Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Redesign of Roller Conveyor System for Weight Reduction

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Abstract— A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. This work presents an application of concept of concurrent engineering and the principles of design for manufacturing and design for assembly, some critical conveyor parts were investigated for their functional requirements, suitability, strength, cost and ease of assembly in the overall conveyor system. The existing system will be modified and optimize for weight, results in material saving by suggesting modification and analysing the critical conveyor parts. The improved design methods and the functionality of new conveyor parts were verified and tested on a new test conveyor system designed and manufactured using the new improved parts. The improved methods for design and production of conveyor components is based on the minimization of materials, parts and costs using the different rules of design for manufacture and design for assembly. Detailed results will be found in the final part of the dissertation.

Keywords— Conveyor system, Analyse, Geometrical Modelling, Optimization, NC Machine.

I. INTRODUCTION

Conveyors are a powerful material handling tool. They offer the chance to boost productivity, reduce material handling damage and minimize labour content in a manufacturing or distribution facility. Conveyors are normally classified as either Unit Load Conveyors that are designed to handle specific uniform units such as cartons or pallets, and Process Conveyors that are designed to handle loose product such as sand, grate, coffee, cookies, etc. which are fed to machinery for further operations or mixing. It is quite common for manufacturing plants to combine both Process and Unit Load conveyors in its operations.

Roller conveyor is not subjected to complex state of loading still we found that it is designed with higher factor of safety. If we redesigned critical parts e.g. Roller, Shaft, Bearing & Frame etc. then it is possible to minimize the overall weight of the assembly. Powered belt conveyors are considerable long (9000 meter to 10000 meter) as compared to roller conveyor. So we can achieve considerable amount of material saving if we apply above study related to roller conveyor to this belt conveyor.

A production line is commonly arranged in a series of workstations and each workstation consists of one or more parallel machines of the same type. To support the loading and unloading tasks for the parallel machines, the conveyors are generally employed as material handling equipment in modern industry. A great deal of research has mostly concentrated on controlling the conveyors with stoppage and queuing. For example, a design of conveyor-equipped material handling system with routing pallets was analysed and simulated. Nevertheless, the stoppage of the closed loop queuing model often resulted in an expensive system. Therefore, the just-in-time (JIT) philosophy is presented to promote a better balance between the machine productivity and the conveyor speed for the material handling task in this study. Numerous real-time modelling designs with theoretical approaches to control the single or multiple conveyor system have been built, but none achieves the maximum profit. The profit and the production efficiency are mostly concerned with Problems challenging the manufacturing industry. Hence, the maximum profit is considered in this study as the objective of the overall production system, including the parallel machines and the conveyors.

In this study, the machine cost is divided into the operation and fixture costs. When the machines are idle or break down, the operation cost is negligible. This is in view of the fact that the consumption of input resources does not exist and the electricity costs of idle machines are relatively small compared with those of the entire system. Thus, when a machine is idle or breaks down, there exist only the repair costs. The marginal operation cost is a linear increasing function of the operation rate; therefore, the operation cost of the conveyor is also proposed in direct proportion to the square of the conveyor operating speed as in other researches. In fact, the higher operating speed of a conveyor requires a higher cost per unit speed. It is realistic to assume that increasing the unit conveyor speed results in a higher operating cost than costs at lower levels, such as maintenance and depreciation costs. In addition, the setup cost of a conveyor is considered in this study. For many years, the decision-making process at the shop-floor level has been propelled by the implicit idea of optimizing the service of machines, and the operational decision makings are still oriented towards finding an adequate balance between work load and machine capacity. However, as the advanced numerical control (NC) machines are extensively used from job shops to flexible manufacturing systems (FMSs), the material handling equipments for loading and unloading such systems becomes significant to the management. There is definitely an economic need not only to control the conveyor speed and the number of parallel machines, but also to find the optimum solution in reaching the maximum profit of a deterministic production quantity. Through this study, the control of the conveyor speed in optimizing the production of the machines and conveyors becomes concretely solvable.

II. LITERATURE REVIEW

Alspaugh M. A. [1] presents latest development in belt conveyor technology & the application of traditional components in non-traditional applications requiring horizontal curves and intermediate drives have changed and expanded belt conveyor possibilities. Examples of complex conveying applications along with the numerical tools required to insure reliability and availability will be reviewed. This paper referenced Henderson PC2 which is one of the longest single flight conventional conveyors in the world at 16.26 km. But a 19.1 km conveyor is under construction in the USA now, and a 23.5 km flight is being designed in Australia. Other conveyors 30-40 km long are being discussed in other parts of the world.

