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Design of a Rope Brake Dynamometer

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Abstract: The aim of this project is to design of a Rope Brake Dynamometer Coupled with Brake and Motor. A Rope Brake Dynamometer, measures the minimum torque and various factors involved while designing is done. This also shows various operations included in the fabrication process.

Key words: Dynamometer · Rope Brake Dynamometer

INTRODUCTION

A dynamometer, or "dyno" for short, is a machine used to measure torque and rotational speed (rpm) from which power produced by an engine or any other rotating prime mover can be calculated. Dynamometer is an instrument for measuring force exerted by men, animals and machines [1].

The name has been applied generally to all kinds of instruments used in the measurement of a force, as for example electric dynamometers, but the term specially denotes apparatus used in connection with the measurement of work, or in the measurement of the horse-power of engines and motors. Dynamometers can be broadly classified into two major types, absorption dynamometers and transmission dynamometers.

Theory of Dynamometer: Dynamometers are used for measurement of brake power. To measure brake power, the engine torque and angular speed have to be measured. A typical dynamometer is shown.

The rotor is driven by the engine under test by mechanical, hydraulic or electromagnetic means. The rotor is coupled to the stator. For each revolution of the shaft, rotor covers the distance 2×π×R×F against coupling force F.

Work done = 2×π×R×F

Now, external torque = S×L, where S is the scale reading and L is the length of dynamometer arm.

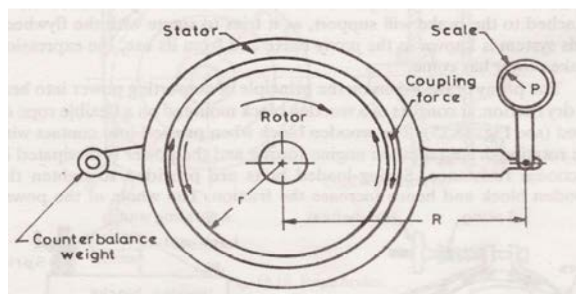

Fig: 1.1: The Dynamometer Principle

- Therefore, S×L = R×F for balance of dynamometer.
- The power is given by, Brake Power = 2×π×N×T / 60

In the absorption dynamometers, the entire energy or power produced by the engine is absorbed by the friction resistances of the brake and is transformed into heat, during the process of measurement. But in the transmission dynamometers, the energy is not wasted in friction but is used for doing work. The energy or power produced by the engine is transmitted through the dynamometer to some other machines where the power developed is suitably measured [2].

Types of Dynamometers:

- Water brake.
- Fan brake.
- Electric motor/generator.
- Mechanical friction brake or prony brake.
- Hydraulic brake.
- Eddy current or electromagnetic brake.

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Parts of a Rope Brake Dynamometer: The basic parts of a rope brake dynamometer are as follows:

- Single phase motor
- Wire Ropes
- Pulley
- Dead Weight
- Spring Balance
- Mild steel frame
- Double block brake

SL. No.	Description	Materials	Quantity
1.	Single Phase Motor	-	1
2.	Wire Rope	Plough Steel Wires	1
3.	Pulley	Cast Iron	1
4.	Dead Weight	Cast Iron	3
5.	Spring Balance	-	1
6	Stand Frame	Mild Steel	1
7	Double Block Brake	EN8 Steel, Mild Steel	1

Wire Ropes: Wire ropes made out of high tensile steel wires, are widely used for lifting loads because of flexibility, smooth operation, higher reliability and long life. This is manufactured out of thin high strength wires in twisted form with central steel or fiber core. The ropes are designed based on safe working load per rope equal to breaking load divided by factor of safety [3]. The factor of safety varies from 3.5 to 10 depending on application. Rope drum diameter is selected depending on rope diameter to keep bending stress due to winding within limits. Drum is grooved for seating of rope. Rope end is clamped by double clamp. The fleet angle is kept within limits to avoid winding of rope one over the other [4].

Advantages of Dynamometer: Among the flexible elements used for hoisting and hauling purposes, steel wire ropes are extensively used.

Steel wires are superior to welded chains, roller chains and hemp ropes because Wire ropes are lighter in weight, offer silent operation, can withstand shock loads, are more reliable and do not fail suddenly [5].

