Optimization of Chain Link of Material Handling Chain Conveyor System from FEA and Experimental Aspects

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***Abstract*— Roller chain drives are widely used in various high-speed, high-load and power transmission applications, but their complex dynamic behaviour is not well researched. Most studies were only focused on the analysis of the vibration of chain tight span, and in these models, many factors are neglected. In this paper, a mathematical model is developed to calculate the dynamic response of a roller chain drive working at constant or variable speed condition. In the model, the complete chain transmission with two sprockets and the necessary tight and slack spans is used. 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 centre 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 analysed by the procedure. Finally, a numerical example is given and the validity of the procedure developed is demonstrated by analysing the dynamic behaviour 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.**

Chain Link assembly is extensively used in the industry, the scope of this work is to review the applications in the industry and explore the design considerations that go into the design of the assembly. The work deals into various application aspects and manufacturing aspects to formulate an idea of the system. Finally Finite Element Analysis (FEA) has been used to conduct structural analysis. Since lot of work has already been done in other components, in this work the focus has been narrowed down to specific component of link and its joint.

***Index Terms*— Chain Link, Optimization**

I. Introduction

Economy of state is dominated by agricultural as well as industrial sector. Sugar factories play important role in economy of state. About 60 percent processes in these factories are based on roller chain conveyers.

Apart from that, other industries also use these chains frequently for process atomization. However, failure of this chain is perennial problem in these industries which causes huge losses to these industries along with its dependents and in turn economic growth of the state. So, roller chain is the most important element of the industrial processes. Fig 1.1 shows the typical roller chain link assembly Most of the time chain is under tension which causes failure of chain assembly which is the major problem for industrial sector. Causes of this failure are improper design. It is important to study the influence of these parameters. All these parameters can be considered simultaneously and chain link design optimally. Optimization is the process of obtaining the best result under given circumstances in design of system. In optimization process we can find the conditions that give the maximum and minimum value of function.

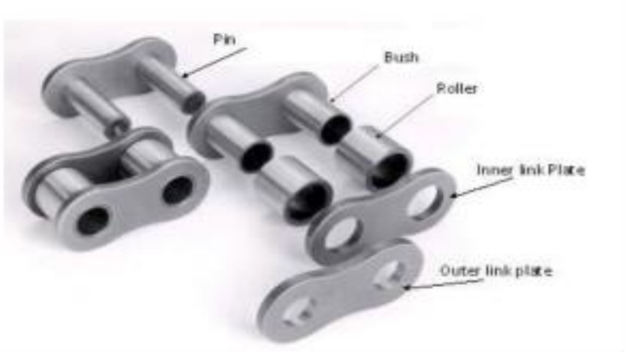

Fig. Chain Components

II. LITERATURE SURVEY

The word meaning “chain” can be traced back to an ancient word in the Indo-European language family. As early as 225 BC, chain was used to draw a bucket of water up from a well. This very early bucket chain was composed of connected metal rings.

In the 16th century, Leonardo da Vinci made sketches of what appears to be the first steel chain. These chains were probably designed to transmit pulling, not wrapping, power because they consist only of plates and pins and have metal fittings. However, da Vinci’s sketch does show a roller bearing.

It took some time for the technology to catch up with the concept. Problems in the manufacturing and processing of steel prevented chain growth until the 19th century, when new technologies made steel chain and bearings realities. In the 1800s, a Frenchman named Gull obtained a patent for a similar chain for use on a bicycle. This chain, called “Gull Chain,” is still used today in hanging applications.

When molded chain was invented in the 19th century, things began to move rather quickly. First came the cast detachable chain, which is composed of identical cast links. Next, the pintle chain, which has a separate pin, appeared. The cast detachable chain and the pintle chain have been improved over the years, and they are still in use today in some special applications. They are being replaced—gradually—by large pitch steel conveyor chain.

In the late 1800s, a new development—the bushing—revolutionized steel chain. Chains with bushings had greater wear resistance than Gull Chain because the bushing acted as a bearing, protecting the pin. At this point, the chain story moves into super speed. Steel bushing chain was used on bicycles, in the rear-wheel drive of early automobiles, and, in 1903, as the propeller drive in the Wright brothers' airplane.

III. Chain Basic Info

A. *CHAIN TYPES*

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

1. Hollow Bearing Pin Chain

   Hollow pin conveyor chain offers the facility for fixing attachments to the outer links using bolts through the hollow pin and attachment, this method of fixing being suitable for use in most normal circumstances. The attachments may be bolted up tight or be held in a 'free' manner. Bolted attachments should only span the outer link as a bolted attachment spanning the inner link would impair the free articulation of the chain.

