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OPTIMIZATION AND PROTOTYPING OF CHAIN TENSIONER USING REVERSE ENGINEERING

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Abstract:
A Chain Tensioner is a device that Adjusts slackness in the chain to enable continuous and proper chain operation. Excessive chain sag can cause vibration and excessive noise and prevent the chain from properly engaging the sprocket, which prevents the chain from operating smoothly. The tensioner ensures the chain remains tight and doesn't fall off the chainring or sprocket. This is particularly important when riding on rough terrain or performing tricks, as it reduces the risk of the chain coming off and causing an accident. There are various types of chain tensioners for various vehicles

Reverse engineering is the method of analyzing and printing a product that already exists. The main purpose of reverse engineering is to improve the existing design of the product and increase its efficiency according to the requirement. Now use Calibry Nest software to scan the Chain tensioner and IdeaMaker software to print the optimized design. Now it is only possible to print a prototype of the product but in the future, with some advanced techniques, it will be possible to print the product using 3D printing technology. Using reverse engineering it is easy to manufacture products with complicated designs using minimal effort and cost.

Keywords:
Calibry Nest, Geomagic Design X, Ideamaker

LITERATURE REVIEW

With the advent of novel engine technologies, such as turbochargers [1, 2] and fuel-stratified injections [3], engines are increasingly adopting timing chain systems instead of gear or belt systems, aiming for reduced fuel emissions. The timing chain system stands out for its zero maintenance requirements, high reliability, and life expectancy that match that of vehicles.

Switching from belt or gear systems to the durable timing chain system enhances fuel efficiency and leads to reduced emissions. However, the timing chain system is not without challenges. Factors, such as the polygon effect, the repetitive impacts of the chain at the engagement points of guides and sprockets, inconsistencies in crankshaft rotation, and variations in camshaft torque, cause substantial transverse vibrations and slapping noises during operation. Hence, ensuring chain tension and diminishing drive noise and lateral vibration become crucial for the system's durability and reliability [4, 5]. Feng et al. addressed the polygon effect and chain drive wear by developing an internal-external compound meshing silent chain, validating it through simulation [6]. Li et al. introduced a dynamic model for the timing chain drive system, analyzing aspects like link rotation speed, chain tension, tensioner force, and variations in the intake camshaft sprocket angular velocity. This research concluded that the silent chain drive system exhibited a markedly reduced polygon effect compared to the sleeve chains [7]. Malik et al. crafted a model for a timing chain drive system tailored for high-speed diesel engines and delved into chain tension and the contact force between the chain, guide rail, and sprocket [8]. Cali et al. significantly ameliorated the dynamic performance of a silent chain drive system by adjusting the meshing angle between the chain and sprocket [9]. Yang et al., using a multibody dynamics analysis, examined the transmission error, chain trajectory, and chain tension of the timing chain drive system. The study further evaluated the impact of vital parameters like sprocket speed, oil injection volume, lubricant viscosity, and injection angle on the system's lubrication efficiency [10]. Collectively, these studies have advanced the understanding and optimization of the timing chain system by exploring its meshing mechanisms and utilizing multibody dynamics simulations.

Over extended periods of operation, the timing chain undergoes elongation, and this elongation intensifies as sprocket speed increases. Excessive elongation can give rise to issues such as tooth skipping and chain slackening, both of which compromise the system's transmission precision and efficiency. Within this system, the tensioner holds significant importance. As the chain elongates, the tensioner's plunger extends due to hydraulic pressure to offset this elongation. This adjustment curtails chain fluctuations and transmission noise, ensuring the steady functioning of the chain-drive-timing system.

Tensioners are frequently employed to diminish transverse vibrations in flexible drive systems. Kraver et al. conducted a comprehensive model analysis to assess the impact of tensioner spring rigidity and dry friction damping on the dynamic traits of a V-belt attachment drive system [11]. Michon et al. developed a model capturing the hysteretic behavior of belt tensioners and ascertained the model's preloads, forcing frequencies, and deflection magnitudes through experiments, noting that the system's response surged with both excitation frequency and amplitude [12]. Chen et al. utilized an adaptive control approach to apply torque to a tensioner arm, thereby reducing the transverse vibration of the controlled span [13]. Podsiedlik et al. introduced a multibarrier electromagnetic tensioner. Its magnetic circuit ensures automatic adaptation to yarn tension variations, diminishes losses in the guidance system, and boosts the system's operational precision [14]. Takagishi et al. constructed an exhaustive chain drive dynamic model and deduced that, in comparison to the spring tensioner, the hydraulic variant is more adept at handling load variations and curbing the chain's transverse vibrations [15]. Hu et al. delved into the damping attributes of a hydraulic automatic tensioner piston in an engine accessory wheel train, employing both numerical solutions and finite element simulations for analysis when stimulated by a straightforward harmonic displacement [16]. Zeng et al. formulated a hysteresis loop model detailing the torque angular displacement dynamics of the tensioner within the engine's front-end accessory drive system. This model considered factors like the tensioner's preload torque, spring stiffness, damping coefficient, and the tensioner arm's moment of inertia, with experimental validations confirming its accuracy [17].

