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Structural and Modal Analysis of Roller Chain

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***Abstract* - The main component in power transmission of motorcycle or industrial conveyers is chain and any defect can lead to ruinous failure of the system. The main objective of the work would be to find the safe load and the sustainability of the different material of the chain using Finite Element Analysis. The FEA is used to determine the foremost effective decision of manufacturing based on the analysis. Finite element modeling provides different insights into the engineering analysis and plays crucial role in understanding the intricacies of the element. A faulty chain set can make your system debilitate or sometimes the situation can become even dangerous. In this paper, static structural analysis and the modal analysis have been done by analyzing two materials for roller chain manufacturing using CAD model of the chain designed in CATIA with some analysis under various conditions in ANSYS.**

Keywords: Chain, Finite Element Analysis, ANSYS, Chain link, Structural Analysis, Modal Analysis.

I. INTRODUCTION

Chain drive has become a common mode of energy transfer as a result of modernization. As the population is hastily increasing day by day, the insistent of Industry is also increasing. As such, there is a demand for roller chains to meet the replacement market as well as for supply to the O.E.M. units. Stainless steel roller chain is attached to motor and gear arrangement in industry application. You can freely design the transmission reduction ratio taking into account the specifications and the working conditions.

In Machines, there's confined and limited space. The function of the chain is similar to that of the belt. Chain is a continuous assembly of roller links and pin links. In roller rings the roller engages with the sprockets creating driving force. The pin links keeps (holds) the rollers in place. The design of roller chain is done such that the amount of friction is far less compared to simpler designs resulting in high efficiency. The chains are of utmost importance for efficient operation and maintaining the correct amount of slack (tension).

The constructs of topic of research work are:

1) Design Consideration
2) Chain Specifications
3) CAD Model of the chain
4) Finite Element Analysis
5) Conclusion

II. DESIGN CONSIDERATION

Roller chains are mostly used for speed transmission. Stainless Steel Roller Chain is first and foremost used in highly abrasive applications due to the anti-corrosive properties of stainless steel. The stainless steel chain is used in strength demanding applications; it can wear out quicker because of stainless steel being a much softer material. Various loads are to be considered for a roll chain. Roller chain lessen loads on the drive motor and driven shaft bearings as no pre-load is required to tension the chain in the static condition.

2.1 Ultimate Tensile Strength

Here Ultimate Tensile Strength is measured by the maximum stress that a chain can withstand while being stretched or pulled before breaking in a single use. To determine the tensile strength of a chain there is a standard test where load or tension is applied gradually until the chain breaks and the load is recorded. In further part factor of safety will be examined using the following.

2.2 Yield Strength

The yield strength of shock damaged material is a crucial aspect of element characterization. The yield strength is approximately 40% to 60% of the minimum ultimate tensile strength and it is determined in further part.

III. CHAIN SPECIFICATIONS

Table 1: Dimensions of Chain

Sr. No	Parameter	Length (mm)
1	Chain Pitch	12.7
2	Pin Height	14.3
3	Pin Diameter	5
4	Roller Outer Diameter	8.5
5	Width of Inner Plate	7.3

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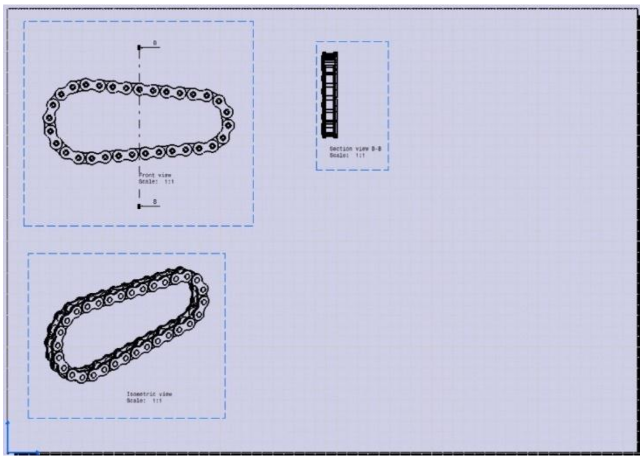

Figure 1: Different Views of Chain Link

IV. 3D CAD MODEL OF THE CHAIN

Fig. 2 is the CAD model of the roller chain according to the specification of the chain.

