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Design and Analysis of Multipurpose Conveyor for Shrink Wrapping Machine

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Abstract: *Conveyor units play an important role in packaging industries for material handling purpose. Different type of conveyors are using for industrial application now-a-days like belt conveyors, screw conveyors, bucket conveyors etc. This paper mainly focus on the design& analysisof a multipurpose conveyor system for shrink wrapping machine which can adjust its length, height used as powered & gravity type. In shrink wrapping machine, packaged goods are sealed in special shrinkable film, and then passed through a steam shrink tunnel. Instantaneously, film encloses the product like a second transparent laminated skin, without any folds. For developing this conveyor system data are collected through market analysis, competitive analysis, and customer need analysis, developed QFD and Product Design Specification. After that a Concept is generated and decomposed that physically & functionally. The best concept also selected by Pugh's method & finally benchmarked. Engineering Analysis is performed which include developing geometry, Qualitative analysis like DFMA, DFMEA and Quantitative Analysis like Design Calculation, material selection, mechanical element selection and Detail Design considering GD & T & Assembly using CATIA V5.*
Keywords -*Conveyor System, Concept Generation, QFD, DFMEA, CATIA V5.*

I. Introduction

Packaging industries develop machineries which can pack product ranging from very small to large sizes. Shrink Wrapping Machine or Shrink Tunnel is commonly used in industries. Major applications for shrink wrapping machines are automobile industries, packaging of industrial Products, food industries etc. In shrink wrapping machine, packaged goods are sealed in special shrinkable films like LDPE, PVCand then passed through a steam shrink tunnel to activate the shrinking property in the film. The film then encloses the product like a second transparent skin without folds or wrinkles. Currently, shrink wrapping machines have a chain/metal mesh conveyor systemin order to move the product from input side to output side. Conveyors are usually of the powered type. The shrinking tunnel unit is an assembly of heaters & blowers which are surrounded by an insulating wall. The major design problem of these machines is the difficulty to adjust the height & length of the conveyor unit. So it is difficult to fit the machine into large production line gaps and height of the tunnel is the limitation for tall products.

This paper is mainly concentrated on the design of a multipurpose length adjusting, height adjusting, powered & gravity type conveyor system which can be used with shrink wrapping machines and also to improve the performance of existing machines. A concept is needed todevelop and also to transform it into the mechanical nomenclature considering all design criteria.

For identifying other problems on the existing machines data is collected through market analysis, competitive analysis, and customer need analysis. This paper also Involve developing House of Quality (QFD), Product Design Specification, concept generation, concept decomposition into physically & functionally, Selection of concept, Engineering Analysis like qualitative and quantitative analysis including detail design is also performed. Then the whole concept is modeled in CATIA V5.

II. Methodology

The methodology or the product development process is an activity that brings up with a solution for the problem through concept generation and converts them to the state of market requirement. The Methodology adopted for this work includes understanding the Opportunity, Concept generation, Qualitative & Quantitative analysis& Detailed Design. Understanding the opportunity include Vision of the product that is what we wish to do? And what is the limitation on existing system? Then it also involves market analysis, customer need analysis & finally competitive analysis. Using these data concept is needed to develop which should meet the opportunity of product in market.Shrink Wrapping machine is a common packaging machinery used in almost all industries. These machines will helps to improve the visual representation of all packed products. The machine is available as SS & MS constructions and machine can be controlled either by PLC Control or Micro-Processor Based Control.

