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Analysis & Prospects of Modification in Belt Conveyors - A Review

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Abstract—
Now a day's Belt conveyor system not only used in mining industries but also applied in cement industries, power plant, food industries, production industries etc. So it is essential equipment for in house material transportation today. The paper presents the review of belt conveyor design modification and latest technologies or methodologies used in different applications to reduce failures, maintenance cost and equipment related fatal accidents occurs during operation. The focus is on methodologies as Design modification, Drum and pulley failures, Belt design and its failure, energy & efficiency, friction, inspection, operation & maintenance and fire & safety. The analysis shows, different design parameters required for different applications such as coal mines, cement and food industries. Some of the common design parameters required in each application and the importance of each parameter which impacts on different application.

Keywords— *Belt Conveyor, Design Modification, Failures, Maintenance, pulley.*

I. INTRODUCTION

As a kind of in house continuous transportation equipment, belt conveyor is widely used in today's modern port, especially in the transport of coal and mineral powder because of its high efficiency and environmental protection. [1]

Belt-conveyors are more acceptable than other means of transporting bulk materials; they neither pollute the air nor deafen the ears. They operate quietly, often in their own enclosures, which when desirable can be located above the confusion and safety hazards of surface traffic or in small tunnels out of sight and hearing. [2]

Belt conveyor is one of the main transport equipment in coal mine, driving drum and belt is its key part. Friction principle is used to initiate mechanical drive for belt conveyor. So friction is the driving force. In order to raise transportation efficiency of belt conveyor, driving force of drum must be increased. Energy saving & efficiency, friction, fire & safety, maintenance and inspection are the other key factors of belt conveyor design. [3] Most of the researchers focused on design modification to reduce the pulley (drum) and belt failures, maintenance cost, breakdowns, energy consumption and overall cost of the system for continuous transportation of material.

The technologies used to reduce failures of the equipment and to increase the operational ability of the system the mechanisms like cam drive system, hydro-viscous soft start, magneto-rheological soft starter, Control strategy of disc braking system to be designed for efficient driving of belt conveyors. Most of technologies focused on Fatigue Failures of Welded Conveyor Drums, shell of drums and fracture analysis of collapsed heavy-duty pulleys and other typical failure analysis on pulley shafts by using finite element method. Conveyor Belt is a key part of belt conveyor system, sometimes its incorrect designing also make an important role in conveyor failure. Therefore belt Safety and Eco-design of non-metallic layer composites with a better capability of elongation should be considered. Transversal Vibrations and tension around a drive drum of a Conveyor Belt with a Low and Time-Varying Velocity are also considered. Control of whole system, operation & maintenance of belt conveyor and their inspection should be managed.

II. METHODOLOGY

There are many methodologies used according to their application and design modification. Most of the researchers focused on design of drive mechanisms of belt conveyors, drum(pulley) and belt failures, energy & efficiency, increasing friction, fire & safety, maintenance and inspection.

A. *Design Modification*

Different designs in the field of drive mechanism and other modification used for reducing starting torque on drive pulley and operational efficiency.

1) Multi-Step Cam Mechanism: A multi-step cam mechanism is preferred to drive belt conveyor for the self-orientation of the conveyed rigid objects. It is also used as velocity reduction, so doing away with costly gear transmissions; thereby reduce the possibility of failure due to gears. [4]

2) Control strategy of a hydro-viscous soft start device: The control system of hydro-viscous soft start (HVSS) device and a fuzzy – immune PID

controller are combined for feedback regulations and adaptability, and derive control algorithm and simulate the results by comparing with conventional PID. [5]

3) Control strategy of disc braking systems: A close loop velocity control system is used for disc braking of downward belt conveyors. The proportional electro-hydraulic valve device is used and simulate by MATLAB. A PID (Proportion Integration Differentiation) is designed to increase the performance of disc braking system. [6]

4) Magneto-rheological soft starter: A magneto-rheological soft starter (MRSS) is a device having magneto-rheological fluid (MRF) between the two disks of MRSS and controlled by an external magnetic field for integrating disks for transmitting torque to belt conveyor and torque transmitted can change by increasing the No. of disks. [7]