S.H. Masoodet. al. [2] presents an application of concept of concurrent engineering and the principles of design for manufacturing and design for assembly, several critical conveyor parts were investigated for their functionality, material suitability, strength criterion, cost and ease of assembly in the overall conveyor system. The critical parts were modified and redesigned with new shape and geometry and some with new materials. The improved design methods and the functionality of new conveyor parts were verified and tested on a new test conveyor system designed, manufactured and assembled using the new improved parts.

The improved methodology for design and production of conveyor components is based on the minimization of materials, parts and costs, using the rules of design for manufacture and design for assembly. Results obtained on a test conveyor system verify the benefits of using the improved techniques. The overall material cost was reduced by 19% and the overall assembly cost was reduced by 20% compared to conventional methods.

Dima Nazzalet. al. [3] discusses literature related to models of conveyor systems in semiconductor fabs. A comprehensive overview of simulation-based models is provided. We also identify and discuss specific research problems and needs in the design and control of closed-loop conveyors. It is concluded that new analytical and simulation models of conveyor systems need to be developed to understand the behaviour of such systems and bridge the gap between theoretical research and industry problems.

In order to shorten the product development time and improve the product quality, 3 dimensions at CAD/CAE system is essential. It is necessary to develop a system which utilizes the concept design data at the early stage for the whole process of the product development. The purpose of this paper is to improve the product quality by the sufficient design study iteration at the early stage of design. A CAD system which can be used for the concept design and an appropriate CAD environment should be developed and another purpose is to shorten the product development time at the late stage of design, this is proposed by C. Sekimoto [4] in his paper.

Chun-HsiungLan [4] discusses multi conveyor systems in supporting machine loading and unloading. The study in this paper not only meditates the concept of balancing the number of parallel machines, the conveyor speed for adjacent pallets, the overall relevant costs and the determination of the number of conveyors into the objective, but also develops a two-staged method to optimize the combined problem to reach a maximum profit.

Moreover, the computerized sensitivity analyses are discussed in this study. This paper contributes an applicable scheme for production design in manufacturing and provides a valuable tool to conclusively obtain the optimal profit of a given production quantity for operations research engineers in today's manufacturing with profound insight. It is concluded that this study definitely provides an adaptable and efficient tool for production design to optimize the profit of a given order quantity.

L. Pavlov etal. [5] presents a very detailed objective function that considers the self-manufacturing costs of the whole structure. The cost function includes all essential fabrication and erection activities. It considers both manufacturing costs as well as material costs. It is formulated in an open manner, offering users the possibility to define their own parameters on the basis of a certain production line. The cost function is implemented into the optimization system for planar steel frames.

The cost optimization not only reduces the overall costs very efficiently in comparison to the classical design approach, it also offers a detailed insight into the structure of all relevant manufacturing and material costs. In further research work the developed cost function should be tested also in other optimization problems and studies such as by implementing it into a topology-related optimization, into optimization of more detailed truss structures

John Usher et al. [6] provides an analysis of the reliability and availability of two common designs of the line-shaft roller conveyor. The first is a standard design in which each roller is belted directly to a spinning line shaft under the conveyor. The second is a new design in which only one top roller is belted to the line shaft and all other rollers are belted to the one powered roller in a series arrangement. The main reason for this design is that the upper belts are faster to replace than belts connected to the line shaft, thus increasing system availability. However, the latter design is less reliable in that the failure of a single belt may lead to multiple roller failures.

III. OBJECTIVES OF THE WORK

The following are the objectives of the study:

1. Study existing conveyor system.
2. Geometry modelling existing conveyor.
3. Analysis of existing roller conveyor.
4. Modification of critical conveyor parts for weight optimization.
5. Analysis of Modified design for same loading condition.
6. Recommendation of new solution with weight reduction.

The mechanical elements of the Roller Conveyor need to be designed individually and tested in the assembly environment. The structure must be tested for external forces acting on the entire assembly.

IV. PROBLEM DEFINITION

The sugar cane of weight 1 Ton has to be transported from unloading station to feeding station at a distance of up to 25 m or more. The method of manual transport by fork-lift requires more time .

A mechanism for continuous and uninterrupted transport is desired. This is carried out with the help of roller conveyor system (Existing system).

The existing system will be redesign and optimize for weight, resulting into material saving by modifying and analysing the critical conveyor parts.