III. Understanding the Opportunity

The most Challenging stages in product design are creativity, complexity, choice & compromise. Product Development is a task of creating, understanding, communication, generating ideas, and considering design parameters. The First phase is to “Understand the Opportunity”. This phase encompasses all activities needed to make the decision to launch a new product development effort. This phase include market analysis which is done to determine the Opportunity of new Product. Market analysis is carried out by collecting data’s from potential customers by meeting them directly, through exhibitions, telephonic survey & by online surveys. Market analysis is carried out in order to identify about the product description, key business, primary & secondary market, assumptions, avenues for creative design & scope limitation. Competitive analysis is the stage to determine the most competing product and the specialties are identified in order to improve its overall performance. Customer need analysis is done to identify the customer opinion about the Product, their suggestion for improving the quality. Customer need Analysis includes customer data, Enquiry Type, type of Industry, Typical uses, likes & dislike and Suggestion for further improvement. To move forward a project planwas developed that outlined the key factor comprises completion of product specification, concept generation, embodiment design and detailed design including qualitative and quantitative analysis. The next phase is to develop the House of quality which comprises the (1) customer voice that include the modifications like length adjusting, height adjusting, powered, gravity type of conveyor and (2) Engineering Characteristics that includes the Engineering parameter that used to convert customer voice into engineering Nomenclatures.

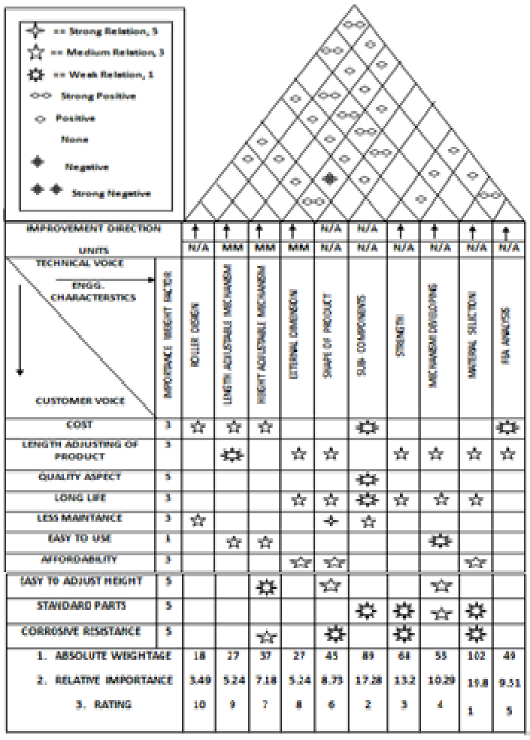

Figure3.1 House of Quality

The Final stage of understanding the opportunity includes developing the Product Design Specification which contains all the factors related to the outcome of product development

IV. Concept Generation and Evaluation

The primary aim of concept generation and evaluation is to ensure that the product can perform all of the major functions. Hand drawn sketches are developed by considering the entire requirement that performed during the stage of understanding the opportunity. Number of possible concepts is generated for length adjusting, height adjusting, powered & gravity type requirements and theses concepts are evaluated using Pugh's evaluation method. Pantograph Mechanism is selected to adjust the length adjusting option, which can be used as powered and gravity conveyors. Bolt-Nut mechanism is used to adjust the height. During this stage a FAST- Diagram is developed that describes the decomposition of the product functionally and physically. After that the concept for whole machinery is developed incorporating these mechanisms and overall feature bench marked with competing products.

V. Embodiment Design

Embodiment design of this work includes the quality aspects, reliability, geometry developing, performing engineering calculation etc. And the whole work is classified as Qualitative Analysis and Quantitative analysis.

5.1 Qualitative analysis

In order to ensure an overall quality design, a complete qualitative engineering analysis of multipurpose conveyor unit is carried out. Also considering the Design for Manufacturing and Assembly (DFMA), Design for Failure Mode and Effects Analysis (DFMEA), as well as Design for Environment (DFE), are followed.

5.1.1 Design for Manufacturing and Assembly (DFMA)

Throughout the process of finalizing the design, we considered the factors for easy manufacturing and assembly by minimizing part and making necessary arrangements for easier maintenance in future. Most of the parts are taken as Standard in order to maintain the overall quality. Design for joining (DFJ) is adequately considered so as to make the assembly procedure easy and the maintenance simple. Riveting of parts is eliminated since maintenance work if required will be difficult and also costly. Also Joining of parts by welding is also eliminated for easier replacement of parts at the time of service.

5.1.2 Design for Environment (DFE)

During the design process we have considered the environmental impact of the product throughout its lifecycle through multiple designs for environment (DFE) guidelines. The guideline involves physical optimization, easy maintenance and repair by allowing easy access to all components of the mechanism such as length adjusting as well as height adjusting, material optimization.