Figure 2: 3D CAD Model

Material Data

1. Stainless Steel 304

Table 2: Material Data of 304 Stainless Steel

Density (Kg/m3)	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
8000	1.9e+11	0.265	1.3475e+11	7.5099e+10

2. Stainless Steel 316

Table 3: Material Data of 316 Stainless Steel

Density (Kg/m3)	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
7969	1.95e+11	0.27	1.413e+11	7.6772e+10

V. FINITE ELEMENT ANALYSIS

5.1 Static Structural Analysis

There are various stages for the process one of which is creating a CAD model of the chain. The model can either be directly created in the ANSYS or any other CAD software. The given chain was modeled in CATIA. The model is then generated in for analysis in ANSYS.

5.1.1 For 304 stainless steel

1. Model Boundary Condition

Fixed support and force is applied to the model as shown in Fig. 3. In fixed support there's no any degree of freedom i.e. there is no displacement at any direction. But in horizontal support vertical motion is restricted by giving no separation contact. Load is applied to the red face of 3000 N and the fix support is at blue.

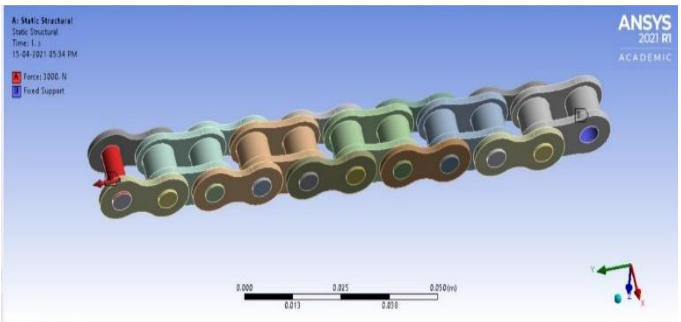

Figure 3: Load Application and Model Fixture

2. Meshing

Meshing involves converting of geometry into nodes and elements. Tetrahedrons type of Meshing is done on this model. After Meshing total 15860 numbers of nodes and 7220 number of elements are obtained for chain link having inner and outer link for stainless steel material.

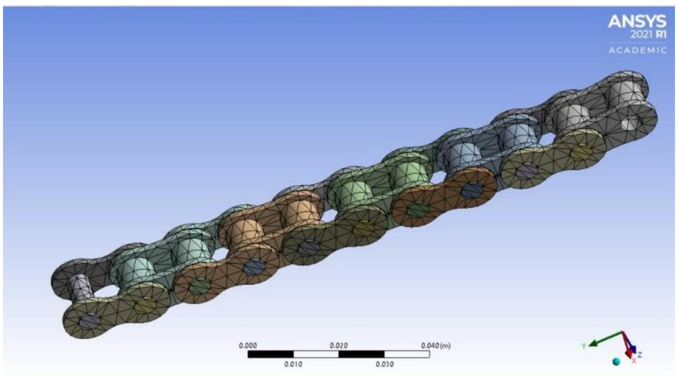

Figure 4: Tetrahedrons Meshing of Model

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3. Total Deformation

The result of Total Deformation is calculated by using FEA. Maximum deformation shown in red color occurs on pin which is 0.65104 m and blue face indicate minimum deformation with the blue color as shown in Fig. 5.

