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To Study Local Behavior in Roller Conveyor Chain Strip

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Abstract: **Chains have been used for centuries to drive machines and move materials on conveyors. Roller conveyor chains have a long history as mechanical elements for transmission. Roller conveyor chain performs efficient and economical in wide range of applications in manufacturing and production industries like sugar mills, paper mill, food processing, cement industry etc. Chain strips are machine elements that are subjected to extreme service conditions such as high tensile loads, friction and sometimes aggressive operating environment.**

Furthermore, as lot of work has been already done on roller conveyor chain parts under tensile loading therefore the present work has been focused to study the local behavior in roller conveyor chain strips. The use of the methodology developed in this study has been demonstrated by application of strain gage on chain strip in a Strain Rosette - 45^o manner and the mechanical testing of these chain strips on Computerized Universal Testing machine. In this way here an attempt has been carried out to study local behavior in roller conveyor chain strip.

1. INTRODUCTION

Chain conveyors are those types of conveyors which are continuously playing an important in various industries. Roller conveyor chains have a long history as mechanical elements for transmission. Roller conveyor chains are specific type of conveyors often used in variety of manufacturing and production applications, such as paint shops, to transport goods in production lines or assembly lines. Ledvina and Hummel [1] have developed a randomized sprocket for roller conveyor chain. A roller Chain and sprocket drive with a randomized sprocket which modulates the roller position on the sprocket by varying the radial seating position of the roller while maintaining a constant chordal dimension between the Seated rollers.

Payet [2] has developed a process and conveyor device for feeding sugar cane in a Mill Train. White and Fraboni [3] have demonstrated roller chain sprockets oriented to minimize strand length variation. Numerous methods have been developed to reduce the radiated noise levels generated by the engagement of roller chains with sprockets. A roller chain strip plate profile was developed by Moster et al., [4]. Material is added to the profile of the strip plates at the location on the strip plate where fatigue failure originates.

A static stress analysis of strip plate of roller chain using finite element method and some design proposals for weight saving investigated by Noguchi et al., [5]. Although they had clear advantages over belts in terms of performance and efficiency, but their larger weight has always been a disadvantage. Failure of engineering components due to presence of defects in the material was common issue. Sujata et al., [6] discovered a failure analysis of conveyor chain strips. These defects were either present in the material from the casting stage or get developed during subsequent hot working and thermal treatment operations. Bhoite et al., [7] studied FEA based effect of radial variation of outer strip in a typical roller chain strip assembly. Sapate and Didolkar [8] discovered metallurgical investigation of failure of coal mill drag chain pin.

1.1 Definition of strain

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (∈) is defined as the fractional change in length, as shown in fig. 1.

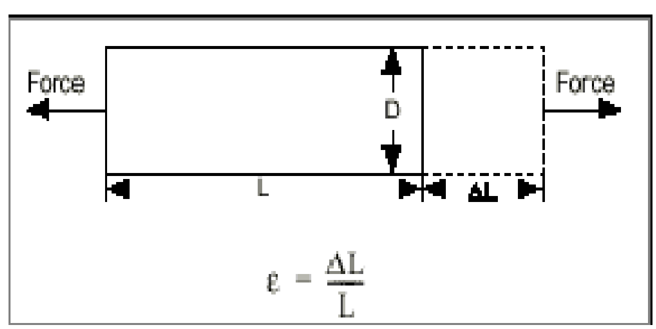

Fig. 1 Definition of strain

Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in. /in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro strain (μ_s), which is $\in \times\ 10^{-6}$.

2. STRESSES ACTING ON CHAIN STRIP

Chain strips are machine elements that are subjected to extreme service conditions, such as high tensile loads, friction, and sometimes aggressive operating environment**.** As these chains operate under various forces, failure of chain assembly is the major problem. The faulty manufacturing processes are another source of failure initiation. Main parts of roller conveyor chain are rollers, bushings, pins and chain strip also known as link plate. In roller conveyor chain there are two chain strips outer and inner respectively.

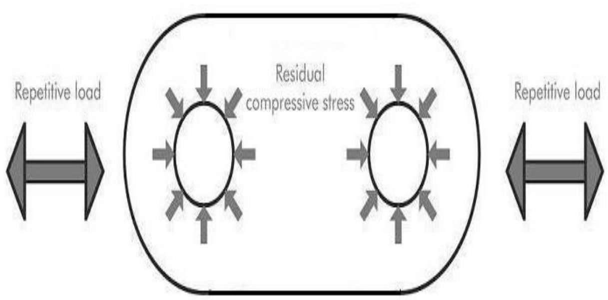

Fig.2 Stresses on chain strip

The above fig.2 shows the stresses acting on the chain strip in a working condition. As the chain revolves on the sprocket continuous repetitive loads are acting on the strips. The tensile forces are applied by pins which are assembled through holes in the strips. The holes in the strips are significant stress risers. The chain strips are primarily tension members, and they also are subjected to substantial bending and stress concentrations around the holes. The chain strips must have enough strength to withstand the tensile forces without deforming or breaking, and they must have enough ductility to withstand substantial bending and to resist fatigue.

