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Optimization of Chain Link of Material Handling Chain Conveyor System from FEA and Experimental Aspects (Paper-II)

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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.

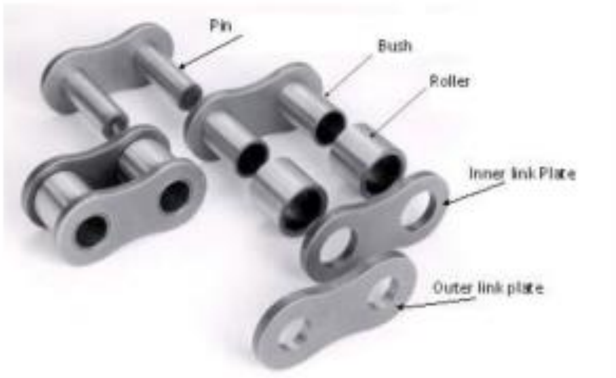


Fig. Chain Components

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. OPTIMAZATION ANALYSIS PARAMETERS & IMAGES

The analysis and optimization for weight reduction of the chain using different materials is as given:

V. DIFFERENT MATERIAL PROPERTIES

Material	**Ultimate Strength MPa**	**Yield Tensile Strength Mpa**	**Weight of chain Kg/m**	**Total Chain weight Kg/m**
SS 60 Mild (low-carbon) Hot Dipped Galvanized Steel	70000 psi 482.63 MPa	60000 psi 413.68 MPa	3.70	171.643
8620 (chrome-nickel-moly) Alloy Steel	97000 psi 668.79 MPa	65000 psi 448.16 MPa	3.55	164.684
1018 Mild (low-carbon) steel	63,800 psi 439.89 MPa	53,700 psi 370.2485 MPa	3.40	157.726

A. *Analysis for Different Materials.*

1. SS 60 Mild (low-carbon) Hot Dipped Galvanized Steel material

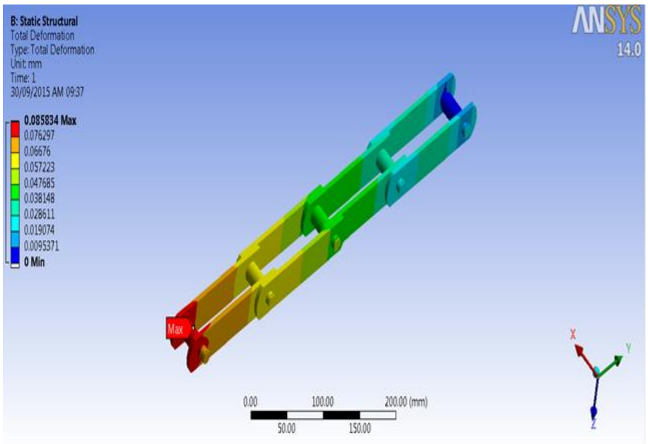


Fig. Deformation on the chain links

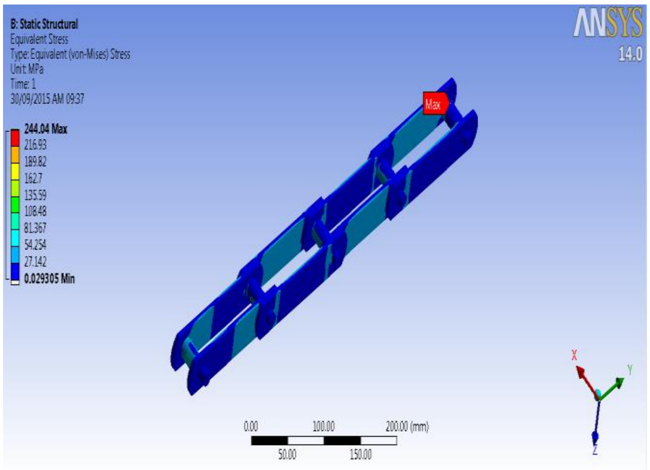


Fig. Von-Mises Stress on the chain links

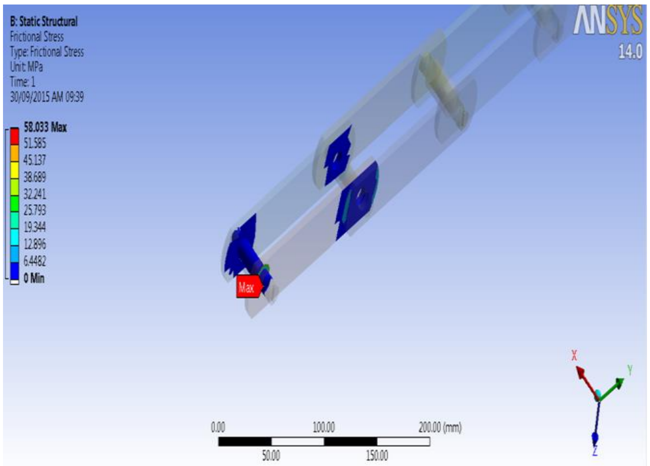
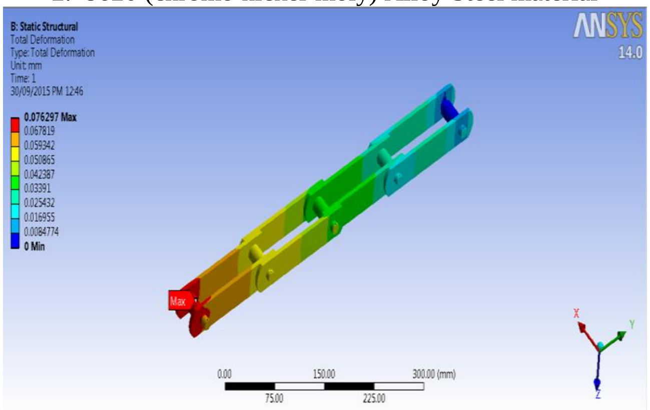