5) Multi-conveyor system for profit maximization: The Multi conveyor control model is proposed by operating no. of conveyors equipped with combined driving system and handling speed variations and average flow time between adjacent pallets for profit maximization and reliability. [8]

6) Mechanism of hydro-viscous soft start: A hydro-viscous clutch and its control system are explain by startup process of a belt conveyor, and numerically analyzed with the modified Reynolds equation, an energy equation and a temperature-viscosity equation. And show the effects of temperature, grooves of the friction disk surface on torque transfer and load capacity of the oil film have also been analyzed. [9]

On the basis of researches design modification step by step has shown as below:

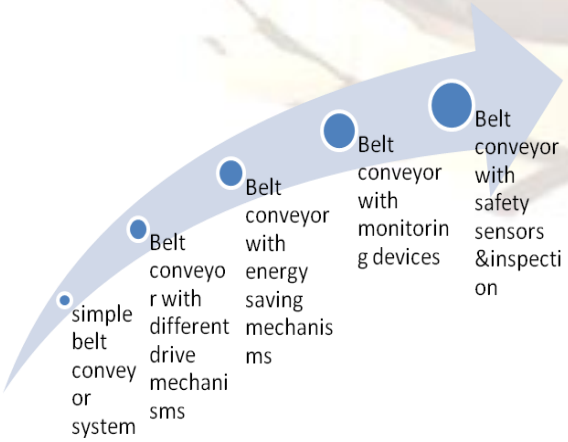

Figure: 1 Step by step designs modification in Belt Conveyor System.

B ***Drum and Pulley Failure***

1) Typical failure and processing: The description of typical failure forms of roller and conveyor are analyzed, and explain the maintenance methods of prevention and elimination of failures to ensure the normal operation of belt conveyor. [10]

2) Fracture in collapsed heavy-duty pulley: Fracture of pulley is analyzed by FEM and fracture macro examination with use of following formulas: $Sf = 32.FS.Mb/\pi D3$. (.5 SUT) where Sf is estimated fatigue limit to the pulley FS is the safety factor, Mb the bending moment and D the shaft diameter SUT the material tensile strength. [11]

3) Conveyor Pulley Shaft Failures: The cause for failures of shafts in a conveyor pulley in iron-making unit at JSW Steel has been investigated. Visual, metallographic, chemical, and fractographic studies were carried out. Fracture studies shows that shaft failed in shear because of overload. [12]

4) Analysis of conveyor pulley using FEM: The integral analysis of pulley parts has been helpful in arriving at some broad design guidelines and stresses and deflections of its various parts has been described for reliable design of pulley by using FEM. [13]

5) Fatigue Failures of Welded Conveyor Drum.: An elastic analysis shows that high cyclic bending stresses were produced at the plate-boss welds when the drums were loaded by the tension in the conveyor belt and Fatigue cracks initiated at the toes of the welds between the plates and the bosses, and propagated through the plates until the shell became detached from the shaft. [14]

6) Fatigue in the shell of a conveyor drum: The shells of a belt conveyor broke in operation due to fatigue in the area of the weld seam between the axle disk and the cylindrical shell due to overloading of drum and compare the original design with actually manufactured drum. [15]

On the basis of researches the variation in causes of failures in drum or pulley as shown in bar chart:

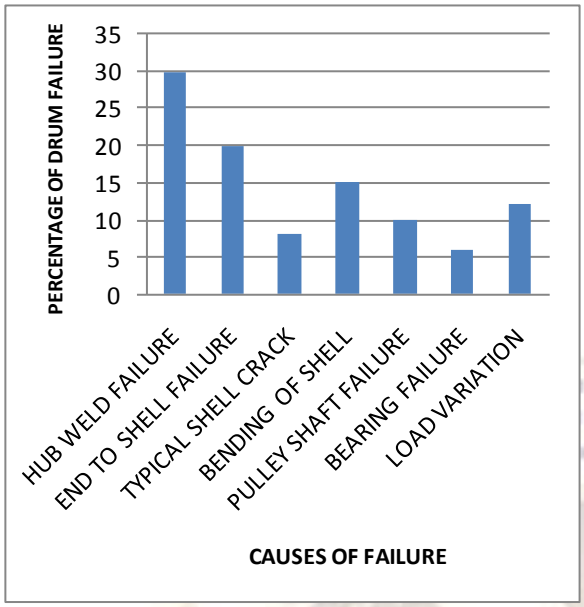

Figure: 2 Percentage in causes of drum failure in Belt Conveyor System.

