MECHANICAL POWER AMPLIFIER WORKING ON A CAPSTAN PRINCIPLE

Thokale M. J.

Asst. Professor (Dept. Of Production Engg., AVCOE, Sangamner)

ABSTRACT

In size and reliable in operation different areas of engineering fields require very precise positioning and movements. The devices, arrangements, or mechanisms used for that purpose takes energy from man or operator, electrical motors, engines, it depends upon its shape, size and the load of part, usually for large load and heavy mountings, and positioning it is very difficult job for an operator. To overcome this difficulty capstan mechanical amplifier plays very important role. It is device consisting drum and gear arrangement and a single electrical motor, which operates on electrical energy. Main advantage of an amplifier is compact action.

Keywords: *Power amplifier, Capstan Principle*

1.INTRODUCTION

Objective: To design and fabrication of mechanical (capstan) power amplifier, to amplify the mechanical power at constant speed & the Precise lifting and movement of heavy loads.

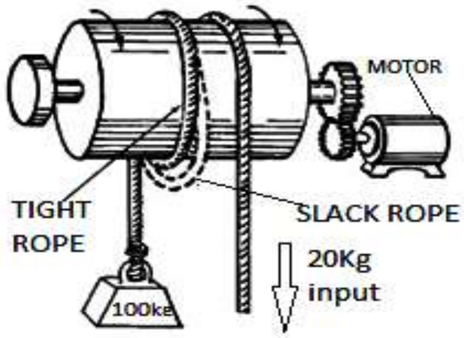
In different areas of engineering fields require very precise positioning and movements. The devices, arrangements, or mechanisms used for that purpose takes energy from man or operator, electrical motors, engines, it depends upon its shape, size and the load of part, usually for large load and heavy mountings, and positioning it is very difficult job for an operator. To overcome this difficulty capstan mechanical amplifier plays very important role. It is device consisting drum and gear arrangement and a single electrical motor, which operates on electrical energy. Main advantage of an amplifier is compact in size and reliable in operation.

Mechanical power amplifier is operates on CAPSTAN principle. CAPSTAN is simple mechanical amplifier-rope wound on motor driven drum slips until slack is takes up on the free end. Force needed on free end to lift the load depends on the coefficient of friction and number of turns of rope. By connecting bands to an input shaft and arm, the power amplifier provides an output in both directions, plus accurate angular positioning.

This mechanical power amplifier has a fast response. Power from its continuously rotating drums is instantaneously available. When used for position control applications, such methods as pneumatic, hydraulic, and electrical systems -even with continuously running power sources-requires transducers of some kind to change signals from one energy form to another. The mechanical power amplifier, on the other hand, permits direct sensing of the controlled motion

2.PRINCIPLE

When the power is absorbed from rope wound rotating drum by means of friction between rope & rotating drum called as CAPSTAN principle. From figure we can have a rotating drum driven by an electrical motor. A band or rope wounded on the drum. Now a100 kg of load is attached to the one end of the rope and effort required to lift the 100 kg of load is only 20 kg because of direction of rotation of drum & direction of pull are same. Hence power is absorbed from motor by means of friction between rope & drum.The amount of



power absorbed is depends upon the coefficient of friction between rope & drum and number of turn of the rope.

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3.DERIVATION POWER AMPLIFICATION FACTOR

Consider,

Input torque = Ti   Output torque = To

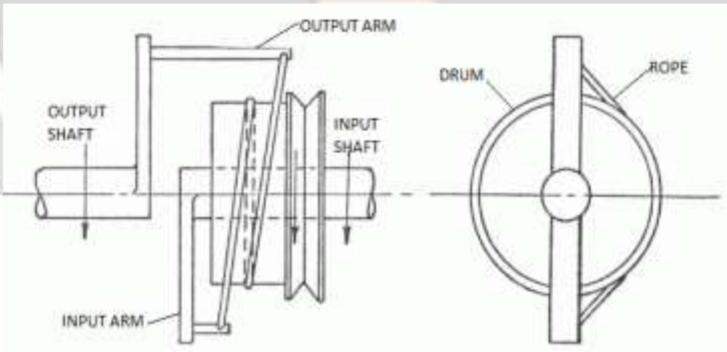
Input tension force in the rope = Fi   Output tension force in the rope = Fo