2. Solid Bearing Pin Chain

   Solid bearing pin chain, while having exactly the same gearing dimensions in the BS series of chain as the equivalent hollow pin chain, i.e. pitch, inside width and roller diameter, is more robust with a higher breaking load and is recommended for use where more arduous conditions may be encountered.

3. Deep Link Chain

   Hollow and solid pin chain has an optional side plate design known as deep link. This chain's side plates have greater depth than normal, thus providing a continuous carrying edge above the roller periphery.

B. *STANDARDS*

Conveyor chain, like transmission chain, can be manufactured to a number of different international standards. The main standards available are:

1. British Standard – BS

   This standard covers chain manufactured to suit the British market and markets where a strong British presence has dominated engineering design and purchasing. The standard is based on the original conveyor chain design.

2. ISO Standard

   Chain manufactured to ISO standards is not interchangeable with BS or DIN standard chain. This standard has a wide acceptance in the European market, except in Germany. Chain manufactured to this standard is becoming more popular and are used extensively in the Scandinavian region.

IV. Design of Chain Link of Conveyor

To enable the most suitable chain to be selected for a particular application it is necessary to know full application details such as the following:

- Type of conveyor.
- Conveyor center distance and inclination from the horizontal.
- Type of chain attachment, spacing and method of fixing to the chain.
- Number of chains and chain speed.
- Details of conveying attachments, e.g. weight of slats, buckets, etc.
- Description of material carried, i.e. weight, size and quantity.
- Method of feed and rate of delivery.

FACTORS OF SAFETY

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,

Working Load = Breaking Load/8

A. *SUITABLE TYPE OF CHAIN HAS TO BE SELECTED FOR HORIZONTAL SLAT CONVEYOR*

Transported material: Anthracite coal
Conveyor length: 22.5 m
Flow: 28 T/h
Conveyor conduit width: 300 mm
Conveyor conduit height: 280 mm
Roller Diameter: 250 mm
Number of chains: 1
Number of teeth of the sprocket: 11
Load distribution: even

1. Material flow Q

   Q = 28 T/h

2. Chain velocity v

   We use the formula: $Q = H.\ B\ .\beta.\ \gamma.\ v.\ 3600$ (T/h)

   v = 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/m3) = 0.7.

3. Weight of transported material P_1

   P_1 = 795.45 kg
   = 7805 N

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:

   FB = 62440 N

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

(SELECTION OF A CONVEYOR CHAIN)

5. Chain weight P

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
dt = 443.68 mm
= 0.444 m

L = 46.39 m (Chain length)
P = 190 kg (Chain Weight)

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

7. Correction coefficient for type of operation Fs
Work hours per day Fs = 1.2
Total friction coefficient Fs = 1.728

8. Determination of velocity correction coefficient Fv
Chain velocity v = 0.22 m/sec, for Z = 11
The resulting value Fv = 0.9

9. Friction coefficient fm
The friction coefficient "fm" describes the influence of friction of transported material vs. conveyor conduit.
fm = 0.4

10. Computation of traction force T
T = 5730 N
(Number of chains 1)

11. Computation of necessary shaft power N
N = 1.26 kW

12. Specific pressure on chain joints pt
Pt = 12.24 MPa < 25 MPa

f = 468 mm2 according to the chain catalogue.
Computed specific pressure is lower than maximum permissible pressure.
The selected chain fulfills requirements.

V. EXISTING CHAIN ANALYSIS

Break strength of chain is = 62440 N

Chain Factor of Safety: 2 (minimum possible/available) - (Complete guide to chain -book)
FOS = 2

Operating load = 2/3 (Brake strength)
= 2/3 (62440)
= 41626.67 N

No of sprockets = 11 ----Given----- (Minimum 5 sprockets will be engaged during rotation of chain)

Hence, load on each chain bush/Pin = 8325.33 N

VI. CHAIN MATERIAL (EXISTING) PROPERTIES

Material	**Ultimate Strength**	**Tensile Yield Strength**	**Chemical Properties**
A513 alloys 1020 Mild steel (low-carbon)	87000 psi	72000 psi	Iron (Fe) - 99.08 - 99.53% Carbon (C) - 0.18 - 0.23% Manganese (Mn)- 0.3 - 0.6 % Phosphorus (P) - 0.04% max Sulfur (S) - 0.05% max
	599.8439 MPa	496.4225 MPa	

