BANSILAL RAMNATH AGARWAL CHARITABLE TRUST`S

VISHWAKARMA INSTITUTE OF TECHNOLOGY

PUNE- 411 037

(An Autonomous Institute Affiliated to University of Pune)

A Dissertation on

Automatic Parking Brake

By

Jaydutt A. Kulkarni (U-31)

Vedant T. Joshi (U-24)

Sushil A. Surwase (U-50)

Kaustubh A. Shinde (U-48)

Guide: Prof. (Dr.) M.B.Chaudhari

Department of Mechanical Engineering

(2015-2016)

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CERTIFICATE

This is to certify that the Major Project Stage-III, titled **“Automatic Parking Brake”** has been completed in the academic year 2015 – 2016, in partial fulfillment of **Bachelor of Engineering – Mechanical Engineering** of **University of Pune.**

PROF. (DR.) M.B. CHAUDHARI
(Guide)

PROF. (DR.) S.R. BAHULIKAR
(H.O.D. Mechanical Dept.)

PROF.P.S. DHANESHWAR
(Examiner)

Place: Pune

Date:

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Jaydutt A. Kulkarni

Vedant T. Joshi

Sushil A. Surwase

Kaustubh A. Shinde

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ABSTRACT

The main motive is to try and automise the parking brake system by completely mechanical means. The idea is to achieve this by adding as little load as possible on the engine as well as by not resorting to any electrical source and/or electronic sensor equipment.

The mechanism is required to perform two basic functions, i.e., to sense the engine speed and to generate the required braking force. It uses the engine rpm as input to sense speed and the centrifugal force, which is a consequence of that speed, helps to actuate the mechanism. When the engine stops, the mechanism comes to rest and the lever mechanism associated with it helps the spring exert the required tension.

It is observed that the parking brake is engaged almost instantaneously, without any manual or electronic actuation. The mechanism occupies relatively less space and uses no external input for its working.

1. INTRODUCTION

In cars the hand brake is a latching brake usually used to keep the car stationary. Automobile e-brakes usually consist of a cable directly connected to the brake mechanism on one end and to some type of mechanism that can be actuated by the driver on the other end. The mechanism is often a hand-operated lever, on the floor on either side of the driver, or a pull handle below and near the steering wheel column, or a located far apart from the other pedals.

Although sometimes known as an emergency brake, using it in any emergency where the footbrake is still operational is likely to badly upset the brake balance of the car and vastly increase the likelihood of loss of control of the vehicle, for example by initiating rear-wheel skid. Additionally, the stopping force provided by using the handbrake instead of or in addition to the footbrake is usually small and would not significantly aid in stopping the vehicle, again because it usually operates on the rear wheels; they suffer reduced traction compared to the front wheels while braking. The emergency brake is instead intended for use in case of mechanical failure, where the regular footbrake is inoperable or compromised, hopefully with opportunity to apply the brake in a controlled manner to bring the vehicle to a safe, if gentle halt before seeking service assistance.

The most common use for an automobile emergency brake is to keep the vehicle motionless. When it is parked, thus the alternative name, parking brakes. Car emergency brakes have a ratchet locking mechanism that will keep them engaged until a release button is pressed. On vehicles with automatic transmissions, this is usually used in concert with a parking pawl in the transmission. Automotive safety experts recommend the use of both systems to immobilize a parked car and the use of both systems is required by law in some jurisdictions, yet many individuals use only the "Park" position on the automatic transmission and not the parking brake.

1.1 Objective: The main objective is to automise the parking brake system by completely mechanical means. A parking brake system should be one which will effectively engage and disengage and while the starting and stopping of the vehicle.

2. LITERATURE REVIEW

2.1 Brakes

The brake system converts the kinetic energy of the moving vehicle into heat.

The brake engineer has two challenges:

1. Create enough deceleration to stop the car as quickly as the driver wishes, without exceeding the drivers comfort level with regard to pedal effort or pedal travel.
2. Manage the resulting heat energy so as not to damage the brake system or the rest of the vehicle.

Classification of brakes:-

1. Mechanical brakes

Operated by lever, springs and pedals

E.g. block brake, drum brake, disc brake, and band brake

2. Hydraulic and pneumatic brakes

Operates by fluid pressure such as oil pressure or air pressure

3. Electric brakes

Operate by magnetic force which includes eddy current brakes, magnetic particle brakes

2.1.1 Block Brake:

A single block or shoe brake is shown below. It consists of a block or shoe which is pressed against the rim of a revolving brake wheel drum. The block is made of a softer material than the rim of the wheel. This type of a brake is commonly used on railway trains and tram cars. The friction between the block and the wheel causes a tangential braking force to act on the wheel, which retard the rotation of the wheel. The block is pressed against the wheel by a force applied to one end of a lever to which the block is rigidly fixed. The other end of the lever is pivoted on a fixed fulcrum O.

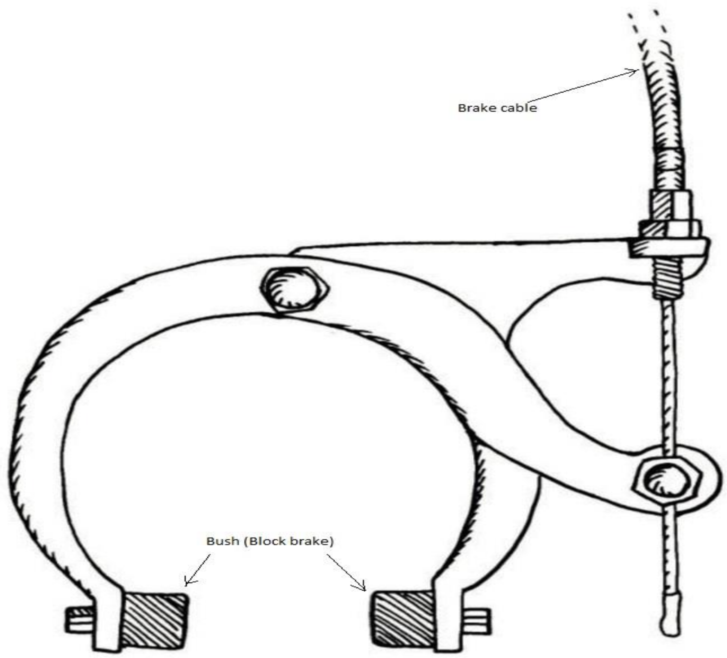


Fig.2.1 Block brake in bicycles

Advantages:

-Wheel Tread is cleaned; Wheel-to-rail adhesion is improved

-Total weight lower than disc brake

-Total price lower than disc brake

-Brake release is easy to identify

Disadvantages:

- Wheels subject to thermal stresses ; danger of thermal cracking
- Rubber-sprung wheel sets cannot be used
- Greater wheel tread wear
- Higher noise emission
- Extra expense to account for large lateral axle movements

Disadvantages of the single - sided block brake

- Wheel motion is loaded one-sidedly

2.1.2 Drum Brake

A drum brake is a vehicle brake in which the friction is caused by a set of brake shoes that press against the inner surface of a rotating drum. The drum is connected to the rotating roadwheel hub.

A drum brake system consists of hydraulic wheel cylinders, brake shoes and a brake drum. When the brake pedal is applied the two curved brake shoes, which have a friction material lining, are forced by hydraulic wheel cylinders against the inner surface of a rotating brake drum. The result of this contact produces friction which enables the vehicle to slow down or stop.

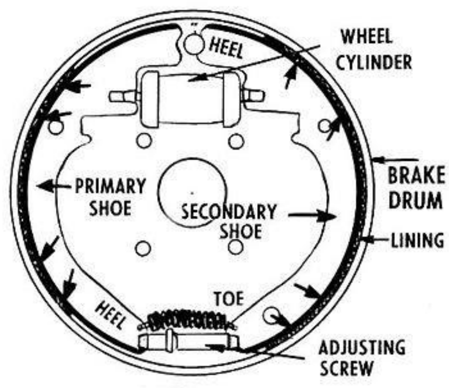


Fig. 2.2 Drum Brake

Advantages:

-Less expensive to produce

-Slightly lower frequency of maintenance due to better corrosion resistance compared to disks.

-Built-in self-energizing effect requires less input force (such as hydraulic pressure).

-Wheel cylinders are somewhat simpler to recondition compared to calipers.

-Minor weight savings, primarily from much smaller and lighter hydraulic cylinders vs. calipers.

Disadvantages:

Drum brakes, like most other brakes, convert kinetic energy into heat by friction. This heat should dissipate into the surrounding air, but can just as easily transfer to other braking system components. Brake drums must be large to cope with the massive forces involved, and must be able to absorb and dissipate a lot of heat. Heat transfer to air can be aided by incorporating cooling fins onto the drum. However, excessive heating can occur due to heavy or repeated braking, which can cause the drum to distort, leading to vibration under braking.

2.1.3 Disc Brake

The disc brake is a device for slowing or stopping the rotation of a road wheel. A brake disc (or rotor in U.S. English), usually made of cast iron or ceramic, is connected to the wheel or the axle. To stop the wheel, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop.

Principle of working in case of disk brake:

When a brake lever or pedal is pressed, the push rod which is connected to lever or pedal and master cylinder piston pushes the master cylinder piston. This movement allows the master cylinder piston to slide and push the return spring inside the bore of master cylinder, which generates pressure in reservoir tank. At this moment a primary seal allows the brake fluid of reservoir tank to flow over it into the brake hosepipes. A secondary seal ensures that the brake fluid does not go other side.

Then the fluid enters in to cylinder bore of caliper assembly via brake hosepipes and pushes the caliper piston or pistons. At this time the piston ring moves in rolling shape with piston. Then the caliper piston pushes brake pad. This movement causes brake pads to stick with brake disc which creates friction and stops the brake disc/rotor to rotate. This way disk brake system stops or slows down the vehicle.

When the brake lever or pedal is released the piston ring pushes the caliper piston back to cylinder bore of caliper till both, caliper piston and piston ring come into their original shape. At this time retraction spring pushes the brake pads to their original position. The return spring in master cylinder assembly pushes the master cylinder piston back into its original position and allows the fluid to flow back to reservoir via hosepipe and master cylinder bore.

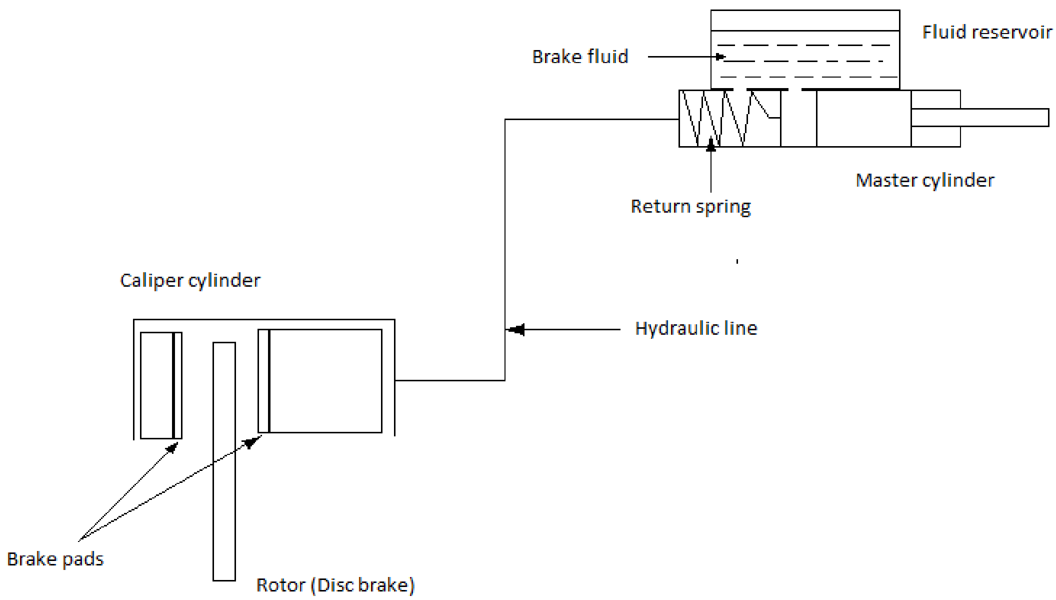


Fig. 2.3 Working principle of disc brake

Advantages:

Disk brake requires less effort (brake torque) to stop the vehicle compare to drum brake.

It generates less heat compare to drum brake for the same brake torque.

Ease of maintenance as disk brake is outside the wheel rim.

It cools down faster compare to drum brake.

If worn out brake shoes are not changed at proper time it can cut the brake drum in drum brake. Disk brake does not have such problem.

It is less likely to skid compare to drum brake in wet condition.

It is much safer than drum brake in hard braking condition. Under such condition drum brake can lock up the rear wheel.

It has brake pad wear indicator which is not there in drum brake.

Disadvantages:

It is expensive compare to drum brake.

More skill is required to operate disk brake compare to drum brake that's the reason why some people are not comfortable with disk brake

If any air remains in disk brake system, it can cause accident as the brake will not work effectively.

Disk brake assembly has more moving parts and much complex than drum brake.

It requires lot of effort at maintenance front like brake fluid (bleeding), change of brake pads etc. compare to drum brake.

2.1.4 Band Brake

• A band is wrapped part round a rotating drum

• Pulling or pushing a lever creates tension in the band

• The difference in tension between the two ends of the belt results in a restraining torque

• It can be used dynamically to just slow down or statically to stop the drum entirely

Used for winch drums, chainsaws and sometimes bicycle brakes.

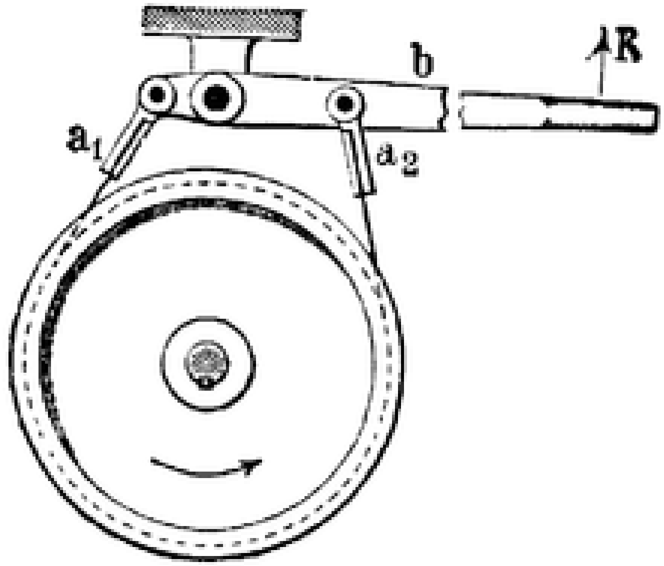


Fig. 2.4 Band brake [1]

Advantages:

With a large coefficient of friction and angle of wrap, the brake is very effective requires low input force to achieve high brake force.

Some materials with a low coefficient of friction have more consistent coefficient across the range of working temperatures.

Disadvantages:

-When hot, suffer a loss of brake force lots of grabbing and chatter.

-With a large coefficient of friction and angle of wrap, it is very sensitive to changes in μ, the coefficient of friction, e.g. light rust on the drum may cause the brake to “grab” or chatter,

-Water may cause the brake to slip, rising temperatures in braking may cause the coefficient of friction to drop slightly but in turn cause brake force to drop greatly.

-Using a band material with low coefficient of friction increases the input force required to achieve a given brake force.

2.1.5 Electromagnetic brake

Electromagnetic brakes slow an object through electromagnetic induction, which creates resistance and in turn either heat or electricity. Friction brakes apply pressure on two separate objects to slow the vehicle in a controlled manner.

Types

1. Eddy current brakes
2. Hysteresis brakes
3. Magnetic particle brakes

2.2 Parking Brake

Emergency brakes are a secondary braking system installed in motor vehicles. Also known as e-brakes, hand brakes and parking brakes, emergency brakes are not powered by hydraulics and are independent of the service brakes used to slow and stop vehicles. There are state and federal laws requiring emergency brakes for motor vehicles.

There are four types of emergency brakes:

- Stick lever, which is generally found under the instrument panel (found in older-model vehicles)
- Center lever, which is found in between separated front seats
- Pedal, which is found to the left of the floor pedals
- Electric or push button, which is found amongst the other console controls

Since most modern braking systems have failsafe measures and warning systems, such as on-dash brake-warning lights and low-fluid sensors, the emergency brake is often used as a parking brake device.

Using only levers and cables, each type of emergency brake is completely mechanical and bypasses the normal brake system. This ensures that a vehicle can be brought to a complete stop if there's a failure of the brake system

When you set the emergency brake, the brake cable passes through an intermediate lever, which increases the force of your pull, and then passes through an equalizer. At the U-shaped equalizer, the cable is split in two. The equalizer divides the force and sends it evenly across the two cables connected to the rear wheels

Motor vehicles use either drum brakes or disc brakes. Drum brakes are common in the rear wheels, while disc brakes are most common on the front wheels (or all four wheels). In a rear drum situation, the emergency brake cable runs directly to the brake shoes, bypassing the hydraulic brake system. In this simple, mechanical bypass, the emergency brake system requires no extra parts to control the brakes

Cars with rear disc brakes have a more complicated emergency brake system, sometimes requiring an entire drum brake system to be mounted inside of the rear rotor, called an exclusive parking brake or auxiliary drum brake

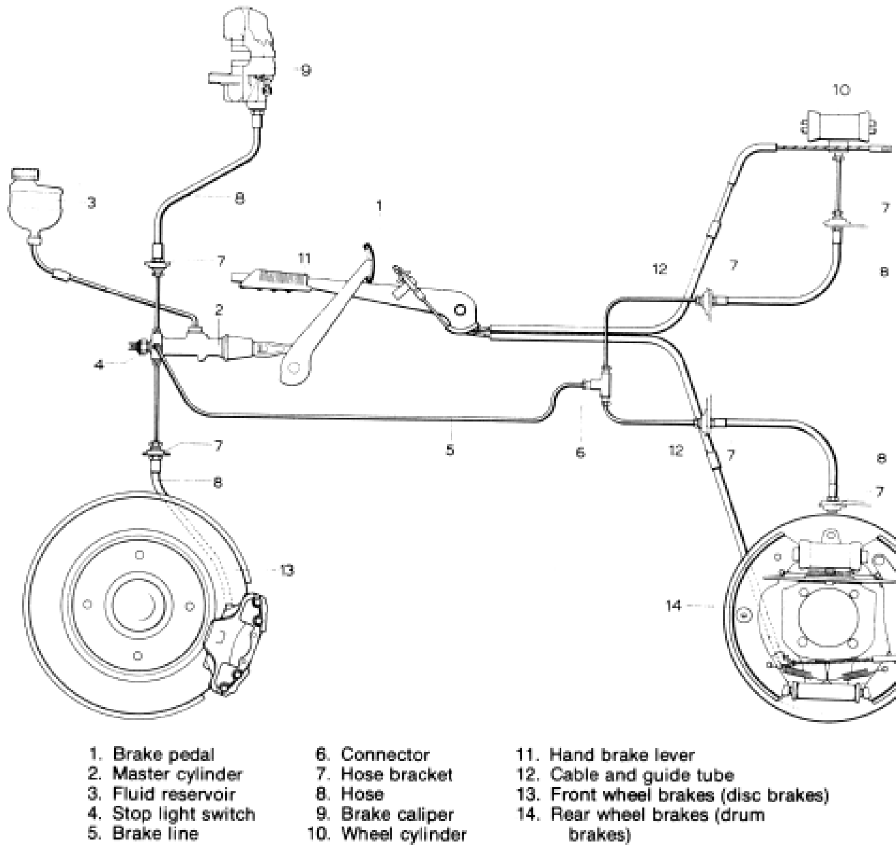


Fig.2.5 Schematic of an e-brake [2]

When the vehicle has rear disc brakes without an auxiliary drum brake, a caliper-actuated parking brake system is used. With this system, an additional lever and corkscrew is added to the existing caliper piston. When the emergency brake is pulled, the lever forces the corkscrew against caliper piston, and applies the brakes, again bypassing the hydraulic braking system.

