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Design Aspects of a Motorised Travelling Tripper

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Abstract— Industries and factories utilise conveyor systems for transport of goods, bulk materials and manufactured parts from place to place in order to save money, time and man power. Time and power are the governing factors for any industry or business firm to excel in the present market. Conveyors are efficient and prevent loss of excess material for transport over enormous distances. Travelling Trippers usually operate at the discharge ends of the conveying systems. Optimisation of these trippers will help arrest the power consumption and will result in better outputs for the efficient working of the system.

Index Terms— Tripper, Motorised, Motorised Travelling Tripper, Conveyors, Bulk Material, Bulk Material Handling Equipment, Bulk, Conveying System, Belt Conveyor, Industrial, Power Plants, Mines, Stacking.

1 Introduction

CONVEYOR BELTS are used all over the world for conveying various bulk materials over long distances, at minimum expenses. Use of conveyor belts helps optimise:

- Fuel
- Energy
- Money
- Time
- Output

These five verticals matter the most in today's world, to obtain the required demand of power. Conveyors are used in various industries which include bulk material handling like; Food, Medicines, Power Plants, Cement Plants, Steel Plants, Sugar Refineries, Industrial Assembly Lines, Packaging Industries etc.

Trippers are an integral part of the conveyor system, which simplify the multiple discharge requirement of bulk material being conveyed. Trippers include of an elevated platform consisting of idlers mounted on a supporting structure. The material is further discharged into chutes, so as to convey the material to another conveyor or storage area. Trippers are basically distinguished in two types:

- Fixed Trippers
- Travelling Trippers

As the name suggests, fixed trippers are stationary, whereas the travelling trippers are movable [4], and can be utilized for discharge in multiple feeding points.

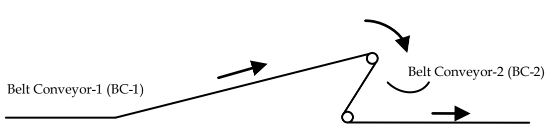

Fig. 1: Fixed Tripper

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Travelling Trippers are further distinguished according to the method of propulsion as:

A. Belt Propelled Travelling Trippers
B. Motorised Travelling Trippers

A. Belt Propelled Trippers:

In this kind of trippers, the power is derived from the conveyor belt through a pulley on the tripper and to the tripper wheel. They are used mainly for slow start and stop of the tripper arrangement.

B. Motorised Travelling Trippers:

Motorised Travelling Trippers, as the name suggests are powered by motors, which are coupled with the wheels of the tripper, to facilitate its movement along the rails.

2 Design Factors

While considering a motorised travelling tripper, it has to be noted that every tripper car handles a large amount of components simultaneously. Hence, the motors have to provide a thrust enough to push the machine forward, considering the weights of all the components. The forces and moments of the various moving and rotating parts have to be considered for calculating the balancing forces of the tripper car.

All the components in a tripper play a vital role in its proper functioning and movement.

To consider the complete weight of a tripper car, the weights of the following components need to be taken into count:

- Drive Motors.
- Couplings.
- Gearbox. Brakes.
- Wheels.
- Belt (Part over tripper assembly).
- Bulk Material.
- Carrying Idlers.
- Impact Idlers.
- Tripper Car Complete Structure.
- Pulleys.
- Walkways.
- Handrails.
- Ladders.
- Electrical Panel.

- Cable Reeling Drum with Motor & Gearbox.
- Weight of Maximum 3 People overboard.
- Flap Gate arrangement with Actuator.
- Bunker Slot Sealing Arrangement.
- Rail Clamps.
- Rail Buffers.
- External Scrapers.
- Complete Chute.
- Hold Down Pulley.
- Miscellaneous Items like Bearings, Bolts, Nuts, Pins etc.

3 Design Philosophy

Along with the complete weight of the tripper, various factors need to be taken into consideration. These factors govern the stability and fluent working of the Motorised travelling trippers.

