E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

DESIGN OPTIMIZATION FOR MODIFICATION OF TROUGH BELT CONVEYOR TO REDUCE MATERIAL SPILLAGE USED IN CLINKER TRANSPORT IN CEMENT PLANT

Shalom Akhai[1] , Harpreet Singh[2]
[1] Department of Mechanical Engineering
[2] Undergraduate Student, Department of Mechanical Engineering

[1] PEC University of Technology,Chandigarh, India
[2] PEC University of Technology,Chandigarh, India
[1] shalom_pkl@yahoo.com

ABSTARCT:
The work present in this paper focuses on the reduction of material spillage from a belt conveyor leading to (1) Excessive Dust emission (2)Frequent maintenance and repair of conveyor which otherwise is not required (3)Loss of power and reduction in material transport efficiency of the belt conveyor. A case study done at ACC Cement plant in Madhya Pradesh, India shows that by proper design analysis & its optimization this problem can be tackled.

Keywords: *Trough Belt Conveyor; Material Spillage; Clinker.*

1. INTRODUCTION

Conveyors form the back bone of bulk material transport inside the plant. Conveyors need to be in excellent condition and should comply with the industry and factory standards. Also the material transported by the conveyors is of dry powder type which results in lot of dust in the plant. According to government norms the plant should be dust free to particular limit. The plant has undergone DEDUSTING in last one and a half years in order to comply with government norms.
The conveyor belt of the Z-1 transport section in the plant was still the cause of concern because of the dust being emitted from it. The objective was to find the causes of the Material Spillage from the conveyor and checking the design of the conveyor for the particular application.
Thus redesigning of the conveyor belt was to be done and to inspect and check the adequacy of the DEDUSTING equipment installed on site.

Material Handling & conveyor systems in Cement Plants

Material Handling is the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal. The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions. Material handling systems range from simple pallet rack and shelving projects, to complex conveyor belt and Automated Storage and Retrieval Systems (AS/RS). Material handling can also consist of sorting and picking, as well as automatic guided vehicles.

Fig. 1 Movement on conveyer belt in cement plant.

2. MATERIAL HANDLING SYSTEM IN FLEXIBLE MANUFACTURING

The material handling system (MHS) is a fundamental part of a Flexible manufacturing system since it interconnects the different processes supplying and taking out raw material, work pieces, sub products, parts and final products. Due to the automated nature of the whole production process, the MHS must respond in concert with timeliness for all requirements of the processes and systems. The MHS is composed of warehouses, buffers, conveyors, transportation vehicles or systems, part sorters, feeders and manipulators.

BELT CONVEYOR

A conveyor belt (or belt conveyor) consists of two or more pulleys, with a continuous loop of material - the conveyor belt - that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport industrial and agricultural materials, such as grain, coal, ores, fines, and lumps material.

Today there are different types of conveyor belts that have been created for conveying different kinds of material available in PVC and rubber materials.

The belt consists of one or more layers of material. They can be made out of rubber. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a woven fabric having a warp & weft. The most common carcass materials are polyester, nylon and cotton. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential.

Material flowing over the belt may be weighed in transit using a beltweigher. Belts with regularly spaced partitions, known as *elevator belts*, are used for transporting loose materials up steep inclines. Belt Conveyors are used in self-unloading bulk freighters and in live bottom trucks. Conveyor technology is also used in conveyor transport such as moving sidewalks or escalators, as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items.

The main advantages of conveyor belt system are:[2]

1. A wider range of material can be handled which pause problems in other transportation means. Belt conveyor can be used for abrasive, wet, dry, sticky or dirty material. The lump size of the transported material is limited by the width of the belt. Belts up to 2500 mm wide are used in mining industry.

2. Higher capacity can be handled than any other form of conveyor at a considerably lower cost per ton kilometer. Conveyor belts with capacity of 11000t/h and even higher can be deployed to match with higher capacity mining machinery.