The outer layers are subjected to intensive wear and break before the inner wires fail. As a result, the wire rope becomes fuzzy long before rupture can be replaced before failure.

Wire ropes are manufactured from plough steel wire having ultimate strength of 1200 to 2400 N/mm^2.

In the process of manufacture, wire ropes are subjected to special heat treatment, which combined with cold drawing, imparts high mechanical properties to the wire.

Ropes intended for operation in damp premises are galvanized to protect them against corrosion.

Selection of Wire Ropes: Wire ropes are selected to meet the following requirements:

- Strength
- Abrasion resistance
- Flexibility
- Resistance to crushing
- Fatigue or endurance strength and
- Corrosion resistance

In most of the cases strength is the criterion for selection of the wire ropes. In practice, the maximum stress in the rope should be below the working stress. Table gives recommended factor of safety for different wire based on their breaking strength.

Where abrasion across a stationary object is a governing factor, large outer wires are necessary and 6×7 constructions offer better resistance. Lang lay ropes offer better resistance to abrasion than regular lay ropes. Flexibility increases with no of outer wires for the given rope diameter. Wire core ropes are not as flexible as fiber core ropes. But wire cores resist crushing better than fiber core ropes.

Construction: Steel wire ropes are manufactured by special machines. Separate wires are twisted into strands and simultaneously the strands are formed into a round rope. The strands are laid in a core made of hemp, asbestos or wire of softer steel. Asbestos or soft wire core is used for ropes subjected to the action of radiant heat. However, a wire core reduces the flexibility of the rope and hence they are used only when ropes are subjected to high compression as in the case of several layers wound over a rope drum. Wire ropes formed from strands are known as double lay ropes. Double lay ropes are classified into

- Cross or Regular lay ropes
- Parallel or Lang lay ropes
- Composite or Reverse lay ropes.

Stress in Wire Ropes: A wire rope will generally be subjected to the following stresses:

- Direct stresses on account of axial force on the rope. The axial force depends on the weight of the load to be lifted, weight of the rope etc.
- Bending stress due to the bending of ropes over sheaves.
- Stress due to acceleration or retardation of moving masses.

- Stress during starting.

Stress due to axial force, $\sigma_1 = W_l+W_r/A_r$

Where,

W_l = Weight of the load to be lifted
W_r = Weight of the rope
A_r = Area of the rope.

Stress due to bending, $\sigma_2 = E_r'd_w / D$

E_r' = $3/8E_r$
where,

E_r' = Modified Young's modulus for the rope
E_r = Young's modulus of rope material.

Stress due to acceleration, $\sigma_3 = (W_l+W_r)\alpha /g\ A_r$

Where,

α = Acceleration of the rope load
g = Acceleration due to gravity,

Stress during starting,
σ_4 = $W_l+W_r/A_r[1+\sqrt{}1+2\alpha hE_r / \sigma_1 lg]$

Where,

α = Acceleration of the rope
h = Slack during starting
l = Length of the rope.

- Effective stress in the rope during normal working = $\sigma_1+\sigma_2$
- Effective stress in the rope during acceleration of the load= $\sigma_1+\sigma_2+\sigma_3$
- Effective stress in the rope during starting= $\sigma_4+\sigma_2$

Parts of a Rope Brake Dynamometer: The basic parts of a rope brake dynamometer are as follow:

- Single phase motor
- Wire Ropes
- Pulley
- Dead Weight
- Spring Balance
- Mild steel frame
- Double block brake

SL. No.	Description	Material	Quantity
1.	Single Phase Motor	-	1
2.	Wire Rope	Plough Steel Wires	1
3.	Pulley	Cast Iron	1
4.	Dead Weight	Cast Iron	3
5.	Spring Balance	-	1
6	Stand Frame	Mild Steel	1
7	Double Block Brake	EN8 Steel, Mild Steel	1

Design of a Rope Brake Dynamometer:

Factors Considered for the Design of a Flywheel: The weight of the flywheel is calculated considering the inertia of the rim and neglecting influence of arms and hub. The velocity of the flywheel rim is calculated as,

$V= \pi Dn$

Where,

D= outside rim diameter of flywheel & N= engine rpm

The radius of gyration k can be determined as,

$k^2= 0.125[D^2+ (D- 2a)]$

Where,

a= rim thickness of flywheel.