The factors to be taken under consideration [2] include:

- Wheel to Rail Friction Factor.
- Belt to Idler Friction Factor.
- Belt to Drive Pulley Friction Factor.
- Material to Belt Friction Factor.
- Belt Cleaner to Belt Friction Factor.
- Radius of Curvature of Belt.

Wheel to rail friction is mandatory to calculate the resistance the tripper might have to overcome while travelling.

Belt to Idler & Belt to Drive Pulley Friction Factors are essential for calculating the Total Power used for driving the belt on the tripper.

3.1 Wheel to Rail Friction Factor (µ1): This factor would depend on the relative friction between the two surface materials. It would vary with the different types of materials used and the surface finish of the wheels and rails.

3.2 Belt to Idler Friction Factor (µ2): The belt to idler friction factor is supposed to vary between 0.3 and 0.4.

3.3 Belt to Drive Pulley Friction Factor (µ3): This factor can vary from 0.4 to 0.45. This factor also depends on the atmospheric conditions of the trippers.

3.4 Material to Belt Friction Factor (µ4): Various different kinds of materials are conveyed from the tripper assembly. All these materials will have different friction factors, which would vary because of the density, lump size, percentage of fines, moisture content and the surrounding environmental conditions. In case of dry coal, this friction factor is considered to vary from 0.5 to 0.7.

3.5 Belt Cleaner to Belt Friction Factor (µ5): Belt Cleaners are required for keeping the belt surface free from sticky material which may further damage the belt as well as the pulleys. The Belt cleaner imposes some pressure on the belt. This pressure may be anything between $3x10^4$ N/m^2 to $3x10^5$ N/m^2. The friction between the belt and cleaner would vary from 0.6 to 0.7.

Other considerations which influence the power selection of the motor for tripper are as follows:

- Travel gradient resistance, general or localized as per track elevation tolerance.
- Cable reeling drums or power supply system resistance.
- Bunker slot sealing resistance.
- Wind resistance, particularly when open to sky.
- Resistance arising by travel wheel motion on rails: The usual tripper (which is not part of large machine like stacker or stacker-reclaimer) has wheel fixed on live shaft running in bearing blocks. These shafts, not being 100% parallel or having differential wear on wheel diameter results into crabbing of tripper, when fitted with cylindrical periphery wheels (simple double flange wheel without taper). This means tripper tends to steer-off rails, which is prevented by flanges. The friction between wheel flanges and rail will result into resistance to the tune of 10% of tripper weight in worst case when all flanges are rubbing. This can be avoided by about 5% taper on wheel periphery.

4 Approach For Design

For designing a travelling tripper [1], designers have to first make the layout for tripper. The first layout is view perpendicular to the head pulley of the tripper. This will show the tripper head pulley and the arrangement of chute. The chute is part of the tripper and hence it is a moving item. This chute should have a clearance from the rail and fixed structures by a few inches. The cross section as said above will decide the height of tripper (tripper lift). Having known the tripper lift, you have to choose the inclination for tripper zone, as allowed for the material being conveyed. You can make the tripper elevation view using the above lift, inclination and allowable concave radius based on the belt tension.

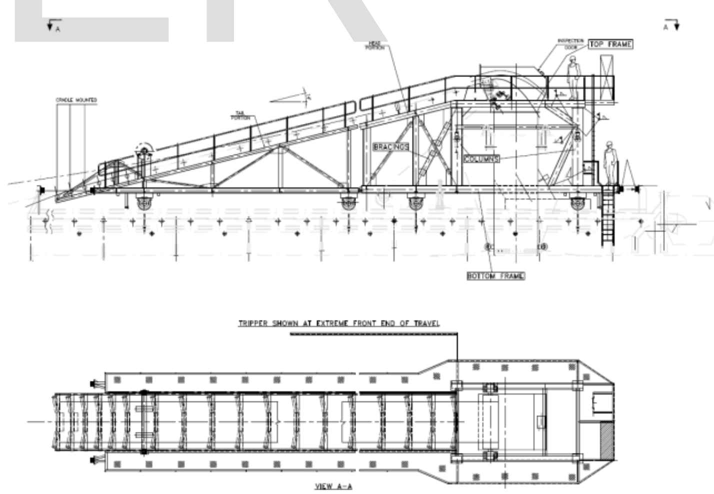

Fig. 2: Conceptual Elevation & Top view of a Motorized Travelling Tripper.