Allowable strength = 299.92 MPa

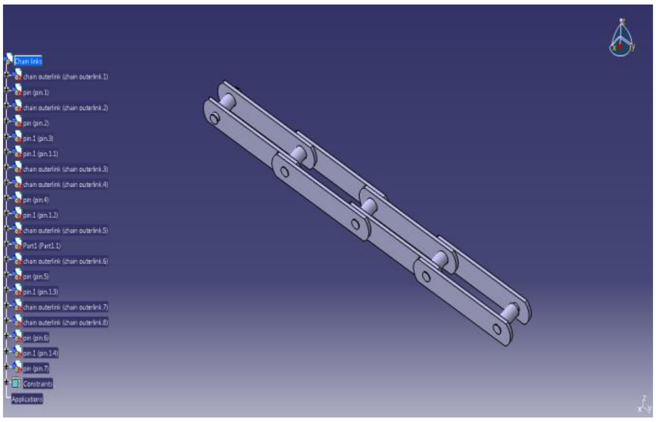

Fig. Chain link assembly

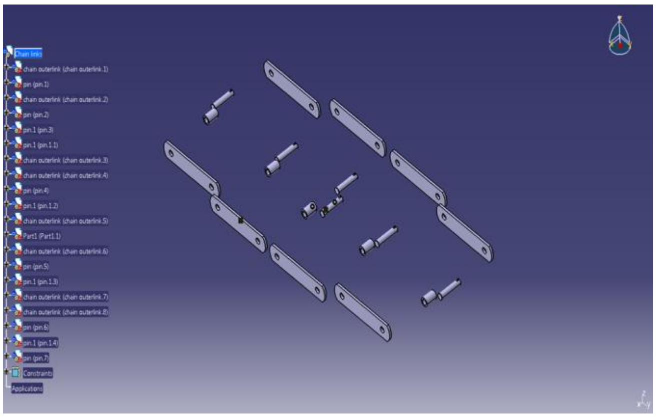

Fig. Exploded view of the chain link assembly

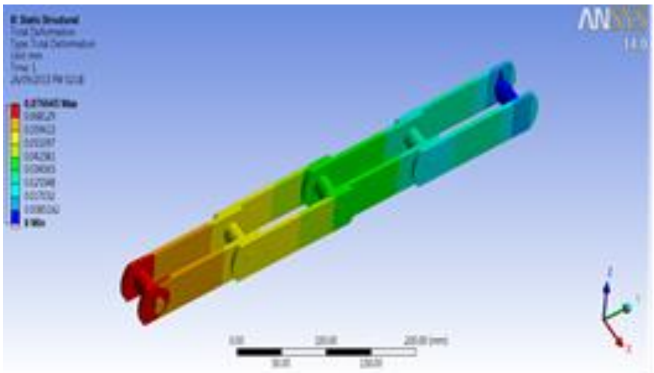

Fig. Deformation on the Existing chain links

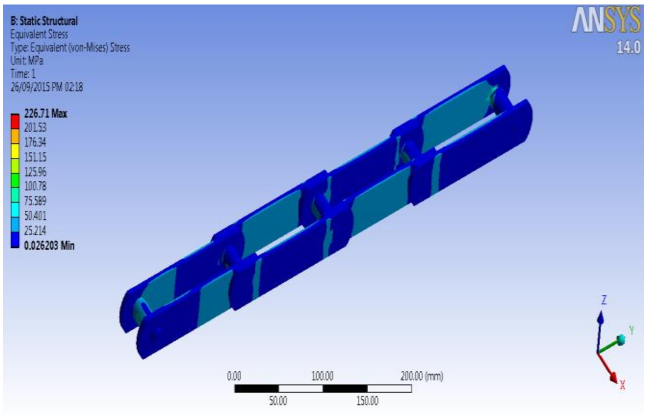

Fig. Von-Mises Stress on the chain links

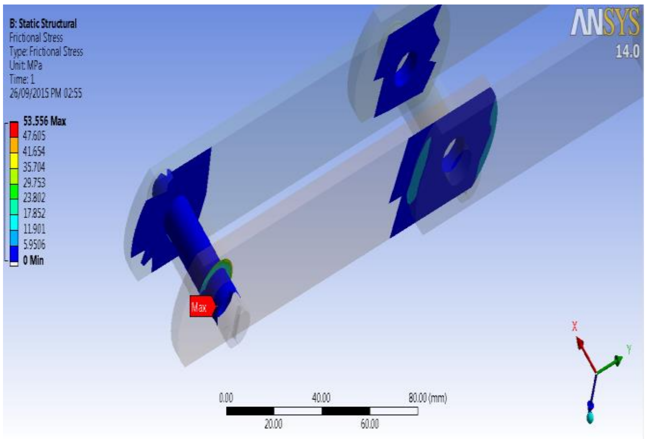

Fig. Frictional Stress on connections of the chain link

VI. Summary

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. The weight saving thus achieved will have a significant impact on cost of the chain, and it will reduce frequent failure of the chain links due to the deformation factor of material.

VII. Future Scope

The further work for the chain links i.e. analysis and optimization for weight reduction of the chain using different materials.

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