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STRESS ANALYSIS OF END LINK CHAIN

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Abstract:

In the world of engineering, there is an important element used in functioning of many machines, that element is chain link. But as many as are its application, it has equal number of times it could fail and we could have a setback in our application. In this review paper, we will explore the possibilities, an end link chain could fail, and the conditions under which it would fail, overall, we would conduct a Stress Analysis using ANSYS FEA software, read on to discover end link chain performs in stress analysis.

Based on previous research, the objective of this review paper is "Stress Analysis of End Link Chain in Finite Element Analysis, using ANSYS Software".

Keywords: **Stainless Steel, End Link Chain, Finite element analysis, Stress Analysis, Ansys**

INTRODUCTION

Chain links are one of the important mechanical elements for securing a ship to a mooring or an anchor and in lifting operations. Metal chain links are manufactured from a straight solid rod that is bent into an oval shape; the ends are then flash welded together. To make the next chain in the link, a straight solid rod is passed through the previously made link, before bending and flash welding the ends. The process is repeated until the required length of the chain is attained,[1]. Post welding heat treatment is carried out to relieve the residual stresses and control the microstructure associated with the welding process. Chain links are made with or without studs[2](see Fig 1).

Figure 1 (End Link Chain / Open Link Chian)

Stress Analysis : Stress analysis involved the determination of the corresponding internal stresses and associated strains. Typically, the starting point for stress analysis are a geometrical description of the structure, the properties of the materials used for its parts, how the parts are joined, and the maximum or typical forces that are expected to be applied to the structure. The output data is typically a quantitative description of how the applied forces spread throughout the structure, resulting in stresses, strains and the deflections of the entire structure and each component of that structure [3]. The analysis may consider forces that vary with time.

Stress analysis may be performed through classical mathematical techniques, analytic mathematical modelling or computational simulation, experimental testing, or a combination of methods[4].

Finite Element Analysis: Finite Element analysis is a numerical procedure for obtaining solution to many of the problems encountered in engineering analysis. It has two primary subdivisions. The first utilizes discrete element to obtain the joint displacements and member forces of a structural framework. The second uses the continuum element to obtain approximate solutions to heat transfer, fluid mechanics, and solid mechanics problem.[5]

The finite element method (FEM) is a numerical technique for solving problems which are described by partial differential equations or can be formulated as functional minimization. A domain of interest is represented as an assembly of finite elements. Approximating functions in finite elements are determined in terms of nodal values of a physical field which is sought. A continuous physical problem is transformed into a discretized finite element problem with unknown nodal values.[6]

When using the finite element method (FEM) to solve mechanics problems governed by a set of partial differential equations, the problem domain is first discretized (in a proper manner) into a set of small elements. In each of these elements, the variation/profile/pattern of the displacements is assumed in simple forms to obtain element equations. The equations obtained for each element are then assembled with adjoining elements to form the global finite element equation for the whole problem domain. Equations thus created for the global problem domain can be solved easily for the entire displacement field.[7]

The variables to be considered in the analysis are:

1. Design and Dimension consideration, while designing the element in AutoCAD software
2. Material Chosen while designing the end link chain in ANSYS software
3. Boundary Conditions to be applied to the element.

II. LITERATURE REVIEW

The various researches have been study for the performance of the connecting rod some of them are**:**

1. Tae-Gu KIM, Seong-Beom LEE and Hong-Chul LEE

The research paper titled "A Case Study on Engineering Failure Analysis of Link Chain" delves into the failure of a chain used in crane hooks and examines the role of installation conditions in stress distribution and ensuing catastrophic failure. The investigation employs fractographic analysis and finite element analysis (FEA) techniques to uncover the failure mechanisms. The chain's material properties are identified as AISI 8622 steel, chosen for its robustness. Results reveal that over-stress caused shear fractures and deformation. FEA simulations indicate that stress distribution is notably affected by installation and load type, with bending forces leading to significantly higher stress levels (2.5 times) compared to plain tensile loads. Notably, the chain can endure approximately 8 tons under tensile loading, as established by FEA. The study underscores the significance of proper installation practices and vigilant load management to avert such failures. Further analysis, incorporating factors like residual stress and load variations, is recommended to refine the understanding of fracture mechanisms.

