CONTENTS.

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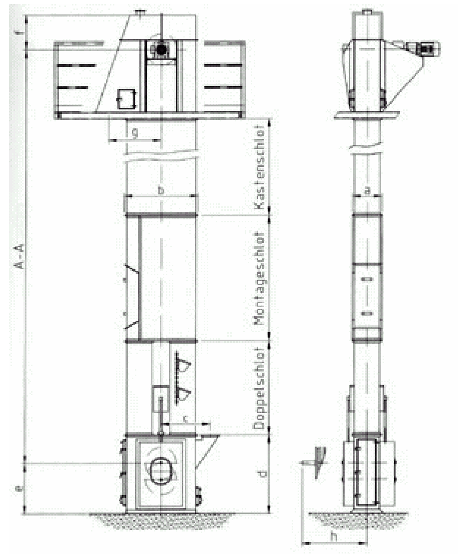
PURPOSE OF BUCKET ELEVATORS.



Bucket elevators are used to lift bulk materials from one height to another. They are a reliable and well-proven piece of equipment.

METHOD OF OPERATION.

Bucket elevators operate by using an endless belt or chain on which rectangular buckets are mounted. The belt or chain revolves between a top and bottom pulley and the buckets move with it. At the bottom the buckets pick up product fed into the elevator boot and at the top the product is discharged as the bucket turns downward over the head pulley.

TYPES OF BUCKET ELEVATORS.

Bucket elevators come in several standard forms with numerous variations to suit the characteristics of the products being moved.

The most common forms of bucket elevator are -

- centrifugal discharge where the speed of the belt around the top pulley flings the product out of the bucket,
- positive discharge, for product requiring slower, less aggressive handling, where a snub pulley below the top pulley orients the buckets downward for emptying,
- continuous discharge, for large lumpy products or very friable products, where the buckets are placed one above the other in close contact with each other, and
- pivoted bucket for transporting materials horizontally.

Along with each type of elevator, different styles of buckets have been developed which better suit the elevator or the materials to be handled.

UNDERSTANDING THE SERVICE DUTY, CONDITIONS AND ENVIRONMENT.

Specify the duty of the belt bucket elevator. What volume or weight of product must it transport in a given time? Determine where it will be located so you can factor the local environment and its effects in your decisions. It is important to know if a lot of dust will be present, or whether there is water present, or whether there are chemical fumes and vapour present.

What height and distance changes are required to move the product? Does the bucket elevator also have to be inclined?

What power supply will be available? Find out the electrical voltage and current capacity.

How will the product be fed into the feed chute? Will an operator be required to control the feed rate or will it be automatically fed to the bucket elevator? What level of control system will be required?

Dust is generated within the elevator by the bucket loading process. Dust can be extracted from the bucket elevator by dust collection systems where necessary. Use methods of dust removal that allow entrainment air to be drawn through the elevator to suspend the dust in the gas stream.

Should an explosive situation arise it will be necessary to design for it. This will include installing bursting panels venting to a safe place and possibly pressure and temperature sensing instrumentation to detect high-risk conditions. The selection of materials suitable for an explosive environment will also be required. As will consideration of static charge build-up control.

Grounding Rod in the Earth

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Chain and sprocket drives are preferred to vee-belt and pulley drives because of their more positive transfer of power. Setting the motor current overload protection to the upper limit of the motor accommodates overload situations.

The selection of the gearbox sprocket size is dependent on the maximum allowable torque. This value can be found from the gear motor manufacturer's catalogue. Once the limiting torque at the gear motor output shaft is known the allowable force for different sprocket sizes can be calculated from the equation $T = F \cdot r$ where

F = force (N) and r = sprocket or pulley radius (m).

Select a sprocket size that is well within the torque rating of the gear motor and has more than 20 teeth. A lesser number of teeth cause excessive forces in the chain links as they come around a tight radius. Less torque is needed with a larger sprocket radius on the gearbox output shaft.

CALCULATE POWER REQUIRED

$$Power(kW) = \frac{2 \cdot \pi \cdot N \cdot F \cdot r}{60 \cdot 1000 \cdot \eta} = \frac{T \cdot \omega}{1000}$$

Where N = revs per minute
F = force at outer edge of the head pulley (N)
r = radius to force (m)
T = torque (Nm)
η = drive efficiency
ϖ = radians per second

The load on the belt results from the weight of product lifted plus the dredging drag as the bucket scoops up the product. A duty factor is used to accommodate start-up loads.

Belt Load = (total bucket load + dredge load)

The bucket load is the sum of the loaded buckets on the upward side. The dredging load can be estimated either by adding an equivalent length (5m for continuous buckets, 12m for spaced buckets) to the belt or by use of the following formula.

