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Design of Wagon Tippler

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ABSTRACT

Handling humans, goods or other essentials is something omnipresent in our life. An industry in particular requires equipment to handle its raw materials, in-process materials or finished goods. Further, the design and operation of these equipments directly influences the production capacity of the plant. Techno-economic studies reveal that for an industry to survive they require fast and efficient systems for handling purposes. Thereby, the study of such a subject would enable an individual to harness his knowledge.

Freight of raw materials (bulk), inputs of an industry calls for fast and efficient means of transportation. Railways in this aspect have proved to be most versatile. The recent increases in industries related to iron & steel making, fertilizers, power sector necessitate a faster means for unloading bulk loads from railways. This job of unloading wagons is effectively done using a wagon Tippler. A tippler is simply a mechanism used to unload railway wagons by tippling the wagons about an axis. Further, it should be noted that no two tippling mechanisms are exactly the same. This work illustrates a modest attempt to carry preliminary design required for a typical tippler unit. This preliminary design can also be extended for different types of wagons.

Keywords: ***Wagon tippler, Metrials, Goods, Transportation, Design.***

INTRODUCTION

Handling things, people or other essentials is something omnipresent in our life. The same is the case with tones and tones of raw material that is to be brought in or scores of finished products that are to be delivered. This broadens the definition of Material Handling as a science concerning with the transportation and subsequent handling of materials (bulk or piece) from one point to another. The distance of transportation may range from a few metes to thousands of kilometers, with its transfer path spanning over different types of phases with each phase having its own requirements for handling. The equipments used for these tasks of movement and storage within a facility or at a site are referred to as “Material Handling Equipments (MHE)”. They range from the smallest of handcarts to the heaviest of cranes or the sophistication of AGV’s. Besides it contribu tion to simple raw materials handling or automation, MHE attains reverence due to its recent offspring’s in the field of defense, nuclear energy and space exploration.

Importance’s of Materials Handling:

The foremost importance of materials handling is that it helps productivity and thereby increases profitability of an industry. Many enterprises go out of business because of inefficient materials handling practices.

Classification of Materials Handling Equipment

In broad sense materials handling equipment can be classified in to the following five major categories:

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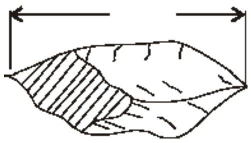
1. Transport Equipment
2. Positioning Equipment
3. Unit Load Formation Equipment
4. Storage Equipment
5. Identification and Control Equipment

Characteristics and classification of materials: Method to be adopted and choice of equipment for a materials handling system primarily depends on the type of material/s to be handled. It is, therefore, very important to know about different types of materials and their characteristics which are related to methods and equipment used for their handling. As innumerable different materials are used and need to be handled in industries, they are classified based on specific characteristics relevant to their handling. Basic classification of material is made on the basis of forms, which are (*i*) Gases, (*ii*) Liquids, (*iii*) Semi Liquids and (*iv*) Solids.

Major characteristics of bulk materials, so far as their handling is concerned are

1. Lumpiness
2. Density
3. Moister Content
4. Fluidity
5. Angle of repose
6. Abrasiveness
7. Strength
8. Corrosiveness
9. Cutting characteristics
10. Stickiness
11. Lumpiness

Lump size of a material is determined by the distribution of particle sizes. The largest diagonal size 'a' of a particle in mm (Fig. 1.2) is called the particle size. If the largest to smallest size ratio of the particles of a lumpy material is above 2.5, they are considered to be upsized



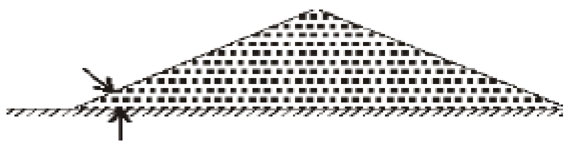
Size of a Particle

Fig 1.1

The average lump size of sized bulk material is = (maximum particle size+minimum particle size) / 2

$$= (a_{max} + a_{min}) / 2$$

Bulk weight or bulk density of a lumpy material is the weight of the material per unit volume in bulk. Because of empty spaces within the particles in bulk materials, bulk density is always less than density of a particle of the same material. Generally bulk load can be packed by static or dynamic loading. The ratio of the bulk density of a packed material to its bulk density before packing is known as the packing coefficient whose value varies for different bulk materials and their lump size, from 1.05 to 1.52. Bulk density is generally expressed in kg/m^3.