Fig. Frictional Stress on connections of the chain link

2. 8620 (chrome-nickel-moly) Alloy Steel material



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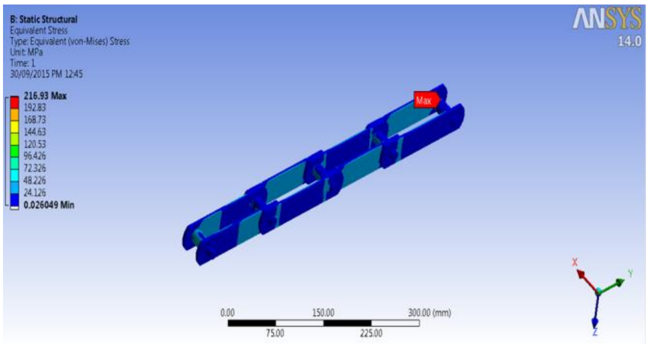

Fig. Von-Mises Stress on the chain links

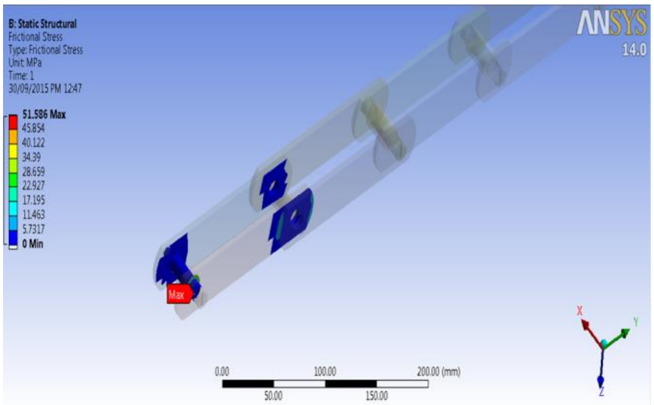

Fig. Frictional Stress on connections of the chain link

3. 1018 Mild (low-carbon) steel material

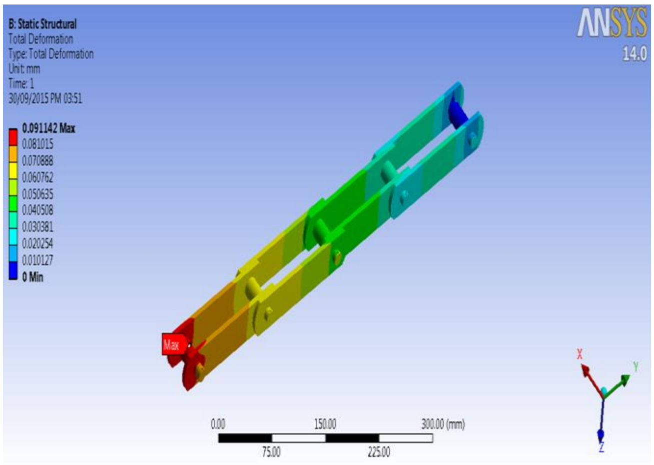

Fig. Deformation on the chain links

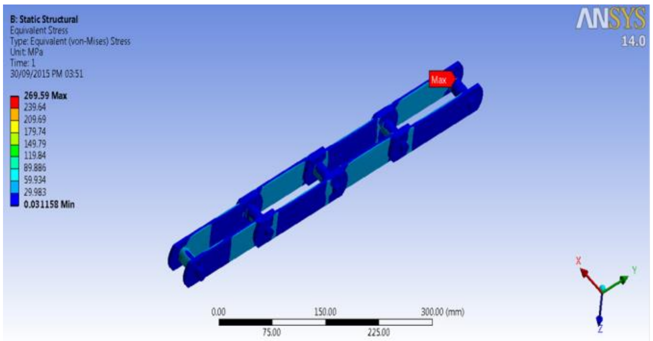

Fig. Von-Mises Stress on the chain links

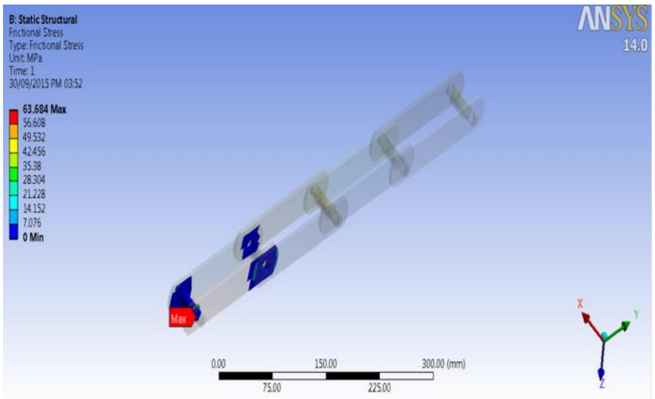

Fig. Frictional Stress on connections of the chain link

In the above figures shows comparison in the Deformation of the chain link, Tensile stresses & Frictional stresses occurred on the chain links for three different materials
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V. EXPERIMENTAL VALIDATION

A. Universal Testing Machine

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

1. Components

- Load frame - Usually consisting of two strong supports for the machine. Some small machines have a single support.

- Load cell - A force transducer or other means of measuring the load is required. Periodic calibration is usually required by governing regulations or quality system.

- Cross head - A movable cross head (crosshead) is controlled to move up or down. Usually this is at a constant speed: sometimes called a constant rate of extension (CRE) machine. Some machines can program the crosshead speed or conduct cyclical testing, testing at constant force, testing at constant deformation, etc. Electromechanical, servo-hydraulic, linear drive and resonance drive are used.

  - Means of measuring extension or deformation - Many tests require a measure of the response of the test specimen to the movement of the cross head. Extensometers are sometimes used.

  - Output device - A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorders. Many newer machines have a computer interface for analysis and printing.