The most common use of the emergency brake is as a parking brake. Those who drive manual transmission vehicles, or stick shifts, usually engage the emergency brake every time they exit the car. If not engaged, the car might just roll away all on its own. Automatic transmission drivers tend to use the emergency brake far less, if at all.

Emergency brake is also engaged anytime the vehicle is parked on a hill, whether it's an automatic or standard transmission. The emergency brake can also be used as an aid to manual transmission drivers to prevent rollback when starting on a hill.

2.2.1 Regulations for Parking Brakes**:**

The parking brake system must follow some standard regulations accepted by all the manufacturers. These regulations take into consideration the safety and rightful working of the system.

The following are a few important regulations that are to be considered while designing a parking brake system.

1. The emergency brake system may utilize parts of the service brakes system on the condition that any failure of a brake device in the service brake system does not prevent the emergency brake from achieving its performance requirements. For this purpose the brakes and any mechanical linkage connected directly thereto, shall be considered as not subjected to failure.
2. The parking brake system shall be independent of the service brake system except that the brakes and any mechanical systems attached directly thereto may be common.
3. The parking brake system shall be able to be applied by means of a single control and once applied, shall be able to be held in that position by purely mechanical means. It shall to release the parking brake unless a means of immediately reapplying it is available.
4. The parking brake shall be shown to be capable of holding the vehicle stationary on an 18 percent gradient in either direction, according to the requirements.

2.2.2 Working:

The parking brake system is a secondary braking system used to hold a parked car in position. They are applied independently of the service brakes. Since there is no inertia to overcome, less braking power is required to hold the vehicle stationary and less force is required to apply. The application of only two of the four brake assemblies are required to hold the vehicle. There are three styles of rear parking brake systems. Two types use the service brake and the other is an exclusive parking brake design. The service type parking brake uses part of the ordinary service brake mechanism and operates the shoe or piston mechanically. The parking brake lever is located near the driver's seat. Pulling the parking brake lever by hand or pressing the pedal with the foot, operates the brake via a cable connected to the parking brake lever of the brake assembly .There are a number of different types of parking brake levers, as shown below. Application depends upon the design of the driver's seat and the desired operating effort.

The parking brake lever is provided with a ratchet locking mechanism to maintain the lever at the position to which it was set, until released. Some parking levers have an adjusting screw near the brake lever so the amount of brake lever travel can be easily adjusted. Travel is determined by the number of clicks of the ratchet mechanism found in the Repair Manual.

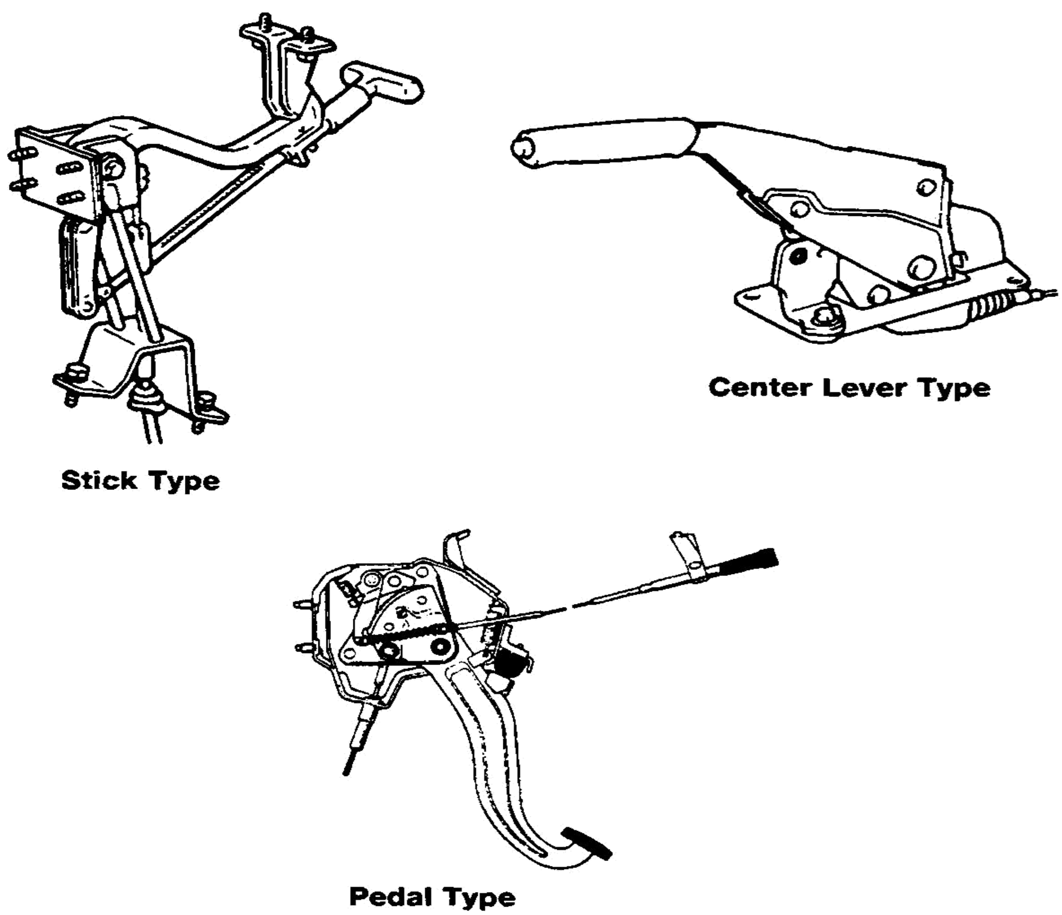


Fig. 2.6 Types of levers

2.2.3 Parking Brake Linkages

The parking brake cable transmits the lever movement through a typical series of components, as shown below, to the brake drum subassembly. The Intermediate Lever multiplies the operating force to the Equalizer. The Equalizer divides the lever operating force to brake assemblies at both wheels. The two major parts may vary in design however, their function remains the same.

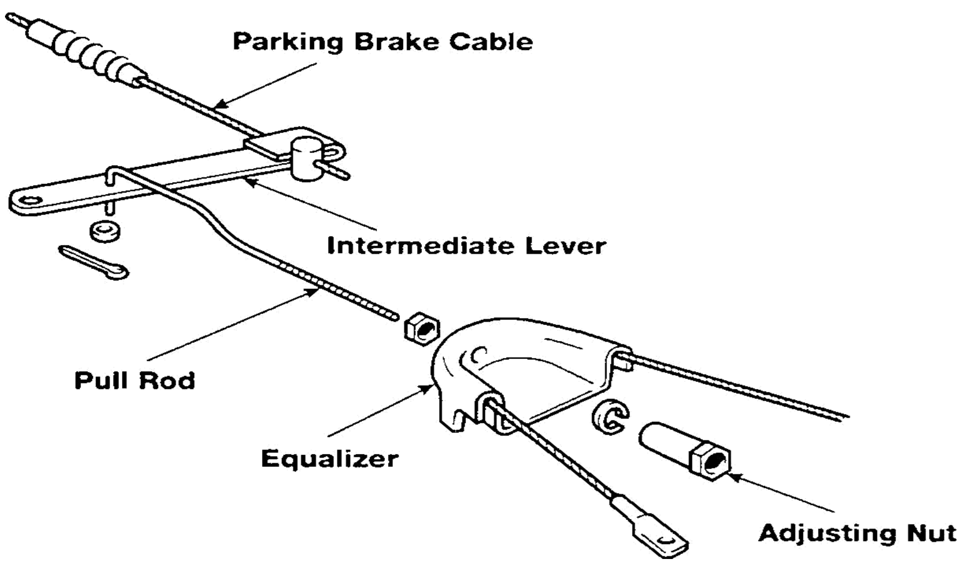


Fig. 2.7 Linkage Components

The intermediate lever multiplies the operating force to the equalizer. The equalizer divides the force to brake assemblies at both wheels.

2.2.3 Drum-type Parking Brakes

On all models using drum brakes on the rear, the cable pulls the parking brake lever. The lever is attached to the secondary shoe at the top and transfers the lever action to the primary shoe through the shoe strut. When released, the brake shoe springs return the shoes to their retracted position.

The cable pulls the parking brake lever and transfers the lever action to the primary shoe through the shoe strut.

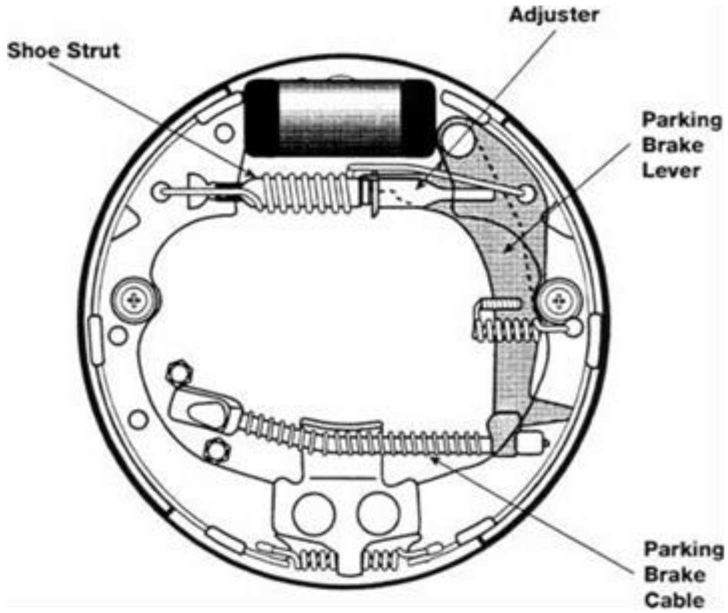


Fig. 2.8 Drum type parking brake components

2.2.4 Disc Parking Brakes

There are two types of rear wheel parking brake systems for disc brakes. The first uses the brake caliper assembly to mechanically apply pressure to the disc. The second type is an exclusive drum brake assembly that applies pressure to an inside drum, which is an integral part of the disc rotor.

Caliper Parking Brake: The parking brake is built into the caliper housing and is provided with an automatic adjusting mechanism to compensate for piston movement as the brake pads wear. The piston is mechanically forced to engage the pads to the rotor.

The adjusting mechanism maintains the operating clearance between the pads and the rotor as the pads wear down with use. The primary assembly which makes this possible is the Sleeve Nut and Adjusting Bolt. The Sleeve Nut is held by the Clutch Spring which allows it to turn in one direction only. The diameter of the Clutch Spring is slightly smaller than the diameter of the sleeve nut and allows it to turn in the unwind direction only. The clutch spring is held stationary with one end attached to the piston.

When the brake pedal is depressed, hydraulic pressure forces the piston to move to the left. The movement of the Piston exerts pressure on the Thrust Plate and Thrust Bearing against the Sleeve Nut causing it to be screwed out from the stationary Adjusting Bolt. The Sleeve Nut can be easily screwed out because the Clutch Spring unwinds and therefore does not prevent the Sleeve Nut from rotating. The distance that the Sleeve Nut screws out from the Adjusting Bolt is equal to the amount of pad wear.

Piston Head:

The piston head is provided with two recesses, one of which engages with a pin that protrudes from the backing plate of the brake pad. This pin prevents the piston from being rotated by the automatic adjuster. The adjusting bolt stopper prevents the adjusting bolt from rotating. The only part allowed to turn is the sleeve nut. The pin on the brake pad is indexed to the recess of the piston head to prevent the piston from rotating.

2.2.5 Parking brake cable power:

Why cable arrangement is used in parking brakes? The emergency or parking brake system is completely mechanical and, by design, effectively bypasses the entire hydraulic system.

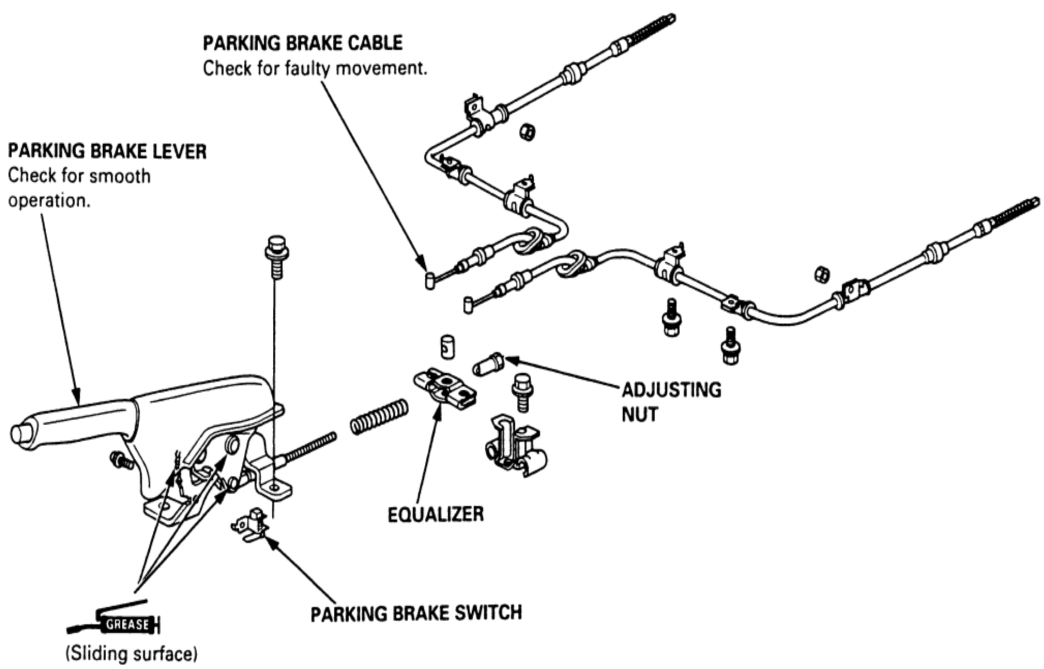


Fig. 2.9 Exploded view

In the event of a total brake failure (for example, a ruptured hydraulic line), the car or truck can still be brought to a safe stop.

Parking brake equalizer:

Regardless of style, some sort of cable system is required in order to physically link the emergency brake hand lever to the rear brakes. In most vehicles, there is a form of parking brake equalizer arrangement. It is designed to equalize the forces to both the left and right rear brakes as the lever is applied. It is essentially a “Y” connection that hooks to a set of shielded cables from each rear brake.

Linking the equalizer (“Y” connection) to the pedal or lever is another cable, often shielded. Adjusted properly and used regularly to avoid seizure from corrosion, the emergency brake system is another simple but effective device found on your car or light truck.

2.3 Advancements in Automatic Parking Brakes

2.3.1 Electronic parking brake:

The idea of an Electronic Parking Brake was completely new when it was first encountered in the 2002 BMW 7-Series, nearly thirteen years ago. That model marked the debut of the electronic parking brake in the U.S. market, with the 2003 Jaguar S-Type and 2003 Lincoln LS also among the first.

An electronic parking brake replaces the mechanical system with an electrical one. By pressing the switch, motors on each brake caliper squeeze the pads into the disc. You'll hear a reassuring whirring of the motors as the button is pressed (or pulled), meaning that you know that the car is held safely, which isn't always a guarantee with a regular handbrake – it's especially reassuring if you're towing.

To release the electronic parking brake, simply attempt to drive off and it will automatically disengage. Sometimes when you first start the car you'll have to put your foot on the brake and push (or pull) the electronic handbrake switch to take it off – this can also happen when you try to reverse. After that you'll normally just be able to drive away to deactivate it.

Drawback of Electronic Parking Brake:

A rather expensive diagnostic laptop is needed to open up the brake calipers so one can remove the pads for maintenance.

2.3.2 Hydraulic Parking Brake [3]

The hand brake engagement and disengagement is done with the help of hydraulic system. When the ignition switch is turned on DCV and pump gets activated fluid flows the pump in to DCV and then thought the hydraulic system which disengages the Hand brake, the same is done when the ignition switch is turned off for engagement of hand brake. This idea was developed in the Department of Automobile Engineering, BIST in Chennai.

2.4 Governors

A governor, or speed limiter, is a device used to measure and regulate the speed of a machine, such as an engine. A classic example is the centrifugal governor, also known as the Watt or fly-ball governor, which uses weights mounted on spring-loaded arms to determine how fast a shaft is spinning, and then uses proportional control to regulate the shaft speed.