Heap Created by a free flowing material

Fig 1.2

Mobility not flow ability of a bulk material is generally determined by its angle of repose. When a bulk material is freely spilled over a horizontal plane, it assumes a conical heap. The angle 'α' of the cone with the horizontal plane is called the angle of repose. Less is 'α', higher is the flow ability of the bulk material. If the heap is shaken, the heap becomes flatter and the corresponding angle of repose under dynamic condition is referred to as dynamic angle of repose α dyn, where α dyn is generally considered to be equal to 0.7α.

Principles of Material Handling: A good materials handling engineer will generally have several years of experience that can be brought to bear on the solution of materials handling problems or the design of materials handling systems. For many years, discussions of principles of materials handling have been published by many experts in the field. The following list has been adapted from two of these sources:

ISSN No: 2348-4845
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1. Eliminate wasteful methods by

- Reducing to a minimum the number of handlings of materials.
- Eliminating unnecessary mixing and subsequent sorting.
- Using mechanical aids to eliminate the use of hand labor in movement of materials.
- Avoiding the unnecessary transfer of materials from floor to workplace or from container to container.
- Increasing the speed of handling.
- Utilizing containers and unit loads.
- Utilizing gravity as a moving force wherever practicable.
- Introducing automatically into the materials handling plan.

2. In laying out the plant:

- Plan a system for materials flow and combine handling with processing wherever possible.
- Provide for continuous or appropriate intermittent flow of materials.
- Provide for the optimal flow of materials between operations and with a minimum of retrograde movement.
- Plant the layout of the work-station area for a minimum of handling of the product.
- Maximize the quantity and size of weight handled.
- Coordinate the overall materials handling throughout the entire plant.
- Provide for safe handling and safe equipment and integrate with the management information and control system.
- Plan for adequate receiving, storage and shipping facilities.
- Make optimum use of building cubage.
- Design adequate aisle and access areas.

Analysis of Materials Handling Problems: It requires establishing an objective, collecting as much factual data as possible, analyzingthedata, applying known principles, and formulating a solution. In collecting the data careful attention should be give to the effect of handling on the product, the present method, and cost factors. Hughes Aircraft described an example of the use of simulation to study

materials handling problem. They describe an effort to combine six storeroom into a single, automated facility. The simulation analysis enables the materials handling and process engineers to identify key interrelationships and dependencies that had to be considered in the new design.

7. General Types of Materials Handling Equipment: Tompkins and White divide materials handling equipment into five classifications. They give the following list but note that numerous variations can exist within each category:

1. Conveyors.
2. Monorails, hoists, and cranes.
3. Industrial trucks.

8. Accounting for Materials Handling Costs: The cost of materials handling arises from two sources: the cost of owning and maintaining equipment and the cost of operating the system. General cost-accounting practice classifies the cost of handling materials as an indirect cost or overhead. This classification is based on the position that the movement of the materials does not contribute to their physical change or add value to them as a product or as a component part thereof.

9. Relation of Materials Handling to Flow of Material and Plant Layout:.

Storage: Material in storage is generally thought to be stationary or idle. But the use of conveyors as storage devices is quite popular. These conveyors may be overhead and constantly moving, yet utilizing ceiling –space storage. Such an installation is pictured in figure 12- 10. Other storage installations may be like the

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skate conveyors shown in figure 12-11b. In one Midwestern furniture plant the complete floor of the finish drying room is covered by a large slat conveyor that moves very slowly: pieces placed on this "floor" at one side of the room are dry when they reach the other side.