3. Longer distances can be covered more economically than any other transportation system. A single belt conveyor or a series of belt conveyors can do this. Belt conveyors can be adopted for cross-country laying.

4. By the use of many forms of ancillary equipment such as mobile trippers or spreaders bulk material can be distributed and deposited whenever required.

5. Many other functions can be performed with the basic conveying like weighing, sorting, picking, sampling, blending, spraying, cooling, drying etc.

6. Structurally it is one of the lightest forms of conveying machine. It is comparatively cheaper and supporting structures can be used for many otherwise impossible structures such as crossing rivers, streets and valleys.

7. The belt conveyor can be adopted for special purposes (fire resistant, wear resistant, corrosion resistant, high angle negotiation etc.) and can be integrated with other equipment.

8. It can be horizontal, incline or decline or combination of all.

9. Minimum labour is required for the operation and maintenance of belt conveyor system.

10. In underground mine transport, belt conveyor can be used in thin seams as it eliminates the rock works that might otherwise be required to gain haulage height. Moreover, belt conveyor can provide continuous haulage service from pit bottom to the surface.

The limitations of conveyor belt are:

1. The loading and transfer points need to be properly designed.

2. Numbers of protective devices have to be incorporated to save the belt from getting damaged by operational problems.

3. The belt needs higher initial tension (40-200% of useful pull).

4. The use of belt is restricted by the lump size. If the maximum diagonal of a irregular lump is X then the belt width (B) is approximately given by: $B \geq Xa + 200$ where, B: Belt width, mm

   X: Longest diagonal of irregular lump, mm ;a: Factor to account for grading. a is taken as 2.5 for graded material and 3 for un-graded material. However, for particular material these values must be properly estimated.

5. Higher elongation of the belt (4% elongation may take place at the working load).

3. TECHNOLOGY OF TROUGH BELT CONVEYOR

Looking at the cement manufacturing process, the importance of belt conveyors becomes evident. There are many possible variations in the design of a trough belt conveyor depending on its purpose and duty.

OPERATING METHOD

A trough belt conveyor comprises an endless, rubberized flat belt suspended between pulleys at either end and is supported along its length by a number of rotating idlers. The belt is driven via pulley (usually the head pulley) and the tension in the belt is maintained by a manually or power operated / gravity take-up device. The material is loaded onto the conveyor at the tail-end via a feed chute and is transported on carrying-side to the head-end where it discharges into a discharge chute which guides the material onto the downstream equipment. Shock resistant elements are located at the loading point to support the belt where the material impacts onto the belt.
Once the material has been discharged from the carrying belt, the return belt is guided back to the tail pulley on return idlers. The impact, carrying, and return idlers are spaced at different intervals. On the carrying-side, the mass of the belt plus the load conveyed is larger than the mass to be supported on the return-side.
Snub pulleys are sometimes incorporated into the design of a conveyor in order to increase the angle of the wrap of the belt on the drive pulley. The larger wrap angle on the pulley allows transmitting more power into the belt when it passes around the drive pulley.

TERMINOLOGY OF ELEMENTS

Schematic display of the mechanical elements of a belt conveyor.