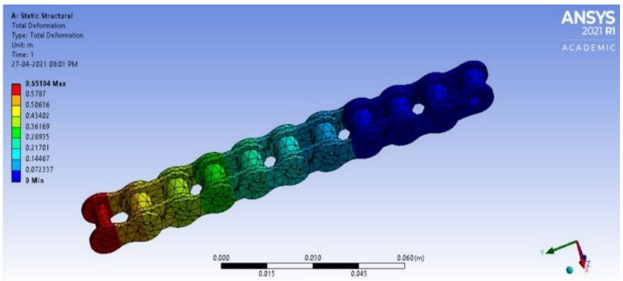

Figure 5: Total Deformation of Model

4. Equivalent Elastic Strain

The result of Chain link for Equivalent Elastic Strain using FEA is maximum at roller which is 0.13744 m/m and minimum at pin 5.296e-005 m/m this result as shown in Fig. 6.

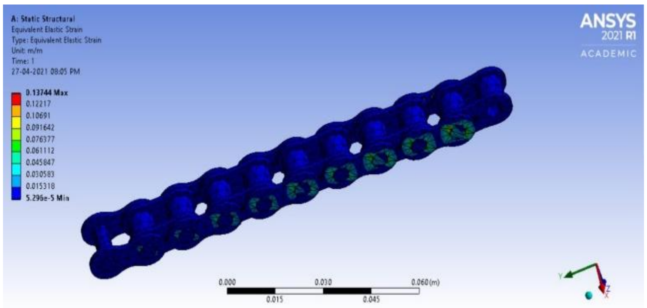

Figure 6: Equivalent Elastic Strain of Model

5. Maximum Shear Stress

The result of Chain link for Max. Shear Stress its Factor of Safety by using FEA is maximum at roller which is 15 and minimum at pin 3.2348e-002. The stress limit type for this model is Tensile Yield Per Material this result as shown in Fig. 7.

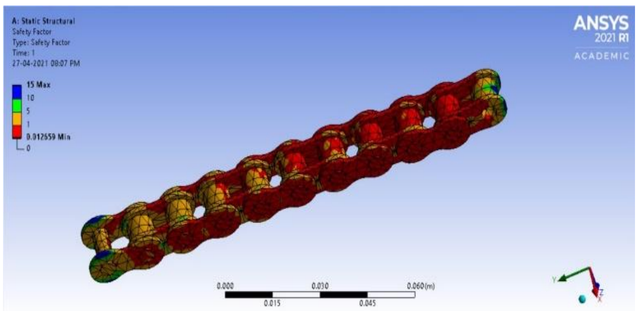

Figure 7: Max Shear Stress Tensile Yield Per Material

6. Maximum Equivalent Stress

The result of Chain link for Max. Equivalent Stress its Factor of Safety by using FEA is maximum at roller which is 15 and minimum at pin 1.2659e-002. The stress limit type for this model is Tensile Ultimate Per Material this result as shown in Fig. 8.

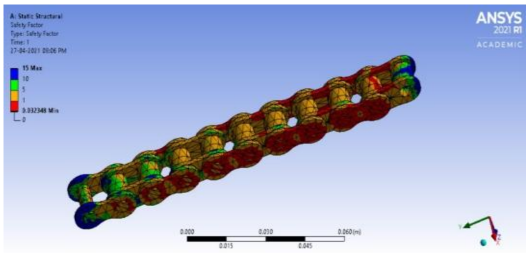

Figure 8: Max Equivalent Stress Tensile Ultimate Per Material

5.1.2 For Stainless Steel 316

1. Meshing

After Meshing total 13795 numbers of nodes and 4415 number of elements are obtained for chain link having inner and outer link for stainless steel material.

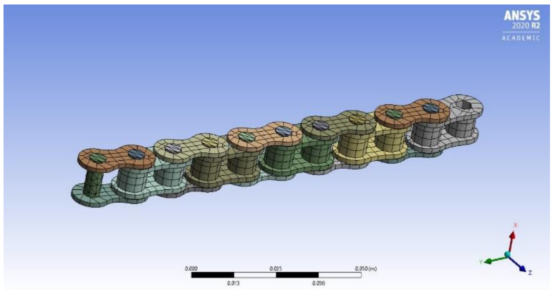

Figure 9: Hex Dominant Meshing of Model

2. Total Deformation

The result of Chain link for Total deformation is calculated by using FEA. In Fig. 10 red face indicates maximum deformation occurs on pin which is 1.5114 m and blue face indicate minimum deformation.