Governors are classified as follows:

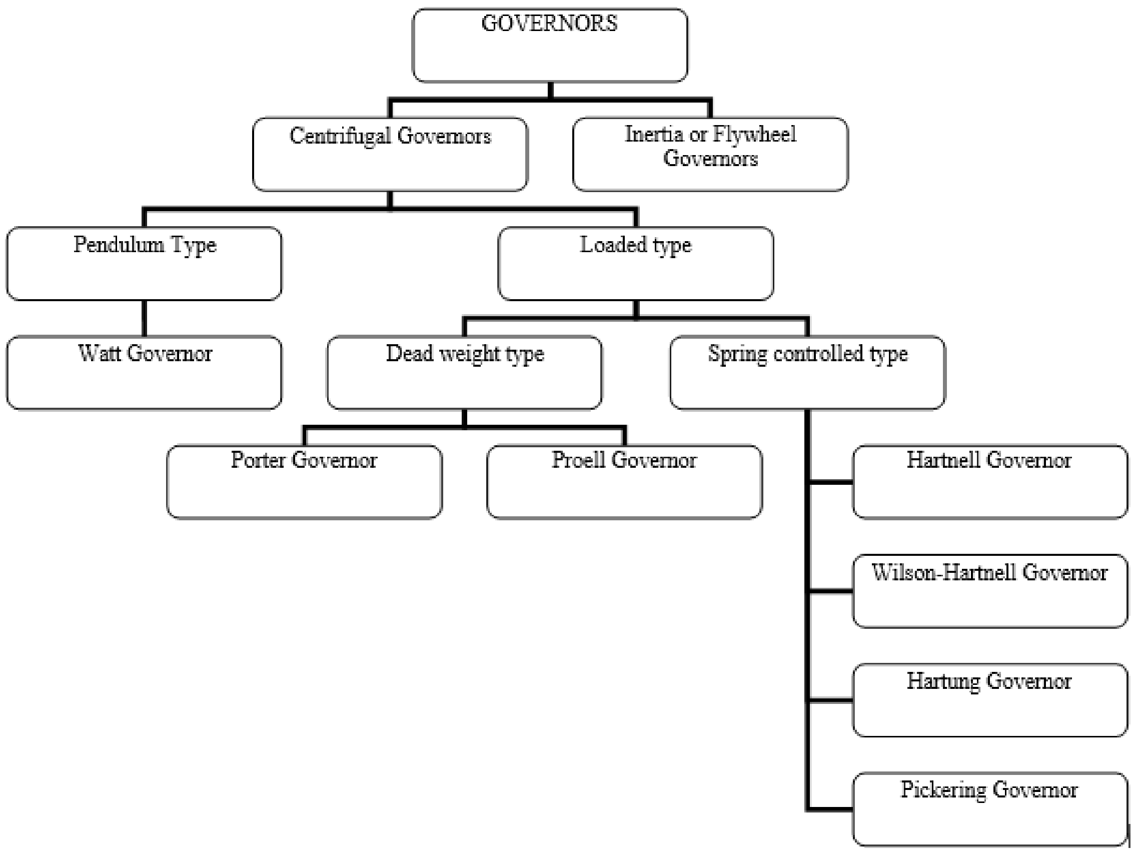


Fig. 2.10 Classification of Governors

Terms used in Governors:

1. Height of a governor: It is the vertical distance from the centre of the ball to a point where the axes of the arms (or arms produced) intersect on the spindle axis. It is usually denoted by h.

2. Equilibrium speed: It is the speed at which the governor balls, arms etc., are in complete equilibrium and the sleeve does not tend to move upwards or downwards.

3. Mean equilibrium speed: It is the speed at the mean position of the balls or the sleeve.

4. Maximum and minimum equilibrium speeds: The speeds at the maximum and minimum radius of rotation of the balls, without tending to move either way are known as maximum and mini- mum equilibrium speeds respectively.

5. Sleeve lift: It is the vertical distance which the sleeve travels due to change in equilibrium speed.

6. Underrun: It is a simple term to describe the ability of the governor to prevent engine speed from dropping below a set idle, particularly when the throttle has been moved rapidly to a decreased fuel setting from maximum full-load position.

7. Deadband: It is the change in speed required before the governor will make a corrective movement of the throttle.

8. State of balance: It is used to describe the speed at which the centrifugal force of the rotating flyweights of the governor matches and balances the spring force of the governor.

As far as this project goes, we will be focusing on the centrifugal type of governors, mainly, Porter and spring controlled governors.

2.4.1 Porter Governor

A schematic diagram of the porter governor is shown in Figure 4.2. There are two sets of arms. The top arms OA and OB connect balls to the hinge O. The hinge may be on the spindle or slightly away. The lower arms support dead weight and connect balls also. All of them rotate with the spindle. We can consider one-half of the governor for equilibrium.

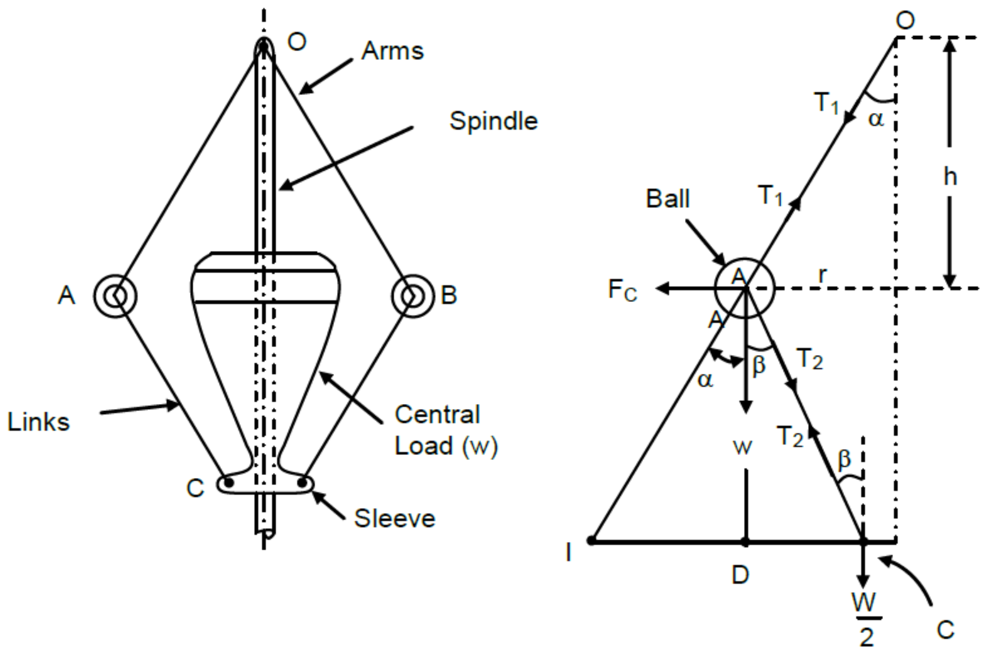


Fig. 2.11 Porter Governor [3]

Let w be the weight of the ball,

T_1 and T_2 be tension in upper and lower arms, respectively,

Fc be the centrifugal force,

r be the radius of rotation of the ball from axis, and

I is the instantaneous centre of the lower arm.

Therefore, the sleeve lift is given by:

$$h = \frac{g}{\omega^2}\left(1 + \frac{W}{2w}\left(1 + \frac{tan\beta}{tan\alpha}\right)\right) \tag{2.4.1}$$

2.4.2 Hartnell Governor

The Hartnell governor is shown in Figure 4.3. The two bell crank levers have been provided which can have rotating motion about fulcrums O and O'. One end of each bell crank lever carries a ball and a roller at the end of other arm. The rollers make contact with the sleeve. The frame is connected to the spindle. A helical spring is mounted around the spindle between frame and sleeve. With the rotation of the spindle, all these parts rotate.

With the increase of speed, the radius of rotation of the balls increases and the rollers lift the sleeve against the spring force. With the decrease in speed, the sleeve moves downwards. The movement of the sleeve is transferred to the throttle of the engine through linkages.

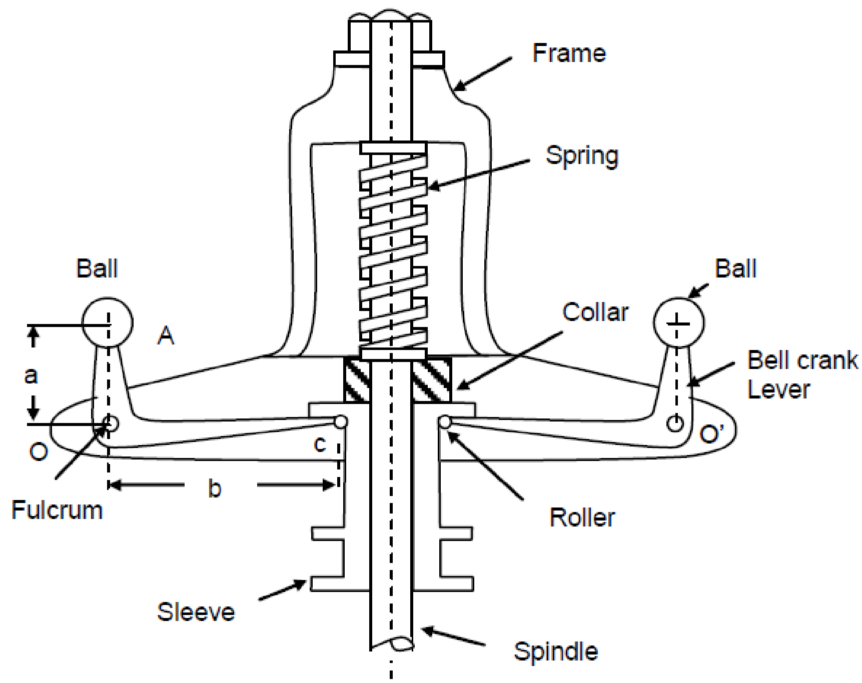


Fig. 2.12 Hartnell Governor [5]

Let r_1 = Minimum radius of rotation of ball centre from spindle axis, in m,

r_2 = Maximum radius of rotation of ball centre from spindle axis, in m,

S_1 = Spring force exerted on sleeve at minimum radius, in N,

S_2 = Spring force exerted on sleeve at maximum radius, in N,

m = Mass of each ball, in kg,

M = Mass of sleeve, in kg,

N_1 and N_2= Minimum and maximum speed of governor at minimum and maximum radius, in rpm,

ω_1 and ω_2 = Corresponding minimum and maximum angular velocities, in rad/s,

$(FC)_1$ = Centrifugal force corresponding to minimum speed

$(FC)_2$ = Centrifugal force corresponding to maximum speed

s = Stiffness of spring or the force required to compress the spring by one m,

r = Distance of fulcrum O from the governor axis or radius of rotation,

a = Length of ball arm of bell-crank lever, i.e. distance OA, and

b = Length of sleeve arm of bell-crank lever, i.e. distance OC.

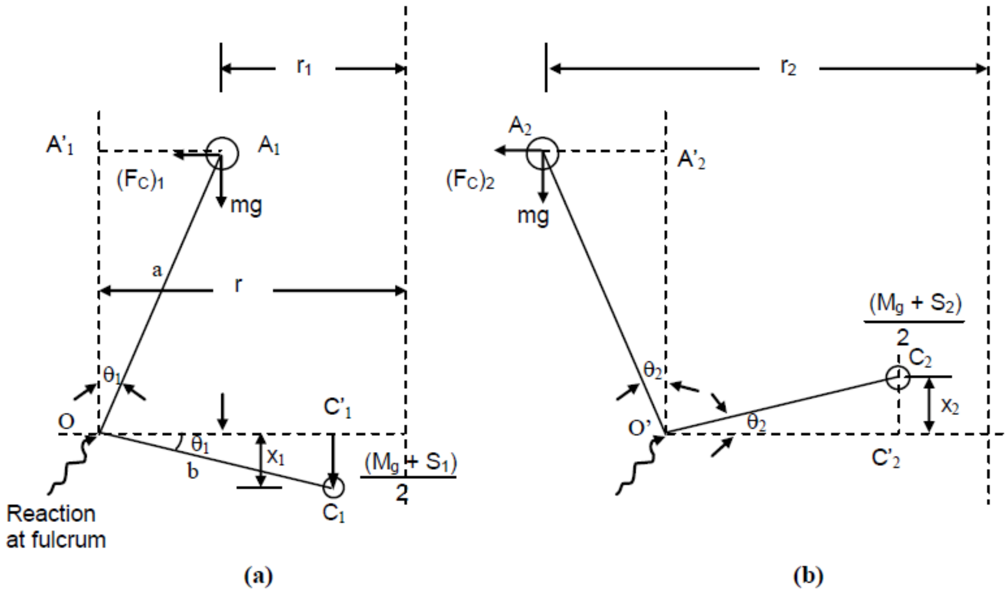


Fig. 2.13 Analysis of Hartnell Governor [4]

For ball radius 'r':

$$Spring\ stiffness, s = \frac{2\left(\frac{a}{b}\right)^2 (Fc - Fc_1)}{(r - r_1)} \tag{2.4.2}$$

$$Fc = Fc_1 + \frac{r - r_1}{r_2 - r_1}(Fc_2 - Fc_1) \tag{2.4.3}$$

2.4.3 Pickering Governor

A Pickering governor consists of 3 leaf springs, which are arranged at equal angular intervals around the governor spindle. The upper end of each spring is fixed by a screw, to a hexagonal nut attached to the spindle. The lower end is fastened to the sleeve, which can move up and down the governor spindle.

Each spring has a flymass ‘m’, attached at its centre. As the spindle rotates, a centrifugal force is exerted on the leaf spring at the centre which causes it to deflect. This deflection makes the sleeve move up. A stop is also provided to limit the movement of sleeve.

Let m = Mass fixed to each spring

e = Distance between spindle axis and centre of mass when the governor is at rest

ω = Angular speed of sleeve

δ = Deflection of the centre of leaf spring for spindle speed ω, which is given by

$$\delta = \frac{m(e+\delta)\omega^2 L^3}{192.E.I} \tag{2.4.4}$$

where E = Modulus of elasticity of spring material

I = Moment of Inertia of cross section of spring about N.A.

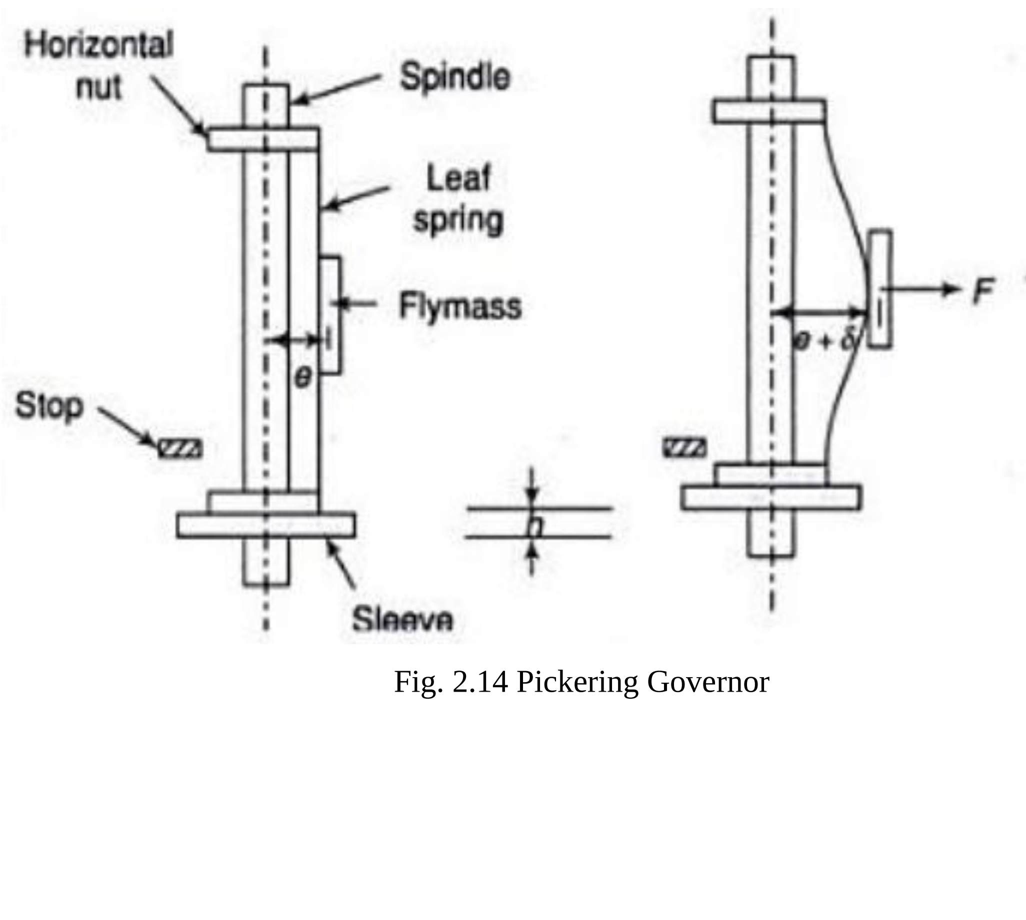


Fig. 2.14 Pickering Governor

Governor Characteristics:

(i) Sensitiveness:- The main objective of a governor is to maintain a constant mean speed as closely as possible, whatever may be the load on the engine. It is desirable that movement of sleeve should be as large as possible corresponding to fractional change of equilibrium speed as small as possible.

Smaller the fractional change of speed for a given displacement of the sleeve or the larger the displacement of sleeve for a given fractional change of speed, the more sensitive is the governor said to be. The sleeve displacement actuates the throttle valve of engine i.e. it regulates the energy supplied to the engine. The sensitiveness (S) is more accurately defined as (as we more bothered about the variation of speed from mean)

(ii) Stability: A governor is said to be stable when for each speed within the working range there is only one radius of rotation of the fly-ball at which governor is in equilibrium. If a governor is in equilibrium in all possible configurations at the equilibrium same speed, such a governor is said to be isochronous. In most of case isochronous governors are not stable and so are useless. (Since sensitiveness is infinite. i.e. for a small speed variation, the governor from its one extreme position will shift to the other extreme).

(iii) Hunting: A governor is said to be hunt if the speed of the engine fluctuates continuously above and below the mean speed. It occurs when governor is too sensitive i.e. for a small variation of speed causes large change in the fuel supply (i.e. sleeve). When the load increases, it causes the reduction in the speed of the governor and actuates the fuel supply valve to wide open. Due to the excess fuel supply the speed increases, governor actuates the fuel supply valve to fully close and the engine speed begins to fall. This cycle is repeated. This sort of governor, which admits maximum or minimum amount of fuel will cause wide fluctuation of speed and thus hunts.

Necessary characteristics of governor for this project:

- Compact
- Light weight
- Economically feasible
- High reliability
- Speed sensitive
- High durability

2.5 Springs

A spring is defined as the elastic element, which deflects under the action of load and returns to the original shape when the load is removed.

2.5.1 Objectives of spring

Following are the objectives of a spring when used as a machine member:

a. Cushioning, absorbing, or controlling of energy due to shock and vibration.

Car springs or railway buffers to control energy, springs-supports and vibration dampers.

b. Control of motion

Maintaining contact between two elements (cam and its follower) in a cam and a follower arrangement, widely used in numerous applications, a spring maintains contact between the two elements. It primarily controls the motion.

Creation of the necessary pressure in a friction device (a brake or a clutch). A person driving a car uses a brake or a clutch for controlling the car motion. A spring system keep the brake in disengaged position until applied to stop the car. The clutch has also got a spring system (single springs or multiple springs) which engages and disengages the engine with the transmission system. Restoration of a machine part to its normal position when the applied force is withdrawn (a governor or valve).

A typical example is a governor for turbine speed control. A governor system uses a spring controlled valve to regulate flow of fluid through the turbine, thereby controlling the turbine speed.

c. Measuring forces

Spring balances, gauges.

d. Storing of energy

In clocks or starters.

The clock has spiral type of spring which is wound to coil and then the stored energy helps gradual recoil of the spring when in operation.