C ***Belt design and its failure***

1) Vibrations with Low and Time-Varying Velocity: By using Kirchhoff's approach an equation of motion will be derived from a coupled system of partial differential equations describing the longitudinal and transversal vibrations of the belt in varying load conditions. The results shows that the frequencies of the belt speed fluctuations play an important role in the dynamic behavior of the conveyor belt. [16]

2) Conditions for field vulcanizing with a better capability of elongation: By using analysis of mean of the Taguchi method, the optimum conditions for field vulcanizing a fabric conveyor belt with a better capability of elongation were obtained at different environmental conditions. The optimum conditions includes (1) curing time of 25 min, (2) curing pressure of 9 kg/cm2, (3) dismantling platen temperature of 90 ˚C and (4) forced cooling of air. [17]

3) Eco-design of non-metallic layer composites for belts: The methods for designing multilayer conveyor belts have been evaluated by using SimaPro 5 software and optimizing the strength properties regarding various belts and their on the environment during operation. This includes Belt Materials with Nanostructure fillers appear to have a more promising effect on the performance of the conveyor belt composite to adapt innovative performance characteristics. [18, 19]

4) Belt Tension around a Drive Drum: A mechanical model is developed to simulate the starting of a drive drum with a distributed mass-spring system for the belting. The model produces the tension distribution in the belt around the drum face including requirements for visco elastic contraction when designing a drive system. [20]

D ***Energy & Efficiency***

1) Energy efficiency optimization: An analytical energy Modeling and energy efficiency optimization of belt conveyors has to be developed. The energy efficiency describes in terms of Performance efficiency, Operation efficiency, Equipment efficiency, and Technology efficiency and evaluates detailed description of factors responsible for energy consumption in belt conveyor system like starting & stopping conditions, conveyor runs without loading, load variations etc. and the parameters to reduce them. [21, 22]

Describe the selection criteria of variable voltage, variable frequency (VVVF) drives systems for conveyor applications, and highlights design considerations and energy saving potential of modern drive systems. [23]

2) Prediction of Armoured Face Conveyor Performance for Increased Efficiency: A computer model has been developed for the dual purpose of analyzing data from existing installations and for predicting the power needed for new applications i.e. the parameters which increase the efficiency can be concluded. [24]

3) ***Optimal control of operation efficiency:*** The Switching control devices and variable speed control systems are proposed in literature to improve energy efficiency of heavy duty belt conveyors, where time-of-use tariff and ramp rate of belt speed are considered. The current implementations mostly focus on lower level control loops or an individual belt conveyor without operational considerations. [25, 26]

D ***Friction***

1) Traction and slip in a wheel-driven belt conveyor: An extension of existing models used for flat belt conveyors to describe the relationship between traction and slip in a wheel-driven belt conveyor with a curved surface. The model includes the viscoelastic properties of the rubber running surface in the form of Maxwell elements. [27]

2) Rolling contact phenomena in a pouch belt conveyor system: A simplified approach to examine the rolling contact phenomena that occur at the surface of a wheel driven rubber belt, determine the rolling friction due to hysteresis and evaluate the

relationship between traction and slip in wheel driven belt conveyors. [28]

E ***Inspection***

Inspection of different types of conveying material has been done by electro-mechanical systems like x-ray, linear array detector, sensors and by using thresholding algorithm. They are used for increasing accuracy of the belt conveyor system. It can detect the size, shape, profile, surface fractal dimension and voids through time integration. [29, 30, 31]

It is feasible to use topographic sensors around a moving conveyor belt carrying solid particulates to provide a continuous measurement. It helps in controlling the parameters and identifies the visual defects present on the surface. A texture analysis has been developed for an automated vision-based solution for identification of paint and substrate defects. [32, 33, 34]