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

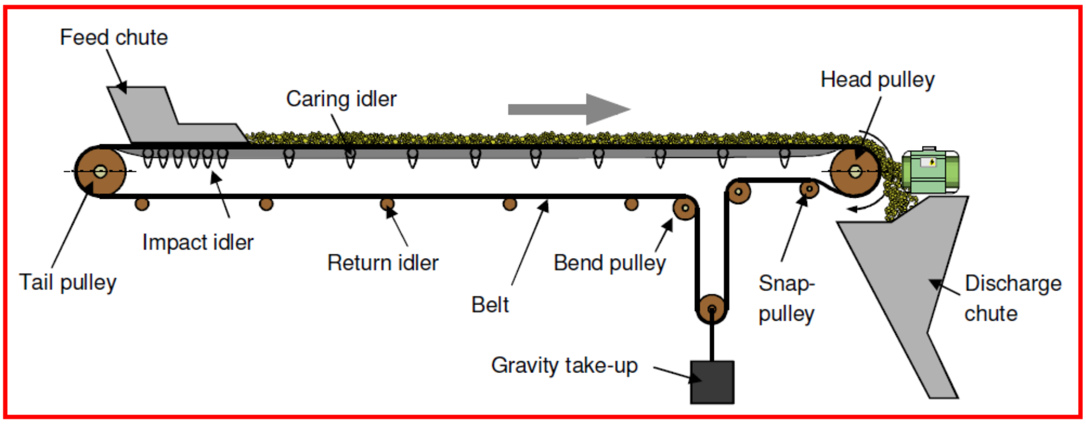


Fig. 2 Schematic of conveyer belt.

IDLER

Idlers are used on a belt conveyor to support the belt on the carrying and return strands. Carrying idlers also support the load in transit along the conveyor. There is an array of idlers available on the market for the use on conveyors in different applications. Some examples of the different types of idlers available are shown below.

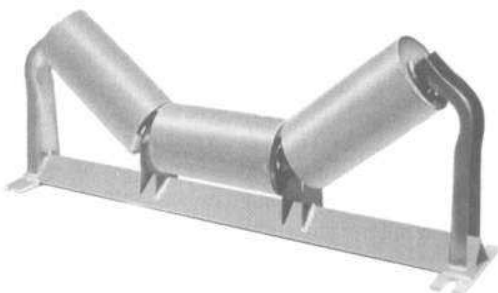


Fig. 3 Idlers used on a belt conveyor to support the belt on the carrying and return strands

Fig: Carrying idler (troughed)

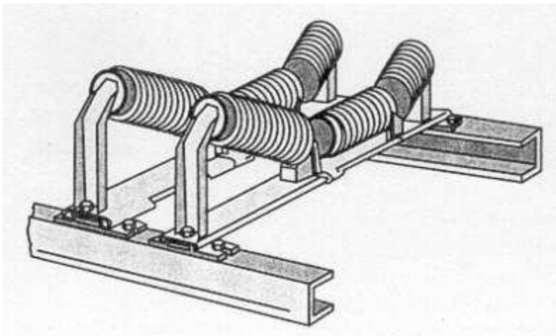


Fig. 4 Impact Idler

IDLER SPACING

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

The spacing or pitch of idlers has a direct impact on the sag of the belt between the idler sets. The idlers on the carrying side of a conveyor must support both, the belt and the load carried by the belt and on the return side, the idlers must support only the empty return belt.

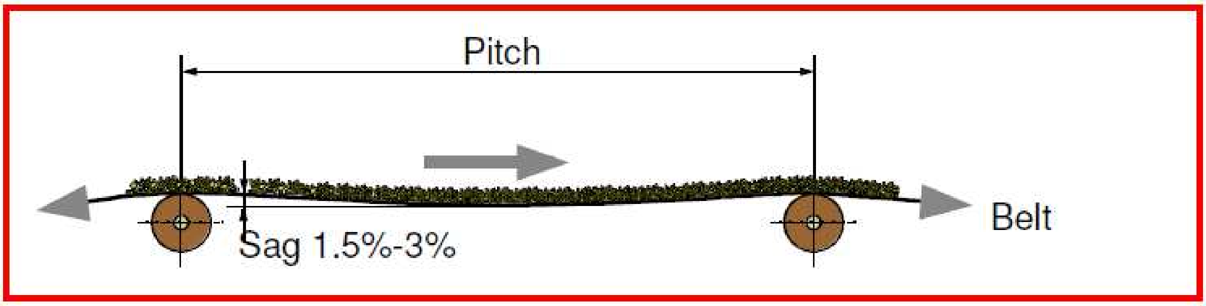


Fig.5 Example Belt sag

An excessive sag in the belt results in a higher power consumption for the conveyor and therefore the pitch of the idlers in conjunction with the tension in the conveyor should ensure that the sag is limited to between 1,5% and 3%.