5.1.3 Design Failure Mode Effect analysis (DFMEA)

DFMEA is a structured approach that ensures potential failure modes and their associated causes have been considered and addressed in product design stage. This procedure is carried out from design conceptualization stage onwards. Each Concept is analyzed by what can go wrong? Where will the Variation come from? How can we prevent or Control? Each Concept is anticipated for cause that what can go wrong? Severity may reflect options like "not feasible" when considering DFM & DFE. The occurrence can be considered based on literature reviews, customer's opinion, and experience and finally recommending corrective action. If the cause of problem is not anticipated it should be done at the time of PFMEA. DFMEA is carried for this work using the aid of the following data Customer Requirements, Competitive analysis, House of quality, Product design specification, Generated Concept, Literature Reviews. The minor failure means failure due to yielding initial stage corrosion formation, but this failure never affects the overall failure of the system. While the Major failure will affect the full system functioning.

Table.5.1 DFMEA Evaluation

Sub-Part	Part & Function	Failure Mode	Failure Effect	S	Failure Cause	O	Design Control	D	RPN	Recommendation
ENCLOSURE	COVERING	Corrosion	MINOR	5	Exposing to direct atmosphere	3	Avoid exposing	2	30	powder coating / heat treatment
			MAJOR	7		1		2	14	
		Yield	MINOR	5	Overloading ,improper loading, alignment	1	Load the part which no yielding will occur	1	5	Increase the gauge of sheet
			MAJOR	8		1		1	8	

		Weld Failure	MINOR	6	Failure occurs during welding because gauge size of sheet is lower.	1	done by skilled person	1	6	Increase the gauge
			MAJOR	7		1		1	7	
LENGTH ADJUSTING	Pantograph	Yield	MAJOR	9	Overloading ,improper loading, alignment	1	Load the part which no yielding will occur	1	9	Increase the gauge of Links
		Rust Formation	MINOR	2	Atmosphere Contact	3	Avoid Contact	3	18	Coating-Chromium
			MAJOR	7		6		3	126	
		Deflection at the center	MAJOR	8	Overloading ,improper loading, alignment	1	Load the part which no yielding will occur	1	8	Provide movable type Supports
	Conveyor Roller	Yield	MINOR	6	Overloading ,improper loading, alignment	2	Load the part which no yielding will occur	2	24	Increase the thickness
			MAJOR	7		2		2	28	
		Rust Formation	MAJOR	7	Atmosphere Contact	5	Avoid Contact	4	140	ALUMINIUM
	Idle shaft	Yield	MAJOR	8	Overloading ,improper loading, alignment	5	Load the part which no yielding will occur	2	80	Increase the thickness
		Rust Formation	MAJOR	8	Atmosphere Contact	5	Avoid Contact	3	120	Provide Heat Treatment

5.2 Quantitativeanalysis
Quantitative analysis involves material selection, performing design calculations, setting geometry etc.

5.2.1 Design Calculation
The design calculation is performed for length adjusting unit, height adjusting unit.

5.2.1.1 Length adjusting
For adjusting the length Pantograph mechanism is used.

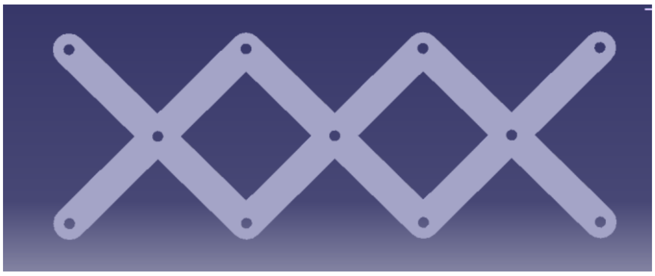

Figure 5.1 Conveyor-Pantograph Mechanisms

The design calculation is start with considering the constraints like weight of product is 75Kg and this 75 kg load is equally shared by two bearings kept at the end of the roller, thus 375N force is acting on bearing and this load is transfered to the shaft which is kept inside the roller. Thus the design calculation starts from the design of this shaft.The Maximum bending moment obtained is 5.625 Nm and FOS taken is 2. Using bending Equation,