2.5.2 Classification of springs:

Based on the shape behavior obtained by some applied force, springs are classified into the following ways:

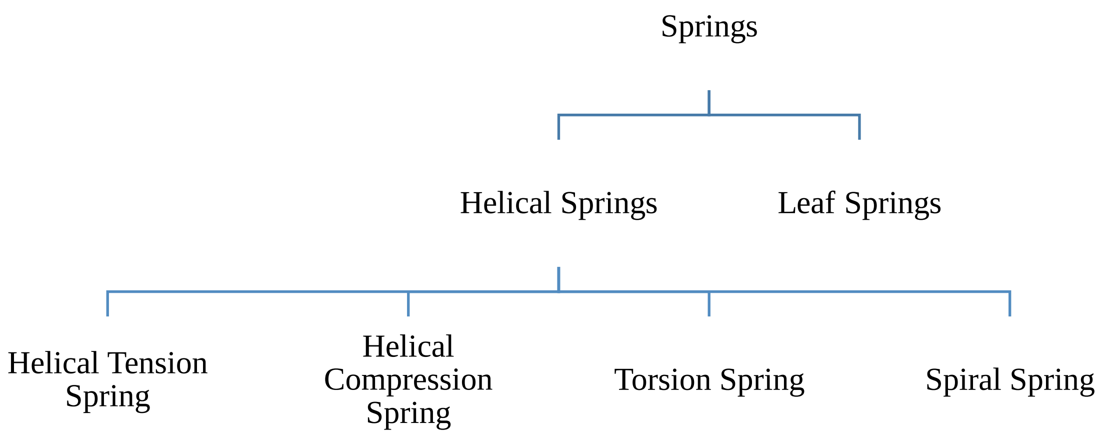


Fig. 2.15 Classification of springs

2.5.2.1 Helical spring

It is made of wire coiled in the form of helix.

Cross-section: Circular, square or rectangular

Classification:

1) Closed coil springs (or) Tension helical springs

2) Open coil springs (or) Compression helical springs

1) Helical tension spring

Characteristics:

It has some means of transferring the load from the support to the body by means of some arrangement.

It stretches apart to create load.

The gap between the successive coils is small.

The wire is coiled in a sequence that the turn is at right angles to the axis of the spring.

The spring is loaded along the axis.

By applying load the spring elongates in action as it mainly depends upon the end hooks

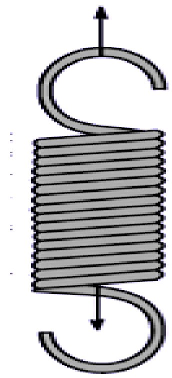


Figure 2.16 Helical tension spring

Applications:

Garage door assemblies

Vise-grip pilers

Carburetors

2) Helical Compression spring

Characteristics

The gap between the successive coils is larger.

It is made of round wire and wrapped in cylindrical shape with a constant pitch between the coils.

By applying the load the spring contracts in action.

There are mainly four forms of compression springs as shown in figure. They are as follows:

a) Plain end

b) Plain and ground end

c) Squared end

d) Squared and ground end

Among the four types, the plain end type is less expensive to manufacture. It tends to bow sideways when applying a compressive load.

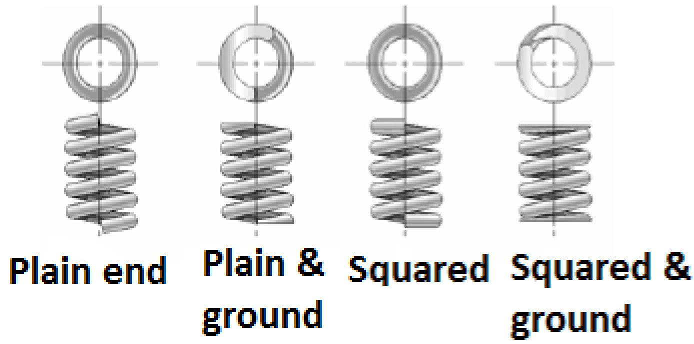


Fig. 2.17 Types of helical compression springs

Applications:

Ball point pens

Pogo sticks

Valve assemblies in engines

3) Torsion spring

Characteristics:

It is also a form of helical spring, but it rotates about an axis to create load.

It releases the load in an arc around the axis as shown in figure4.

Mainly used for torque transmission

The ends of the spring are attached to other application objects, so that if the object rotates around the center of the spring, it tends to push the spring to retrieve its normal position.

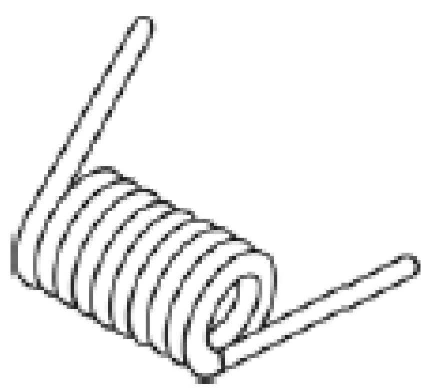


Fig. 2.18 Torsional spring

Applications:

Mouse tracks

Rocker switches

Door hinges

Clipboards

Automobile starters

4) Spiral spring

Characteristics**:**

It is made of a band of steel wrapped around itself a number of times to create a geometric shape.

Its inner end is attached to an arbor and outer end is attached to a retaining drum.

It has a few rotations and also contains a thicker band of steel.

It releases power when it unwinds.

Application:

Alarm timepiece

Watch

Automotive seat recliners

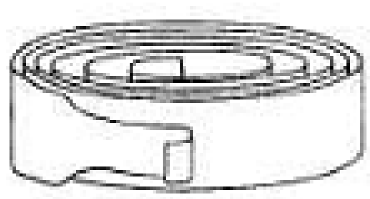
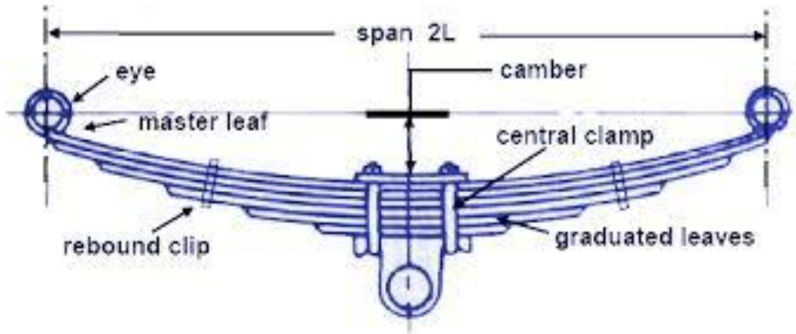


Fig. 2.19 Spiral spring

2.5.2.2 Leaf Spring

A Leaf spring is a simple form of spring commonly used in the suspension vehicles.



2.20 Leaf spring

Characteristics**:**

Sometimes it is also called as a semi-elliptical spring, as it takes the form of a slender arc shaped length of spring steel of rectangular cross section.

The center of the arc provides the location for the axle, while the tie holes are provided at either end for attaching to the vehicle body.

Heavy vehicles, leaves are stacked one upon the other to ensure rigidity and strength.

It provides dampness and springing function.

Application**:**

Mainly in automobiles suspension systems.

Advantages**:**

It can carry lateral loads.

It provides braking torque.

It takes driving torque and withstand the shocks provided by the vehicles.

2.5.2.3 Terminology of Helical Springs

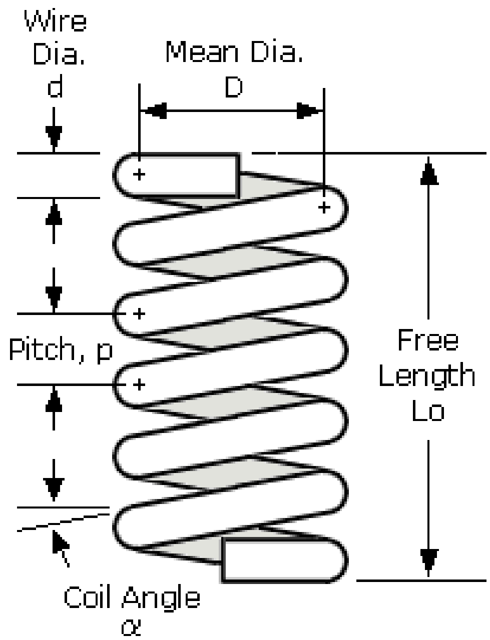


Fig. 2.21 Spring terminology

d = wire diameter of spring (mm)

Di = inside diameter of spring coil (mm)

Do =outside diameter of spring coil (mm)

D = mean coil diameter (mm) = $(D_i+D_o)/2$

There is an important parameter in spring design called spring index. It is denoted by letter C.

The spring index is defined as the ratio of mean coil diameter to wire diameter.

C = D/d

In design of helical springs, the designer should use good judgment in assuming the value of the spring index C. The spring index indicates the relative sharpness of the curvature of the coil.

A low spring index means high sharpness of curvature. When spring index is low (C< 3), the actual stresses in the wire are excessive due to curvature effect. Such a spring is difficult to manufacture and special care in coiling is required to avoid cracking in some wires. When the spring index is high (C >15), it results in large variation in coil diameter. Such a spring is prone to buckling and also tangles easily during handling. Spring index from 4 to 12 is considered better from manufacturing considerations. Therefore, in practical applications, the spring index in the range of 6 to 9 is still preferred particularly for close tolerance springs and those subjected to cyclic loading.

There are three terms - free length, compressed length and solid length that are illustrated in the figure. These terms are related to helical compression spring. These lengths are determined by following way

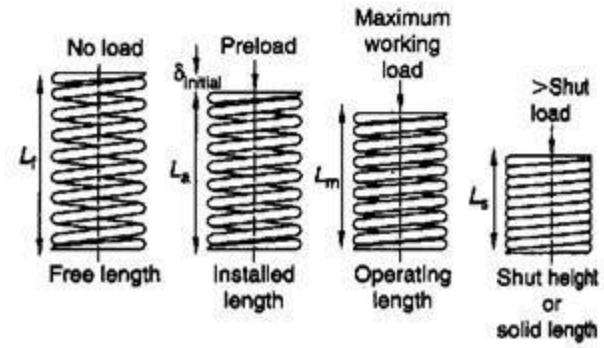


Fig.2.22 Various lengths associated with spring

1) Solid length: solid length is defined as the axial length of the spring which is so compressed, the adjacent coils touch each other. In this case, the spring is completely compressed and no further compression is possible. The solid length is given by.

Solid length = $N_t d$

where N_t = total number of coils

2) Compressed length: Compressed length is defined as the axial length of the spring that is subjected to maximum compressive force. In this case, the spring is subjected to maximum deflection. When the spring is subjected to maximum force, there should be some gap or clearance between the adjacent coils. The gap is essential to prevent clashing of the coils.

The clashing allowance or the total axial gap is usually taken as 15% of the maximum deflection. Sometimes, an arbitrary decision is taken and it is assumed that there is a gap of

1 or 2 mm between adjacent coils under maximum load condition. In this case, the total axial gap is given by,

Total gap = (N_t-1) x gap between adjacent coils

1) Free length: Free length is defined as the axial length of an unloaded helical compression spring. In this case, no external force acts on the spring. Free length is an important dimension in spring design and manufacture. It is the length of the spring in free condition prior to assembly.

Free length is given by,

Free length = compressed length + y

= solid length + total axial gap + y

Pitch = Pitch of coil is defined as the axial distance between adjacent coils in uncompressed state of spring. It is denoted by p. It is given by,

P = total length/ (Nt-1)

The stiffness of the spring (k) is defined as the force required producing unit deflection.

Therefore,

k=F/Y

k= stiffness of the spring (N/mm)

F = axial spring force (N)

Y = axial deflection of the spring corresponding to force p (mm)

There are various names for stiffness of spring such as rate of spring, gradient of spring, scale of spring or simply spring constant. The stiffness of spring represents the slope of load deflection line. There are two terms are related to the spring coils, viz. active coils and inactive coils. Active coils are the coils in the spring, which contribute to spring action, support the external force and deflect under the action of force. A portion of the end coils, which is in contact with the seat, does not contribute to spring action and called inactive coils. These coils do not support the load and do not deflect under the action of external force.

The number of inactive coils is given by, Inactive coils = Nt – N where N = number of active coils

2.5.2.4 Design consideration for helical spring

The design of a helical compression spring involves the following considerations:

Modes of loading–i.e. whether the spring is subjected to static or in frequently varying load or alternating load.

The force deflection characteristic requirement for the given application.

Space restriction.

Required life for springs subjected to alternating loads.

Environmental conditions such as corrosive atmosphere and temperature.

Economy desired.

Considering these factors the designer select the material and specify the wire size ,spring diameter ,number of turns, spring rate, type of ends ,free length and the surface condition.

A helical compression spring, that is too long compared to the mean coil diameter, acts as a flexible column and may buckle at comparatively low axial force.

Springs which cannot be designed buckle-proof must be guided in a sleeve or over an arbor.

This is undesirable because the friction between the spring and the guide may damage the spring in the long run.

It is therefore preferable, if possible, to divide the spring into buckle proof component springs separated by intermediate platens which are guided over an arbor or in a sleeve.

2.5.2.5 Design procedure for helical compression spring:

1. For the given application, estimate the maximum spring force and the corresponding deflection of the spring.
2. Select the suitable spring material and find out ultimate tensile strength.
3. Assume a suitable value of spring index.
4. Calculate Wahl’s Factor

$$k = \frac{4c - 1}{4c - 4} + \frac{0.615}{c} \tag{2.5.1}$$

5. Determine wire diameter

$$\tau = \frac{8 * F * d * k}{\pi d^3} \tag{2.5.2}$$

6. Determine mean coil diameter

D = Cd

7. Determine no of active turns of coils

8. Determine the solid length

9. Determine the actual deflection

10. Assume a gap of 0.5 to 2mm between adjacent coils

Find total axial gap= (Nt-1)*gap between two adjacent coil

11. Determine free length

Free length = compressed length + y

= solid length + total axial gap + y

12. Determine pitch of the coil

P = total length/ (Nt-1)

13. Determine rate of spring

14. Check whether guide is required or not.

2.5.3 Spring Materials

One of the important considerations in spring design is the choice of the spring material. Some of the common spring materials are given below.

Hard-drawn wire: This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 1200C.

Oil-tempered wire: It is a cold drawn, quenched, tempered, and general purpose spring steel. However, it is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 1800C. When we go for highly stressed conditions then alloy steels are useful.

Chrome Vanadium: This alloy spring steel is used for high stress conditions and at high temperature up to 2200C. It is good for fatigue resistance and long endurance for shock and impact loads.

Chrome Silicon: This material can be used for highly stressed springs. It offers excellent service for long life, shock loading and for temperature up to 2500C.

Music wire: This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. However, it cannot be used at subzero temperatures or at temperatures above 1200C. Normally when we talk about springs we will find that the music wire is a common choice for springs.

Stainless steel: Widely used alloy spring materials.

Phosphor Bronze / Spring Brass: It has good corrosion resistance and electrical conductivity. That's the reason it is commonly used for contacts in electrical switches. Spring brass can be used at subzero temperatures.

2.5.4 Spring manufacturing processes

If springs are of very small diameter and the wire diameter is also small then the springs are normally manufactured by a cold drawn process through a mangle. However, for very large springs having also large coil diameter and wire diameter one has to go for manufacture by hot processes. First one has to heat the wire and then use a proper mangle to wind the coils.

2.6 Belt Drive

Belt drives are called flexible machine elements. Flexible machine elements are used for a large number of industrial applications, some of them are as follows.

1. Used in conveying systems

Transportation of coal, mineral ores etc. over a long distance

2. Used for transmission of power.

Mainly used for running of various industrial appliances using prime movers like electric motors, I.C. Engine etc.

3. Replacement of rigid type power transmission system.

A gear drive may be replaced by a belt transmission system

Flexible machine elements has got an inherent advantage that, it can absorb a good amount of shock and vibration. It can take care of some degree of misalignment between the driven and the driver machines and long distance power transmission, in comparison to other transmission systems, is possible. For all the above reasons flexible machine elements are widely used in industrial application

Although we have some other flexible drives like rope drive, roller chain drives etc. we will only discuss about belt drives.

Selection of the Belt Drive:

1. Speed of the driving and driven shafts.

2. Speed reduction ratio

3. Power to be transmitted

4. Centre distance between the shafts.

5. Positive drive requirements.

6. Shaft layout.

7. Space available.

8. Service conditions.

2.6.1 Types of Belt Drives [According to application]

Light Drives: used to transmit small powers at belt speeds up to about 10 m/s in agricultural machines and small machine tools.

Medium Drives: Used to transmit medium power at belt speed 10 m/s but up to 22 m/s as in machine tools.

Heavy Drives: Used to transmit large powers at belt speed above 22 m/s as in compressor & generators.

2.6.2 Types of Belt [According to shape]

Flat Belt: used in factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another when two pulleys are not more than 8 m apart.

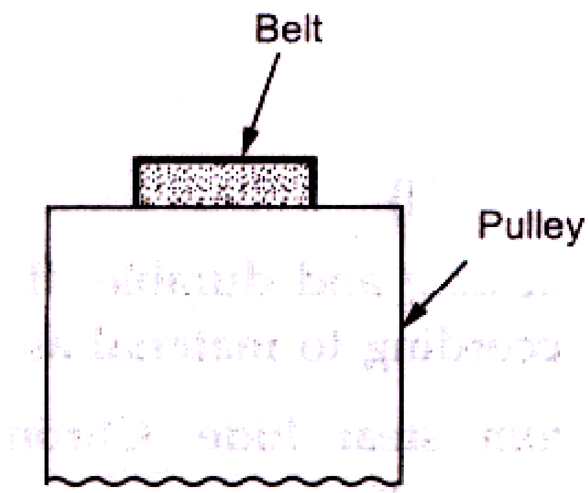


Fig.2.23 Flat belt

V-Belt: used in factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another when two pulleys are very near to each other.