BELT

The different types of belt conveyor systems demand differences in the design, manufacturing techniques, operation and maintenance of the belting on a conveyor. This section provides information on each type of belt and elaborates on the standard types of belting as well as factors to be considered when choosing a particular belt.

Fabric belt

A fabric plied belt consists of a single or multi-layered series of synthetic fabric layers alternate with rubber based shock absorbent layers. The "top" and "bottom" sides of the belt consist of hard wearing, abrasion and cut resistant rubber covers.These covers protect the belt from damage, especially at the loading points of the conveyor.

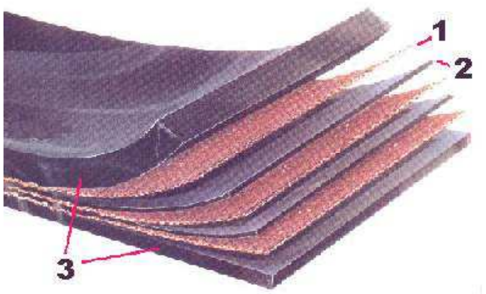


Fig.6 Example fabric belt

STEEL CORD BELT

Steel cable belting usually consists of steel and rubber only. Sometimes, there are fabric plies involved. Steel cable belts consist of steel cables manufactured of high tensile steel wire. These steel cables are surrounded by a layer of high grade rubber to facilitate adhesion to the outer covers and to improve lateral tear resistance. As with fabric belting the "top" and "bottom" sides of the belt consist of hard wearing, abrasion and cut resistant rubber overs.

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

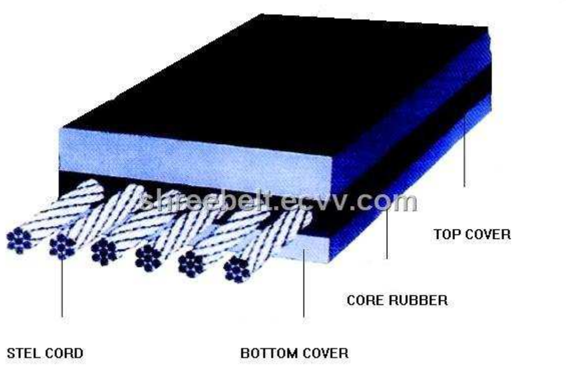


Fig.7 Example steel cord belt

BELT SELECTION CRITERIA

The procedure for selecting a conveyor belt for any given application involves the evaluation of a number of factors pertinent to the installation. The designer must bear in mind that there is a variety of 'standard' belts to choose from a supplier and that the properties of each belt have been incorporated to suit a number of basic criteria such as hot material, large or small lump size, etc.

The following fundamental criteria must be considered by the engineer for each belt selection.

TENSION RATING

All conveyor belts have been rated according to the operating tensions they will be able to withstand. Usually this tension rating is expressed in kN/m of the belt width. These ratings have been standardized within the industry and normally include a generous factor of safety i.e. 6.7 : 1 for steel cord- and 10 : 1 for fabric belting respectively.

Fabric belt tension strength Belt Operating Tensions at 10:1 Safety Factor

Table 1: Maximum tension for fabric conveyor belts

Belt Type	Operating Tension kN/m width	Whole Belt Strength kN/m width (min.)	Maximum Allowable Working Tension kN/m Width	Available in the following number of plies
EP 160	16,0	160	16	2
EP 200	20,0	200	20	2
EP 250	25,0	250	25	2 3
EP 315	31,5	315	31.5	2 3 4
EP 400	40,0	400	40	2 3 4 5
EP 500	50,0	500	50	2 3 4 5 6
EP 630	63,0	630	63	2 3 4 5 6
EP 800	80,0	800	80	2 3 4 5 6
EP 1000	100,0	1000	100	3 4 5 6
EP 1250	125,0	1250	125	3 4 5 6
EP 1600	160,0	1600	160	4 5 6
EP 2000	200,0	2000	200	5 6