  - Conditioning - Many tests require controlled conditioning (temperature, humidity, pressure, etc.). The machine can be in a controlled room or a special environmental chamber can be placed around the test specimen for the test.

  - Test fixtures, specimen holding jaws, and related sample making equipment are called for in many test methods.

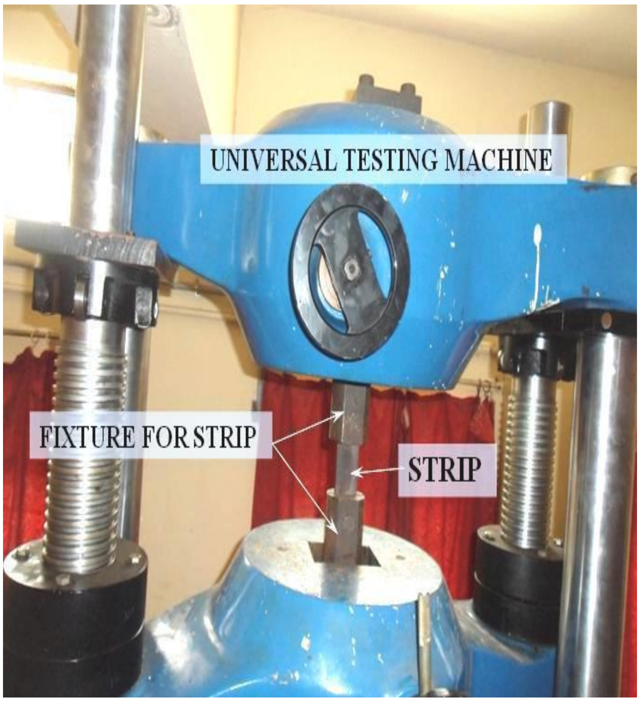

Fig. Testing of Chain Link on UTM

2. Observation of Experimental Validation

Average observation in case of Material Optimization		
Material	**Stress, N/mm²**	**Deformation, mm**
Existing Material	230.5	0.0801
8620 (chrome-nickel-moly) Alloy Steel	235.0	0.0850
Average observation in case of Chain Thickness Optimization		
Thickness of Chain, mm	**Stress, N/mm²**	**Deformation, mm**
5 (Existing Material)	52.10	0.040
5 (Selected Material)	49.85	0.049
4.4	70.05	0.200

VI. COMPARISON WITH EXISTING

As per above figures comparison of above three different material with the existing material used for the chain links.

VII. COMPARISON OF EXISTING CHAIN MATERIAL

Material	Allowable strength, MPa	Deformation (mm)	Von-Mises Stress, MPa	Frictional Stress, MPa	Total Chain weight (Length of chain *Weight/m)
Existing Material	299.92	0.0766	226.71	53.556	190
SS 60 Mild (low-carbon) Hot Dipped Galvanized Steel	241.31	0.0858	244.04	58.033	171.643
8620 (chrome-nickel-moly) Alloy Steel	334.395	0.0762	216.93	51.586	164.684
1018 Mild (low-carbon) steel	219.945	0.0911	269.59	63.684	157.726

VIII. SUMMARY

It is clear that 8620 (chrome-nickel-moly) Alloy Steel material is having more positive points and less weight (13.32%) compare to existing chain

IX. CONCLUSION

The weight saving thus achieved will have a significant impact on cost of the chain, and more importantly with a lighter chain, the cost savings during operation will also be significant.

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