3. APPLICATION OF STRAIN GAGE ON CHAIN STRIP

It is not possible (currently) to measure stress directly in a structure. However, it is possible to measure strain since it is based on displacement. There are a number of techniques to measure strain but the two more common are extensometers (monitors the distance between two points) and strain gages. Strain gage provides an extremely simple and accurate way to measure even slight deformation of a solid surface. Strain gages are constructed from a single wire that is wound back and forth. The gage is attached to the surface of an object with wires in the direction where the strain is to be measured.

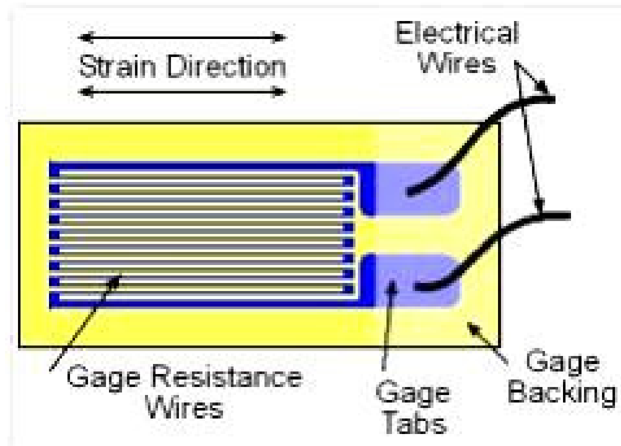

Fig.3 Basic linear strain gage

Above fig.3 shows the basic linear strain gage. The electrical resistance in the wires changes when they are elongated. Thus, the voltage change in the wires can be collaborated to the change in strain. Most strain gage measurement devices automatically collaborates the voltage change to the strain, so the device output is the actual strain.

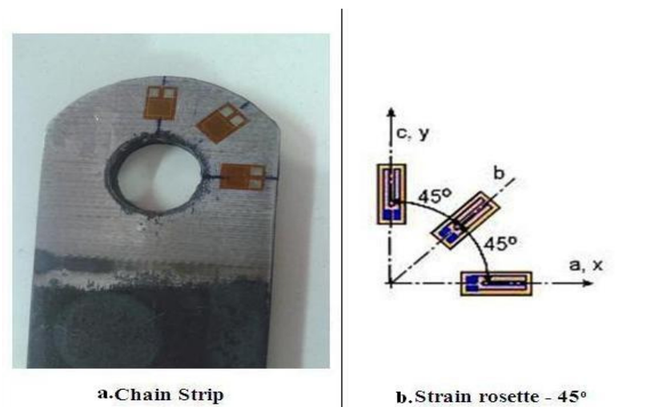

Fig.4 Strain rosette 45^0

Since a single gage can only measure the strain in only a single direction, two gages are needed to determine strain in the $\in_x$ *and* $\in_y$. However, there is no gage that is capable of measuring shear strain. Any three gages used together at one location on a stressed object are called a strain rosette. To increase the accuracy of a strain rosette, large angles are used. A common rosette of three gages as shown in figure 4 this structure is called Strain Rosette - 45^o. In fig.4 left side shows a chain strip pasted with three gages and right side b shows the Strain Rosette - 45^o structure. For this rosette gages the angles are as below.

$$\phi_a = 0^0, \phi_b = 45^0, \phi_c = 90^0$$

Three gages are attached to the strip in three different angles as indicated above. Any rotated normal strain is a function of the coordinate strains $\in_x, \in_y$ and γ_{xy} which are unknown in this case therefore three strains $\in_a, \in_b$ and $\in_c$ are required along three directions a, b, and c to determine state of a strain at a specific point on the chain strip. Thus, if three different gages are all rotated, that will give three equations, with three unknowns $\in_x, \in_y$ and γ_{xy}.

These equations are,

$$\varepsilon_a = \frac{1}{2}(\varepsilon_x + \varepsilon_y) + \frac{1}{2}(\varepsilon_x - \varepsilon_y) Cos2\phi_a + \frac{1}{2}\gamma_{xy}(Sin2\phi_a)$$

$$\varepsilon_b = \frac{1}{2}(\varepsilon_x + \varepsilon_y) + \frac{1}{2}(\varepsilon_x - \varepsilon_y) Cos2\phi_b + \frac{1}{2}\gamma_{xy}(Sin2\phi_b)$$

$$\varepsilon_c = \frac{1}{2}(\varepsilon_x + \varepsilon_y) + \frac{1}{2}(\varepsilon_x - \varepsilon_y) Cos2\phi_c + \frac{1}{2}\gamma_{xy}(Sin2\phi_c)$$

(Equation.1)

4. STRAIN GAGE PASTING ON CHAIN STRIP

A strain gage can only give best results if it is bonded to the piece in such a manner so that the strain experienced by gage grid is precisely the same as the strain of the test specimen. To achieve this proper installation of gage is very important. Surface preparation, gage preparation, adhesive preparation, gage installation, lead wire connections are the necessary steps for pasting of strain gage on the specimens.