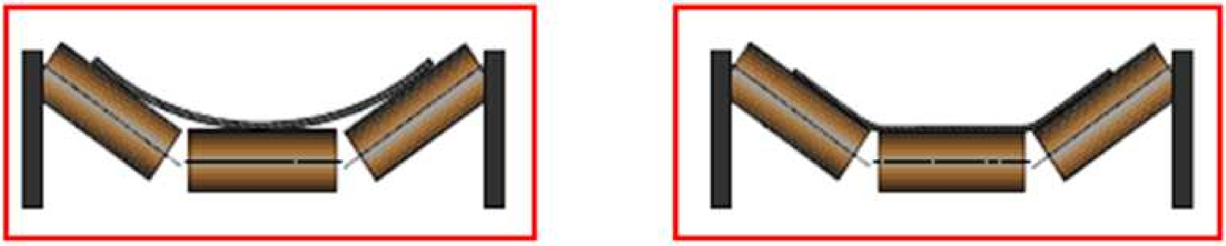
NUMBER OF PLIES (FABRIC BELT ONLY)

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

The selection of the conveyor belt must also ensure that the full load of material for which the conveyor has been designed can be supported on the belt, as the belt spans between two idler sets. The following table is a guide to the minimum number of plies considered necessary for a correct load support, based on a belt sag between idlers being limited to a maximum of 2% of idler span.

Troughability of fabric belt

In addition to the selection of a belt based on the minimum number of plies, the stiffness of a fabric belt across its width is affected by the number of plies in the belt i.e. more plies result in a stiffer belt. If the belt is too stiff, it will not stay correctly in the troughed idler sets (see example below) in an empty condition. This often results in misalignment of the belt relative to the conveyor structure. The following table indicates the maximum number of plies, which a fabric belt should have, to ensure the correct troughability and belt alignment.



(a) Incorrect -as belt too stiff. (b) Correct

Fig.8 Troughability

PULLEY LAGGING

There are primarily three categories of lagging, which are used on pulleys and they are described below: Rubber lagging is applied to pulley shells in order to improve the friction between the pulley and the belt. Conveyor drive pulleys are often supplied with diamond grooved lagging.

Fig.8 Pulley with rubber lagging

Ceramic lagging or lining of a pulley is used in instances where the pulley operates in extremely aggressive conditions. An example of such conditions are the pulleys on a bucket elevator, where the pulleys operate within the enclosed elevator housing and material cannot be prevented from becoming trapped between pulley shell and belt.

4. GENERAL THEORETICAL DESIGN GUIDELINES

All belt conveyors shall be designed according to the applicable guidelines (DIN, CEMA,ANSI).From experience, see some initial characteristics of bulk material, density, physical conditions etc.

BELT SPEED

A number of factors should be considered when determining the correct conveyor belt speed. They include the material particle size, the inclination of the belt at the loading point, degradation of the material during loading and discharge, belt tensions and power consumption.

- **Belt speed:**

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

− In general the maximum belt speed shall not exceed 2.0 m/s.
− Conveyors handling dry fine material (i.e. raw meal, cement) shall not exceed 1.25 m/s.
− Belt speed for conveyors less than 50 meters in length shall not exceed1.5 m/s.
− Conveyors longer than 500 m (overland) can operate faster than 2.0 m/s.

- **Belt width**

− Belt width shall not be less than 800 mm, for special applications 650 mm belts may be used. In packing plants 500 mm flat belts may be applicable.
−The minimum belt width for reversible conveyors shall not be less than 800 mm.

Table 2: Maximum Lump size considerations for different belt widths, based on material size distribution.