Packaging: Whether packaging is or is not a phase of materials handling is to some degree an academic question. The unit load is in itself a "package". Generally speaking, however, the term packaging is used to cover the preparation of the final product for shipment, particularly if the product is a consumer good.

Calculation Of The Average Tippling Speed: The section deals with the basic (preliminary) design calculations required to design a Wagon tippler. A typical rake of 56 wagons (as per S.E. Railways), is taken as basis for calculation.It is assumed that takes about 8 ½ hours for a rake of 56 wagons to be unloaded.

(as specified by S.E. Railways)

Total time available per rake = 8 ½ hours

Time taken for decoupling / coupling or exchange = 1 ½ hours

So, time available for tippling operation = 8 ½ hours - 1 ½ hours = 7 hours

i.e., time available for 56 wagons = 7 hours

$\Rightarrow$ Time available for 1 wagon = $(7\times60)/56 = 7.5$ minutes

This 7.5 minutes time involves, the time for

- Pulling the wagon onto the tippler unit
- Placing the wagon in position
- Tippling the wagon
- Pushing the wagon out (after tippling)

For a typical tippler, it takes approximately 4 minutes for pulling, placing and pushing operations.

$\Rightarrow$ Time available for the tippling operation / wagon = 3 ½ minutes

This is the time each wagon spends at the tippler unit.

The 3 ½ minutes for tippling operation consists of

1. Time tippler rotates in forward direction (t_1)
2. Idle time without rotation, at extreme position (t_2)
3. Time the tippler rotates in backward direction (t_3)

$\Rightarrow$ 3 ½ minutes = $t_1 + t_2 + t_3$

The idle time, t_2 is taken as 20 seconds, it is taken depending on material characteristics,

The time taken for forward and reverse rotation is the same

i.e., $t_1 = t_3$ = 95 seconds

Average angular velocity (ω) = (Angular displacement)/time taken

= (150 x ∏/180)/95

$\Rightarrow$ Angular Velocity, ω = 0.027568 rad/sec

Average tippling speed, N = $60\omega/2\prod$

= 60x0.027568/2∏

= 0.26315 r.p.m.

General design procedure for Spur Gears

. Find the static tooth

Static tooth load (Ws) = f_e .b Π m.y.

Where f_e = Flexural endurance limit in N/m.m.2

b = Face with of gear in mm.

M = module

Y = Luwis form factor.

For safety against breakage,

Ws should be greater than W_D ($W_S > W_D$)

Finally, find the wear tooth end by using the relation,

Wear tooth load (Ww = Dp b. Q.k

Where Dp = Pith circle diameter of Painion in m.m.

b = Face width of the Pinion in m.m.

$Q = \text{Ration factor} \Rightarrow \frac{2 \times V.R}{V.R + 1}$

$V.R. = \text{Velocity Ratio} = \frac{T_G}{T_P}$

K = Load - stress factor (also known as material combination factor) in N/m.m.^{2}

The load stress factor depends upon the maximum fatigue limit of compressive stress, the pressure angle and the modules of elasticity of the materials of the gears. According to Buckingham, the load stress factor is given by the following relatio

$K = \frac{(f_{es})^2 \cdot \sin\varnothing}{1.4} \; (1/E_P + 1/E_G)$

Where f_{es} = Surface endurance limit in N/mm^2

$\varnothing$ = Pressure angle

Ep = Young's Modulus of the material of the pinion in N/ mm^2

The wear load (Ww) should be less than the dynamic load (W_D). i.e. = Ww > Wd

GEAR BOX DESIGN:

STAGE - 1:

Input speed, speed of pinion (N_P) = 1000 r.p.m.

Speed reduction ratio = 6

Output speed, speed of gear (Ng) = $\frac{1000}{6}$ = 166.667 r.p.m.

Assuming minimum number of teeth on pinion (Tp) = 18

For 20 ° full depth involute)

Number of teeth on Gear (T_G) = Tp x reduction ration

= 18 x 6 = 108

Considering a module (m) = 8 mm

Diameter of Pinion (Dp) = m x Tp = 8 x 18 = 144 mm

Diameter of Gear (D_g) = m x Tg = 8 x 108 = 864 mm.

