DESIGN AND DEVELOPMENT OF MECHANICAL POWER AMPLIFIER

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Abstract

Precise positioning and movement of heavy loads are two basic jobs for all-mechanical power amplifier. A capstan is simply a cylinder with a flexible body such as a string or cable wrapped around it. Capstans are generally used to assist in the lifting or pulling of heavy objects. By controlling the input tension on the cord, a capstan can dynamically amplify the input. It is hypothesized that a single capstan with multiple cords wrapped about it can act as numerous mechanical amplifiers. Present invention offers a new type of power amplifier which is structurally much simpler than previous amplifier. By using capstan friction principle mechanical power amplifier is designed for position and force controlling application.

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1. INTRODUCTION

Mechanical power amplifier is based on capstan principle. 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. Rope is wrapped about a drum which is rotated by electric motor. 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. Generally speaking, 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 capstan friction equation or belt friction equation, also known as Eytelwein's formula relates the hold-force to the load-force, if a flexible line is wound around a cylinder. Because of the interaction of frictional forces and tension, the tension on a line wrapped around a capstan may be different on either side of the capstan. A small holdingforce exerted on one side can carry a much larger loading force on the other side; this is the principle by which a capstan-type device operates.

The formula is:

$$T_{\text{load}} = T_{\text{hold}}\ e^{\mu\phi}$$

where $T_{\text{load}}$is the applied tension on the line, $T_{\text{hold}}$is the resulting force exerted at the other side of the capstan, $\mu$is the coefficient of friction between the rope and capstan materials, and $\phi$is the total angle swept by all turns of the rope, measured in radians i.e., with one full turn the angle $\phi = 2\pi$.

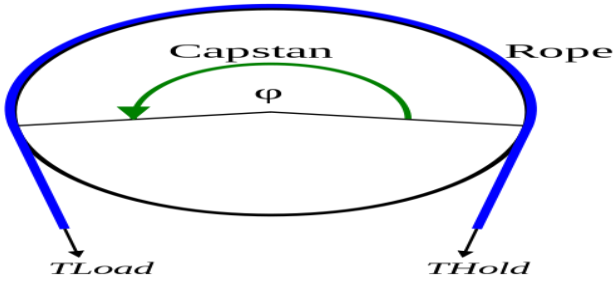

Fig 1 Diagram of capstan friction equation

2. CURRENT PRACTICES

Philip K. Budge[1] has carried out the work on improvement in precision motive devices and improved mechanical driving mechanisms of inexpensive manufacture and high power capacity in which mechanical power amplifier is used for the regulation of powered output movements under command of control signals of low power level. The objects of his invention is to provide novel and improved motive devices of relatively inexpensive construction which produce high-torque mechanical outputs in response to control signals of low torque or force levels.
J.M. Harries[2] has worked on the mechanical power amplifier based on the principle of a capstan force multiplier which is sensitive, bi-directional, with little back lash and very little inherent inertia. Mechanical power amplifier used as a multi- stage amplifier or a general control and instrument amplifier. Mechanical amplifier has both heavy duty and light duty applications, such as vehicle steering and guidance, crane, hoist, elevator and low power application such as servomechanisms, and general control instruments for controlling the output force.

Starkey, Michael M.[3] studied the capstan principle and used it to control the output. As amplifier control the output force, the amplifier is used for lifting load. When a tension is applied to the end of the cord pointing in the direction of the capstan's rotation, friction will be transferred to the cord and the tension will effectively be amplified. He found out

amplification factor for different angle of swept and plot graph of amplification factor vs input torque and compare amplification factor for different angle of swept.

Attaway,StephenW.[4] has worked on the mechanics of friction in rope and presents that the, key factor for the mechanical amplifier to work is its ability to develop friction between the rope and drum. He gives the Capstan Friction formula that is used in the mechanical power amplifier.

Smallridge,B.[5] has studied the potential of using a single drive to control multiple members as well as the importance of responsive members that relax immediately with the input force. Smallridge recommended a limit of three wraps around the tracked drive drum to avoid the issue of binding. He referred to a generic solution of reversing the drive drum and relaxing the input tensile signal if binding did occur in the system.

3. WORKING OF MECHANICAL POWER AMPLIFIER

Flywheel motor drives the gear train using belt pulley arrangements. The left hand gear train, drives left hand drum in clockwise direction whereas the right hand gear train drives, the right hand drum in counter clockwise direction. Both the drums are rotated in exactly opposite direction but at the same speed. Input arm & output arm are connected together by band A & band B. Band A drives the output when input arm is rotated in clockwise direction whereas band B drives the output when input arm is rotated in counter clockwise direction. When the load is applied on the output arm; assuming that input arm is rotated in clockwise, band A tightened on left hand drum & absorb kinetic energy from drum & multiply it by number of turn & deliver it to output shaft. As input & output shaft are engaged they rotated at the same speed; hence the same power that is applied to input arm will be multiply as per number of turn & delivered to the output shaft. Output load depends upon the coefficient of friction between drum & band (rope) and the number of turns of rope.