Belt Width [mm]	Lump Size (mm)		Belt Width [mm]	Lump Size (mm)	
	Uniform	Mixed with app 90% Fines		Uniform	Mixed with app 90% Fines
600	*125*	*200*	1350	275	450
800	150	250	1500	300	500
900	175	300	1800	350	600
1000	200	350	2100	400	700
1200	250	400	2400	500	800

Belt conveyor sub system design guidelines
Idler design
• Trough angle shall not be less than 30°.
• Carrier and return idler diameter shall be designed according to DIN (15207-1 /22107) or CEMA (Class C) or equivalent, (bearing life L10 = 60'000 h at 500 rpm), guaranteed idlers failure less than 2% replacement per year, within 5 years after commissioning.

CARRIER AND RETURN IDLER DIAMETER:
• > 100 mm for 650 to 1000 mm belts
• > 127 mm for belts 1200 mm and wider
• Carrier idler spacing shall not exceed 1250 mm for all belt widths.
• High-density polyethylene impact bars at loading points are the preferred solution. As an alternative: rubber protected impact idlers with spacing of 300 mm for all belt widths may be proposed.
• Return idler spacing shall not exceed 3000 mm for all belt widths. Self-aligning belt idlers and guide idlers shall be used, where necessary.
• For conveyors, handling sticky materials, return idlers shall be rubber disc rolls or anti-adhesive rubber tubes.
• Permanent lubrication for all idler bearings (sealed for life).

5. CONSTRUCTION DESIGN GUIDELINES
CONVEYOR DRIVE DESIGN
• Head drive is the preferred solution (except for downhill conveyors).
• Helical gear speed reducer shaft mounted or coupled directly to head shaft
• Full load start must be ensured.
• All drives larger than 37 kW (50 HP) shall incorporate a soft start device. If fluid coupling is used, it shall be designed for heavy duty starting condition.
• Backstop for inclined belt conveyors shall be installed.

BELT TENSIONING STATIONS DESIGN

• Up to 50 m horizontal center distance screw tensioning, if not sufficient, vertical gravity type shall be used.
• Over 50 m horizontal center distance vertical gravity, horizontal gravity or winch tensioning shall be used.

WEATHER PROTECTION COVERS

• Conveyors or parts thereof outside buildings shall be either in enclosed galleries or shall be provided with belt covers.
• Belt covers where used shall be semi-circular metal sheets complete with quick removing clamps and handles for ease of maintenance and inspection, from one side of the conveyor.
• For plants located in Europe, quick removing clamps can not be used. In order to be in compliance with European safety standard, belt covers has to be supplied whit bolts, which can be removed only with correspondent tool
• For conveyors handling dry fine material (i.e. cement) the lower edges of the covers should extend to 300 mm below the return belt line.

6. BELT CONVEYOR TRAINING

Belt alignment procedure:
It is essential to train the belt to ensure that both strands run straight and on the center line of the conveyor.
HGRS recommends the following steps to achieve good conveyor belt training and protect them from damages.
1. Check that the conveyor structure is perfectly straight and correctly leveled.
2. Check that the head, tail, take-up bend and snub pulleys are all correctly.
mounted. They must be on level and with their axes perpendicular (right angled) to the center line of the conveyor
3. Ensure that all troughing and return idlers are correctly mounted and with their axes perpendicular (right angled) to center line of the conveyor. All rollers must rotate freely.
4. Ensure that all self-aligning idlers, when fitted, are pivoting freely.
5. In the case of gravity or winch take-up, ensure that the take-up assembly is square and free to move. In the case of manually operated screw take-up gears, ensure that the pulley is correctly square to the line of the belt.
6. Ensure that all parts of the conveyor are greased and / or oiled where necessary.
7. Ensure that all pulleys and idlers are clean and in proper condition.
8. Where skirt plates are involved, check that the seal skirt board is correctly fitted and adjusted.
9. Check along the conveyor and make sure, that there are no items, which could cause damages to moving equipment.
10.Check that the belt splice is correctly installed and that the belt is straight.

