ISSN 2395-1621

Design of Chain Conveyor System and Analysis by FEM

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ABSTRACT

Economic strength of country is governed by Agricultural and Industrial sector. Various agricultural products play vital role in economy, sugar cane is one of such product which is backbone of sugar industry. Sugar cane industry heavily rely on the use of roller chain conveyors, around 60-70% processes make use of roller chain system. Problem in working of conveyor system leads to economic as well as material losses affecting overall annual progress report of state government. Imperfection in design and different types of stresses developed during working are the root causes of failures. Optimization in design procedure and use of Finite Element Method for concerned parameters will lead for best solution of chain conveyor system.

Keywords— Finite Element Method, Roller chain conveyor, Stress.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Generally agricultural and industrial sectors are key of state economy. Sugar is one of the important industries of state as well as country. Roller chain conveyer system is mostly used for production of sugar around 65 processes depends on it. This system also used in various types of industries. Failure in chain is big problem of industries because it breaks the economic growth due to losses. Mostly failure in chain is due to tension which is the big problem for agriculture as well as industrial sector. Improper design is mainly responsible for chain failure. For obtaining the best results, optimization under given circumstances in design of chain conveyor system. With the help of optimization process we can find the conditions that give the maximum and minimum value of function [1, 2].

A) Chain Types

There are two main types of conveyor chain - hollow bearing pin and solid bearing pin.

i)Basic Structure of Roller Conveyor Chain:

Chains are used in a variety of applications in engineering practice. In general, there are three basic types of system; hoisting and securing chains, conveying and elevating chains and power transmission chains. Conveyors chains are used when material are to be moved frequently between specific points. Depending on the materials to be handled and the move to be performed, a variety of conveyors can be used. All roller chains are constructed so that the rollers are evenly spaced throughout the chain. Several types of roller chains are used in conveyors, many of single-pitch or double-pitch conveyors chain but here below Fig.1 shows the basic structure of roller conveyor chain[3].

Main components of roller conveyor chain are pin, link plate (strip), bushing and roller. The pin link plate i.e. strip is the assemblies of two pins that are press fitted into the holes of two pin link plates. The press fit between pin and the pin link plate prevents the pin from rotating. Usually there is a repeated loading, sometimes accompanied by shock. The pin is subject to shearing and bending forces transmitted by the plate. There is slip fit between bushing and pin. The bushing is subject to shearing and bending stresses transmitted by the plate and roller, and also gets shock loads when the chain engages the sprocket[4].

In addition, when the chain articulates, the inner surface forms a load-bearing part together with the pin. The outer surface also forms a load-bearing part with the roller's inner surface when the roller rotates on the rail or engages the sprocket. There is slip fit between the bushing and the roller. The roller is subject to impact load as it strikes the sprocket teeth during the chain engagement with the sprocket. After engagement, the roller changes its point of contact and balance. It is held between the sprocket teeth and bushing, and moves on the tooth face while receiving a compression load. A major advantages of roller chian is that the rollers rotate when contacting the teeth of the sprocket[3,4,5].

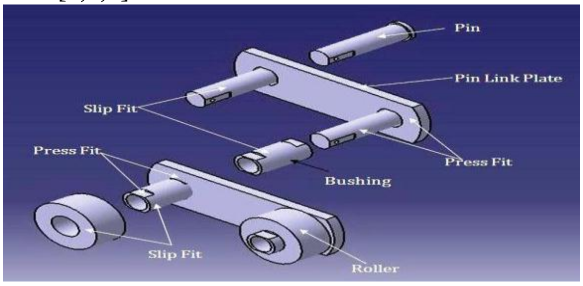

Fig. 1 Basic components of chain link

II. LITERATURE SURVEY

Tushar D. Bhoiteet. al. [1]studied into various application aspects and manufacturing aspects to formulate an idea of the system. Finally for shape optimization finite element analysis is used. Since lot of work has already been done in other components, outer link was a main component for this work. Within the outer link, most dimensions in the industry are parametrically defined, however one dimension, the radius that is in between inter connecting holes is left to manufacturer convenience. In this paper we assess the impact of this radius on the stress in the system and see if material saving and consequently efficiency increment is possible.

M. Koray KESİKÇİ et. al. [2]widely worked in literature the theoretical differences and the superiorities of the techniques over each other. Roller chains are used as pulling and driving members of materials handling mechanisms are inspected. Boundary and finite element methods are used for stress analysis of a standard roller chain link. Considered Standard roller chain under maximum load to find out various mechanical calculations. Differentiate between both techniques with each other and the results of literature, the appropriate method for the roller chain problem is proposed.