Length of arms = L(arm)   Coefficient of friction = μ

Speed of shaft both shaft = N   Number of turns = n

Angle of lap = θ = n×360 (rad)   Torque amplification factor = X

Speed of drum = Nd



Theoretical expression

Fi = Ti / L(arm)
By using the Equation…
Tight side / Slack side =e^μθ
Fo = Fi * e^μθ
To = Fo * L(arm)
= [Fi * e^μθ] * L(arm)
= [(Ti/L(arm)) * e^μθ] * L(arm)
= Ti * e^μθ ……………………..(Machine design by Khurmi & gupta)
Amplification Factor = X =To / Ti
= Ti * e^μθ / Ti
= e^μθ ……………..(Theory of Machines.Khurmi & Gupta.)
Capacity of drum driving motor-
P = Td * angular speed of the drum
= (To-Ti) * 2πN(d)/60 ….Watts.

Energy lost in friction-

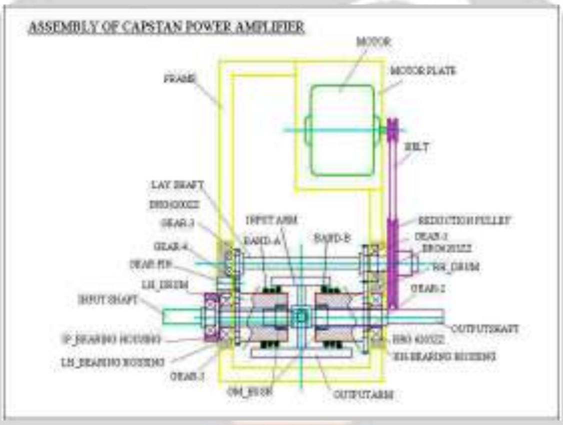
$$E_f = T_d * 2\pi \text{ (Speed of slip)}/ 60$$

$$= T_d * 2\pi (N_d - N)/60 \quad \ldots\text{Watts.}$$

Law of conservation of energy-

$$(P)_{input} + (P)_{drum\ motor} \geq (P)_{output}$$

4. CONSTRUCTION



The Capstan mechanical power amplifier consists of the following parts:-

Electrical motor: The electrical motor is a single phase AC motor of 50 watt capacity and 0 to 6000 rpm variable speed. The speed control is done by means of an electronic speed variator. The motor carries the motor pulley which connected to the reduction pulley mounted on the lay shaft; this forms the drive for the system.

Lay shaft: The lay shaft is held between two ball bearings mounted in bearing housing. The lay shaft carries a set of gears from the gear train and the reduction pulley at one end.

Gear train: The gear train comprises of five gears namely:

a. Gear-1 : 1.5 module, 32 teeth , face width 5mm
b. Gear-2 : 1.5 module, 64 teeth , face width 5mm
c. Gear-1 : 1.5 module, 18 teeth , face width 5mm
d. Gear-2 : 1.5 module, 40teeth , face width 5mm
e. Gear-1 : 1.5 module, 18 teeth , face width 5mm
f. Gear-2 : 1.5 module, 40teeth , face width 5mm

LH & RH Drums: The left and right hand drums are mounted in bearings 6005ZZ respectively in the support the output shaft. The band is wound on the drums and it is further connected to input and out arms bearing housing and carry bearings 6005ZZ that respectively at its two ends.

Input and output Arms: The input and out arms are connected to the input shaft and output shaft respectively. The bands wound on the drums are connected to these arms at their two ends.

Input shaft: The input shaft is mounted in ball bearing 6203zz held in the input shaft housing at one end where as the other end is connected to the input arm

Output shaft: The output shaft held in gunmetal bush bearings mounted inside the load drums and it is made hollow at one end so that the input shaft passes through it.

Frame: The frame is the structural member that supports the entire power amplifier assembly, the LH & RH bearing housings, motor plate are welded to the frame.

Load Pulleys: These set of pulleys 50 mm diameter A-section pulleys are provided for the loading arrangement of the input and output shafts.

Friction Band: The friction band is a cotton beaded rope of 6 mm diameter with the left hand band wound on the left hand drum and the right hand band wound on the right hand drum. The ends of these bands are fixed to the input and output arms respectively.