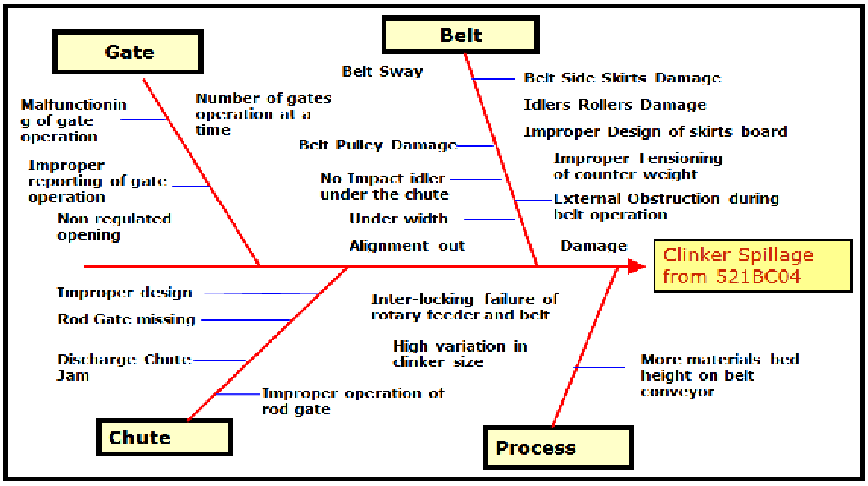


Fig.8 Cause and effect diagram.

E-ISSN: 2321–9637
Volume 1, Issue 4, November 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

7. DETAILS OF THE MODIFIED & OPTIMIZED DESIGN CARRIED OUT.

1. Details of Material to be conveyed
   Material name – Clinker
   Material density – 75 lb/ft^3 or 1200kg/m^3
   Lump Size - dust to 2 inch maximum or 150mm uniform
   CEMA Class – Abrasive Class 6
2. Centre to Center distance of Conveyor or pulley to pulley distance = 49m
3. Type of belt recommended – Fabric type
4. Troughing angle to be used 35degrees
5. Slope Conveyor = 0(horizontal conveyor)
6. Required Loading rate 350 t.p.h
7. Belt Speed <2 m/sec
8. Belt Width required = 30 inch or 800 mm standard (EP800 type)
9. Belt tensioning station suitable – gravity take up pulley type because of space constraint at Tail pulley end
10. Details of the Fabric Belt selected
    Top cover thickness --- 4mm
    Bottom cover thickness— 2mm
11. Volumetric flow rate of Clinker
    Volume flow rate = TPH/(Density of material)
    = 350 tph/ 1200 kg/m^3
    = 292 m^3/h (rounded off)
    So belt speed selected is 1.5 m /sec and β=20degree
12. Idler Dimension
    Belt width = 800mm so
    d1=108mm ; l3 = 315mm; h1= 85mm
13. Idler Spacing
    Impact idler = 0.25m
    Carrying idler = 1.2m
    Return idler = 3m
14. Calculation of Horse Power of the Drive required(absorbed power).
    Belt speed in fps = 300
    HP_0 = 0.75 (for conveyor centers 150feet apart)
    $HP_e = (300/100)* HP_0 = 2.25$
    HP_m = 3.15 (150 feet center to center)
    $HP_j = 0$
    $HP_{req} = HP_e + HP_m + HP_j$
    = 2.25+3.15+0
    = 5.4 HP
15. Motor Horse Power required
    Motor $HP_{min} = HP_{req}$/(Drive efficiency) = 5.4/0.7=7.71 HP
16. Description of standard motor selected
    Rated motor power 10HP ; Speed 1500 rpm ; Shaft Diameter 38 mm ; Frame Size 132M
17. Gear Box required for the belt speed of 1.5 m/sec = 1:25 ratio
18. Maximum Operating tension of the belt
    Width * max allowable tension
    0.8m * 80kN/mwidth = 64kN
    As the application requires support rollers so this tension is never approached.
    As a design consideration half of this tension may be selected if required.
    Also this tension includes a factor of safety of 10.
19. Pulley Diameters
    Head pulley = 650mm (630mm is available so selected)
    Tail & take up pulleys = 450mm
    Any other low tention snub and bend pulleys = 410mm
20. Bearing Details for Head and tail pulley shafts (diagram for reference only)