Shoji NOGUCHI et. al. [3] suggested some approaches regarding stress reduction and weight saving of roller chains plate. Stresses are 3% higher in proposed design, but the weight reduced in 10%. Material of link plate was resin and tensile tests carried out for good result.

XU Lixinet. al. [4]investigated a mathematical model for calculationof dynamic response of a roller chain drive working at constant or variable speed condition. This model used two sprockets and the necessary tight and slack spans for complete chain transmission. The effect of the flexibility of input shaft on dynamic response of the chain system is taken into account, as well as the elastic deformation in the chain, the inertial forces, the gravity and the torque on driven shaft. The nonlinear equations of movement are derived from using Lagrange equations and solved numerically. Given the center distance and the two initial position angles of teeth on driving and driven sprockets corresponding to the first seating roller on each side of the tight span, dynamics of any roller chain drive with two sprockets and two spans can be analyzed by the procedure.

Finally, a numerical example is given and the validity of the procedure developed is demonstrated by analyzing the dynamic behavior of a typical roller chain drive. The model can well simulate the transverse and longitudinal vibration of the chain spans and the torsional vibration of the sprockets. This study can provide an effective method for the analysis of the dynamic characteristics of all the chain drive systems.

V. Kerremanset. al. [5] studied various wear and different environment conditions for chain conveyor system, soiled with water, foreign particles, chemicals or other contaminants. Normal use will result in wear of the components of the chain which can lead to unexpected failure and costly production downtime. Today, few literatures on the wear of conveyor chain is available and there are almost no reliable test-rigs to generate and measure chain wear in a reproducible manner. In this research the different components of conveyor chains and the loading conditions are described. Additionally, the applications and (dis)advantages of chains with polymer rollers are discussed. The chain wear mechanisms found in literature are listed. Abrasive and adhesive wear between pin, bushing, roller and track are discussed. From the contact mechanics of the chain and pressure-velocity limit of the roller materials, the design constraints for the laboratory test-rig were derived. The capabilities and working principles of the developed test-rig are explained in this work.

III.DESIGN OF CHAIN CONVEYOR

To ensure the selection of chain for a particular application and it is necessary to consider following factors:

I. Conveyor type.
II. Centre distance and inclination from the horizontal of conveyor.
III. Chain attachment type, chain spacing and method of fixing to the chain.
IV. Chain speed and number of chain
V. Details of weight of slats, buckets, etc for conveying
VI. Weight, size and quantity of particular material.
VII. Method of operating environment and rate of delivery.

Chain manufacturers specify the chain in their product range by breaking load. Some have quoted average breaking loads; some have quoted minimum breaking loads depending upon their level of confidence in their product. To obtain a design working load it is necessary to apply a “factor of safety” to the breaking load and this is an area where confusion has arisen. As a general rule, for most applications a factor of safety of 8 is used [8].

Working Load = Breaking Load/8
For horizontal slat conveyor selecting suitable chain type:
Transported material: brow coal
Conveyor length: 25 m
Flow: 30 T/h
Conveyor conduit width: 350 mm
Conveyor conduit height: 250 mm
Roller Diameter: 250 mm
Number of chains: 1
Number of teeth of the sprocket: 11(pre-selected)
Load distribution: even

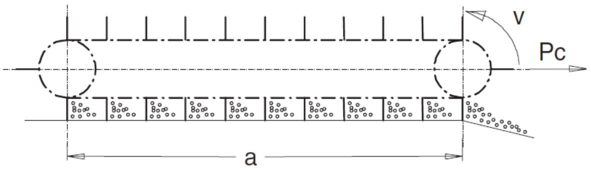

Fig 2.Horizontal slat conveyor

1. Material flow Q   Q = 30 T/h
2. Chain velocity v   Q = H. B .β. γ. v. 3600 (T/h)

$$v = \frac{Q}{H.B.\beta.\gamma.\ 3600}$$

$$v = \frac{30}{0.35 \times 0.25 \times 0.6 \times 0.7 \times 3600}$$

= 0.22 m/sec.

Where,
H= Conduit Height (m)
B= Conduit width (m)
β = conveyor repletion coefficient = 0.5 to 0.6
γ = specific weight of transported material (T/m^3) = 0.7 (Ref. Table 8) [8]

3. Weight of transported material P_1

$$P1 = a.\ \frac{Q}{3.6\, v}$$

$$P1 = 25 * \frac{30}{3.6 \times 0.22}$$

= 946.96 kg
= 9290 N

Where,
a = Conveyor length (m) = 25 m

4. Selection of suitable chain
Selected chain must resist the weight of transported material multiplied with safety coefficient (k = 8).
Thus its break strength must be:

$$F_B = P_1.\ k = 9290 \times 8 = 74320 \text{ N}$$

Corresponding type of chain according to DIN 8167 (ISO 1977) is MRC 80 x 125[9].