2. Sridhar Idapalapati, Alfred R. Akisanya, Kelvin M. Loh, Stedston Yeo

The research paper titled "Failure Analysis of a Failed Anchor Chain Link" examines the failure of a metal chain link with a stud during a ship anchoring operation. The study employs visual observation, optical and scanning electron microscopy analyses, along with hardness and tensile tests, to determine the cause of failure. The chain link's chemical composition, tensile strength, yield strength, and elongation met recommended design values. However, cross-sectional microstructure examination reveals that the failure occurred along the flash butt weld due to improper welding and heat treatment. A pre-existing edge radial crack on the outer surface, painted over, initiated the fracture. Inclusions near the surface, decarburized boundaries, and a decarburized weldment strip weakened the weld and led to crack initiation. The main cause of the chain link failure was localized carbide segregations and embrittlement from improper flash welding and heat treatment. The research highlights the importance of better inspection and maintenance to detect such defects early.

3. Shubhangi S. Kulkarni and Prof. N. K. Chhapkhane

The paper "Comparison of Studless and Studded Chain Using Finite Element Analysis" by Shubhangi S. Kulkarni and Prof. N. K. Chhapkhane investigates the performance of studless and studded chains in mooring systems using Finite Element Analysis. Studless chains are durable and less prone to corrosion, while studded chains offer strength and reduced knotting during handling.
Using ANSYS software, the researchers modelled both chain types and subjected them to angles from 0° to 5°. Results showed that studded chains exhibited slightly higher stress (3-5%) but maintained consistent stress levels as angles increased. Studless chains showed proportional deformation growth with increasing angles, while studded chains demonstrated slower deformation due to added studs, showcasing their improved resistance to proof load.

Conclusively, studded chains, despite a modest weight increase, offer superior strength, stiffness, and stress stability, making them preferable for robust mooring applications.

4. Amila Mešić1, Mirsad Čolić2, Elmedin Mešić2, Nedim Pervan2

The research by Amila Mešić, Mirsad Čolić, Elmedin Mešić, and Nedim Pervan delves into stress analysis of chain links, employing a combination of analytical, numerical, and experimental approaches. The study centers on oval welded long link chains, commonly utilized in various applications.
Analytical calculations hinge on the curved carriers stretching theory, enabling stress distribution assessment across link sections. This analysis spans different angles and considers the deformation of fibres due to tension and compression. In the numerical realm, CATIA software is employed to create a parameterized 3D model of a chain segment. Numerical simulations reveal stress distribution and deformation patterns under varying loads.

The experimental facet incorporates strain gauge measurements on the actual chain links. These measurements are then compared with the results obtained from numerical and analytical analyses. The findings affirm the reliability of the numerical modelling, suggesting that the analysed chain is well-equipped to handle the loads stipulated by the manufacturer.

5. Philippe Bastid and Simon D Smith

The research paper titled "Numerical Analysis of Contact Stresses and Fatigue Damage" by Philippe Bastid and Simon D Smith, explores the effects of contact stresses and residual stresses on fatigue damage in offshore mooring chain links. The paper focuses on the practice of proof loading chain links to around 70% of their specified breaking load and investigates the resulting stress distributions. Finite element analyses are conducted on different sizes and grades of chain links, revealing that proof loading generates both compressive and tensile residual stresses. The study finds that high tensile residual stresses at the periphery of the contact zone can impact fatigue life, particularly for larger chain links. The paper highlights the importance of considering both the KT point and the contact region when assessing fatigue damage and suggests that current design codes may not be fully conservative for larger chain links. Further validation work and experimental data are recommended for more precise conclusions.

6. V.J. Papazoglou, G.M. Katsaounis, and J.D. Papaioannou

The paper titled "Elastic Static Analysis of Chain Links in Tension and Bending" by V.J. Papazoglou, G.M. Katsaounis, and J.D. Papaioannou investigates the behaviour of mooring chain links under different loads. The study focuses on tension, vertical bending, and horizontal bending scenarios. The authors use both analytical methods and finite element modelling to analyse stress distributions within the links. They compare results from these approaches and find good agreement. The concept of stress concentration factors (SCFs) is discussed to assess stress intensification due to localized loading. An equivalent modulus of elasticity is introduced to account for stretching and bending effects in chain links under tension, providing values for use in mooring calculations. This paper's findings shed light on the behaviour of chain links under various loads, aiding in the design and analysis of mooring systems.

7. Luigi Solazzi , Nicola Danzi, Marcello Gelfi, Lucio Enrico Zavanella

In the research Paper called Failure analysis of a pair of failed chain links. The analysis included visual inspections, dimensional measurements, macroscopic and microscopic examinations, SEM-EDX analysis, tensile and micro-hardness tests, and analytical calculations. The contact area between links showed significant wear and corrosion deposits. Fractures occurred in the contact zone between links.

Measurements of the chain links revealed deviations from the nominal dimensions, especially in the corroded areas, indicating material loss due to wear and corrosion. Fracture surfaces showed corrosion and a reduction in cross-sectional area, indicating a weakening of the material.