Dredge load (N) = $\frac{90 \cdot W_b}{P_s}$

where W_b = weight of material in each bucket (kg)
P_s = Bucket spacing on belt (m)

A quick check on the load can be done using the formulas for work and power. W = F.s (Nm) and P = W/t = F.v (W).

The first iteration gearbox output RPM can be determined from the knowledge of the head pulley RPM and use of the 3:1 sprocket reduction suggested above.

The head pulley speed is 38 RPM. A 3:1 reduction produces 114 RPM at the gear motor output shaft. Check the gear motor ratios available from the manufacturer and select the closest next higher shaft speed gearbox.

Often it is necessary to choose a sprocket size and number of teeth and then to confirm the selection through an iterative process of checking calculated against allowable torque.

Start with a 25-tooth ½" simplex chain 101 mm diameter sprocket on the gearbox output shaft and a 76-tooth 307 mm diameter sprocket on the head pulley.

The selection of sprockets and chain will be confirmed later.

CALCULATE POWER REQUIRED

The linear height of the bucket elevator is 5.5 m and bucket spacing is 0.7 m. This means there are 16 buckets in total, with 8 buckets on the upward and 8 on the downward legs.

The load from the material weight is calculated by multiplying the bulk density of the product by the volume in each bucket by the number of buckets.

Bucket load = $L_b = 1700 kg/m^3 \cdot 0.0005 m^3 \cdot 8 \cdot 9.8 = 67N$

The dredging load = $\frac{90 \cdot 1700 kg/m^3 \cdot 0.0005 m^3}{0.7m} = 109N$

Total pulley load = (67 N + 109 N) = 176 N

This load acts at the centre of the buckets, which have a projection of 100 mm. The radial distance to the bucket centers is 150 mm + 50 mm = 200 mm

Power pulley = $\frac{2 \cdot \pi \cdot 38 \cdot 176 \cdot 0.2}{60 \cdot 1000 \cdot 0.98} = 147W$

As a check on the calculation -

To lift 5,000 kg/hr to a height of 5.5 m allowing for 50% efficiency overall.

W = $\frac{5000 \cdot 9.81 \cdot 5.5}{0.5} = 540 kNm$

$P = \frac{W}{t} = \frac{540,000}{3600} = 150W$ (which is close to the previous answer considering the actual efficiency is unknown).

CONFIRM DRIVE ARRANGEMENT POWER

The load on the motor is transferred through the drive from the head pulley. Simple ratio calculations back to the gear motor shaft will allow determination of the torque at the output shaft. This torque is then compared to the allowable torque to confirm the suitability of the gear motor.

The power through the gearbox must be increased in accordance with -

- The manufacturer's service factors requirement for intermittent operation and shock loading.
- Drive efficiency.

With the power through the drive train known, the chain supplier can confirm the chain selection or calculations performed using appropriate formula.

DETERMINE PULLEY DRIVE SHAFT SIZE

The drive shaft size is calculated to handle the stresses generated by a bogged or jammed conveyor. Allowance is made for stress concentrations causing metal fatigue and service factor corrections are also applied. The diameter of the shaft is selected so that the stresses are well within the shaft material's metallurgical capacity.

By this stage initial dimensioned drawings can be sketched using the information compiled from the previous calculations.
Commence by constructing a free-body diagram of the head pulley located in its bearings with the drive sprocket mounted at the drive end. The head pulley will be mounted to the shaft using hubs at each end. This allows the uniform load produced across the pulley by the belt to be drawn as point loads on the shaft at the mid point position of each hub.

The position and orientation of the gearbox drive has not yet been determined. It is best to design for the loading arrangement that produces the greatest stresses and size the shaft accordingly. This permits the gearbox to be located in any orientation in future.

The loads on the shaft are its own self-weight, the belt and bucket weights, the belt tension load (from product weight and friction drive requirements) and the drive sprocket force generated by a bogged or jammed conveyor. The bearings counter all these forces and keep the shaft in place.

$Power = (T_1 - T_2) \cdot v$ (Watt)

where T_1 = tight side tension (N)
T_2 = loose side tension (N)
v = belt speed (m/sec)

Also $\frac{T_1}{T_2} = e^{\mu\theta}$ where e = 2.718 (base of natural logs)

μ = Coefficient of friction
θ = arc of contact in radians

The coefficient of friction for rubber on steel is 0.25 and for rubber on rubber 0.35. The arc of contact is 180 degrees for bucket elevators provided the bottom pulley is the same diameter as the head pulley.

CONFIRM DRIVE ARRANGEMENT POWER

Power at the head pulley is 147 W. Torque at the head pulley sprocket is directly proportional to the inverse of the diameters at which the torque acts.