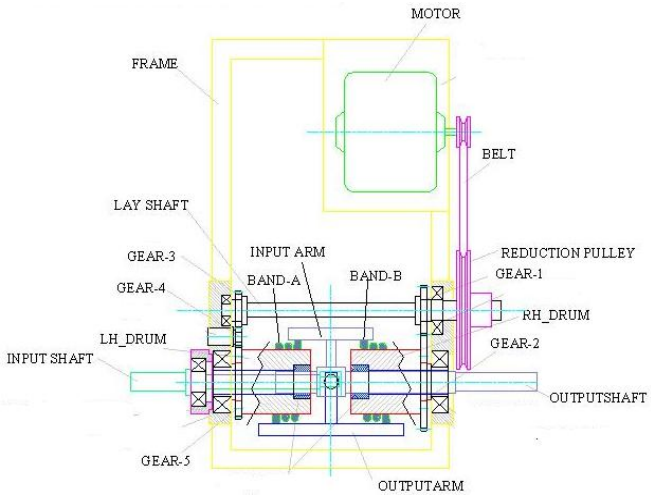

Fig 2 Schematic diagram of mechanical power amplifier

4. DESIGN OF MECHANICAL POWER AMPLIFIER

Design of mechanical power amplifier consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy and efficiency.

4.1 System Design

System design mainly concerns with various physical constrains, deciding basic working principle, space requirements, arrangements of various components etc. Following parameters are looked upon in system design.

a) Selection of system based on physical constraints. The mechanical design has direct norms with the system design hence system is designed such that dimensions obtained in mechanical design can be well fitted into it.
b) Arrangement of various components made simple to utilize every possible space.
c) Ease of maintenance and servicing achieved by means of simplified layout that enables quick decision assembly of components.
d) Scope of future improvement.

4.2 Mechanical Design

In mechanical design the components are listed down and stored on the basis of their procurement in two categories,

- Design parts
- Parts to be purchased.

For designed parts detailed design is done and dimensions there obtained are compared to next dimensions which are already available in market. This simplifies the assembly as well as the post production and maintenance work. The various tolerances on work are specified the process charts are prepared and passed to manufacturing stage.

The parts to be purchased directly are selected from various catalogues and are specified so as to have case of procurement. In mechanical design at the first stage selection of appropriate material for the part to be designed for specific application is done.

In mechanical design, selection of drive motor, design of belt, design of lay shaft, design of left hand drum, design of right hand drum, design of input shaft, output shaft & selection of bearing is carried out.

5. ANALYSIS OF COMPONENTS OF MECHANICAL POWER AMPLIFIER

In fabrication and assembly, assembly of the mechanical power amplifier is carried out. It is essential to verify the performance of the model before its implementation. With this view, maximum stress of components is found out by using ANSYS software.