$$\sigma_b = \frac{32M}{\pi d^3} \quad (1)$$

d = 6.7058 mm

and selected the standard size as 12 mm. The bearing selected for roller is NTN 6000 zz. The load is transferred to the conveyor roller in the form of UDL. The material chosen for conveyor roller is aluminum because of lower weight, resistance against corrosion. The maximum bending moment for the conveyor roller is 14.025 Nm. The selected roller has a dimension of outer diameter 32 mm and inner diameter 24 mm and the factor of

safety for selected roller is 23.5 times higher. Hence the design will be safer. The length of the conveyor is adjusted using pantograph mechanism. The material used for the mechanism is C-15, From Fig 5.2
Calculation starts from, Taking Moment about B,

∑MB= 0

Fy=W-FxtanΦ (2)

∑Fx = 0

Fx=Rx1 (3)

∑Fy=0.

Fy-W/2-Ry1=0

Ry1=W/2-Fy (4)

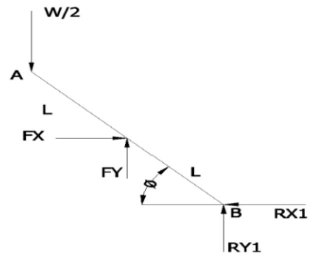

Figure 5.2. Free body diagram inner.

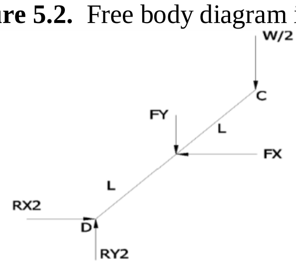

Figure.5.3. Free body diagram outer.

From Fig 5.3,
Taking moment about D,

∑MD = 0

Fx = W/tanΦ+Fy/tanΦ

=W/tanΦ (5)

∑Fx=0

Fx=Rx2 (6)

∑Fy=0

-Fy-W/2+Ry2=0

Ry2=W/2+Fy (7)

The rotary motion of the rollers are developed using chain& sprocket. The chain pull required to transfer this system is,

Cp = $9.81\mu_c[(2.05 + W_c xL) + W]$ (8)

Where W = 900 kg,Wc = 1.68kg and L = 2.4 m. Chain pull obtained after considering FOS and Coffcient of friction is 2222.16 N. And the chain selected is ISO 10B, 15.875 mm Pitch and sprocket selected is,15.875 mm Pitch of simplex type. The conveyor should rotate at 75 rpm. The driver shaft is subjected to combined bending and torsion and the dimension is calculated using,

a) *Max. Shear Stress Theory*

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_3) \quad (9)$$

$$\frac{1}{2}(\sigma^2 + 4\tau^2)^{1/2}$$

b) *Octahedral shear Stress Theory*

$$\tau_{oct} = \frac{\sqrt{2}}{3}((\sigma)^2 + 4(\tau)^2)^{1/2} \quad (10)$$

Taking FOS 2 and Material as En8D and standard shaft diameter selected is 20mm and the same dimension is used for driven shaft also. The bearings which kept as support for driver shaft are NTN 6004 ZZ, SKF 6302, NTN 6003 ZZ and the circlip used are Heavy A 20,17 & 35 IS, Light A 10 IS.

6.2.1.2 Height adjusting Mechanism

The mechanism adopted for height adjustment is bolt-Nut mechanism, with the help of chain system.
M10 threaded Stud is used with following parameter l =100mm, Radius of gyration = 2.5 mm, a = 78.53 mm², Both End fixed at the time of loading, n =1, Assuming FOS = 2, σcr = 320Mpa, σall = σcr/FOS.
Using Rankine's Formula,

$$Pc = \frac{a x \sigma_{all}}{1+C\left(\frac{L}{r}\right)^2} \qquad (11)$$

$$= 10355.6N$$

Load Carrying Capacity = 13.8 times safer.
Sprocket Selected is SKF PHS 06B-1B10.The effort required to rise and lower the weight is calculated.