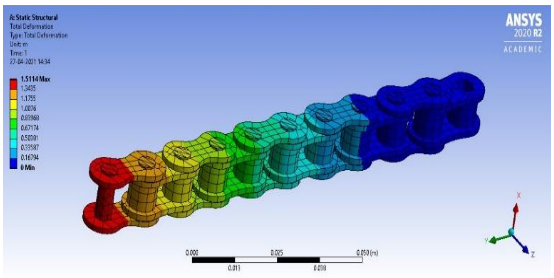

Figure 10: Total Deformation of Model

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3. Equivalent Elastic Strain

The result of Chain link for Equivalent Elastic Strain by using FEA is maximum at roller which is 0.39608 m/m and minimum at pin 7.0669e-006 m/m this result as shown in Fig. 11

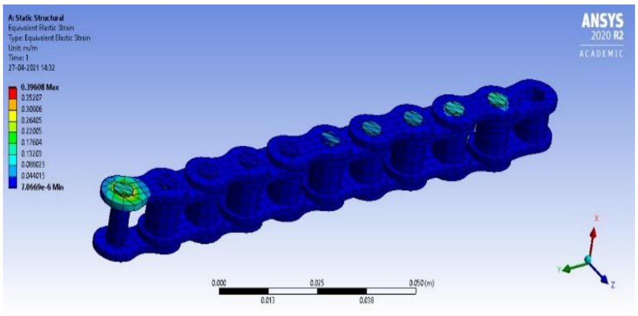

Figure 11: Equivalent Elastic Strain of Model

4. Maximum Shear Stress

The result of Chain link for Max. Shear Stress its Factor of Safety by using FEA is maximum at roller which is 15 and minimum at pin 0.58597e-002 this result as shown in Fig. 12.

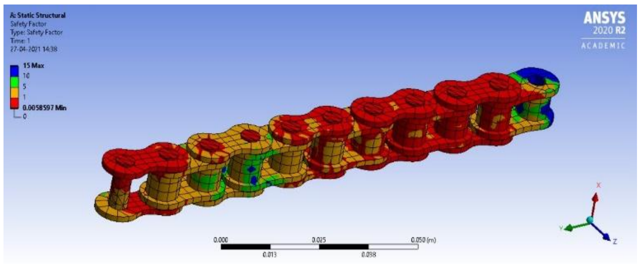

Figure 12: Max Shear Stress Tensile Yield per Material

5. Maximum Equivalent Stress

The result of Chain link for Max. Equivalent Stress its Factor of Safety by using FEA is maximum at roller which is 15 and minimum at pin 1.4033e-002 this result as shown in Fig. 13.

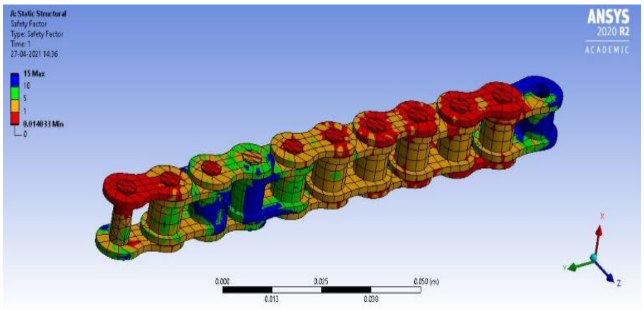

Figure 13: Max Equivalent Stress Tensile Ultimate per Material

OBSERVATION

Table 4: Final results of 304 Stainless Steel

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	MAXIMUM SHEAR STRESS (FOS)	MAXIMUM EQUIVALENT STRESS (FOS)
Minimum	0 m	-3.0052e-005 m	5.296e-005 m/m	3.2348e-002	1.2659e-002
Average	0.22097 m	8.2515e-005 m	9.2046e-003 m/m	2.3642	0.94827
Maximum	0.65104 m	2.6255e-004 m	0.13744 m/m	15	15