The tripper elevation view as fixed above is to be supported by a suitable number of wheels. The fundamental need of the design is that there should be positive load on all wheels in all situations (if load becomes negative, then tripper becomes unstable). Also, one has to see the variation in wheel load due to deformation of the frame in conjunction with manufacturing and installation tolerance of tripper itself and the supporting rails.

5 Structural Analysis

The tripper shall comprise of a four wheeled main unit with a trailer section that is pin supported from the main unit and supported by two non-driven wheels at the other end. The trailer shall serve to support the leading tripper carry idlers. In no case shall three wheel sets be supported from a rigid frame.

The tripper shall be mounted on single flanged wheels and motorised for a longitudinal travel velocity, in forward or reverse direction, of 0.5 m/sec on rails running parallel to the conveyor.

The wheels shall be fabricated from cast steel and designed in accordance with the crane design codes.

Drive shall be transmitted through the two most heavily laden wheels. The drive shall be designed to accelerate and stop the tripper without wheel slippage. The coefficient of friction between the rail and wheel shall be based on wet conditions. The drive shall be designed to account for the variation in loads with conveyor loading, direction of travel and also considering a stationary conveyor.

A power release brake shall be incorporated into the drive to hold the tripper in a fixed position when no power is being supplied to the drive motor, then automatically release when power is re-supplied. The brake shall be designed to stop the tripper without wheel slippage during all possible operating conditions, including a broken conveyor belt. Actuated wheel clamps shall be fitted to the tripper where the drive brake is not suitable.

The conveyor belt line along the tripper shall have one or more radii to suit the design criteria for any tripper location, belt cover condition or conveyor loading.

Belt lift-off during conveyor start-up will not occur with the belt loaded at 20% capacity or more.

1. The belt does not lift off the last three idlers preceding the tripper head pulley during an empty start.
2. Belt edge buckling does not occur at any position along the tripper during normal loaded running and stopping.

The tripper shall be fitted with a belt hold down roller to limit belt lift during empty running. The roller shall feature two spaced wheels to avoid material interference during low conveying rates.

The tripper bend pulley shall be located so that, under any condition as described above, the belt:

1. Does not contact any part of the tripper such as wheel axles etc.
2. Does not lift off the last three idlers preceding the conveyor drive pulley.

The conveyor belt line shall be designed to prevent belt lift up into the loading skirts under all possible operating conditions. As a guide, the loading area should be inclined up towards the tripper.

6 Case Study for Calculation

The chute for the tripper can take many forms. It can discharge to one or both sides, or it can include a flap valve to direct the material to either side or back on to the belt.
The tripper can be moved in the following ways:

1. By hand, through gearing or a rope winch.
2. By power from the conveyor belt, by means of a friction drive engaged by hand.
3. As in the previous case, but having the drive reversed automatically on reaching the end of the required travel.
4. By a separate motor.

Which method is chosen depends on how often the tripper is to be moved and how big it is.

Model Calculation for Travelling Tripper Travel Drive Power (for Motor propelled Tripper):

TABLE 1
Values & Notations of Factors Required for Tripper Power Calculations (typical)