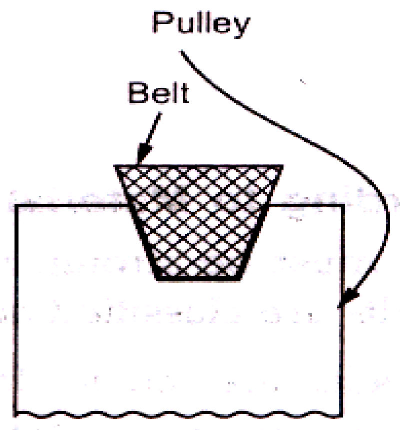


Fig.2.24 V-belt

Circular or Rope Belt: used in factories and workshops, where a greater amount of power is to be transmitted, from one pulley to another when two pulleys are not more than 8 m apart. E.g. Crane

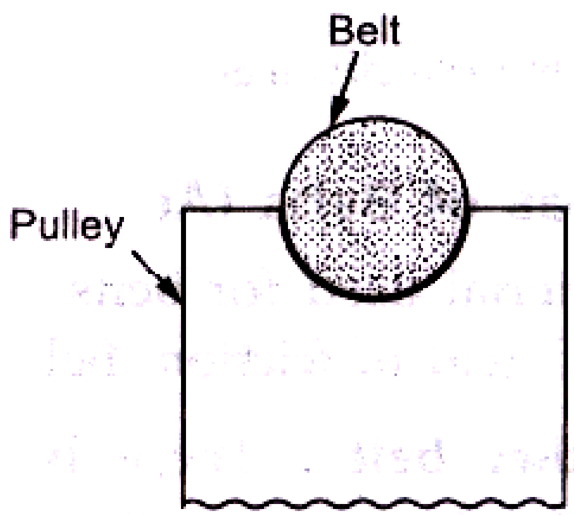


Fig.2.25 Rope belt

Timing Belt: They are toothed belts which transmit power by means of teeth rather than friction. Hence there is no slip occurring in these types of belts. They need toothed wheels. E.g. CNC m/c, Automobiles

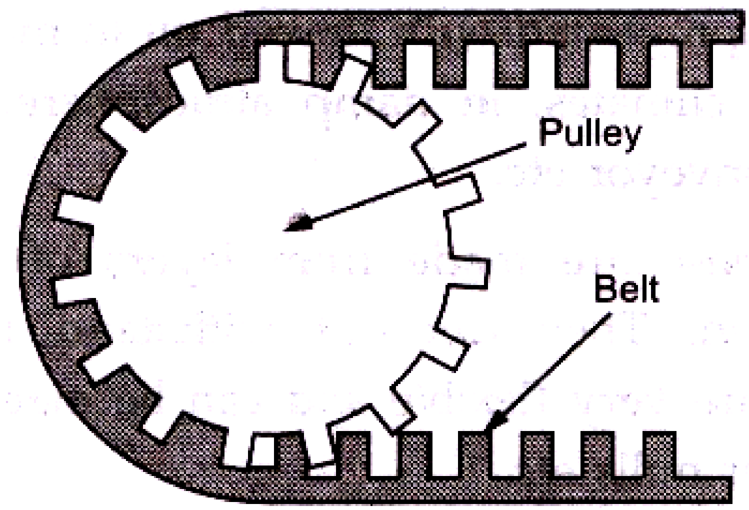


Fig.2.26 Timing belt

2.6.3 Types of Belt Drive [According to its Arrangement]

The power from one pulley to another can be transmitted by different arrangement of the belts.

Open Belt Drive:

It is used, when shafts are arranged parallel and rotating in the same direction, In this case, the driver A pulls the belt from one side (i.e. lower side) and delivers it to the other side (jet. upper side).

Thus the tension in the lower side belt will be more than that in the upper side belt. Hence lower side belt is known as tight side, whereas the upper belt is known as slack side.

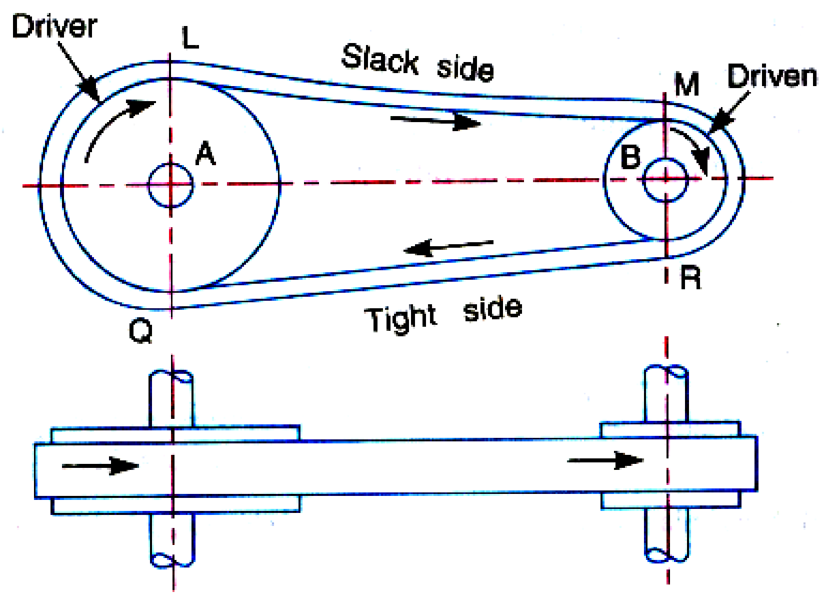


Fig. 2.27 Open belt

This belt drive is used when shaft are arranged parallel and rotating in the opposite direction. A crossed belt drive can transmit more power than open belt drive, as the angle of wrap is more. However, the belt has to bend in two different planes and it wears out more.

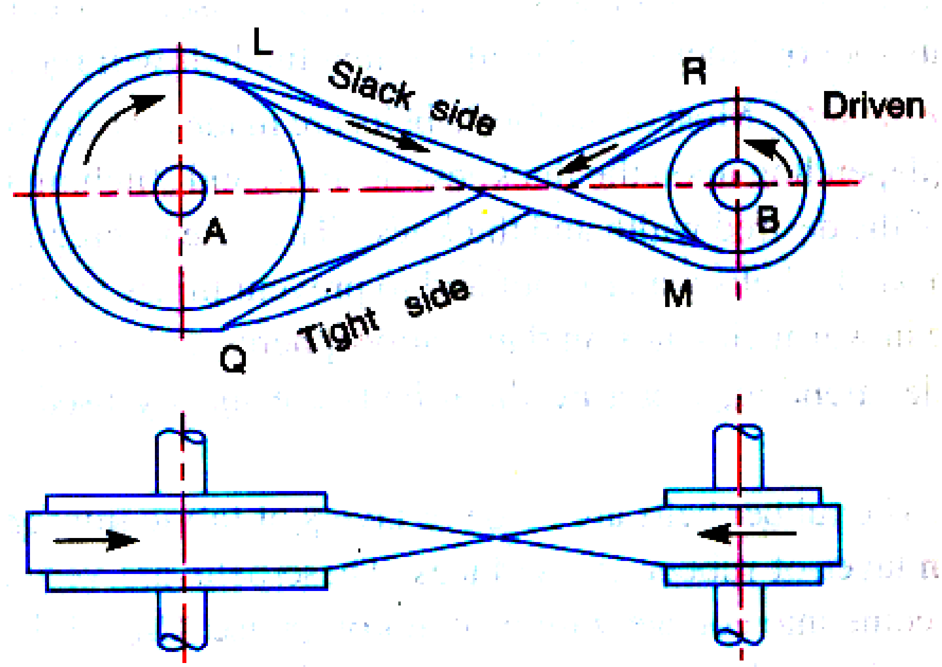


Fig.2.28 Cross belt

V-belt Drive Design Process

- Need rated power of the driving motor/prime mover. BASE sizing on this.
- Service factor based on type of driver and driven load.
- Center distance
- Power rating for one belt as a function of size and speed of the smaller sheave
- Belt length (then choose standard size)
- Sizing of sheaves. Most sheaves should be limited to 6500 ft. /min belt speed.
- Belt length correction factor
- Angle of wrap correction factor. Angle of wrap on smaller sheave should be > 120°
- Number of belts
- Initial tension in belts

Advantages of belt drive

- They are simple. They are economical.
- Parallel shafts are not required.
- Overload and jam protection are provided.
- Noise and vibration are damped out. Machinery life is prolonged (shock-absorbed).
- They are lubrication-free. They require only low maintenance.
- They are highly efficient (90–98%, usually 95%). Some misalignment is tolerable.
- They are very economical when shafts are separated by large distances.

Disadvantages of belt drive

- The angular-velocity ratio is not necessarily constant or equal to the ratio of pulley diameters, because of belt slip and stretch.
- Heat buildup occurs. Speed is limited to usually 35 m/s. Power transmission is limited to 370 kW
- Operating temperatures are usually restricted to –35 to 85°C.
- Some adjustment of center distance or use of an idler pulley is necessary for wear.
- A means of disassembly must be provided to install endless belts.

2.6.4 Chain drive

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles.

It is also used in a wide variety of machines besides vehicles.

Most often, the power is conveyed by a roller chain, known as the drive chain, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. The gear is turned, and this pulls the chain putting mechanical force into the system.

3. DESIGN OF COMPONENTS

Design Consideration:

- Should generate the required braking force
- Should be purely mechanical
- Should be durable
- Should be reliable
- High efficiency
- Minimal hysteresis
- Uniform brake factor performance with minimal fading
- Good response behavior
- Sufficient lining service life
- Minimal down times for lining change
- Minimal weight
- Small dimensions
- Good cost/benefit – ratio

Design Procedure:

The actuator mechanism designed is the only one of its kind. As there are no such existing mechanisms there was no standard procedure available for designing it. There were no assumptions and estimations available. So the only way to design was to consider initial values and then optimize t by a series of iterations.

The actuator that we chose had the physical dimensions similar to that of a governing mechanism. Therefore, for the first iteration, the watt governor was considered. By keeping the space constrains in mind, a suitable value of radius was assumed and an approximate fly ball mass was computed. This gave us a value to start with. Then the next iterations were with Portal and Proell governors. These were done by varying the sleeve to fly ball mass ratio. The objecting in doing so was to reduce the overall mass of the system.

For the further optimization of weight and size we chose the hart Nell type governor, which drastically reduced the weight of the system.

The next task was to optimize all the dimensions (weight and mass) simultaneously. So we came up with new mechanisms and modifications, the result of which is the final actuator proposed in this report. This actuator is independent of any fly ball and sleeve weight, which makes it much safer and easier to manufacture.

3.1 Design of actuator

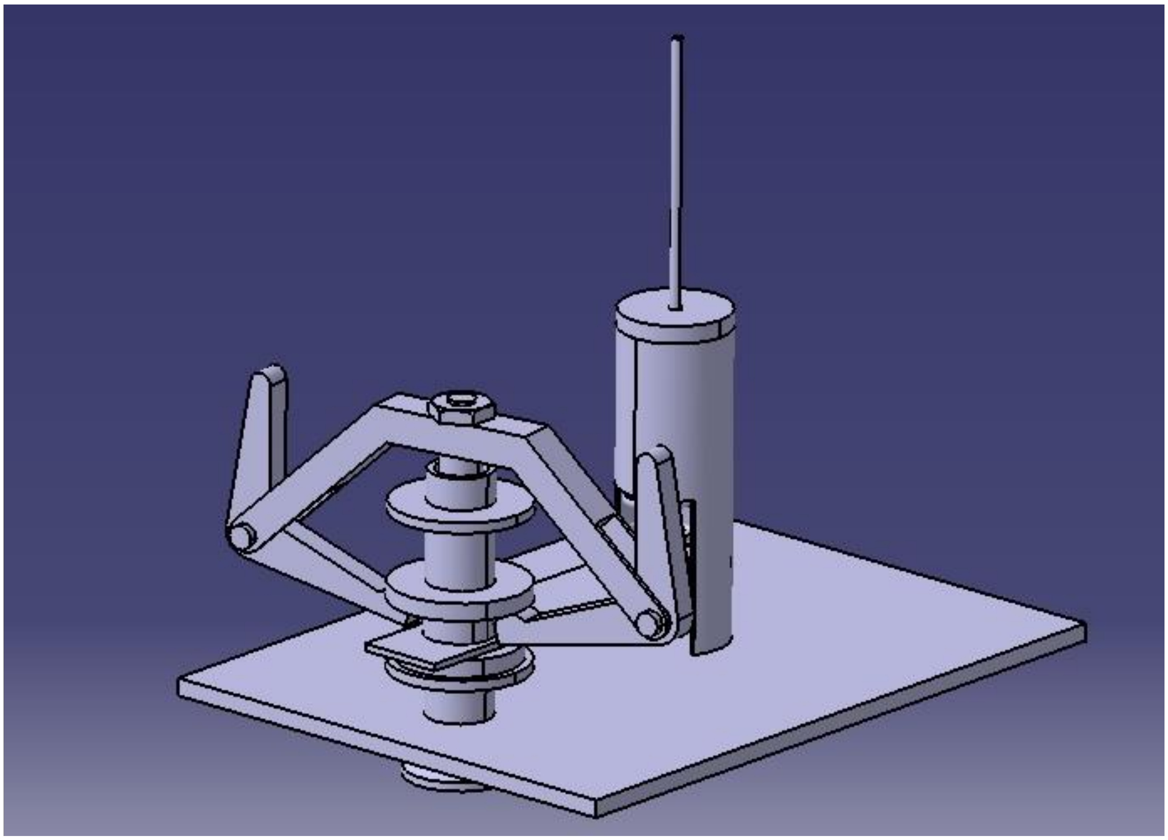


Fig. 3.1 Actuator

Taking mechanical advantage as 1

The governing equation is

$$F_2 - F_1 = \frac{kx_2 - kx_1}{2} * b$$

x = 20mm

k = 10 N/mm

$F = m\omega^2 r$

Case 1

$\omega_1 = 0$, $F_1 = 0$

$\omega_2 = 800 \text{ rpm} = 83.77 \text{ rad/s}$

Let, m = 60 gm =0.06 kg, r = 60 mm = 0.06m

$x_2 = 25.05 \text{ mm}$

Case 2

Maximum compression in the spring = 40mm

$$m\omega^2 r_3 = \frac{k(x_3 - x_1)}{2}$$

N = 1433 rpm

Case 3

Reaction at stopper at maximum rpm

By moment balance,

$F_3 * a = (R + kx_{max}) * b$

$a = b$, by geometry, $r_3 = 74\text{mm} = 0.074\text{mm}$

Reaction, $R = 585.9 \text{ N} \approx 586 \text{ N}$

3.2 Design of bell-crank lever

Forces acting,

l_1 = distance of reaction R from the selected cross section.

d_1 = diameter of the pin.

F_3 = centrifugal force acting on bell-crank = 986N

R = Reaction force on bell-crank= 586N

Resultant $= \sqrt{R^2 + {F_3}^2} = 1146.9\text{N}$

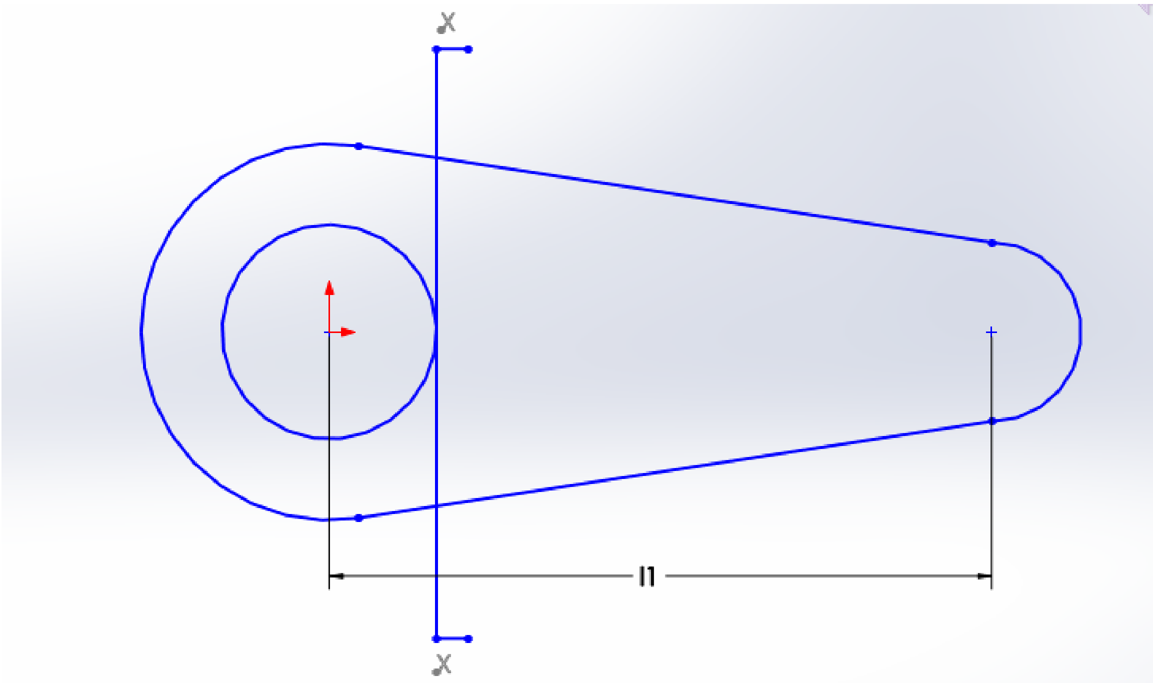


Fig. 3.2 Bell-crank lever cross-section

Taking section at maximum bending moment

$M_b = P(l_1 - d_1) = 1146.9(36 - 8) = 32115.7925$ Nmm

$l_1 = 36$mm

$d_1 = 8$mm

d = height of cross-section of bell-crank

b = width of cross-section of bell-crank

$$I = \frac{bd^3}{12}$$

Material of lever and pin is plain carbon steel having S_{ut} =723N/mm^2

Factor of safety, (fs) =5

$$\frac{M_b * y}{I} \leq \sigma_b$$

d≥13.86mm

b≥6.93mm

Diameter and length of fulcrum pin

$P = R(d_1 * l_p)$

Permissible bearing stress, $P = 10\ \mathrm{N/mm^2}$

Length of pin, l_p=15mm

$1146.9 = 10(8\,l_p)$

$l_p = 14.33\text{mm} \approx 15\text{mm}$

Fig. 3.3 Bell-crank lever

3.3 Stopper

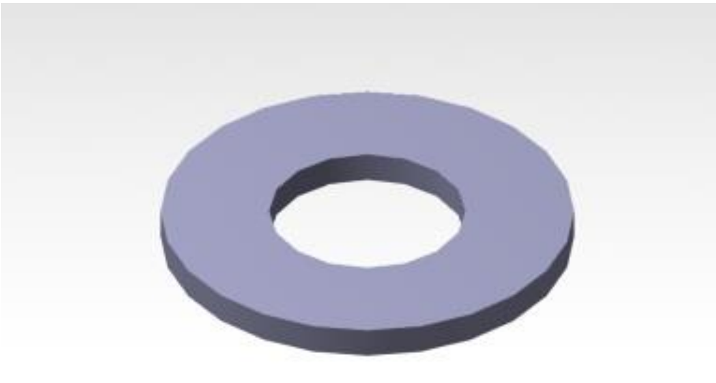


Fig. 3.4 Stopper

3.4 Spindle

Fig. 3.5 Spindle

3.5 Design of spring

Type of spring: Helical compression spring

Material: Grade-II Spring steel

Modulus of rigidity, G = 81370 N/mm^2

Ultimate tensile strength = 1990 N/mm^2

Deflection, δ = 40mm

Stiffness of spring, K = 10 KN/m

$P = K\delta = 400\ N$

Shear stress , $\tau = 0.5\ S_{ut} = 0.5 * 1990 = 995\ N/mm^2$

Spring Index, C = 8

Wahl Factor , $K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.3$

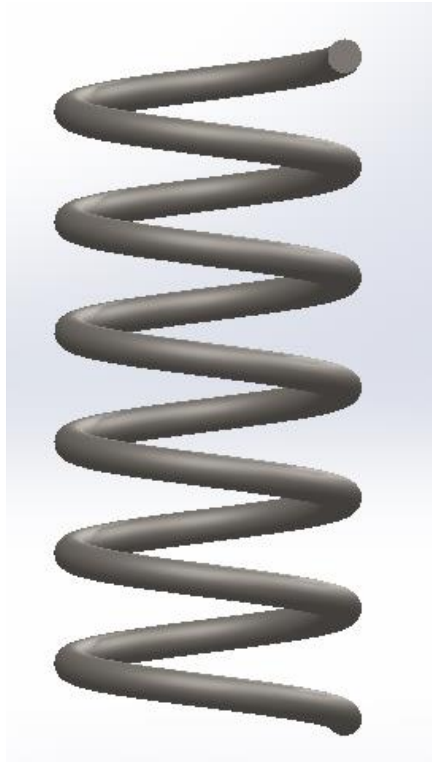


Fig. 3.6 Spring

$\tau = K_w * (8PC)/\pi d^2$

Thus, d = 2.94mm ≈ 3mm

D = 3*8 = 24mm

$\delta = \frac{8PD^3N}{Gd^4}$

Thus, Active number turns = 6

Style end = Square and ground

Total number of turns , $N_{total} = N + 2 = 8$

Inactive number of turns = 2

Solid length = $N_t * d = 8 * 3 = 24mm$

Actual deflection, $\delta = \frac{8PD^3N}{Gd^4} = 30mm$

Total gap = $(N_t - 1) * \text{Gap between adjecent spring} = (8 - 1) * 2 = 14mm$