Gravity Roller Conveyor:

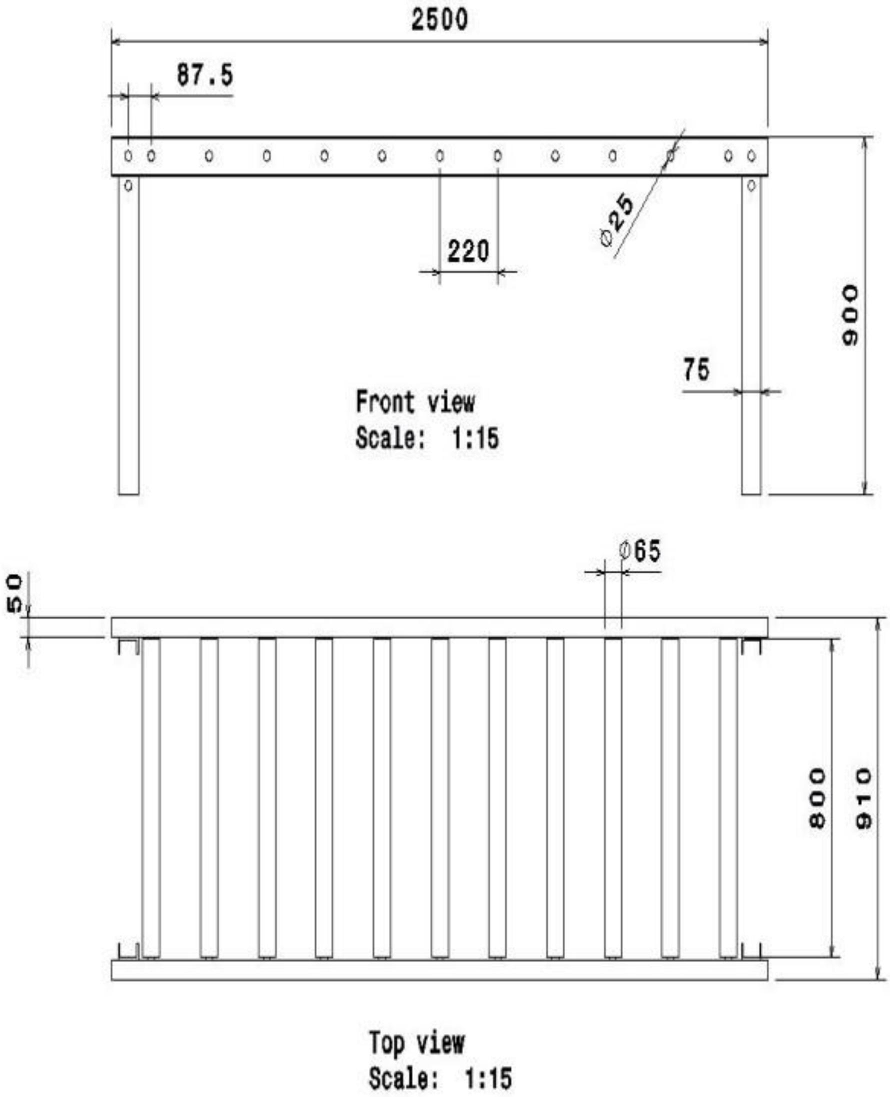

Fig 1: Existing conveyor assembly

V. DESIGN CALCULATION FOR EXISTING DESIGN

A. Design of C- Channels for Chassis

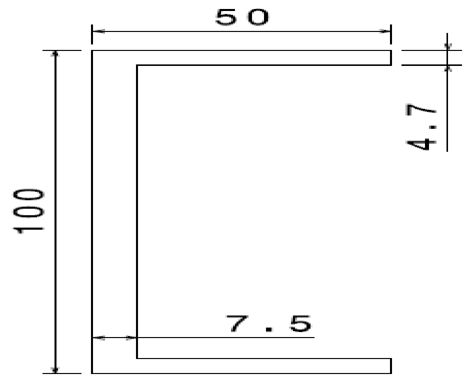

Fig 2 : C Channel

1) Material- Rolled steel C-10,
E= 2.10*105 Mpa, ρ= 7830 Kg/m3,
Syt = 490 Mpa

2) Calculation for given dimension
L= 2500 mm, W= (1000/2) = 500 kg on each channel,
Considering load act at a center& Factor of Safety =2,
Allowable Stress (σall) = Syt / Fs = 490/2 = 245 Mpa
Maximum bending moment (Mmax)
Mmax = WL/4 = 500*9.81*2.5/4
Mmax = 3065.625 Nm
Given C- Channel, ISMC 100
h= Depth of section, tf = thickness of flange, tw = thickness of web, A= Sectional area Ixx = Moment ofInertia along x-axi
h= 100 mm
b = 50 mm
tf = 7.5 mm
tw = 4.7 mm
A = 11.50 cm2
y = 50 mm
Ixx = 2000.5 mm2
Maximum bending stress σb= Mmax*y/ I
= 3065.625*(50) / (2000.05)
σb = 76.638 MPa

3) Checking Factor of Safety for design
Fs = σall / σb = 245/ 76.638
Fs = 3.1968
As Calculated Fs is greater than assumed Fs, Selected Material can be considered as safe.