F ***Operation & maintenance***

1) ***Optimization of overland conveyor performance:*** The description of key elements (Capability, Reliability, and Economy) which are considered when designing overland conveyors to ensure effective capital expenditure, long trouble free life, low maintenance and cost effective operation. [35]

2) Conveyor Belt Maintenance: This manual not only includes proper care of the belt itself but also includes care and maintenance of the frame and accessories. [36]

3) ***Improvement in drive system using maintenance data:*** It presents an objective methodology for maintenance data analysis which identifies strengths and weaknesses in the maintenance management system, opportunities for improvements, and evaluates maintenance key elements against maintenance best practice. [37]

4) Belt Conveyor monitoring and control system: This research makes an in-depth analysis of implementation possibilities and requirements of the ARM-based monitoring of belt conveyor system by using LM3S8962 chip. The fault detection and control of belt conveyor can be done through the on-site sensors information signal collection by remote monitoring of belt conveyor and the motor protection. [38]

5) System design vs. Reliability: Advances in computer hardware and software for allowing engineers and designers to get an unprecedented feel for belt conveyor performance via 'virtual prototyping' techniques. This helps in decision makers with additional and improved information during the design process. [39]

6) Operation and Maintenance of Coal Handling System in Thermal Power Plant: It presents effect and working principle of coal handling system in thermal power plant. Analysis the operation and work of major equipment in this system, describes the main malfunctions form at key equipment and emphasized some main problems of these mechanical devices which should pay attention on use and maintenance. [40]

Reliability of conveyor belt system depends on four distinct categories shown as below;

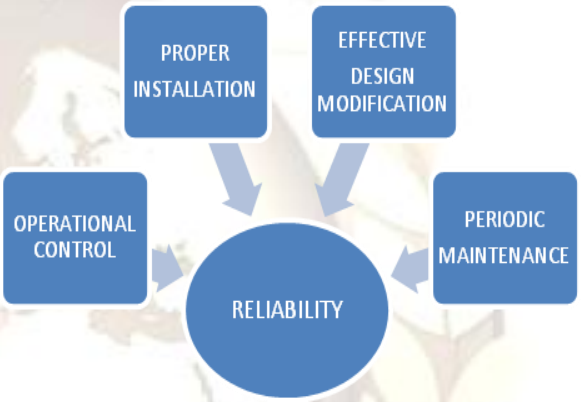

Figure: 3 Dependency of conveyor belt reliability.

H ***Fire & safety***

An experimental and computational study should be conducted to characterize the initiation and spread of fire along the upper and lower surfaces of a conveyor belt. Develop a step by step structure for creating safety training program and its implantation. Register all safety records of conveyor system and discuss the proper training to improve an overall efficiency and productivity. [41, 42]

Site-specific analysis required issues relative to passive vs. active learning and classroom-based vs. self-paced training by developing and implementing an interactive multimedia-based safety-training tool to reduce hazards in critical applications [43]

III. ANALYSIS

According to the review, belt conveyor is essential equipment for transporting material from one point to other unloading point. The parameters which impacts on designing of conveyor system are drum & belt design, drive mechanism, fire and

safety controls, operation & maintenance, dust emission control, inspection and energy & efficiency controls. But all above parameters varied according to the requirement; however some parameters are equally impacts on each application, like drum & belt failure, energy & efficiency, drive mechanism, maintenance control and safety controls.

Following bar chart shows the variation in designing parameters of belt conveyor system in coal mines, cement industries and food industries. Chart shows impact of different parameters while designing belt conveyor system for different applications. In this chart impact factor is taken from 0-5 (varied according to the researches) on Y-axis and parameters on the X-axis.