Free length, F_l= Solid length + deflection + total gap = 24 + 20 +14 = 68mm

Pitch $= \frac{F_l}{N_t - 1} = \frac{68}{7} = 9.55mm$

3.6 Lever

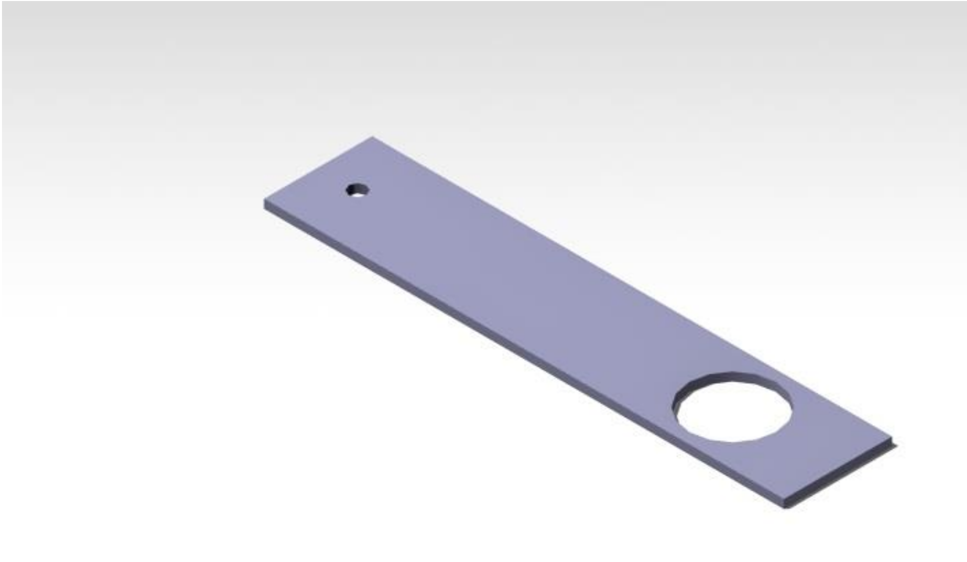


Fig. 3.7 Lever

3.7 Belt drive

Calculation of belt drive

Power to be transmitted, P = T*ω

Torque, T = 0.858 N-m

Angular velocity=ω=$\frac{2\pi N}{60}$

Revolutions per minute, N = 1750 rpm

P = 157.23W

Cross-section of belt: z

z-section is used because low power transmission

Recommended minimum pitch diameter of pulley = 85mm

Minimum allowable pitch diameter of pulley = 50mm

F_a= 1.1

Design power = F_a*P = 172.96 W

Diameter of bigger pulley (D)=Diameter of smaller pulley(d)=50mm

Length of Belt

$$L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C}$$

C=Center to centre distance of pulley=200mm

L=557mm

Standard belt length=L_p= 640mm

Corrected Center to center distance of pulley=241.46mm

F_c=0.84

$\propto_s$=Angle of wrap=180^0

F_d=1

Power rating=P_r =1.35 KW

Number of belt=$\frac{P*F_a}{P_r*F_c*F_d}$ =0.167

Number of belts= 1

Mass of belt=ρ*Volume

Density of leather belt=ρ=0.97 g/cm^3

Cross-sectional area of belt=96cm^2

Mass of belt=ρ*A*L

Mass = 0.93kg/m

3.8 Power, energy and torque:

The actuator mechanism consumes energy to rotate its own mass about the central axis. Power is consumed by the mechanism when the engine accelerates and decelerates. To determine the power consumed by the system we need to know the maximum torque required but the system. As the actuator rotates in the same sense as that of the engine, the acceleration of the engine will equal the acceleration of the actuator. The maximum acceleration of the engine will be when the engine generates maximum torque.

Every engine manufacturer specifies the maximum torque generated by the engine and the speed at which this torque is generated. Also the overall moment of inertia of the engine is known and is approximately same for the engines falling under a particular category. From this data the maximum acceleration of the engine is determined. This value will be same for the engine as well as the actuator.

Now, the torque needed by the actuator is the angular acceleration times the moment of inertia of the mechanism which can be determined using CAD software. Thus the maximum power consumed by the actuator is torque times the angular speed of the system plus the power required to overcome the parasitic losses.

The energy consumed in the system is equal to the angular kinetic energy of the actuator plus the energy stored in the spring. The maximum energy consumed will be at maximum speed of the engine.

Calculations:

I_{eng} = 0.386 kg-m^2

I_{act} = 6.57*10^{-4} kg-m^2

T_{max} = 200N-m

N= 1750 rpm

ω= 183.6 rad/s

N_{max}= 4500 rpm

ω_{max}= 471.23 rad/s

$$T_{max} = I_{eng} * \alpha_{max}$$

$$200 = 0.386 * \alpha_{max}$$

$$\alpha_{max} = 518.134 \text{ rad/s}^2$$

$\alpha_{\text{engine}} = \alpha_{\text{system}}$

$\alpha_{\text{system}} = 518.134 \text{ rad/s}^2$

$T_{sys} = 6.57 * 10^{-4} * 518.134$

$T_{sys} = 0.858\text{Nm}$

$P = T_{sys} * \omega$

$P = 0.858 * 183.6$

$P = 157.52 \text{ W}$

Assuming the parasitic losses in the system to approximately 10% of the power.

P_{loss}= 0.1*157.52

P_{loss}= 15.752W

Total power is the summation of the required power plus the losses

P_{total}= P + P_{loss}

P_{total}= 157.52+15.752

P_{total} = 173.272 W

Kinetic Energy

$K_{max} = 0.5 \times I_{sys} \times \omega_{max}^2$

$K_{max} = 0.5 \times 6.5 * 10^{-4} \text{ X } 471.23^2$

$K_{max} = 72.94 \text{ J}$

Potential energy:

k= stiffness of spring

δ= maximum deflection in spring

k= 10 N/mm

δ= 30mm

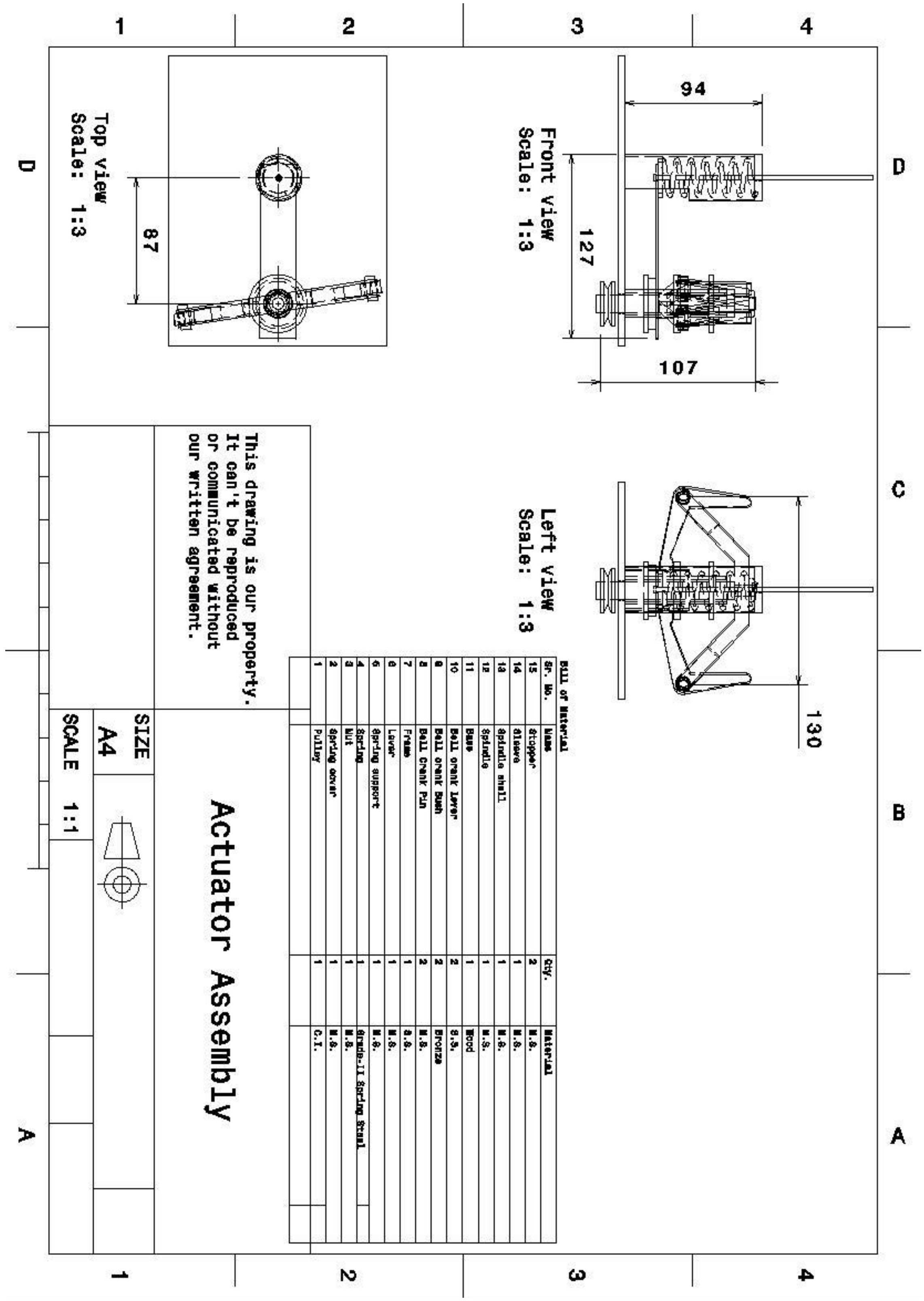
$P_{max} = 0.5*k*\delta^2$

P_{max} = 4.5 J

Total energy= Kinetic + potential

T = 77.44 J

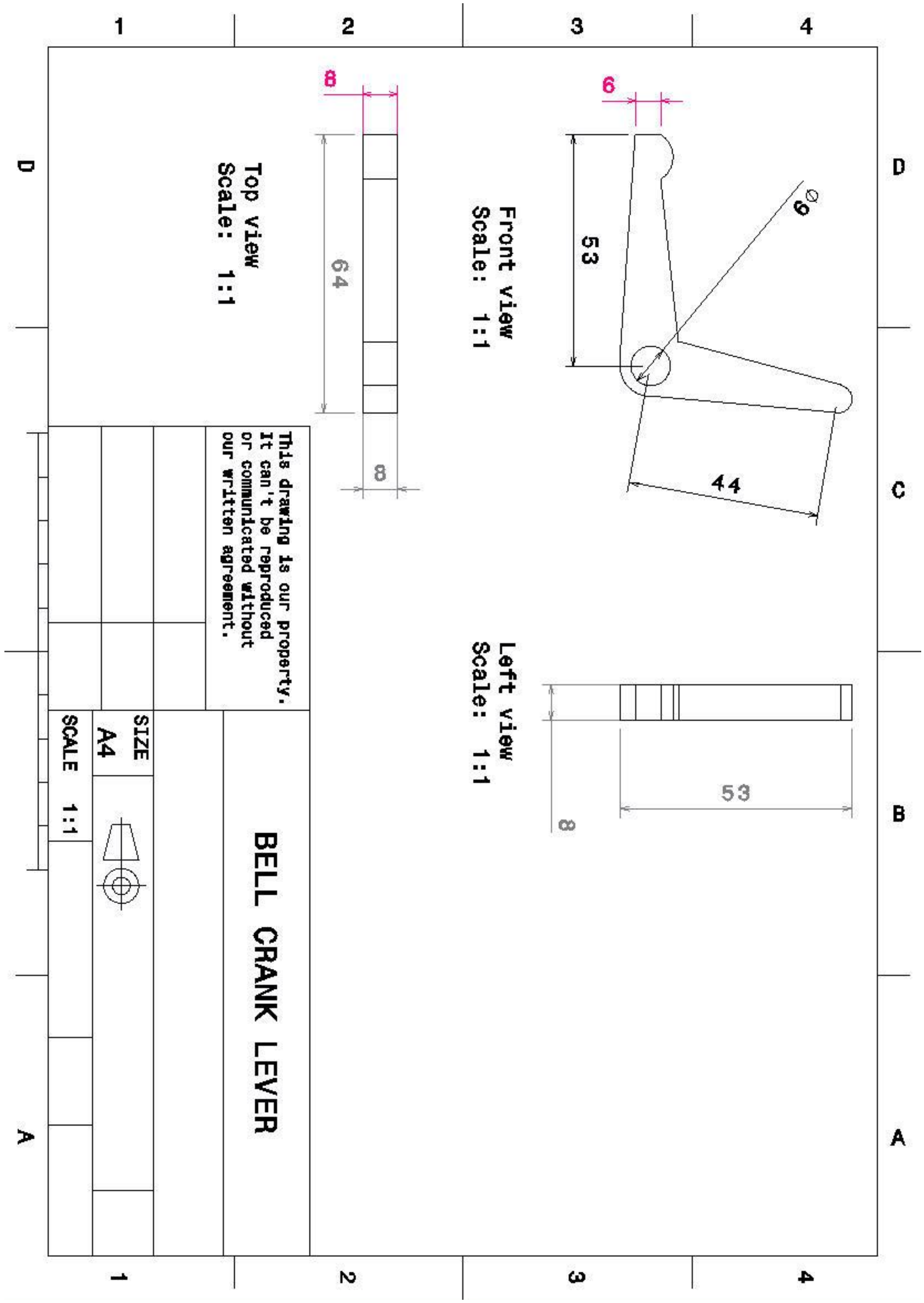
1. Actuator assembly



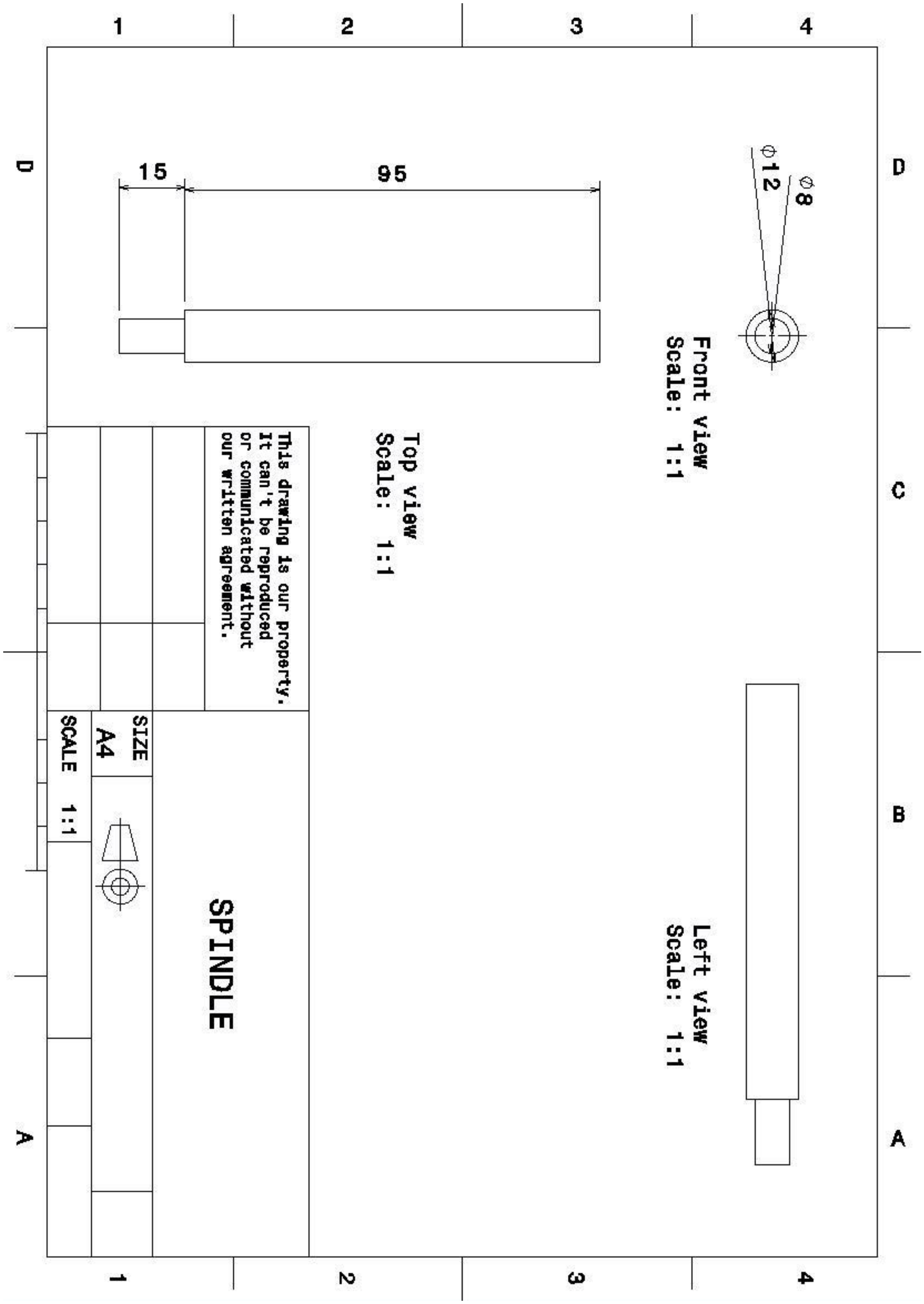
Bill of Material

Sr. No.	Name	Qty.	Material
15	Stopper	2	M.S.
14	Sleeve	1	M.S.
13	Spindle shell	1	M.S.
12	Spindle	1	M.S.
11	Base	1	Wood
10	Bell crank lever	2	S.S.
9	Bell crank Bush	2	Bronze
8	Bell Crank Pin	2	M.S.
7	Frame	1	S.S.
6	Lever	1	M.S.
5	Spring support	1	M.S.
4	Spring	1	Grade-II Spring Steel
3	Nut	1	M.S.
2	Spring cover	1	M.S.
1	Pulley	1	C.I.