4) Maximum Deflection (ymax) = WL3/48EI
= (500*9.81*2.53) / (48*210*10^3* 2000.05*10^-6)
ymax = 3.801 mm
As compared to length 2500 mm deflection of 3.801 mm is very negligible. Hence selected channel can be considered as safe.

5) Weight of C-frame = cross-section area*length of frame* mass density
= (11.50*10-4*2.5*7830)

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= 22.51125 kg/ per frame
= 2*22.51125= 45.0225 kg.

B. Design of Roller

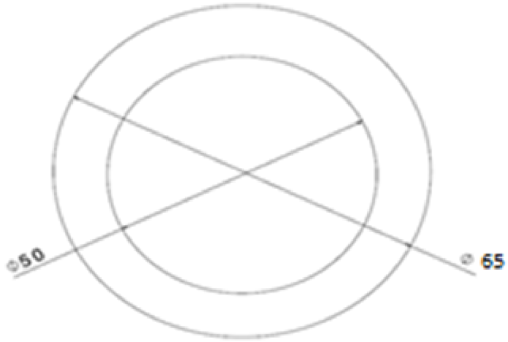

Fig 3 : Roller

1) Material – MS
E= 2.10*105 Mpa, ρ= 7860 Kg/m3, Syt = 590 Mpa
Considering uniformly distributed load & Factor of Safety =2
Allowable Stress (σall) = Syt / Fs = 590/2= 295 Mpa

2) Calculation by considering given roller dimension
W= 1000/3= 333.33 kg (Load act on 3 rollers at a time -------Given)
D1= Outer diameter of roller = 65 mm
D2= Inner diameter of roller = 50 mm
w = Width of roller = 800 mm
y = Distance from neutal axis = 0.075/2 = 0.0375

3) Maximum Moment (Mmax)
Mmax = W*L2/8 = (333.33*9.81*.82)/8
Mmax = 261.5973 Nm
4) Moment of Inertia (I)
I =Π (D14 - D24)/64
= Π (0.0654 – 0.054)/64
I = 5.69427*10-7 m4

5) Maximum bending stress σb = Mmax * y/ I
= 261.5973 * 0.0375 / 5.69427*10-7
σb = 17.23 Mpa

6) Checking Factor of Safety for design
Fs = σall / σb
= 295/17.23Fs = 17.12
As Calculated Fs is greater than assumed Fs, Selected Material can be considered as safe.

7) Maximum Deflection (ymax) = 5*W*L3/384EI
= (5*333.33*9.81*.83) / (384*2.10*1011* 5.69427*10-7)
ymax = 1.82 mm

As compared to length 800 mm deflection of 1.82 mm is very negligible. Hence selected channel can be considered as safe.

8) Weight of Rollers = Cross-section area*width * Mass density* number of rollers
= Π (0.0652 - 0.052) *0.8*7860*11/4
= 93.7068 Kg

C. Design of Shaft

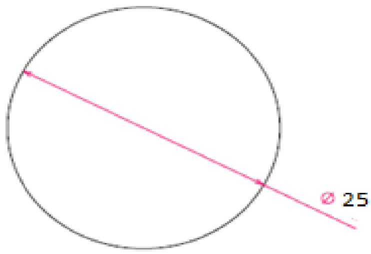

Fig 4: Shaft

1) Material – MS
E= 2.10*105 Mpa, ρ= 7860 Kg/m3, Syt = 560 Mpa
Considering uniformly distributed load & Factor of Safety =2
Allowable Stress (σall) = Syt / Fs = 560/2=280 Mpa

2) Calculation by considering given Shaft dimension
W= 1000/3= 333.33 kg (Load act on 3 rollers at a time)
D = Outer diameter of shaft = 25 mm
w = Width of shaft = 860 mm
y = Distance from neutral axis = 0.02/2 = 0.01

3) Maximum Moment (Mmax) =
Mmax = W*L2/8 = (333.33*9.81*.862)/8 Mmax = 302.308 Nm

4) Moment of Inertia
I = Π (D4)/64 = Π (0.0254)/64 I = 1.9174*10-8 m4

5) Maximum bending stress σb = Mmax * y/ I
= 302.308 * 0.01/ 1.9174*10-8 = 157.66Mpa

6) Checking Factor of Safety for design
Fs = σ / σb = 560/157.66 Fs = 3.5519
As Calculated Fs is greater than assumed Fs, Selected Material can be considered as safe.