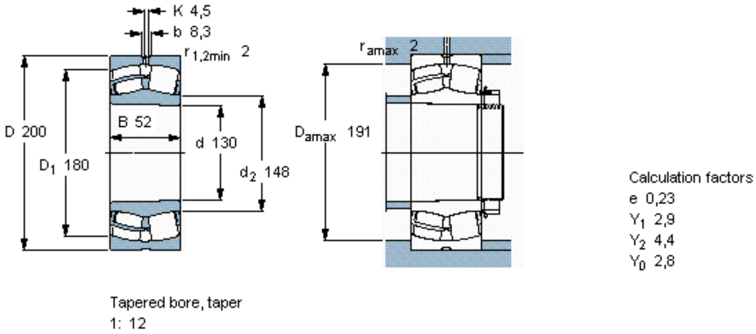


Fig.9 Bearing Details.

Type of bearing 23026 CCK / W33* SKF
Name - **Spherical roller bearings, cylindrical and tapered bore**
The Pulley shafts undergo Sag due to which this type of bearings are employed.

21. Details of number of idlers , pulleys , bearings etc
No. of carrying idlers = 38
No. of impact idlers = 10 & No of return idlers = 18

8. SOLUTIONS SUGGESTED

After completion of the project various suggestion were made to the company regarding the design and operation of the conveyor belt in the Z1 transport section.
1. It was advised to use the impact rollers at the feed point .
2. The transition distance of the belt was not adequate and it was increased .
3. The skirt board welding was advised to be redone as it had many leaks and was also causing wear to the belt material.
4. It was advised that the CCR operator should stop the Motorised Gate first and then turn the Belt off.
This would ensure there is no pilling up of material at the feed point and the belt would be empty during the next start up.
5. Installation of a pneumatic gate for quick closing down of the feed chute was advised .
6. Inorder to avoid dust emission it was advised to install bag filter for collecting dust from the Skirt Board area.
7. The skirt board installed was not according to the standards so replacement of the skirtboard was suggested.

9. CONCLUSION & FUTURE SCOPE

The material spillage from the conveyor belt is a significant problem not only from the point of view of environment and government regulations , but also beause of number of labour hours lost in the cleaning , cost incurred due to frequent repairs or rollers and other conveyor parts etc.
Conveyor systems are present in alomost in every manufacturing unit be it a steel plant, mineral and ore processing facility, food and agro industry you name it.Thus knowing the basics of conveyor systems is essential for a mechanical engineer both for maintenance and design applications.

References

[1]Holcim CMS Mechanical process technology Transport and Dust Collecting Manual Version 1.07. CEMA
[2]Belt Conveyor guide by K Pathak Indian institute of technology kharagpur
[3]Textbook of "Machine Design" by Dr. P.C.Sharma and Dr. D.K.Aggarwal; S.K. KATARIA & SONS Publishers of Engineering and Computer Books. ISBN : 81-85749-09-4
[4]Textbook of "Machine Design" by R.S.Khurmi S.Chand & Co. Pvt.Ltd. Edition 2012 . ISBN : 81- 219- 2537-1
[5 Textbook of "Engineering Tribology" By: Amandeep Singh Wadhwa, Dhanpat Rai & Co. (P) ltd. ISBN : 978-81-7700-063-4.
[6] Textbook of "Theory of Machines" By: Dr. V.P.singh, Dhanpat Rai & Co. (P) ltd.
[7]Textbook of "Elements of Mechanical Engineering" By: Amandeep Singh Wadhwa and Shalom Akhai, Dhanpat Rai & Co. (P) ltd. ISBN : 978-81-7700-063-4.