Table 5: Final results of Stainless Steel 316

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	MAXIMUM SHEAR STRESS (FOS)	MAXIMUM EQUIVALENT STRESS (FOS)
Minimum	0 m	-2.7598e-004 m	7.0669e-006 m/m	5.8597e-003	1.4033e-002
Average	1.1544 m	-6.597e-005 m	1.2019e-002 m/m	1.6896	3.3949
Maximum	0.54773 m	8.4283e-005 m	0.39608 m/m	15	15

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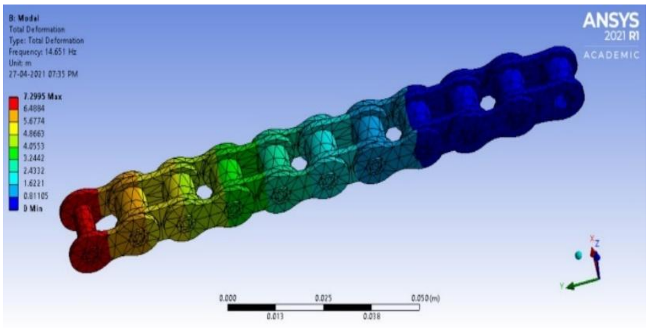
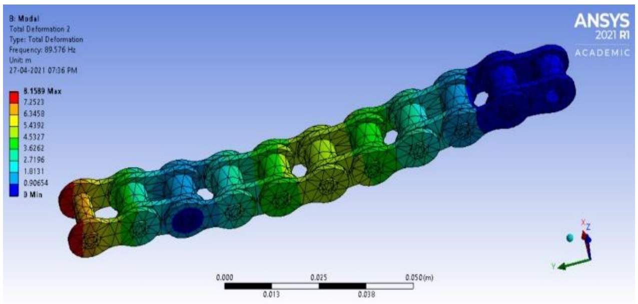
5.2 Modal Analysis

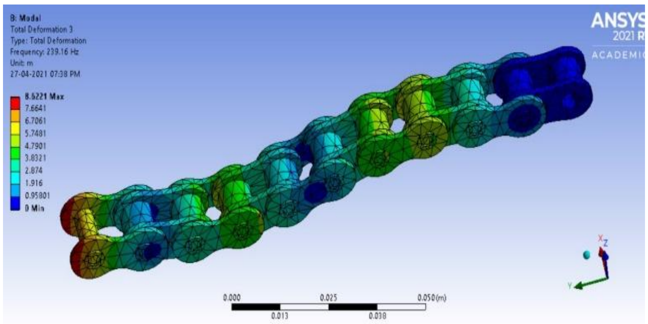
It is mainly used to determine the natural frequency and mode shape of mechanical component. The modal analysis enables the design to prevent resonant vibration or to vibrate at a specific frequency and provides engineers with an idea of how the design will respond to different dynamic load types.