Selection of a conveyor chain
5. Chain weight
The selected chain's weight per meter is q = 4 kg/m; its pitch is p = 125 mm and the assumed number of teeth of the sprockets is Z = 11
Total chain weight is:

$$d_t = \frac{p}{\sin\frac{180}{z}}$$

$$= \frac{125}{\sin\frac{180}{11}}$$

= 443.68 mm
= 0.444 m

$L = 2 * a + \pi * d_t = 2 * 25 + \pi * 0.444 = 51.39$ m (Chain length)

P = L * q = 51.39 * 4 = 206 kg (Chain Weight) [8].

6. Selection of friction coefficient f_r
The chain slides on steel guide way.
The estimated reading of Table 2 is $f_r = 0.3$.

7. Correction coefficient for type of operationF_s
See Table 4:
Load balance - centered load Fs = 1.0
Load characteristics - small fluctuations Fs = 1.2
Frequency of start/stop under load Fs = 1.0
Operating environment - medium dusty Fs = 1.2
Work hours per day Fs = 1.2
Total friction coefficient $F_s = 1.728$

8. Determination of velocity correction coefficient Fv
Chain velocity v = 0.22 m/sec. see Table 5; for Z = 11 the resulting value Fv = 0.8

9. Friction coefficient f_m
The friction coefficient "f_m" describes the influence of friction of transported material vs. conveyor conduit.
See Table 8 - for given material, $f_m = 0.7$

10. Computation of traction force T

$$T = 9.81\ \frac{(P.fr + P1.fm).Fs.Fv}{\text{Number of chains}} \text{ N}$$

$$T = 9.81\ \frac{(206 * 0.3 + 947 * 0.7)\ 1.728 \times 0.8}{1}$$

T = 9828 N (Number of chains 1)

11. Computation of necessary shaft power N

$$N = \frac{T\,v}{1000}$$

$$= \frac{9828 * 0.22}{1000}$$

= 2.166 kW

12. Specific pressure on chain joints p_t

$$P_t = \frac{T}{f}$$

$$= \frac{9828}{468}$$

$_t$= 21 MPa< 25 MPa(see Table 6)

f = 468 mm^2according to the chain catalogue.
Computed specific pressure is lower than maximum permissible pressure listed in Table 6.
The selected chain fulfils requirements.

13. Sprockets
The design and actual condition of the sprocket influences the chain operating life the most. Generally speaking, the following recommendations should be followed:

a) Sprockets of the biggest possible diameter should be employed to lower the pressure on chain joints and the polygonal effect.
b) Driving wheels should be located at conveyor end, especially with complicated conveyor designs (e.g. conveyors that include fermentation or dry-up compartments).
c) If the conveyor employs two or more interconnected chains, their driving sprockets must not be interlocked.

The following formula can be used to determine the pitch. outer and root diameters of a sprocket[8]:

$$D_p = \frac{p}{\sin\frac{180}{z}}$$

$$= \frac{125}{\sin\frac{180}{11}}$$

= 443.68 mm
= 0.444 m

$D_e = D_p + (0.6875)\ D$ (mm)
= 443.68 + 0.6875 x 250

= 620 mm
= 0.620 m
$D_i = D_p - D$ (mm)
= 443.68 – 250
= 195 mm
Where:Dp = pitch diameter (mm) p = chain pitch (mm)
De=outer diameter (mm) Z= number of teeth
Di = root diameter (mm)D = dia of chain roller (mm)

IV. SOFTWARE USED FOR MODELING & ANALYSIS

Catia V5 R20

P1, P2 and P3 are three basic platforms of CATIA V5. P1 is used for small and medium sized process oriented companies that wish to grow toward the large scale digitized product Definition. P2 is used for product, process and resource modeling which is prefer in advanced design engineering companies. P3 is used for Aerospace Industry, where high quality surfacing or class-A surfacing is used for designing. A good feature is that any change made to the external data is notified to user and the model can be updated quickly. A workbench is defined as a specified environment consisting of a set of tool, which allows the user to specific design tasks in a particular area.

A) Part design workbench

It is a parametric and feature-based environment. Solid models can create with help of part design workbench. Sketch is the main requirement of this system. Sketcher toolbar is used as drawing instruments. While drawing a sketch, user can afford various applicable constraints.