5.1 Lay Shaft

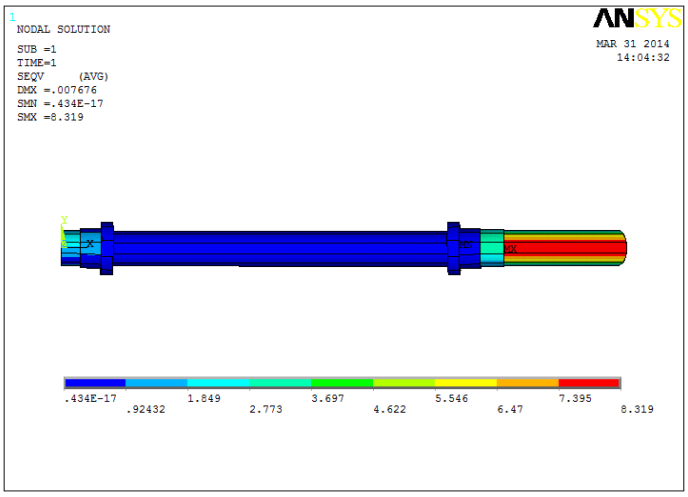

Fig 3 Stress concentration of lay shaft

5.2 Input shaft

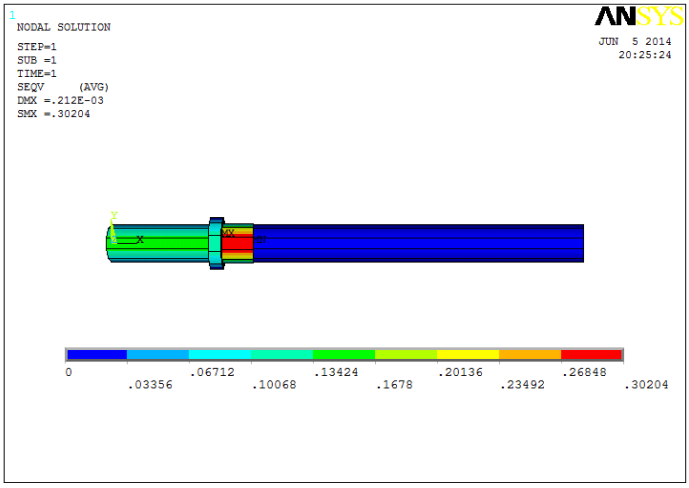

Fig 4 Stress concentration of input shaft

5.3 Output Shaft

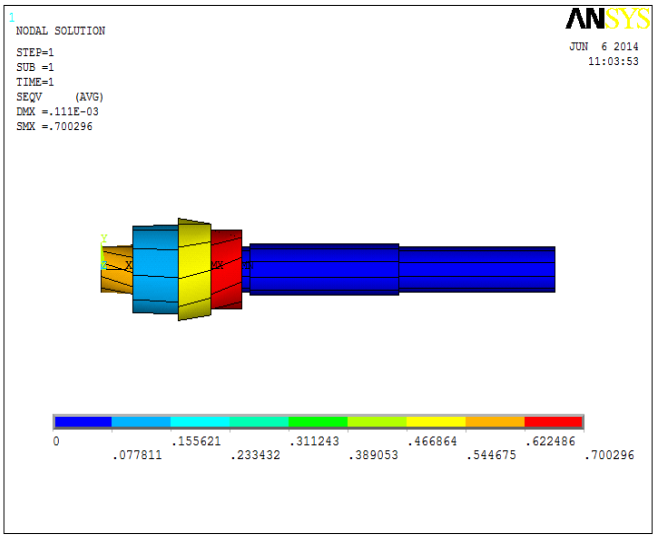

Fig 5 Stress concentration of output shaft

5.4 Left Hand Drum

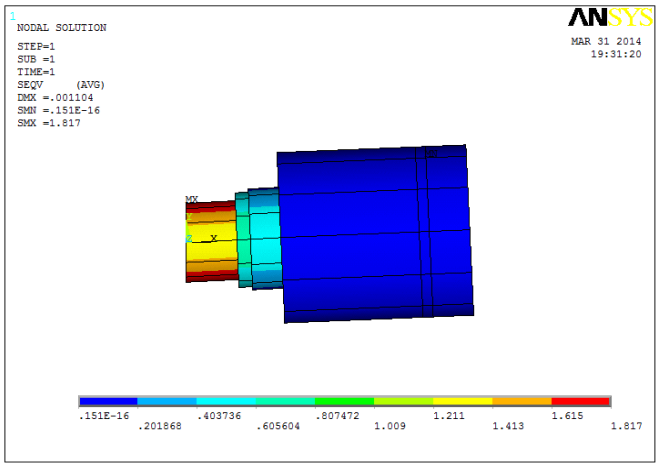

Fig 6 Stress concentration of left hand drum

5.5 Right Hand Drum

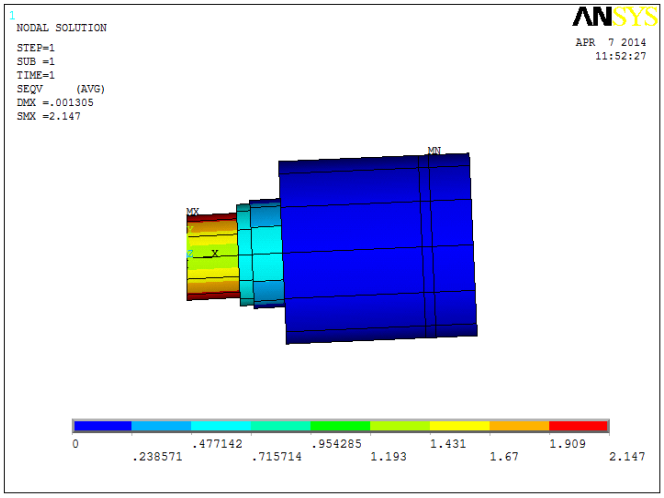

Fig 7 Stress concentration of right hand drum

CONCLUSIONS

1. Mechanical power amplifier is based on capstan principle. Amplification factor provided by mechanical power amplifier depend upon co-efficient of friction between rope material and drum material, number of turns of rope wound round drum and speed of drive motor.
2. By using mechanical power amplifier it is possible to obtain variation in output power in controlled condition.
3. Theoretically and by using ANSYS stress induced in the components of mechanical power amplifier is found out. As stress induced in the components of mechanical power amplifier is within given limit, design of components is safe.

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BIOGRAPHIES

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