5. WORKING

By connecting bands A and B to an input shaft and arm, the power amplifier provides an output in both directions, plus accurate angular positioning. When the Input shaft is turned clockwise; the input arm takes up the slack on band A, locking It to its drum. In as much as the load end of locked band A is connected to the output Arm, it transmits the clockwise motion of the driven drum on which it is wound, to the output shaft. Band B therefore slacks off and slips on its drum. When the Clockwise motion of the input shaft stops, tension on band A is released and it slips on its own drum. If the output shaft tries to over run, the output arm will apply Tension to band B, causing it to tighten on the counter clockwise rotating drum and stop the shaft.

Motor delivers power to the input shaft in clockwise direction where as drives drum-B in anticlockwise direction. The torque amplification depends upon the coefficient of friction between drum and band, diameter of the drums and the number of wraps on the bands on their respective drums.

6. DESIGN

Design 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.Hence a careful design approach has to be adopted. The total design work has been split up into two parts;

A. SYSTEM DESIGN

B. MECHANICAL DESIGN

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 distinctions and dimensions thus obtained in mechanical design can be well fitted in to 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.

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.

This selection is based on standard catalogues or data books;

e.g.:- (PSG DESIGN DATA BOOKS)

(SKF BEARING CATALOGUE) etc.

APPROACH TO MECHANICAL DESIGN OF 'CAPSTAN POWER AMPLIFIER'

In design the of parts we shall adopt the following approach;

- Selection of appropriate material.
- Assuming an appropriate dimension as per system design.
- Design check for failure of component under any possible system of forces.

Our present model is an demonstrative set up in order to show the motion and power transmission capabilities of the proposed 'CAPSTAN POWER AMPLIFIER'

Thus a drive motor is selected as follows

DRIVE MOTOR

TYPE : - SINGLE PHASE AC MOTOR.

POWER : - 1 /15 HP (50 WATTS)

VOLTAGE : - 230 VOLTS, 50 Hz

CURRENT : - 0.5 AMPS

MAKE : - RONAK

SPEED : - MIN = O rpm

MAX = 9000 rpm

7. ADVANTAGES

Four major advantages of this all-mechanical power amplifier are:

1. Kinetic energy of the power source is continuously available for rapid response.

2. Motion can be duplicated and power amplified without converting energy forms.

3. Positon and rate feedback are inherent design characteristics.

4. Zero slip between input and output eliminates the possibility of cumulative error.

One another advantage is the case with which this device can be adapted to perform special functions - jobs for which other types of systems would require the addition of more costly and perhaps less reliable components.

8. TESTING

We have tested the project model by using suitable experimental setup.

Experimental setup

For testing of the project model, we attached two links to the input and output shafts respectively. Both the link have provision to attach the known weights for measuring the input & output torques.

Measuring procedure:

1. Start the model.
2. Balance the both the links by keeping weights at ends of attached links.
3. Now put extra known weight at end input link.
4. Again, balance both the links by putting the weights at end of the output link.
5. Then calculate both input & output torques by measuring weights & lengths of links.
6. Finally calculate power amplification factor by taking ratio of output to input torque.

Theoretical Calculation-

Amplification Factor = X =To / Ti

= Ti * e^μθ / Ti

= e^μθ

Where,

Coefficient of friction between cotton rope & alloy steel drum (μ) = 0.25

Angle of lap = 2 turns

$= 2*360^{0}$

= 720* (π/180) rad.

= 12.57 rad.

Amplification Factor =

X = e^μθ

= e^(0.25*12.57)

= 23.16

Actual calculations:

Input torque (Ti) = weight * length of link

= (0.200*9.81) * 0.172 = 0.33746 Nm.

Output torque (To) = weight * length of link

= (1.2*9.81) * 0.172 = 2.024784 Nm.

Power amplification factor = output torque / input torque

= 2.024784 / 0.33746

= 6.00

9. CONCLUSION

Following conclusions we have obtained after fabrication & testing the mechanical power amplifier,It is possible to amplify the mechanical power at constant speed by using capstan principle.

1. We obtained theoretical power amplification factor as 23.14 for

θ= 2 turns & μ= 0.25.

2. We obtained actual power amplification factor after testing as = 6.00
3. As we increases, the number of turn's power amplification factor also increases.
4. Power amplification factor depends upon the coefficient of friction between rope and rotating drum. Power amplification factor increases with increase in coefficient of friction.
5. There is difference between actual & theoretical result because of improper manufacturing, miss-alignments in assembly, friction, inadequate lubrication, error in the measurements.
6. It creates noise during working.

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