The weight of the flywheel is given by:

$W= 24\times\pi\times k\times a\times b\times\omega$

Where,

W = Weight of the flywheel material & k= radius of gyration
ω = Specific weight of flywheel material
a = Rim thickness of flywheel
b = width of flywheel

Figure 3.1 below shows construction of a typical flywheel. Flywheels up to 8 feet in diameter are cast solid and above this size they are made in halves. The hub is split and joined by a key. The halves are connected by bolts through a hub. The flywheels used for automotive applications have teeth for starter engagement. Flywheels are balanced by drilling holes in the heavier part of the flywheel rim. Wooden plugs are then driven into the holes. The diameter of the clamping bolt is approx one-sixth of the shaft diameter. This completes our discussion of flywheels.

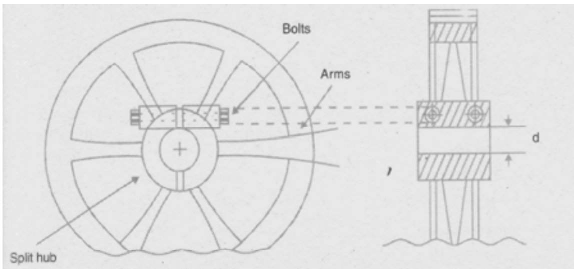

Fig. 3.1: Flywheel Construction

Factors Considered for the Design of Wire Ropes

Selection Procedure: The following procedure may be employed for selecting wire ropes.

- Note down the weight to be lifted, weight of sheaves, hooks lifting speed, acceleration etc.
- Select suitable group of wire. Where flexibility is required select 6×19 or 6×37 group. 6×7 group is suitable for abrasion resistance.
- For preliminary calculations, take factor of safety as 2.5 times the value given in table. Obtain the design load by multiplying the factor of safety with the dead load acting on the rope.
- Select suitable rope based on the design load.

Determine the weight, area, diameter, of wire etc.

- Determine the breaking strength using Indian Standards.
- Determine the weight of the rope and add with the weight to be lifted (F_1)
- Determine the bending stress.
- Determine the equivalent load, which will produce the bending stress (F_2). For this multiply bending stress by area of rope.
- Determine the load due to acceleration.
- Determine the load during starting.
- Calculate the load during normal working, during acceleration and during starting.
- Calculate the actual factor of safety by comparing the maximum load on the rope with the breaking strength of the rope.
- Compare the factor of safety with the value given in table.
- Select suitable diameter of the rope drum and sheaves.
- Calculate the length of the drum to accommodate the required wire rope.

Designation of Wires: Wire ropes are designated by the number of wires in each strand, number of strands, its diameter, its construction and its grade. The diameter of the wire rope is that of the smallest circle enclosing it. The grade of wire is the minimum tensile strength of the wire used. The table 3.1 gives the grade of wires and their tensile strength range.

Grade of wire	Tensile strength range N/mm^2
120	1200 to 1500
140	1400 to 1700
160	1600 to 1900
180	1800 to 2100
200	2000 to 2400

Strength of wires used for ropes

Rope construction	Weight N/mm^2 (approx)	Wire dia d_w	Area (approx)
16×7	3.4d^2	0.106d	0.38d^2
6×19	3.7d^2	0.063d	0.38d^2
6×37	3.5d^2	0.045d	0.38d^2
8×19	3.46^2	0.05d	0.38d^2

Characteristics of Wire Ropes

Purpose	Construction	Minimum ratio
Mining	All	100
installations	6×37	15 to 22
Cranes and allied	8×19	8×19
hoisting equipments	Scale 6×24	Filler wire 8×19 8×19
	6×19 Filler wire	Warrington 18 to 25
	6×19	18 to 23
	6×19 Warrington	19 to 27
	6×19 Scale	24 to 3

Ratio of Drum and Sheave Diameter to Rope Diameter

Factors Considered for the Design of Block Brakes

Design Procedure for Block Brakes:

- From the given data note down the braking torque and speed.
- Select brake drum diameter D taking into account the torque and space availability.
- Calculate the tangential force, F_t for the torque and radius.
- Select materials for brake drum and shoe linings. Table may be used for guidance.
- Find the normal force to be applied on the drum, N= F_t/μ.
- Determine the area of the brake shoe friction surface based on permissible bearing pressure (table).
- Determine the dimensions of the lever to obtain the required force on the shoe.
- Determine the cross section of the lever based on the strength.
- Heat dissipating capacity is to be checked for brake drums meant for absorbing heavy power.