Fig.5 Strain gage pasted on Strip

Figure 5 shows strip without pasting of stain gage and the strip pasted with strain gage. For pasting of the strain gage the contact surface should be very smooth, clean and dust proof. Due to their extremely small solder tabs, smaller gages can be very challenging to attach to leads. As the output voltage changes are so small, it is recommended that shielded cable be used for leads to reduce noise. The gage is attached to the surface of an object with wires in the direction where the strain is to be measured.

$$\phi_a = 0^0, \phi_b = 45^0, \phi_c = 90^0$$

By putting these values in equation 1 we get,

$$\varepsilon_a = \varepsilon_x$$

$$\varepsilon_b = \frac{1}{2}(\varepsilon_x + \varepsilon_y) + \frac{1}{2}\gamma_{xy}$$

$$\varepsilon_c = \varepsilon_y$$

Solving for $\varepsilon_x, \varepsilon_y$, and γ_{xy} we get,

$$\varepsilon_x = \varepsilon_a$$

$$\varepsilon_y = \varepsilon_c$$

$$\gamma_{xy} = 2\varepsilon_b - (\varepsilon_a + \varepsilon_c)$$

By using above equations we can find out the strain values i.e. $\in_x, \in_y$ and γ_{xy}. The rosette gage covers smaller area hence will give more results in a region in which the strains are varying. As we used rosette having all the gages in one plane they are giving better results, however if this rosette is mounted on a thin member subjected to sever bending, a considerable error will be introduced since each gage is at a different distance from the neutral axis.

5. EXPERIMENTAL PERFORMANCE ON UTM

The below fig. 6 shows the photograph of complete experimental setup. It shows a Computerized Universal Testing Machine of 100 Tonne capacity.

Chain strip is clamped between the two jaws of UTM by using fixture. A strain gage of 45^0 rosette structure same as shown in fig.4 is pasted on the chain strip and it is connected to the instrument named "10 Channel Strain Gage Indicator". Two computers are used, one for operating the UTM and another used for recording the strain gage data. The UTM having two operating valves, the left one is used to release the hydraulic oil pressure after conducting every test and the right one is used to gradually increase the hydraulic oil pressure.

After applying the Strain Rosette - 45^0 on the chain strip as shown in fig.5 the connections from gages to the 10 Channel strain gage indicator are made as shown in fig.6. While assembling the chain strip in the fixture for testing an intensive care have to take because the gage wire and extension wire connection should not break. Before starting the test i.e. application of any load on the chain strip, the strain gage reading units of the 10 Channel strain gage indicator are made to zero.

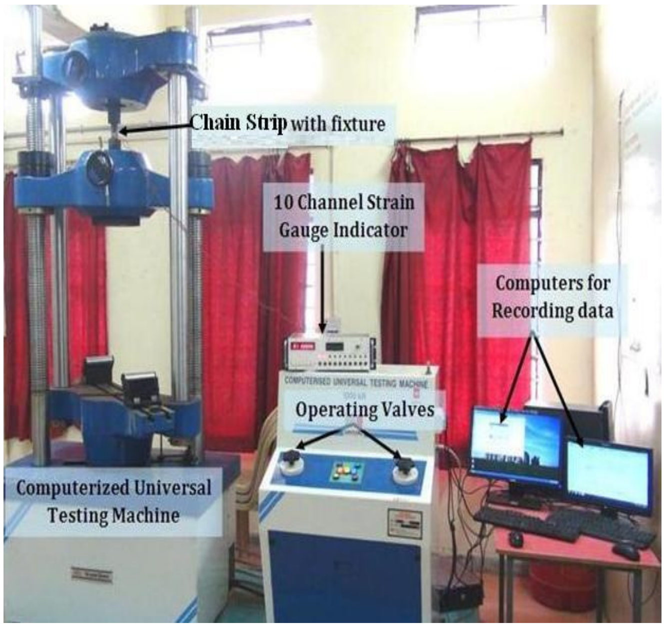

Fig.6 Photograph of complete experimental setup

The UTM test input data is entered in the right side computer and alternately the strain gage data is recording in the left side computer. By checking all the connections the test is started by gradually opening the right side valve. The strain in each direction is going to change. By using the recorded data in both the computers the graphs are plotted against the load in KN on X-axis and strain in μ_s on Y-axis. In the same way five chain strips are tested on UTM and graphs are drawn for each plate as below.