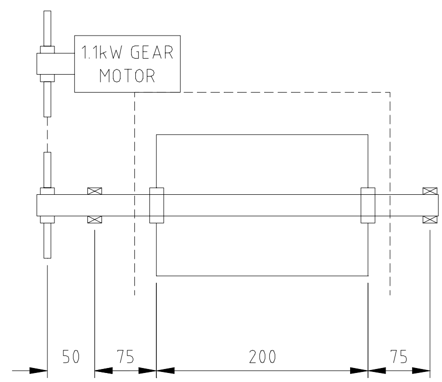
In this calculation the gearbox service factor is 2 and chain drive efficiency is 0.98.

Gear motor power = $\frac{147 \cdot 2}{0.98} = 300W$

The logical choice is to select a small 0.55 kW or 1.1 kW 4-pole motor. For the calculation use a 1.1 kW motor, as this will permit altering sprocket sizes if operating duties change in future.

DETERMINE PULLEY DRIVE SHAFT SIZE

The conceptual sketch for the head pulley is shown below.



The forces are oriented in the vertical, including the drive sprocket force. This arrangement produces the highest loads on the shaft. The gearbox can be oriented in the horizontal. Such an arrangement would not have vertical loads at the sprocket. The sprocket load would then be at 90 degrees to the belt tension. This would produce less overall stress in the shaft and a smaller shaft could be used. However in this design the worst-case orientation will be used.

It is necessary to determine the tension in the belt to lift the full buckets and overcome the dredging load.

The power through the head pulley is 1.1 kW.

$$T_1 = \frac{\frac{P}{v}}{1 - \frac{1}{e^{\mu\theta}}} = \frac{\frac{1100}{1.2}}{1 - \frac{1}{e^{0.25 \cdot \pi}}} = 1.68kN$$

$$T_2 = 0.77kN$$

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The bearing at the other end of the shaft is the loose bearing and moves in its housing to permit the shaft to grow or shrink as the temperature changes. The same arrangement applies to the bottom pulley.

Where a bucket elevator is transporting basically dust free product in a moisture-free environment it would be acceptable to choose maintenance free bearings with integral dust and moisture seals. These bearings come greased for life and have no need for additional lubrication. It would be best to provide an external seal in the bearing housing as well to provide a second level of protection for the bearing.

Where there is dusty product and/or moisture (steam, rain, hose down spray, fog, snow, condensation, etc) it is best to choose a bearing and housing that allows purging with fresh grease. As the fresh grease is pumped in, the old contaminated grease is pushed out and the rolling elements get clean lubricant to run in.

This also means that someone has to pump the grease in and that it has to be done on a regular basis without fail. If necessary clearly appoint someone competent who is responsible to insure the greasing is done. Greasing is a critically important job to the success of your equipment and the people doing the greasing really need to understand lubrication and the important part that they play in keeping plant and equipment operating properly.

BEARING HOUSING SELECTION AND POSITION.

On the lower pulley and the non-drive end of the top pulley use bearing housings with only one shaft entrance and a bolted and gasketed cover at the other. That means there is only one way for contaminants to enter. Why have two places that can give you problems? Don't use housings with end cover inserts pushed into place, they can also be easily popped out and let dirt/moisture into the bearing. Only use housings with bolted end covers and make sure there is a gasket to stop fine dust/ moisture getting in.

If you mount the bearing housing direct to the elevator panels you will find the bearings fail often. As soon as the shaft seal fails the product and dust will enter the bearing. You will never know a seal has failed until the bearing fails. Regular purging with clean grease will extend the time between failures but will not stop the original problem.

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EXPLOSION PROTECTION.

A complete analysis of explosive conditions is beyond the scope of these notes. Though a brief overview is useful to the designer, user and maintainer.

Should explosive products, like grains and flammable solids such as coal and sulphur, need to be elevated it will be necessary to design for the high likelihood of explosion. Recognised practice in explosive situations is to use twin-leg bucket elevators where the upward leg is in a separate enclosed housing to the downward leg. The two legs come together at the top to discharge and at the bottom to pick-up product.

It is likely bursting panels venting to a safe place need to be installed, and possibly pressure and temperature sensing instrumentation to detect high-risk conditions.

Selection of materials of construction and use of rigid structural designs suitable for an explosive environment are also required.

The important aspect of explosion control is to prevent the 'Fire Triangle' ingredients (fuel, oxygen, and ignition energy) from occurring at the same time.

The fuel is always present in the product itself. Usually it is the dust that is most explosive. If the dust concentration is kept lower than the amount needed to sustain a flame then even if an ignition source is present no explosion is possible.

Oxygen can be displaced by inert gasses such as carbon dioxide or nitrogen. But inert gasses do not support human life and their use introduces other dangers.

The most common method to prevent explosions in dust collectors is to prevent the build-up of ignition energy. This can either be from a spark or from local high temperatures. Sparks occur because of static charge build-up or parts making contact. Local high temperatures are the result of rubbing and wear.

Having an electrical path connecting the electrical charge to earth controls static. This means only using materials with electrical conducting properties for the bucket elevator construction and then electrically