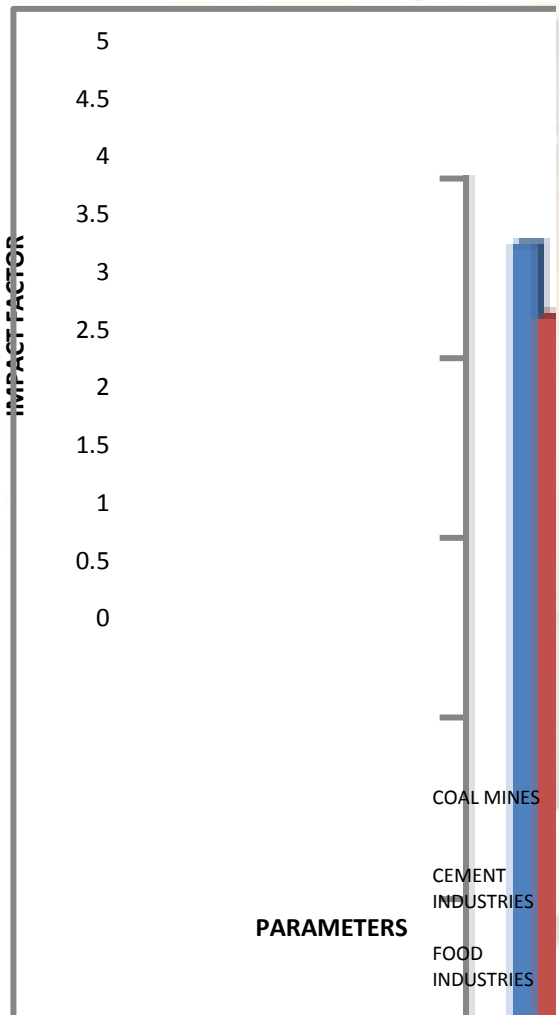

Figure: 4 Impact of Design Parameters in different industries.

According to the chart most of the researchers focused on key components drum &belt failure after that energy & efficiency, then maintenance and drive mechanism. The above parameters are approximate equal importance in all applications, but fire & safety; dust emission control is most important parameter for coal mines then in cement industries. Design of non reactive belts and inspection are most important parameter in food industries then in cement industries. Therefore different design requirement and combination of design varies industry to industry shown in bar chart as below;

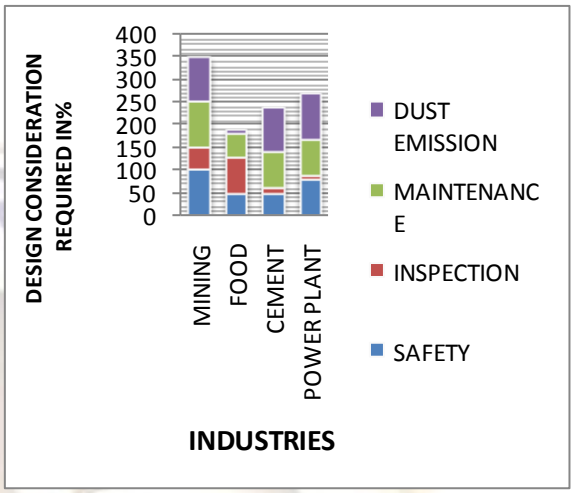

Figure: 5 Percentage of Design Parameters required in different industries.

From above analysis most effective belt conveyor system design depends on maintenance control, energy & efficiency control, equipment fatal accidents and drums & belt failures. The following chart shows above discussion.

Figure: 6 Parameters make Effective belt conveyor system.

IV. CONCLUSION

As requirement of continuous transportation equipment, belt conveyor is widely used in today's modern port, especially in the transport of coal and mineral powder. The belt

conveyor now designed for industries like food and cement, so the designing parameters varied according to their application such as in food transfer, belt must be non reactive with the food transported, dust emission control system is required in coal and cement industries, fire & safety is main consideration in coal industries, but others parameters like drum & belt failure, energy &efficiency, drive mechanism, friction and maintenance are common in all applications. So the most effective belt conveyor system design depends on maintenance control, energy & efficiency control, equipment fatal accidents and drums & belt failures. To fulfill above requirement it is to be needed further proper designing of conveyor system which is desired for the application keeping all parameters in mind and by inventing new approaches towards better design. It has been also focused on inspection and online monitoring of all components while transferring coal through belt conveyor to reduce maintenance cost & fatal accidents in mines.

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