Wire frame and Surface Design workbench

This is used for creating wire frame or surface models of basic and advanced surfaces. Required shape also provided to user.

B)Assembly design workbench

Assembling the components using the assembly constraints available in this workbench.

C) Drafting Workbench

Documentation of the parts or assemblies are function of drafting workbench. It consists drawing views and their details. Drafting techniques are mainly divided in:

Generative drafting

Interactive drafting

The generative drafting technique is used to automatically generate the drawing views of the parts and assemblies, the parametric dimensions added to the component in the part of design workbench during its creation can also be generated and display automatically in the drawing views. The generative drafting is bi-directionally associative in nature. Interactive drafting used for generating the bill of material and balloons in the drawing views, user needs to create the drawing views by sketching them using the normal sketching tools and then adding the dimensions.

Ansys 14.0

Ansys is used for analysis which is developed by finite element modeling and meshing. ANYAS 14.0 consists new enhancement that improves the solution procedure and features high performance computing due to shared memory. Ansys run on windows 32- and 64-bit systems PCG Lanczos method provides a robust and efficient option for large modal analyses.

D) Different Types of Element

I) Element;

As the geometry of the structure modal has been established the grid points are connected by finite element, each element has its own characteristics. The different element is described below:

II) Line Element (1D Element);

Line elements are also called one-dimensional elements, are used to represent rod and beam behavior. A one-dimensional element is one in which the properties of the element are defined alone a line or curve. Typical applications for the one-dimensional element include truss structure, beam, stiffeners and many others. A rod element support tension, compression and axial tension, but not bending. A beam element includes bending.

III)Surface Element (2D Element);

Surface elements, also called two-dimensional elements, are used to represent a structure whose thickness is small compared to its other dimensions. Surface elements can model plates, which are flat or shells, which have single curvature (Like a cylinder) or double curvature (Like a sphere). For grid points connected to plate elements, stiffness terms exist for five of the possible six degrees of freedom-the rotational DOF about the normal to the plate is “unconnected”.

IV)Solid Elements (3D Elements);

Solid (Three-Dimensional) elements are used to represent the behavior of thick plates and solids. Solid elements connect only translational degrees of freedom, no rotational degrees of freedom are connected to solid elements.

V)Scalar Elements;

Scalar elements are referred to as zero dimensional elements, consists of the springs, masses and viscous dampers. All scalar elements are defined between two degrees of freedom and ground. Stiffness for scalar elements has to be defined.

Chain Link Model
According to DIN 8167

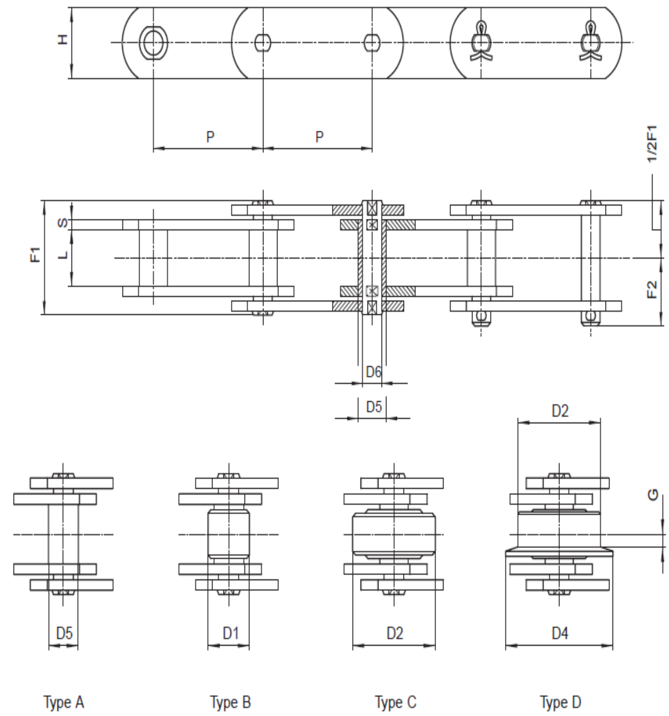

Fig 3. Chain Link Model[9]

Type A is used with following Specifications for MRC 80 x 125.