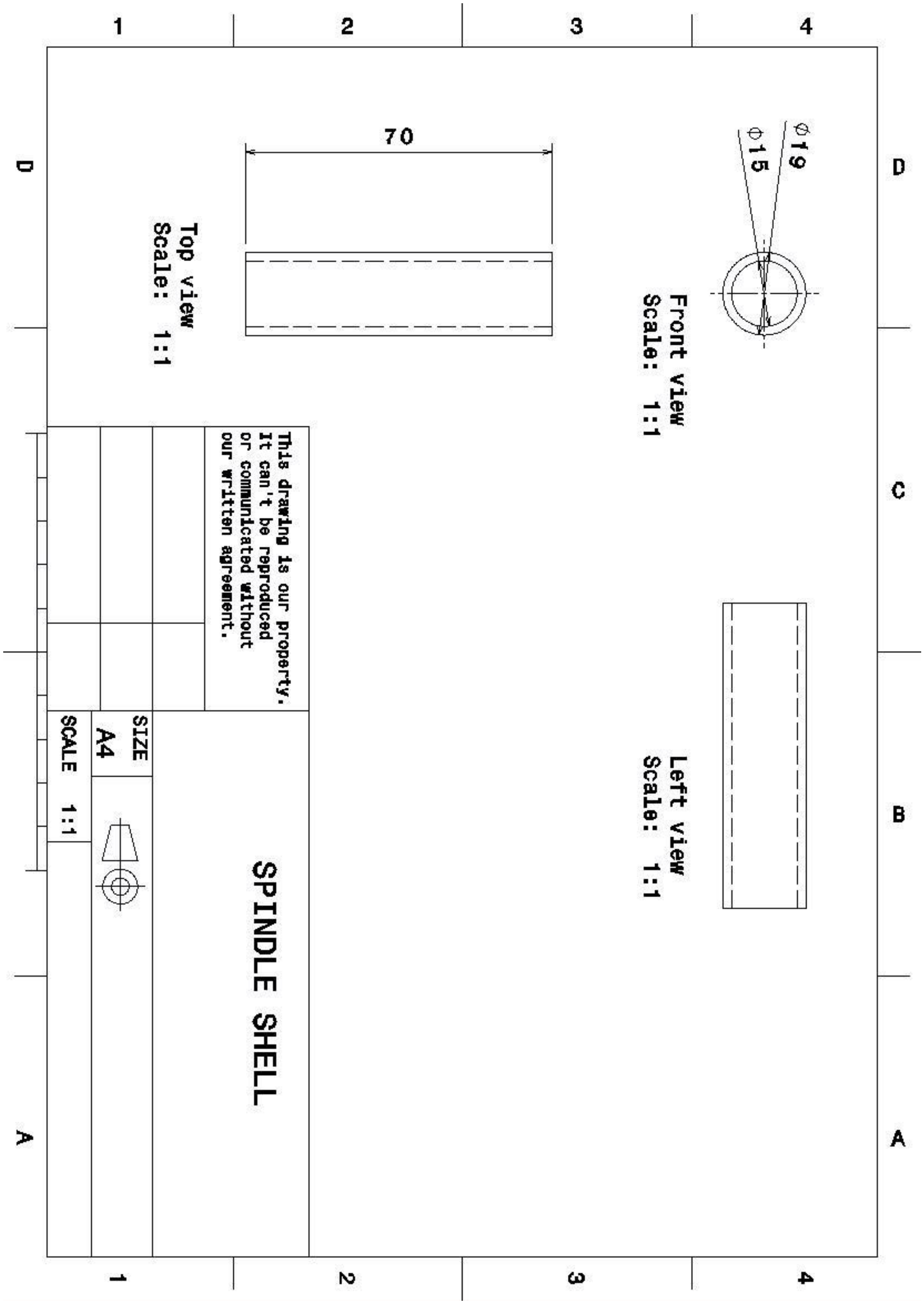
2. Bell-crank lever



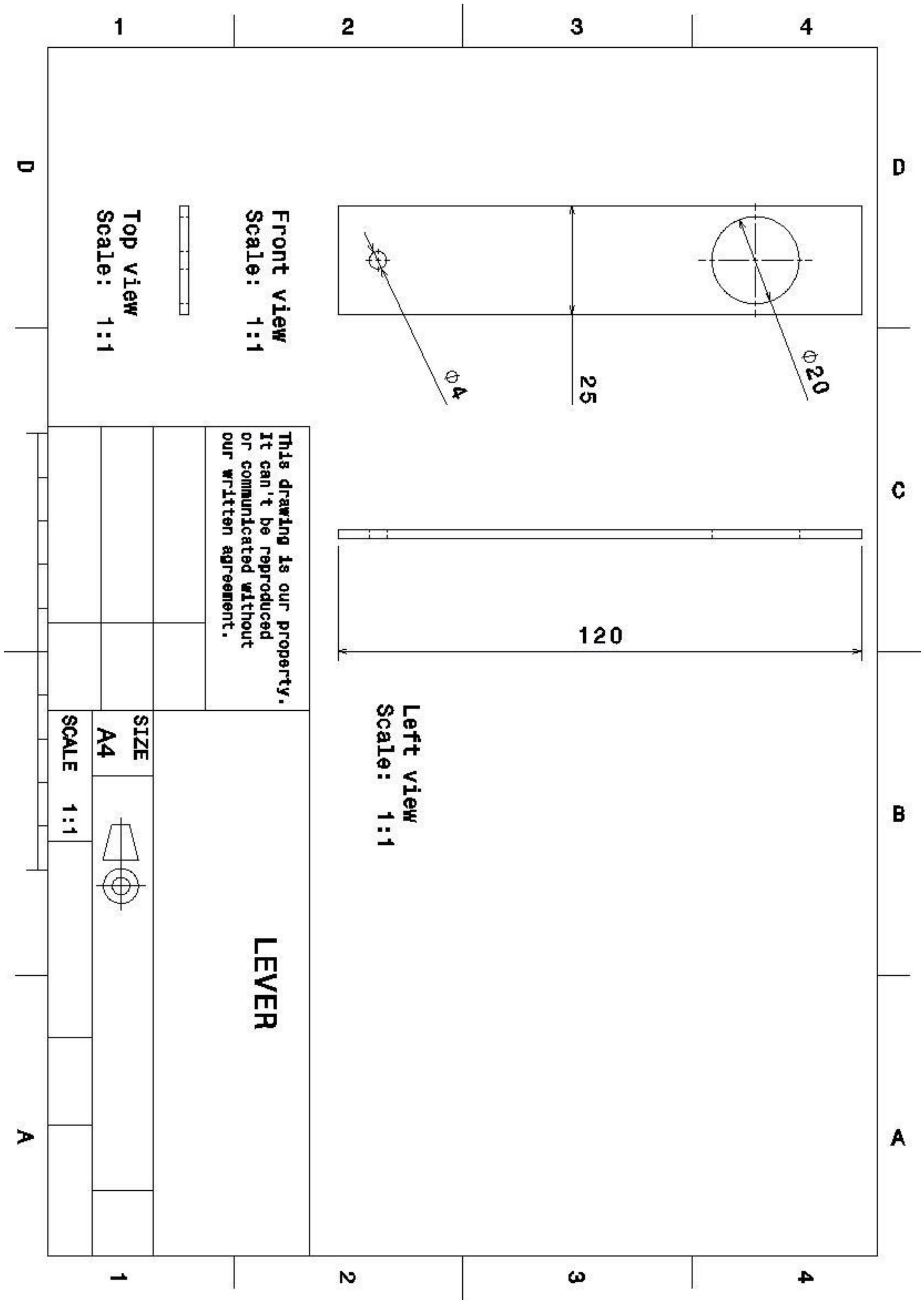
3. Spindle


15
95
⌀12
⌀8
Front view
Scale: 1:1
Top view
Scale: 1:1
Left view
Scale: 1:1
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
SPINDLE
SIZE
A4
SCALE 1:1

4. Spindle cover



5. Lever



Front view
Scale: 1:1
Top view
Scale: 1:1
Left view
Scale: 1:1
Φ4
25
Φ20
120
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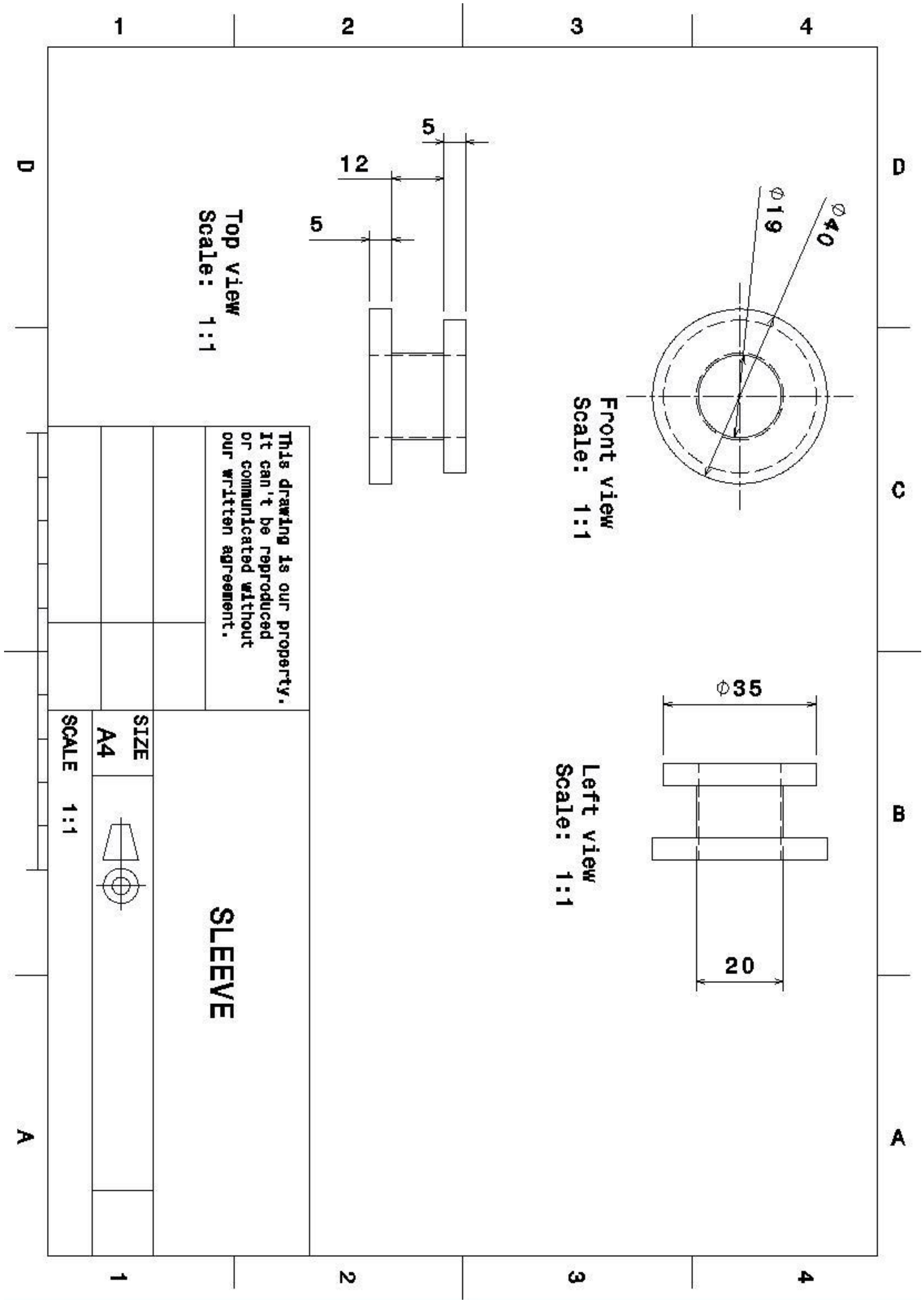
SIZE
A4
SCALE 1:1
LEVER

6. Sleeve


Top view
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
5
12
5
⌀19
⌀40
⌀35
20
This drawing is our property.
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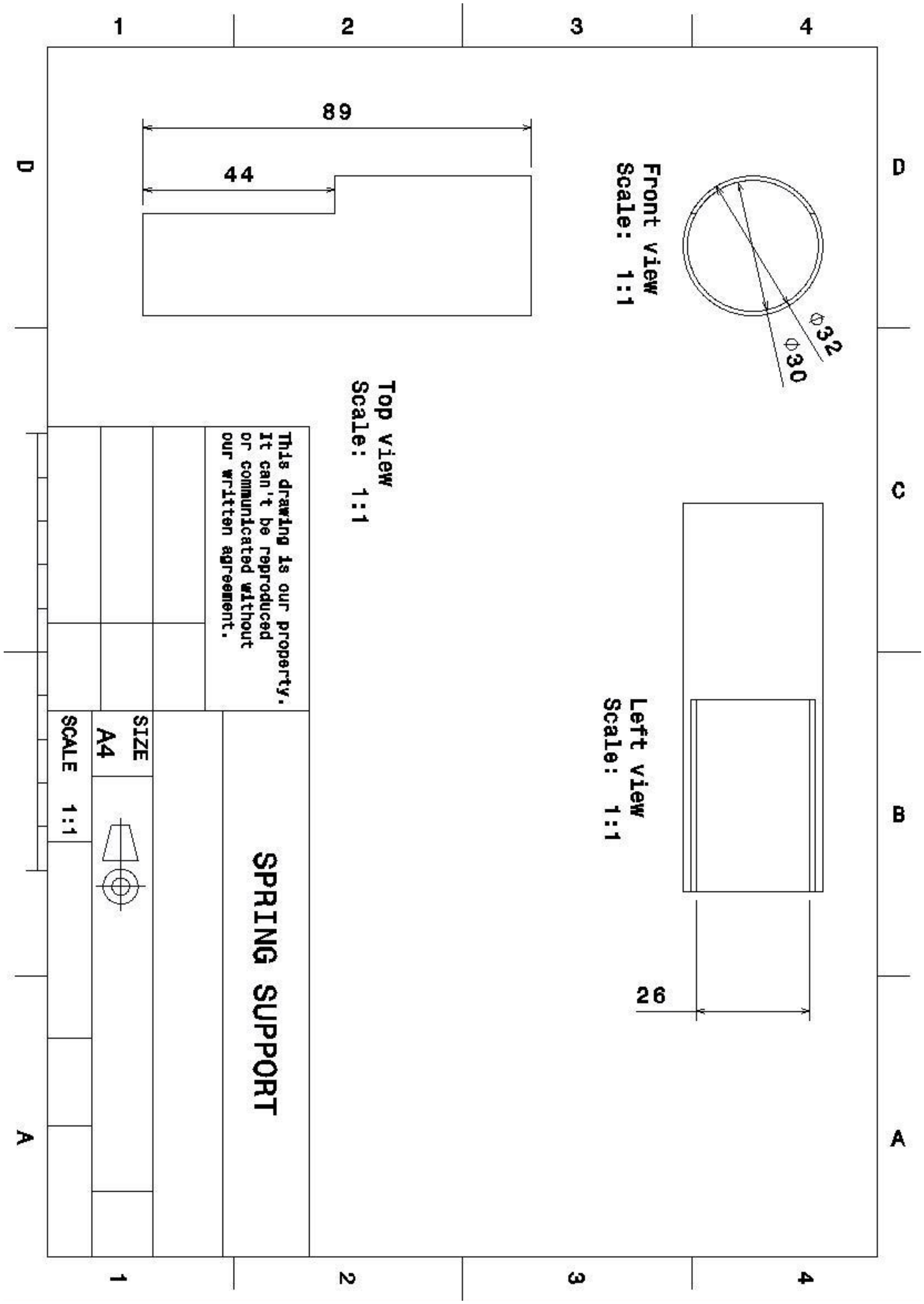
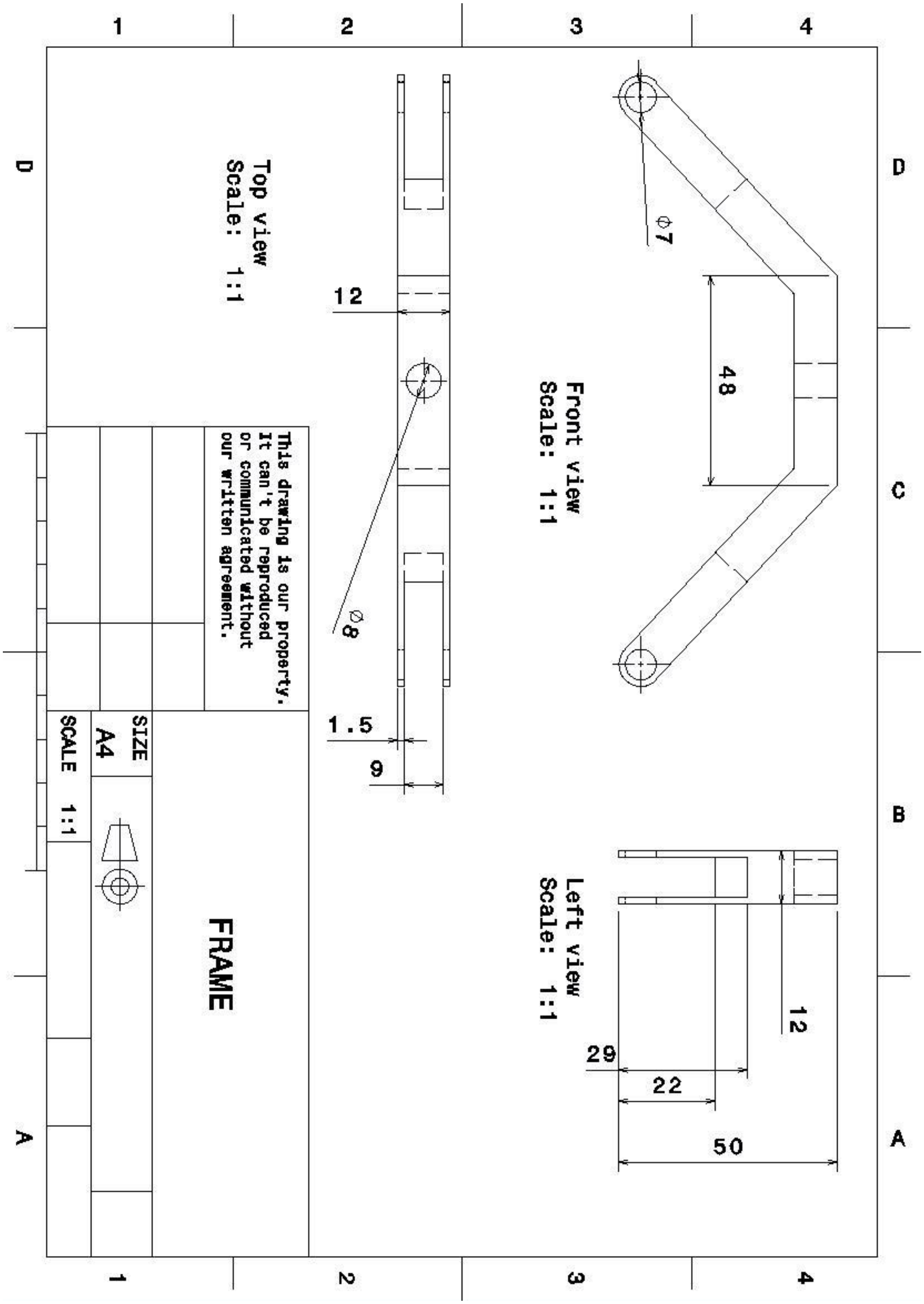
SIZE
A4
SCALE 1:1
SLEEVE