Here both pinion of gear wheel are assumed to be made up of same material, so pinion is weaker than the gear wheel.

Tangential tooth load (W_T) = $\frac{P}{V}$ x Cs

Where power (P) = 100 x 10^3 W

Velocity (V) = $\frac{\Pi\, Dp\, Np}{60} = \frac{\Pi \times 144 \times 1000}{60}$

= 7539.8223 mm/sec.

Service factor (Cs) = 1.25 = 7.539 m/sec.

$W_T = \frac{100 \times 10^3}{7.539} \times 1.25$

$= 16.57 \times 10^3$ N

Dynamic tooth load (W_D) = $W_T + \frac{21v\,(b.c + W_T)}{21\,v + \sqrt{(b.c + W_T)}}$

Where W_T = Tangential tooth load = 16.57 x 10^3 N

V = Velocity = 7.539 m /Sec.

b = Face width = 80 mm

c = Dynamic factor = 450.68 N/ mm^2

(for 20^0 full depth and steel too steel)

$W_D = 16.57 + \frac{21 \times 7.54\,(8 \times 450.68 + 16.57 \times 10^3)}{21 \times 7.54 + \sqrt{(8 \times 450.68 + 16.57 \times 10^3)}}$

$= 38.07 \times 10^3$ N

Static load (or) Beam strength (Ws) = f_e .b. Π m.y.

Where f_e = Flexural endurance limit = 260 N / mm^2

b = Face width = 80 mm

m = Module = 8 mm

y = Lewis form factor for Tp = 18 and 20^0 full depth

involute teeth.

$= \frac{Y}{\Pi} \Rightarrow \frac{0.308}{\Pi} \Rightarrow \frac{0.098}{\Pi}$

$\therefore$ Ws = 260 x 80 x Π x 8 x 0.098

= 51.23 x 10^3 N

Since Ws > W_D , then design is sage against breakage.

Wear tooth load (Ww) = Dp. b. q. k

Dp = Diameter of the Pinion = 144 mm

b = Face width of the Pinion = 80 mm

Q = Ratio Factor

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$= \frac{2 \times V.R}{V.R. + 1} = \frac{2 \times 6}{6 + 1} = 1.714$

K = Load - stress factor

$= \frac{(f_{es})^2 \,.\, \sin \varnothing}{1.4} \; (1/E_P + 1/E_G)$

f_{es} = Surface endurance limit = 910 N/ mm^2 (taken from table)

$\varnothing$ = Pressure angle = 20^0

Ep = Young's modulus for the material of the pinion = 2x10^5 N / mm^2

E_G = Young's modulus for the material of the gear = 2x10^5 N / mm^2

$\therefore K = (910)^2 . \sin 20^0 \; \frac{(1/2\times10^5 + 1/2\times10^5)}{1.4}$

= 2.02 N/ mm^2

Wear tooth load (Ww) = Dp . b. Q. K

= 144 x80 x1.714 x2.02

= 39.88 x10^3 N

Since Ww > W_D, then design is safe against wear.

For 20^0 Full depth Involute.

Taking module = 8 mm

Addendum	= 1m	=	8 mm
Dedendum	= 1.25mm	=	10mm
Work Depth	= 2m	=	16 mm
Minimum total depth	= 2.25m	=	12.56mm
Total thickness	= 1.5708m	=	12.56mm
Minimum Clearance	= 0.25m	=	2mm

Pinion and End Ring design:

Input speed, speed of Pinion (Np) = 4.62 r.p.m

Speed Reduction ratio $= \frac{3800}{216} = 17.592$

Output speed, speed of gear (Ng) $= \frac{4.62}{17.592} = 0.262$ r.p.m.