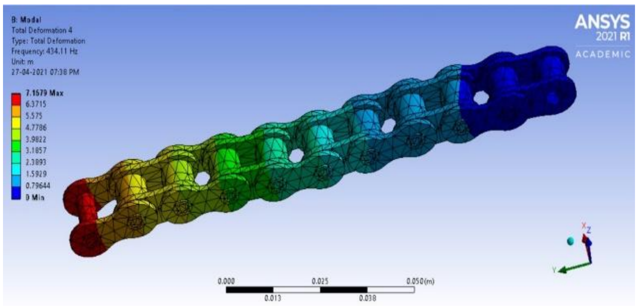
5.2.1 For 304 Stainless Steel

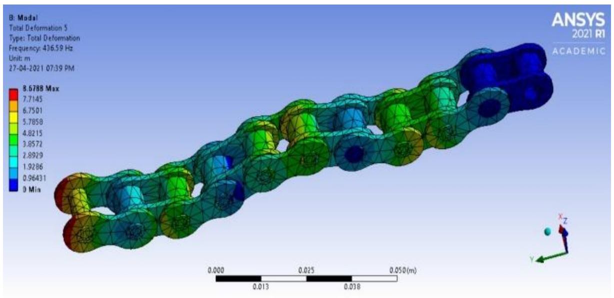
- Total Deformation

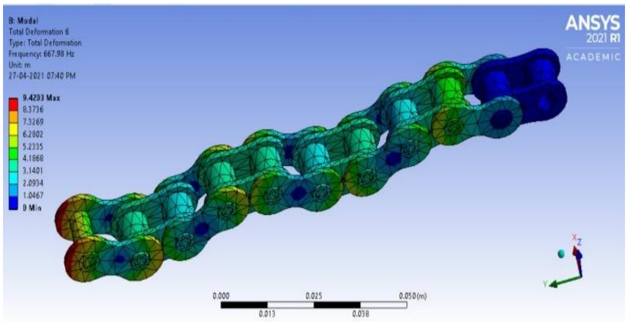




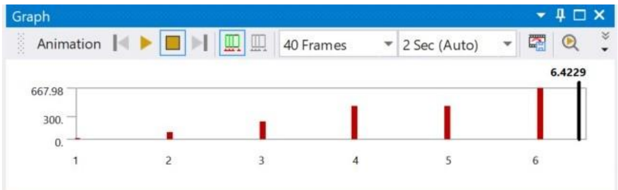








GRAPH AND TABULAR DATA

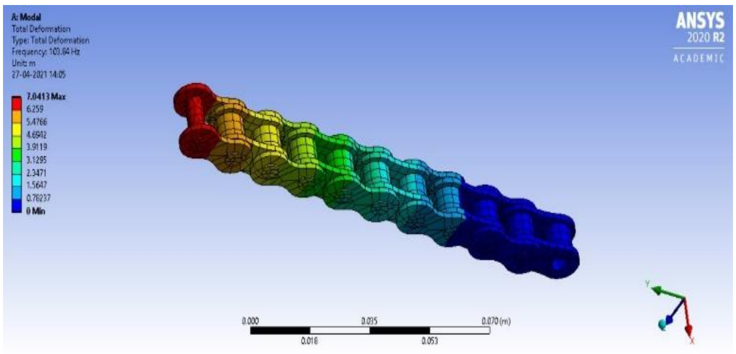


Tabular Data

	Mode	Frequency [Hz]
1	1.	14.651
2	2.	89.576
3	3.	239.16
4	4.	434.11
5	5.	436.59
6	6.	667.98

5.2.2 For 316 Stainless Steel

- Total Deformation



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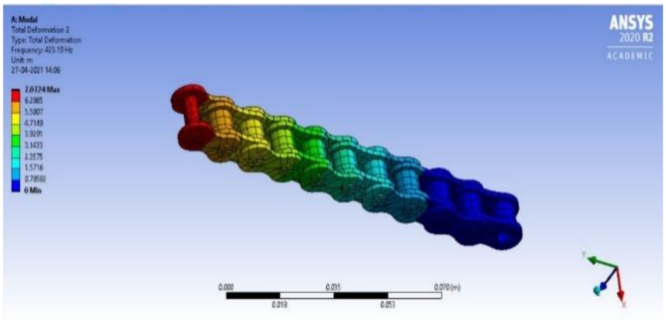