The microstructure of the chain links revealed bainitic-martensitic structures. Stress Corrosion Cracking (SCC) was observed, and corrosion-induced cracking was noted in the samples.

Tensile tests on the chain links demonstrated reduced strength due to corrosion. The micro-hardness profiles showed surface hardening and indicated corrosion-induced material loss in the intrados of the chain links.

Theoretical breaking forces were estimated using the calculated stresses and compared to nominal breaking forces. Percentage reductions in force were approximately 50% for sample A and 65% for sample B, corresponding to the percentage reductions in area.

Overall, the study revealed that the failure of the chain links was primarily caused by corrosion-induced material loss, leading to reduced cross-sectional area and mechanical strength. The methods employed provided insights into the degradation process and its effects on the chain links' mechanical properties.

Table 1. (Result comparison table).

Author	Material used	Method of Analysis	Outcomes
Tae-Gu KIM, Seong-Beom LEE and Hong-Chul LEE	AISI 8622 steel	Finite Element Analysis using ANSYS	I. The maximum Von-Mises stress is 455 MPa from ANSYS under axial tension. II. The stress is 1,236 MPa, under Bending conditions. III. Considering the case of five tons of tensile load, the analysis result is approximately 460 MPa, which is lower than that of the yield strength of the material. IV. The stress magnitude occurred by a bending force is 2.5 times greater than that of a plain tensile load.

Sridhar Idapalapati, Alfred R. Akisanya, Kelvin M. Loh, Stedston Yeo	Stainless Steel	Visual observation, optical and scanning electron microscopy analyses of the fracture surfaces in combination with hardness and tensile tests are used to establish the cause of failure	I. It was established that the underlying cause of chain link fracture was due to brittle overload, arising from a pre-existing crack.
Shubhangi S. Kulkarni and Prof. N. K. Chhapkhane	Structural Steel	Structural Nonlinear Analysis	I. Mass of stud less chain was 142.2kg and for studded chain the mass is 159.3kg. II. There is mass increase of 12% is observed, but at the same condition, displacements have reduced by 200%. III. The stress developed in the stud less chain is less than studded chain. It is almost 3 to 5 % more stress developed in the studded chain.
Amila Mešić, Mirsad Čolić, Elmedin Mešić, Nedim Pervan	14x50 G80 E5	Numerical Analysis and Experimentation on measuring tape stress analysis	I. The Load of Chain Set was 80kN II. The Value of Ultimate Force was 242 kN
Philippe Bastid and Simon D Smith	Grades R3S, R4, and R5 materials.	Finite Element Analysis	I. The extent of yielding (where the Von Mises stress is above 875MPa) is significant. II. Proof loading generates compressive and tensile residual stresses. High tensile residual stresses at the periphery of the contact zone can be detrimental to fatigue life.
V.J. Papazoglou, G.M. Katsaounis, and J.D. Papaioannou	Stainless Steel	Analytical Solutions	I. For the case of the studded link, the highest tensile stresses are observed on the inside surface of the link at an angle of approximately 25° with respect to the horizontal axis.
Luigi Solazzi , Nicola Danzi, Marcello Gelfi, Lucio Enrico Zavanella	Stainless Steel	Macroscopic examination. The stereo-microscope. (EDX) survey. Tensile and micro-hardness tests.	I. The actual stresses were 2 to 3 times higher due to reduced cross-sectional areas. II. Estimations showed a 50% reduction in breaking strength for sample A and 65% for sample B.

III. CONCLUSION

- To sum it up, the performance of Open Link Chain under Stress Analysis depends on a variety of factors like tensile strength, material, shear, moment induced, fatigue stress, Von Misses stress. Magnitude and Direction of these forces, stress would influence the material, hence would directly impact the working life of the chain.
- The use of ANSYS FEA software has made it possible to accurately predict the behaviour of different materials under varying loads and conditions. This helps manufacturers make informed choices regarding the selection of material and dimension for End Link Chain.
- Research into the production of End Link Chian using various materials is still ongoing. By utilizing advanced modelling techniques like ANSYS FEA software along with innovative manufacturing processes, we can continue to push boundaries in this field.

IV. FUTURE SCOPE

- After examining Stress Analysis by various method, it was discovered that this study activity offers a large research Potential.
- There is still scope for some new knowledge and data that would elongate the working life of the end link chain.
- Data discovered would help in selection of new material to overcome the existing difficulties and the necessary precautions would also come fourth for the chains that are currently installed.
- It will boost the life of the fundamental element, End Link Chain.

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