Assuming minimum number of teeth on Pinion (Tp) = 18

Number of teeth on gear (Tg) = Tp x reduction ratio

= 18 x 17.592

= 317

Considering a module (m) = 40 mm

Face width (b) = 10 m = 400 mm

Diameter of Pinion (Dp)= m x Tp = 40 x 18 = 720 mm

Diameter of Gear (Dg = m x Tg = 40 x 317 = 12,680 mm

Here both pinion of gear wheel are assumed to be made up of same material, so pinion is weaker than the gear wheel.

Tangential tooth load (W_T) $= \frac{P}{V} \times Cs$

Where P = Power = 100 x 10^3

$V = \text{Velocity} = \frac{\prod Dp\, Np}{60} = \frac{\prod \times 720 \times 4.62}{60}$

=174.16 mm/Sec

= 0.174 m/Sec.

Cs = Service factor = 1.25

$W_T = \frac{P}{V} \times Cs$

$= \frac{100 \times 10^3}{0.174} \times 1.25$

= 717.67 x 10^3 N

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Dynamic tooth factor (Wd) = $W_T + \frac{21v\,(b.c + W_T)}{21\,v + \sqrt{(b.c + W_T)}}$

Where W_T = Tangential tooth load = 717.67×10^3 N
V = Velocity = 0.174 m /Sec.
b = Face width = 400 mm
c = Dynamic factor = 699.74 N/mm ^{2}
(for 20 ^{0} full depth and steel to steel)

$W_D = 717.67\times10^3 + \frac{21\times0.174(400\times699.74+714.67\times10^3)}{21\times0.174+\sqrt{(400\times699.74+717.67\times10^3)}}$
$= 721.30 \times 10^3$ N

Static load (or) Beam strength (Ws) = f_e .b. Π m.y.

Where fe = Flexural Endurance limit = 260 N/mm^2

b = Face width = 400 mm
m = Module = 40 mm
y = Lewis form factor for Tp of 18 and 20 ^{0} full depth Involute teeth
$y = \frac{Y}{\Pi} \Rightarrow \frac{0.308}{\Pi} \Rightarrow 0.098$

Ws = 260 x 400 x 40 x ∏ x 0.098
= 1281.28×10^3 N

Since Ws > Wd, then design is safe against the breakage.
Wear Tooth load (Ww) = Dp. b. Q. k

Dp = Diameter of the Pinion = 720 mm
b = Face width of the Pinion = 400 mm
Q = Ration Factor
$= \frac{2 \times V.R}{V.R. + 1}$
$= \frac{2 \times 17.592}{17.592 + 1} = 1.89$

K = Load stress factor

$= \frac{(f_{es})^2 . \sin\varnothing}{1.4}\ (1/E_P + 1/E_G)$

f_{es} = Surface endurance limit = 770 N/mm2
∅ = Pressure angle = 20 ^{0}
E_P = Young's Modulus for the material of the pinion.
= 2×10^5 N / mm^2
Eg = Young's Modulus for the material of the end ring
= 2×10^5 N / mm^2

$K = \frac{(770)^2 \times \sin 20^0}{1.4}\ (1/2\times10^5 + 1/2\times10^5)$
= 1.44 N/mm^2

Wear Tooth load (Ww) = Dp. b. Q. k

= 720 x 400 x 1.89 x 1.44

= 783.82×10^3 N/mm^2

Since Ww >. W_D, then design is safe against the wear
For 20^0 Full depth involute,
Taking module = 40 mm

Addendum	=	1m	=	40 mm
Dedendum	=	1.25mm	=	50 mm
Work Depth	=	2m	=	80 mm
Minimum total depth		= 2.25m	=	90 mm
Total thickness		= 1.5708m	=	62.832 mm
Minimum Clearance		= 0.25m	=	10 mm

CONCLUSION

This work is limited to the design of the Wagon Tippler for a specified rate tippling i.e 56 wagons in 8 ½ of hours which includes the design of the gear box and the basic dimensions of the Tippler. The scope of this work can be extended by writing a computer code so that for any rate of Tippling one can obtain the design details of the Wagon Tippler by giving the required rate of tippling as input parameter and the corresponding dimensions of tippler as an output.

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