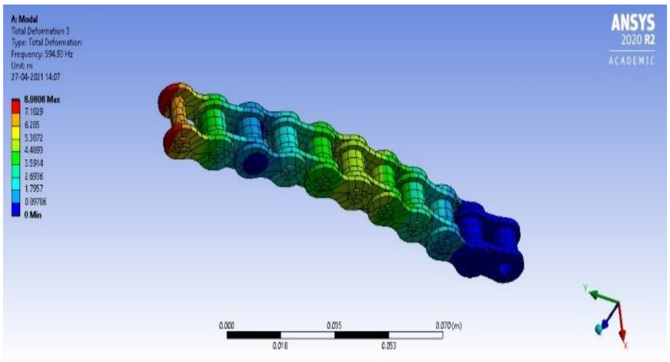

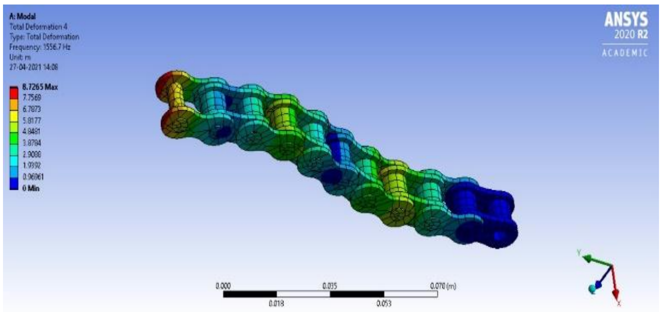

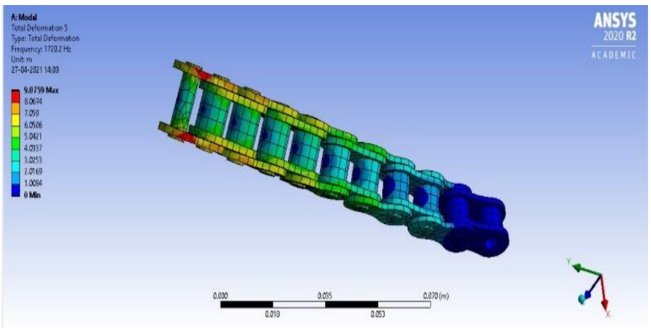

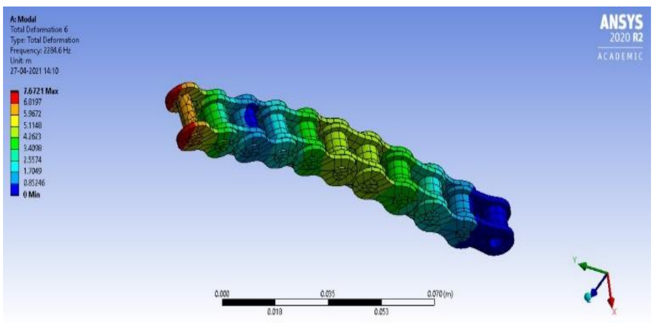

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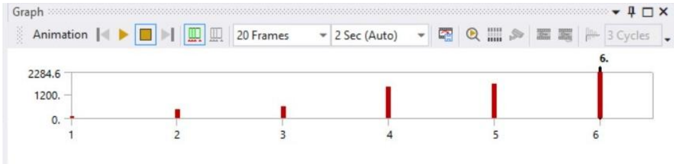

Tabular Data

	Mode	Frequency [Hz]
1	1.	103.84
2	2.	423.19
3	3.	594.93
4	4.	1556.7
5	5.	1720.2
6	6.	2284.6

VI. CONCLUSION

304-Grade Stainless Steel is a reliable grade used with roller chains and it has a material property of highly corrosion resistance and non-magnetic. **316-Grade** Stainless Steel is the secondly most used reliable grade. 304 offers strength and unchallenging maintenance for which stainless is appreciated. 316 offers vastly superior corrosion resistance to chlorides and acids. 304 stainless is also cheaper in cost compared to 316, another reason for its popularity. It has been observed from the result of table 4 and 5 that total deformation and equivalent elastic strain of 304 is more than 316 and 316 stainless steel material offers more factor of safety than stainless steel 304. Thus the material 316 is effortlessly more suitable for fulfilling the desirable conditions required for smooth running of a roller chain in exchange for cost. For various total deformations the particular value of frequency is shown in the paper. Thus, FEA method is used to analyze the state of a body in given particular loads with a given geometry. The applied method utilizes FEA software for analyzing the consequences of the changes within the values of the design parameters.

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