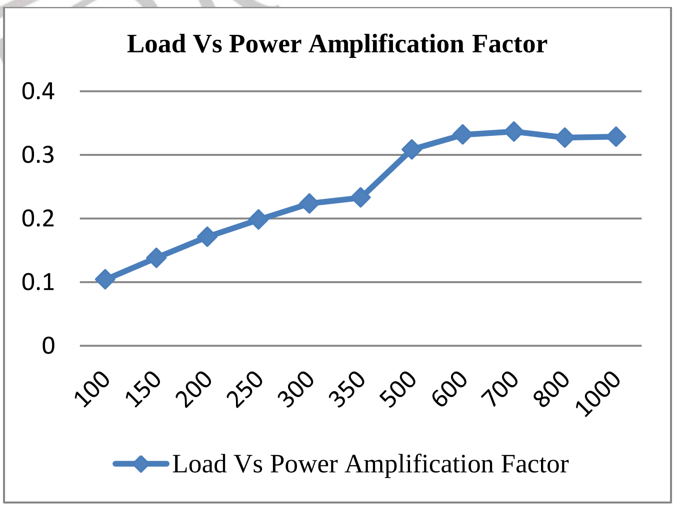

Fig.6 Load Vs Power Amplification Factor

Figure 5 shows as there is application of load, speed at output get reduces which cause increase in output torque and figure 6 shows that there is an increase in power amplification factor with increase in load.

Performance Characteristic Curve For:

Band Material – Steel

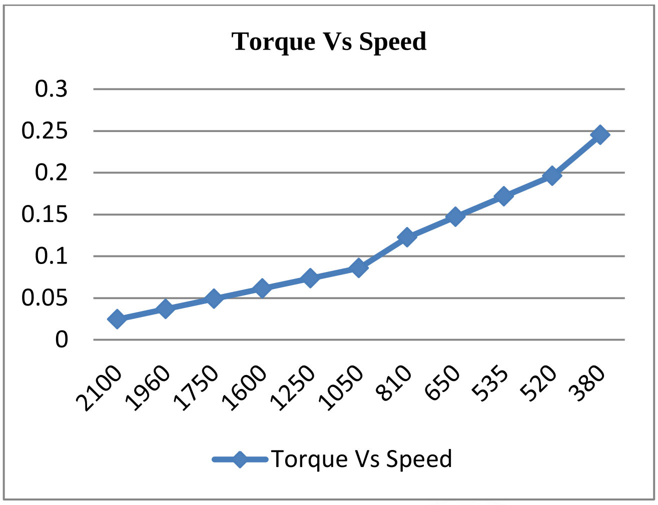

Fig.7 Torque Vs Speed

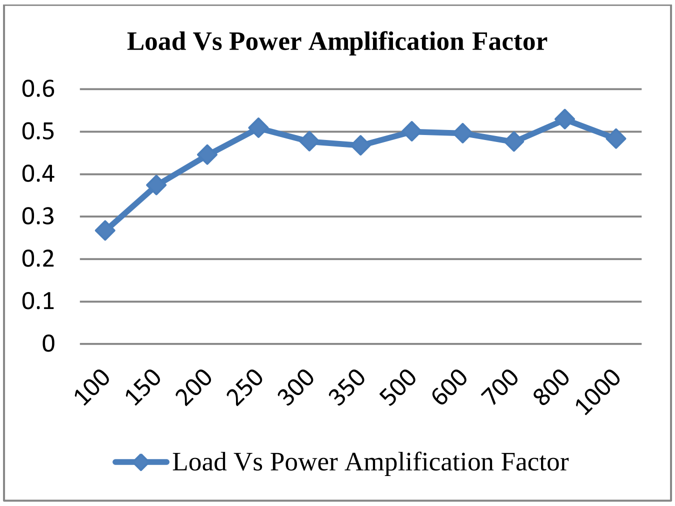

Fig.8 Load Vs Power Amplification Factor

Figure 7 shows, as there is application of load, speed at output get reduces which cause increase in output torque and figure 8 shows that there is an increase in power amplification factor with increase in load.

From all three materials of band it might be seen that, as there is application of load then there is an increase in power amplification factor which leads to give a greater load carrying capacity with such capstan theory.

So, according to application of load from no load condition to loading up to 1000gm for this mechanism, the operational behaviour of system shows that, there is an increase in load carrying capacity with respect to number of turns to be wrapped, diameter of drum and coefficient of friction.

As there are three wounds of band on capstan for each test materials which result in averagely 2.8 times increase in load carrying capacity. So such capstan based mechanical power amplifier acted as mechanical torque booster.

IV. CONCLUSION

A rotating capstan can act as a mechanical amplifier when the input tension is applied to a band wrapped about the capstan is pulled in the same direction as the capstans rotation. With this thesis it is proven that the rescue load is in relation with holding load as per the number of turns of band wound along the capstan. As the three wraps of woven cotton, leather and steel are used separately in this mechanism, which resulted in increasing approximately 2.8 times load holding capacity.

The given system with three wraps has by far the greatest load holding capacity for leather band and then for woven cotton and steel band.

The benefits of such capstan system would be utilized for industrial as well as construction, marine and domestic applications. And mostly preferred in automation industry for accurate linear positioning and lifting of heavy loads.

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