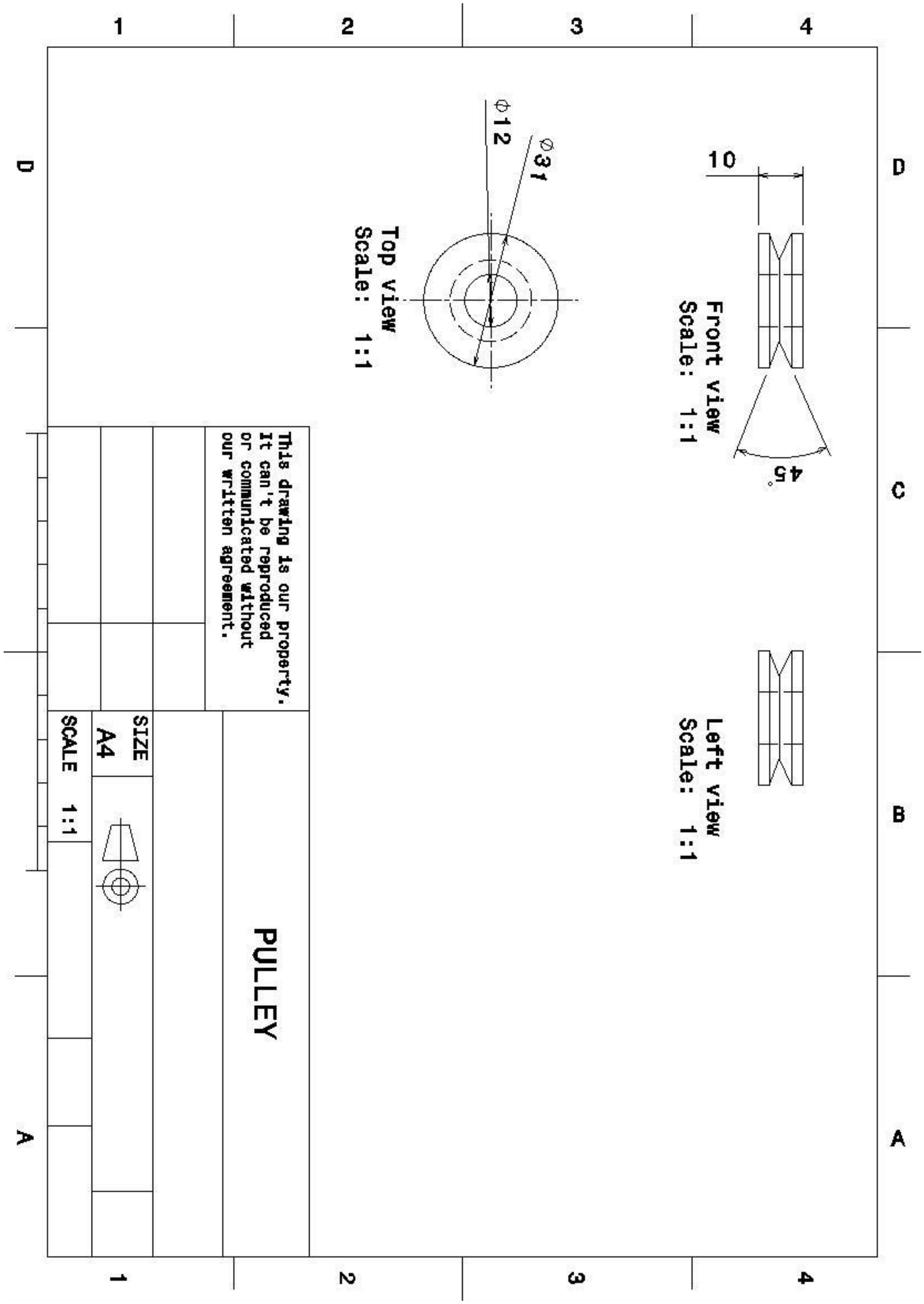
7. Spring support



8. Frame


Top view
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
SIZE
A4
SCALE 1:1
FRAME
12
1.5
9
48
29
22
50

9. Pulley


Top view
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
⌀12
⌀31
10
45°
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
SIZE
A4
SCALE 1:1
PULLEY

4. MANUFACTURING AND MATERIAL SELECTION

Material selection is one of the foremost functions of effective engineering design as it determines the reliability of the design in terms of industrial and economical aspects.

Material selection criteria

1. Mechanical properties

When a certain design is going to be actually produced it must be subjected to a number of manufacturing practices depending on the material and the design process. At the completion of production it must be totally fit for the service phase, too. In order to predict the reliability of both of these requirements, the materials must be able to withstand a certain load. Therefore the material must possess a certain strength and stiffness. Selected materials are examined for strength and stiffness values, and then potential materials are further inspected for other desired properties.

2. Wear of materials

Wear is a problem when the materials are contacting each other in a product. So it must be ensured that the selected materials have sufficient wear resistance. One of the best examples for this is designing gears to cope with wear. There are many production techniques available to improve the wear resistance and make the material is more suitable for the application. This is also very important factor to consider when selecting a material for a particular design. In the engineering design process this has to be considered with great care.

3. Corrosion

The importance of material selection in engineering is clearly visible in corrosive environments. Also it is an important engineering design criterion for designs open to the environment for a longer period of time. Some materials are very likely to be corroded in the service depending on the service environment. Metals like iron are heavily prone to corrosion if it not prepared to resist.

4. Ability to manufacture

Although the material is well capable of using for the design, it may be difficult to manufacture. If this selection criteria is neglected the manufacture process might be very costly making it unprofitable as a commercial product. So before selecting the materials this fact also must be considered. These facts are widely varied with the type of manufacturing method.

5. Cost

Cost is a critical fact to consider when selecting materials for a certain design for most products. The cost factor can be neglected when performance is given the top priority. When estimating costs, all the associated cost factors must be considered to get a more reasonable value. It may involve the transportation, processing, etc. costs.

These are the main facts to consider when selecting a material for a design, but there are a number of other factors which become essential depending on the particular product. In some occasions particular properties of the material may become the dominant factor over other properties. For example, electrical conductivity is vital for an electrical application so it must be given the priority. In mechanical engineering, designing for light weight is important for certain body parts of vehicles where aluminum is used instead of steel. An inability to meet the maximum operating temperature may be the reason to exclude the most profitable material for a certain high temperature design. Once a short list of materials is selected, the best possible candidate that gives the maximum performance with minimum cost must be determined.

Component wise manufacturing:

4.1 Spring

The selection of material for the spring depends upon the following factors

1. The load acting on the spring.

2. The range of stresses through which the spring operates.
3. The limitation of mass and volume of the springs.
4. The expected fatigue life.
5. The environmental condition.
6. The severity of deformation encountered while making the spring.

Selected Material: Grade-II spring steel

Grade-II is used as spring is subjected to moderate load cycles.
Spring steel has a very high yield strength.
This allows objects made of spring steel to return to their original shape despite significant deflection or twisting.
Moderate cost.

Manufacturing process:
Coiling
Grinding (To make end flat)

4.2 Sleeve

Sleeve is mainly subjected to wear. Hence, wear is the criterion for selecting material for the sleeve.

Selected Material: Mild steel

Cheapest.
Easy to manufacture.
Can be case-hardened to improve wear resistance.

Manufacturing process:

Boring

Turning

Facing

4.3 Spindle

The main function of the spindle is to support the frame and bell-crank lever and it takes minimum load.

Thus, criterion for selecting material is cost only.

Material selected: Mild steel

To minimize cost mild steel is used as it is cheapest and it is also easy to manufacture.

Manufacturing process:

Turning

Facing

4.4 Stopper

Stoppers are welded to spindle shell.

Thus, criterion for selecting material for stopper is weldability.

Material selected: Mild steel

It is a soft material, mild steel is easy to weld, whereas high-carbon steels, such as stainless steel, require the use of specialized welding techniques.

Manufacturing process:

Boring

Turning

Facing

4.5 Spindle Shell

Spindle shell and sleeve has surface contact. Stoppers are welded on spindle shell.

Thus, criterion for selecting material is wear and weldability.

Selected material: Mild steel

Easy to weld.

Can be case-hardened to improve wear resistance.

It has a weak resistance to corrosion, mild steel must be painted or sealed to keep it from rusting. Putting a coat of grease or oil on mild steel also helps to protect it from corrosion.

Manufacturing process:

Boring

4.6 Bell-crank lever and Frame

It is mainly subjected to bending failure. Thus, criterion for selecting material is bending strength.

Selected material: Stainless steel

Strength is high.

Corrosion resistance.

Stainless steel also retains strength and shock resistance even at high temperatures.

Stainless steel has excellent fatigue and impact resistance.

Manufacturing processes:

Water jet cutting

5. ASSEMBLY, WORKING AND INSTALATION

5.1 Working

Generation of brake force

The input to the actuator is given directly through the engine. Therefore, the actuator revolves with the same speed as the engine. As the arms of the actuator are coupled to the spindle, that generate a centrifugal force due to their self-weight. This force is transmitted to the other end of the arm. Here the arm is in contact with the sleeve and thus the centrifugal force is transmitted to the sleeve.

The arm is actually a bell-crank lever pinned at its centre. As the mechanism gains speed the upper half of the arms tends to move outward pushing the other half of the lever upward. Thus, imparting the sleeve with a translating motion along the vertical axis. The sleeve is connected to a spring with help of a linkage. As the sleeve travels, the spring travels with the same rate. The force acting on the spring is the centrifugal force.

The spring is initially compressed and is connected to the brake wire. When the actuator is at rest the spring imparts a tension in the brake cable. The cable is connected in such a way that when the actuator is set in motion, that is, when the engine starts, the spring gets compressed and the brake cable gets slacked. This releases the tension in the spring and hence the parking brakes are disengaged.

5.2 Installation

Mounting

The idle place for mounting the mechanism is near the engine. The spindle of the actuator is given input directly from the engine with help of a belt pulley transmission system.

The crankshaft of an engine is extended from one side to provide power to the AC compressor. This is the optimum and the most feasible point of sensing the engine speed and extracting the required power. If this shaft is further extended by a length equal to the thickness of the pulley plus a safety clearance, the driver pulley or the input pulley can be mounted here. The input pulley of the actuator can be mounted on this shaft. The rest of the mechanism can be mounted on the side of the engine such that the driver and the driven pulley are in the same plane. The brake force generated can be transferred with the help of a cable to the parking brake drum.

5.3 Cost of manufacturing and experimental set-up

Table 5.1 Cost of material and manufacturing

Sr. No.	Part name	Cost of material in ₹	Cost of manufacturing (in ₹)	Total cost (in ₹)
1	Stopper	15	-	15
2	Sleeve	20	-	20
3	Spindle	10	-	10
4	Spindle shell	8	-	8
5	Bush	10	15	25
6	Bell crank arm	20	175	195
7	Bell crank pin	5	5	10
8	Frame	20	175	195
9	Lever	10	-	10
10	Spring	-	30	30
11	Spring support	10	15	25
12	Belt	60	-	60
13	Pulley	200	-	200
14	Bearing	75	-	75
15	Brake cable	110	-	110
16	Motor	550	-	550
Grand total				1548

The total cost of manufacturing does not include the cost of braking assembly as we have used an existing braking assembly for demonstration and experimental purposes.

6. CONCLUSION

The actuator mechanism designed and manufactured serves the purpose of generating the required braking force without the use of any electronic or pneumatic system. The automatic parking brake has an edge over the existing manual and electronic parking brake system.

Firstly, the automatic parking brakes engage and disengage instantaneously, just by sensing the engine speed unlike other mechanism where either a lever has to be pulled of a button has to be pressed. The actuator mechanism used in the automatic parking brake is an autonomous system and uses no external power source. Rather it uses the power available at the engine idling which anyways goes to waste.

Moreover, the weight of the actuator mechanism is a much less than the actuating mechanism of the mechanical as well as electronic parking brake. This eventually improves the overall performance of the vehicle as total mass of the vehicle is reduced by a small percentage. This is an added advantage served by this mechanism over others.

Lastly, the overall manufacturing and installation cost of the automatic parking brakes is much lower than any existing parking brake system. The main reason for a low manufacturing cost of the automatic parking brakes is that the use of any electronic sensor or any electrical actuator like motors is avoided. As the system is completely made of mechanical components and linkages, the reliability of the parking brake is also high.

7. FUTURE SCOPE

7.1 Applications

1. The actuator mechanism can be used in other mechanical applications as well. One of the application is lift. The brakes of the lift can be engaged using this actuating mechanism. This eliminates the use of motor end electric power to generate the required force.

The actuating mechanism developed is a force regulating mechanism. Therefore, this mechanism can be used to damp the vibrations in the engine at every rpm. This is possible when the actuator is combined with the tuned vibration absorber set up. The tuned vibration uses a motor which runs at the rpm equal to the natural frequency of the system. The motor excites the system to its natural frequency. A spring mass system is attached to the system with a suitable spring stiffness and mass. This spring mass set-up is attached such that it absorbs the vibration of the system. Every system has a different natural frequency and needs an individual set of spring mass system to absorb the vibrations. The applications of the actuator help us to generalize a particular setup to absorb the vibrations of system at different frequencies using a single spring. The actuator mechanism can be used to sense the motor speed which is equal to the natural frequency of system. The actuator will apply a proportional force such that the vibrations will be absorbed using a single spring.

2. Another modification that is possible is installation of an advanced belt drive, as shown in Fig. 7.1. This transmission system consists of two pulleys, one of the pulley that is mounted on spindle of the actuator is a tapered pulley, while the second pulley is regular pulley.

The belt used in this case in flat belt as the belt has to slide over tapered pulley, the belt is controlled or shifted by a de-railer which is connected to the spring of actuator mechanism. Now as the input rpm of driver pulley increases the rpm of actuator also increases, the actuator further tends to compress the spring. The de-railer is connected in such a way that when the spring compresses, the belt is pushed over the pulley. Due to this, the diameter of driven pulley increases as the belt slides over the tapered area. As a result of this, rpm at the actuator end reduces. Hence this helps in regulating the speed of actuator.

This mechanism can be used where fluctuation in speed is high and also the range of speed is high.

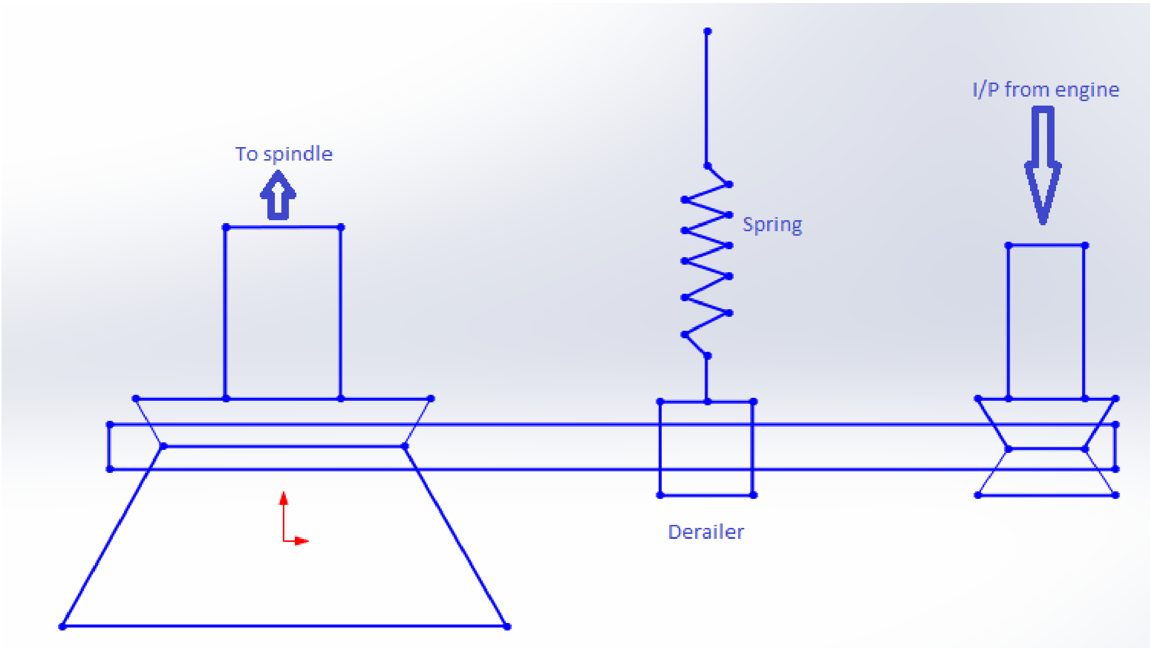


Fig. 7.1 Modification in the actuator mechanism

7.2 Cost estimation

The cost estimation is according to an estimated quotation given by 'Unde Ancillaries and Toolings' in Aurangabad. The quotation included the final cost of every part per thousand orders placed.

The cost estimation of spring was given by a local spring manufacturer for grade-II spring steel.

The cost estimation of belt and pulley was given by a local dealer.

The cost estimation of water-jet cutting was taken from Kakade laser cutting Pune.

Table 7.1 Cost estimation

Sr. no.	Part name	Estimated cost/1000 units manufactured in ₹
1	Stopper	7-10
2	Sleeve	10-13
3	Spindle	6-8
4	Spindle shell	6-8
5	Bush	10-12
6	Bell crank arm	125-140
7	Bell crank pin	8-10
8	Frame	130-150
9	Lever	10-12
10	Spring	20
11	Belt	40
12	Pulley	70-85
13	Miscellaneous	30-50
Grand total		472-558

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