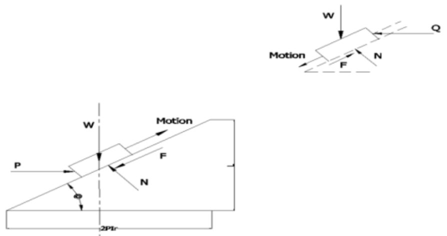

Figure 5.5 Free Body Diagram-thread

Fig.5.5 Free Body Diagram
Effort required raising the load,F_{t_R}

$$F_{tr} = P$$

ΣFx = 0,

$$P - F\cos\theta - N\sin\theta = 0 \qquad (12)$$

ΣFy = 0

$$-W + N\ \cos\theta - F\sin\theta = 0$$

$$p = F\cos\theta + N\sin\theta$$

$$W = -F\sin\theta + N\cos\theta$$

$$\begin{Bmatrix} P \\ W \end{Bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} F \\ N \end{Bmatrix}$$

$$\begin{Bmatrix} F \\ N \end{Bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}^{-1} \begin{Bmatrix} P \\ W \end{Bmatrix} \qquad (13)$$

Transforming the equation in the form of matrix and we obtain,

$$\begin{Bmatrix} F \\ N \end{Bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} P \\ W \end{Bmatrix} \qquad (14)$$

When the block just moves up the plane, Fmax = μN

$$\frac{Fmax}{N} = \mu = \frac{P\cos\theta - W\sin\theta}{P\sin\theta - W\cos\theta}$$

$$P\cos\theta - W\sin\theta = \mu\,(P\sin\theta + W\cos\theta)$$

$$P(\cos\theta - \mu\sin\theta) = W(\sin\theta + \mu\cos\theta) \qquad (15)$$

$$\frac{F_{tr}}{W} = \frac{P}{W} = \frac{\sin(\emptyset+\theta)}{\cos(\emptyset+\theta)}$$

$$F_{t_R} = \text{W}\tan(\emptyset+\theta) = 71.57\text{ N} \qquad (16)$$

Similarly,
Effort required lowering the Load,F_{t_L}

$$Q = F_{t_L} = W\tan(\emptyset - \theta) = 49.65N \qquad (17)$$

Thus Effort Required to Raise the Load is taken for Design Calculation, Effort at driver Sprocket Tangential force, F_T = 4x71.57 = 286.28 N Torque Required, T = 4.41 Nm Assuming the system is at No Lubrication & Dirty Condition, FOS = 16,F_T = 16x 286.28 = 4.58 KN. Selecting Chain 06B-1 R957 Having Minimum Bearing Load, W_B = 8.9271 KN, FOS = W_B/ 286.28 = 31.18 times Safer

5.3 Engineering analysis

Once the design calculation is over the next stage is to evaluate the critical parts in design using analysis software. This is done to find the location where stress is concentrated and to reduce this stress and also to optimize parts.

VI. Detailed Design

Engineering drawing is done after Qualitative and Quantitative analysis for the generated concept. From the quantitative analysis we get the geometry & material property, the next stage is to draw the parts by considering all design criteria. Once this stage is over next is to check the 2D part assembly. Then only the detailed 3D modeling will start. Once the detailed drawing is over next the overall machinery is modeled in CATIA V5 which includes parts modeling, Generative sheet metal design and Assembly design.

Figure 6.1 Assembled view in CATIA V5

VII. Conclusion

In this research work include all the design development procedures are carried out as per industrial procedure. To meet the demand of a length adjusting, height adjusting powered type conveyor system for shrink wrapping machine we researched the market, spoke with the customers and met with key individuals in the field in order to fully define the scope of our task. From this research, customer requirements were defined which were turned into engineering specifications and correlated using the aid of a QFD diagram. From the QFD the most important design characteristics arelength adjusting, height adjusting, material Selection, quality, cost are considered at the time of design calculation. To move forward with the design a project plan was developed that outlined key factor comprised of completion of product specification, concept generation, embodiment design and detailed design including qualitative, quantitative analysis, detailed design.

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