Sr. No.	Description	Notation	Value	Unit
1	Machine Design Capacity	Q	2100	TPH
2	Belt width	BW	800	
3	Material Density	ρ1	800	KGf/Cu.M
		ρ2	1000	KGf/Cu.M
4	Gradient of Track	s	1/100	
5	Angle formed by Track	α	0.57	Degree
6	Tripper Conveyor Speed	Vb	3	M/Sec
7	Weight of Machine	Wm	29	Tonne
8	Height of Material Lift	H	3.9	M
9	Machine Travel Speed(Max)	Vm	10.5	M/min
10	Acceleration**[3]**	a	0.1	M/sec2
11	Drive Efficiency	η	70	%
12	No. of Travel Drive Motor		2	Nos.
13	Inclined Belt length in Tripper	Lt	16.5	M
14	Wind Pressure	q	0.25	KN/m2
15	Wind Velocity	Vw	0.5	M/Sec
16	Effective Wind area	A	20	m2
17	Wheel Diameter	D	500	mm
18	Aero Dynamic Coefficient	C	1.3	
19	Motor Margin	F1	1.2	
20	Frictional Coefficient of Bearing	μ	0.025	Mfg. catalogue

Sr. No.	Description	Notation	Value	Unit
21	Bearing Inner Diameter	d	130	mm
22	Friction factor of Wheel Flange	μw	0.002	
23	Lever arm of Rolling resistance (based on experience)	f	0.5	mm
24	Frictional resistance	fr	0.02	
25	Weight of rotating parts (16 nos. @ 48 Kg. / M)	ql	768	N/m
26	Live load on belt	qm=Q/Vb	1907.5	N/m

CALCULATIONS:

Resultant coefficient of Friction (μf) is given by
μf = (2/D) x [f+ (μ x d/2)] + μw = 0.0105

1.1 Power required due to Frictional resistance (Pf)
=WmxμfxVm/η
=0.5329 KW

1.2 Power required due to Wind Force(Pw)

1.3 = q x A x C x Vw/η
=4.64 KW

1.4 Force required to overcome slope(Fn)
= WmxSin (α)
=2.83 KN

1.5 Power required due to slope(Pn)
=FnxVm/η
=0.707 KW

1.6 Force to achieve desired acceleration Fa
= Wm x a/g
=2.9 KN

1.7 Power to achieve desired acceleration(Pa)
=Fa x Vm/η
=0.725 KW

1.8 Power required due to Tripper Conveyor material resistance(Pr)
= (Q x H x Vm)/ (Vb x η)
=1.3271 KW

1.9 Power required due to conveyor rotating parts friction Pc
= fr x Lt x (qm+ql) x Vm/η
=0.5367 KW

1.10 Total Power consumption Ptotal
Pt=Pf+Pn+Pa+Pr+Pc+Pw
=8.5 KW

1.11 Motor Power (Pma)
= Ptotal/n
=4.25 KW

1.12 Selected Motor (Pm)
= (Pma) x1.2
=5.1 KW
∴ Travel motor selected 2 x 5.5 KW, 1000 RPM.

Hence, the standard motor selected for the motorised tripper travel is 5.5kW. Two motors are used, as they would be installed on both the sides of the tripper, so as to nullify any imbalance of forces while travelling. To minimize the overhang of belt, the tripper structure has been designed with concave and convex curves.

Moreover, there are options of drive system. Drives with chain and sprocket; direct drive with hollow shaft mounted gearbox alongwith motor and brake. Direct drive is also given with hollow shaft mounted geared motor with an inbuilt brake.

This machine can be controlled either by local operation from the machine or by remote operation from control station with selector switch.
The machine is usually provided with all safety controls and limit switches, such as over travel limit switch, chute-jamming switch, etc. Trippers are provided with cradle assembly, mounted on the machine to protect the conveyor belt from damage due to the impact of the material being discharged back on it, during the self discharge operation.

7 CONCLUSION

Trippers are important equipments in the Mining industry, the benefits of which are as follows:

i) Extreme Tonnages: Build and maintain large volume stockpiles of bulk material on limited land available.
ii) Quality material: Minimized loader use prevents damaging and expensive stockpile segregation.
iii) Versatile machines: Pile up material on either side and create custom heights, lengths and locations.
iv) No Trucks or Loaders required.

The objective of this paper is to guide the Bulk Material Handling engineers to understand the Motorised Travelling Tripper with the use of simple physics and to avoid the complexities during operation.
The authors wished that this paper would be in good use as well for the beginners and experienced professionals for Bulk Material Handling industry.

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