Table 3.5: Friction Co-efficient and Allowable Pressures

	Friction Co-efficient			
Materials in contact	Dry	Greasy	Lubricated	Allowable pressure N/cm^2
Cast iron on Cast iron	0.2- 0.15	0.1- 0.16	0.1- 0.05	100-170
Bronze on cast iron	-	0.1-0.05	3.1-0.05	60- 80
Steel on cast iron	0.3- 0.2	0.12- 0.07	0.1- 0.06	80- 140
Wood on cast iron	0.25- 0.2	0.12- 0.08	-	40- 60
Fibre on metal	-	0.2- 0.1	-	7- 20
Cork on metal	0.35	0.3- 0.25	0.25- 0.22	6- 10
Leather on metal	0.5- 0.3	0.2- 0.15	0.15- 0.12	7- 20
Wire asbestos on metal	0.5- 0.35	0.3- 0.25	0.25- 0.2	27- 55
Asbestos on metal	0.48- 0.4	0.3- 0.25	0.25- 0.2	27- 110
Asbestos on metal (short action)	-	-	0.25- 0.2	140- 200
Metal on cast iron (short action)	-	-	0.1- 0.05	140- 200

Design Procedure for Helical Springs: Design of helical spring involves a numerous variable factors. Hence no definite rules can be given for the design procedure. The principal dimensions to be designed are the pitch diameter or mean coil diameter D, size of the wire d, the number of coils n and the free length, l.

First the maximum load on the spring or the force which it must exert is found out from the available data. In case of variable loads, mean load and amplitude of load are determined. Applying suitable factor of safety approximate value of design stress is determined. In case of varying loads design stress is found out by constructing soderberg line. Next, mean coil diameter is fixed on the basis of space limitations or other factors. Wire diameter can be found out assuming $K_s = 1.0$.

Now based on this preliminary wire diameter, the size factor is found out. The diameter of wire can be obtained by using equation.

$d= v8\ FCk_s/\pi\tau_{max}$

The nearest standard size of wire is to be selected. A large size decreases the working stress and gives a slightly stiffer spring while a smaller size gives a softer spring with increase in stress.

The number of coils required is found to give the required deflection. If the number of active turns is too small the coil diameter can be decreased and if it is too large, coil diameter can be increased. This will make corresponding change in wire diameter. Free length of the spring is determined. Actual performance may be checked by testing the spring and slight alteration in the design may be made to get more exact requirements.

Design Calculation: The various notifications used in the design calculation of rope brake dynamometer are as follow:-

Let
W = Dead load in newtons,
S = Spring balance reading in newtons,
D = Diameter of the wheel in metres,
D = Diameter of ropes in metres,
N = Speed of the engine shaft in r.p.m.

- Therefore net load on the brake = (W- S) ×N

We know distance moved in one revolution = π×(D+d)×m

- Work done per revolution = (W-S)×π×(D+d) N-m
  And work done per minute = (W-S)×π×(D+d)×N N-m

Hence, Brake Power of the engine,

- B.P. =Work done per minute / 60 = (W-S)×π×(D+d)×N / 60

If diameter of the rope (d) is neglected, then brake power of the engine,

- B.P. = (W-S)×π×D×N / 60

Construction of the Project:
Double Block Brake:

- Take a EN8, steel 135×128×55 mm.
- Clean the surface by surface grinding process.
- Make a hole of dia 19mm with the help of drilling and boring machine upto dia 19.8 mm. Take the centre of the hole as a reference, then dimension of the Double Block Brake is measured and marked.
- Milling machine is used to provide a required shape of Double Block Brake.

Stand Frame:

- Take mild steel hollow rod of 1000mm (4 nos.), 600mm (4 nos.) and 400mm (4 nos.)
- Clean the surface by surface grinding process.
- All the rods are welded by electric arc welding to make a frame.
- Three mild steel plates are welded to form the base for motor.

Lever:

- Take a mild steel rod of 279mm and circular plate with dia 55mm.
- Clean the surface by surface grinding operation.
- Fix the rod by using circular plate using electric arc welding.

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