7) Maximum Deflection (ymax) =
ymax = 5*W*L3/384EI
= (5*333.33*9.81*.863) / (384*2.10*1011* 1.9174*10-8)
ymax = 6.7258 mm
As compared to length 860 mm deflection of 6.7258 mm is negligible. Hence selected channel can be considered as safe

8) Weight of Shafts = cross-section area*width * mass density* number of shafts

= Π (0.01252) *0.86*7860*11 = 36.498 Kg

D. Bearing

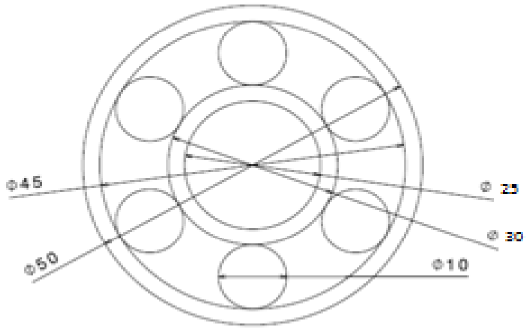

Fig 5: Bearing

1) Standard MRC Bearing,
MRC Bearing number CONV-4 SF, Weight =0.0998 Kg
d= Bore diameter = 25 mm
D=Outer diameter = 50 mm
B= width = 25.4 mm
Bearing is suitable for High radial loads, economical. Total bearing used = 40

2) Total weight of Bearing = 22*0.0998
= 2.1956 kg

E. Design of C- Channels for Supports

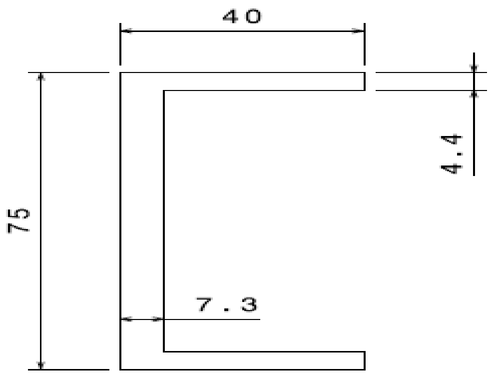

Fig 6: C- Channels for Supports

1) Material- Rolled steel C-10
E= 2.10*105 Mpa, ρ= 7830 Kg/m3, Syt = 490 Mpa

2) Calculation of given dimension
Considering load act at a center& Factor of Safety =2
Allowable Stress (σall) = Syt / Fs = 490/2= 245 Mpa
Load acting = (Load capacity +Weight of C- frame + Weight of Roller + Weight of Shaft + Weight of Bearing) /4
Load acting = (1000+ 45.0225 + 93.7068 +36.498 +2.1956) / 4 = 294.355 kg
L= 900 mm, W= 300 kg on each channel,

Volume 02, Issue 10, [October – 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

Maximum bending moment (Mmax)
Mmax = WL/4= 300 *9.81* .9/4
Mmax = 662.175 Nm
Given C- Channel, ISMC 75
h= Depth of section, tf = thickness of flange, tw = thickness of web,
A= Sectional area Ixx = Moment of Inertia along x-axis
h= 75 mm
b= 40 mm
tf = 7.3 mm
tw = 4.4mm
A = 8.72cm2
y = 37.5 mm
Ixx = 67.865 cm2
Maximum bending stress σb= Mmax *y/I
= 662.175 *(37.5*10-3)/ (67.865 *10-8)
σb = 36.59 MPa

3) Checking Factor of Safety for design
Fs = σall / σb
= 245/ 36.59
Fs = 6.69
As Calculated Fs is greater than assumed Fs, Selected Material can be considered as safe.

4) Maximum Deflection (ymax) =
ymax = WL3/48EI
= (300 *9.81*0.93) / (48*2.10*1011* 67.865 *10-8)
ymax = 0.3136 mm
As compared to length 900 mm deflection of 0.3136 mm is very negligible. Hence selected channel can be considered as safe.

5) Weight of Channels = cross-section area*length * mass density* number of Channels
= (8.72*10-4*.9*7830*4)
= 24.58 Kg

Sr. No	Name of Component	Weight (Kg)
1	C- Channel for Chassis	45.0225
2	Rollers	93.7068
3	Shafts	36.498
4	Bearing	2.1956
5	C- Channel for Supports	24.58
	Total	202.0029

Table 1- Total Weight of Conveyor Assembly

VI. EXPECTED CONCLUSION

The existing system will be redesign and optimize for weight, resulting into material saving by modifying and analyzing the critical conveyor parts. Detailed results will be found in the final part of the dissertation.

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