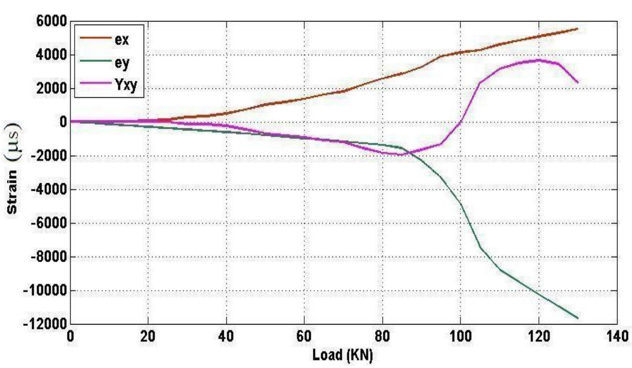

Fig.7 Graph of Load v/s Strain for sample no.1

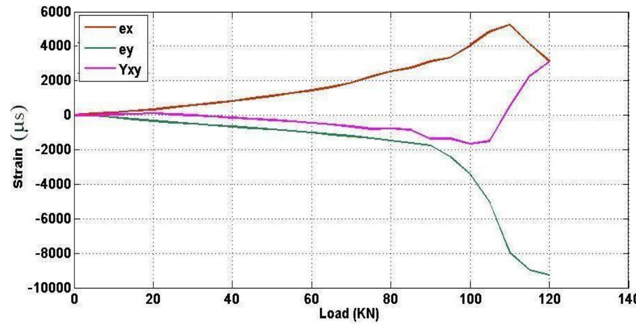

Fig.8 Graph of Load v/s Strain for sample no.2

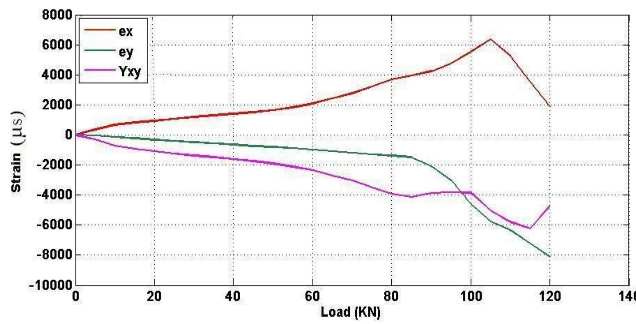

Fig. 9 Graph of Load v/s Strain for sample no.3

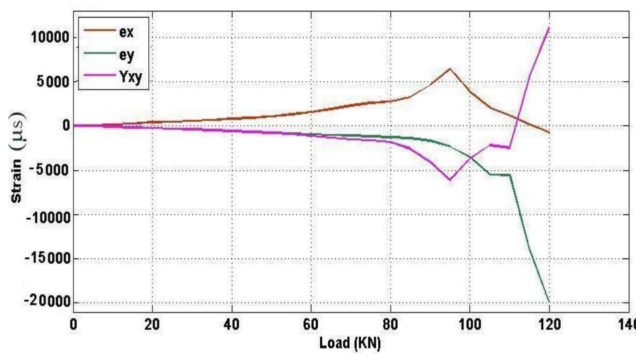

Fig. 10 Graph of Load v/s Strain for sample no.4

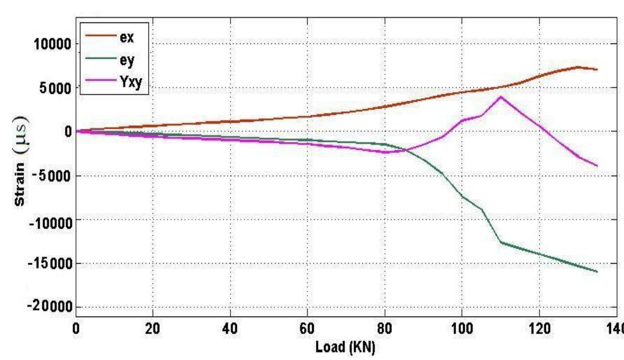

Fig.11 Graph of Load v/s Strain for sample no.5

6. CONCLUSION

The present investigation examines the demonstration and use of strain gages to study the local behavior of roller conveyor chain strip. From all the tested samples and above graphs following conclusions were drawn:

With increase in load:

- There is linear behavior of strain in loading direction.

$$\{\in_x \propto \ Load\ applied\}$$

- There is inversely proportional relation up to around 90KN, followed by exponential decreasing behavior in perpendicular to loading direction.

$$\{\in_y \propto \ 1/\text{Load applied}\}$$

- Whereas for 45^0 inclined strain gage there is linear decreasing behavior up to 85KN later followed by exponential growth.

$$\{\gamma_{xy} \propto \ 1/Load\ applied\}$$

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