Table 4.1 SPECIFICATIONS OF CHAIN LINK MODEL [9]

Chain N.	P mm	L mm	D1 mm	D2 mm	D4 mm	G mm	D5 mm	D6 mm	H mm	S mm	F1 mm	F2 mm	Breaking load N	Breaking load N*
M 20	40	16	12,5	25	32	3,5	9	6	18	2,5	33	19	20.000	32.000
“	50	“	“	“	“	“	“	“	“	“	“	“	“	“
“	63	“	“	“	“	“	“	“	“	“	“	“	“	“
“	80	“	“	“	“	“	“	“	“	“	“	“	“	“
M28	50	18	15	30	36	4	10	7	20	3	36	20,5	28.000	42.000
“	63	“	“	“	“	“	“	“	“	“	“	“	“	“
“	80	“	“	“	“	“	“	“	“	“	“	“	“	“
“	100	“	“	“	“	“	“	“	“	“	“	“	“	“
M 40	63	20	18	36	45	4,5	11	8	25	4	40,5	24	40.000	60.000
“	80	“	“	“	“	“	“	“	“	“	“	“	“	“
“	100	“	“	“	“	“	“	“	“	“	“	“	“	“
“	125	“	“	“	“	“	“	“	“	“	“	“	“	“
M 56	63	24	21	42	50	7	15	10	30	4	45	26	56.000	85.000
“	80	“	“	“	“	“	“	“	“	“	“	“	“	“
“	100	“	“	“	“	“	“	“	“	“	“	“	“	“
“	125	“	“	“	“	“	“	“	“	“	“	“	“	“
“	160	“	“	“	“	“	“	“	“	“	“	“	“	“
M 80	80	28	25	50	60	7	18	12	35	5	54,5	30,5	80.000	125.000
“	100	“	“	“	“	“	“	“	“	“	“	“	“	“
“	125	“	“	“	“	“	“	“	“	“	“	“	“	“
“	160	“	“	“	“	“	“	“	“	“	“	“	“	“
“	200	“	“	“	“	“	“	“	“	“	“	“	“	“

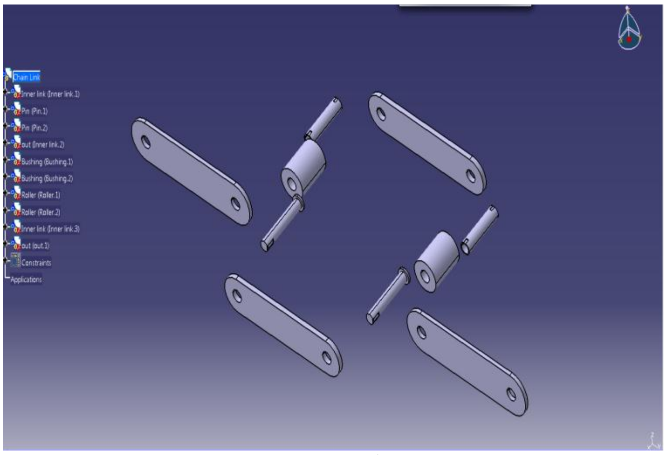

Fig 4. a) 3-D model of chain link

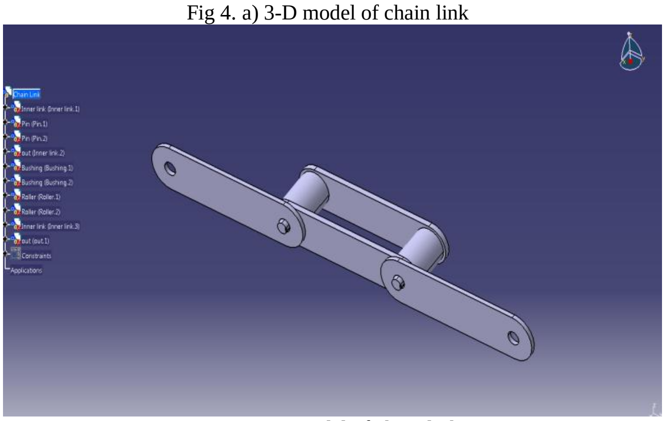

Fig 5. 3-D model of chain link

V. CONCLUSION

The stress analysis was performed by FEM, and some methods were considered with the suppression of the increase in stress. The design proposal for the use of a centrally located hole in a link plate has a beneficial effect on weight saving and yields a negligible stress though this optimization seems insignificant on its own, it must be noted that in a typical industrial application, thousands of such links will be needed.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to **Dr.C.LDHAMEJANI**, Principal Jaihind College of Engineering, Kuran for providing me an opportunity to present a paper on **“**DESIGN of CHAIN CONVEYOR SYSTEM and ANALYSIS by FEM**”** This Paper is in complete without the guidance of many peoples.

I sincerely thank to my project guides **Prof. H.K. Mishra(ME Co-ordinator)** for guidance in carrying out this paper. who has been constantly a source of encouragement for this paper work. I wish to avail myself of this opportunity, express a sense of gratitude and love to my friends and my beloved parents for their manual support, strength, and help for everything

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