Pavel NOVOTNÝ and Václav PÍŠT□K [18], there is a clear trend to use chain or belt drives for the design of timing drives. Computational simulation of these drives has not been developing for too long due to high demands on computational technology. They focused on the simulation of the dynamics of the timing chain drive with the use of a multibody system. A mass-produced four-cylinder in-line engine with two camshafts and two valves per cylinder has been used as a computational model. It will help in improving the design parameters from both technical and economic point of view.

Sine Leergaard Pedersen [19], in this work simulation and analysis of large roller chain drive systems, such as e.g. used in marine diesel engines is done. A novel formulation for the simulation of the dynamics of roller chain drives using a continuous contact force method is developed in their work. The model of the contact surface between the rollers and sprocket has shown to be an important issue regarding the numerical stability of the simulation program and a model with a real tooth profile proves superior to other applied models. With this model, it is possible to perform a dynamic simulation of large marine engine chain drives. Through the application of this method, it is shown that the interrelated dynamics of the elements in the chain drive system are captured and the contact problem is characterized. The chain drive model is compared with simplified analytical results, while the necessary experimental validation is left for future studies.

James C. Conwell and G. E. Johnson [20], this work is related to the design and manufacturing of a new test machine configuration that will offer some advantages over the currently developed model. The newly designed machine provides more realistic chain loading and allows link tension and roller sprocket impact monitoring during normal operation. These new machine features offer new advantages and allow more data collection options.

C. Pereira et al. [21], in this work, a multibody methodology was used to address the kinematic and dynamic effects of roller chain drives was presented. The chain itself was modeled as a collection of rigid bodies, connected by revolute clearance joints. Each clearance revolute joint, representing the connection between a pair of links, was made up of the pin link/bushing link plus the bushing link/roller pairs if the chain is a roller chain. Furthermore, the problem of contact initialization and its coordination with the numerical integration procedures is taken into account by controlling the time step size of the numerical integration algorithm in the vicinity of the impact. This methodology is demonstrated through its application to the study of a bicycle roller-chain drive being the methodological assumptions discussed in the process.

MotoyasuSakaguchiet al. [22], in this work a method for reducing friction loss in the engine timing chain was investigated using multi-body dynamics simulation. The method known as the link-by-link model was employed in the simulation to enable the representation of the behavior of every single link of the chain and its friction due to contact. To predict the friction under actual engine operating conditions, a model that takes camshaft torque fluctuation and crankshaft rotational speed fluctuation into account was created. This simulation was used to verify the detailed distribution of friction in each part of the chain system as well as the changes of friction in the time domain. The simulation was used to verify the predicted effects of these measures, with the result that reducing the moment of inertia of the camshaft and reducing the initial load on the chain tensioner was confirmed to reduce friction loss.

R. S. Dwyer-Joyce et al. [23], a photoelastic stress analysis technique has been used to determine the contact stresses in an automotive chain drive tensioner. The tensioner in normal operation is subject to high magnitude, short duration impact stresses. These stresses are known to cause surface damage, wear, and surface pitting. To adequately design the drive system layout, a means for stress quantification is needed. A replica tensioner was made from epoxy resin and tested in a variety of configurations. A simple model has been created to relate the chain link load to the resulting www.ijera.com tensioner subsurface stress field. This model has been used to correlate the observed and predicted location of isochromatic fringes, and hence to evaluate the chain link load from the photoelastic fringe pattern. Once the load was determined the contact model was used to determine the magnitude and location of the resultant peak stresses. Measured impact stresses were found to be several times higher than those which would have been calculated from a static analysis

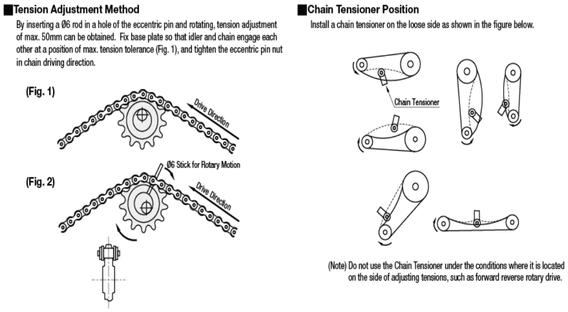
C. Weber et al. [24], in this work the new test method was developed to facilitate the direct measurement of the real timing chain load under all engine conditions. The measuring principle is based on a strain-gauged chain link in combination with a telemetric transducer system. It guarantees the continuous observation of the link force during the complete chain revolution to identify significant dynamic effects, which are responsible for noise, wear, and incorrect valve timing. In this paper, an experimental investigation of the dynamic behavior of an engine timing chain drive system has been performed.

Kevin Maileet al. [25], in this work a design for reliability methodology based on the Design for Six Sigma(DfSS) Define – Characterize – Optimize - Verify (DCOV) process, applied to the development of a cost-effective timing chain drive for a four-cylinder diesel engine. CAE model for the timing chain drive was used to study the distribution of the chain loads, which provided an essential input both for the concept selection stage and for the development of a reliability model for the timing chain. Design of Experiment (DoE) study on the CAE model aimed at investigating the significant factors for chain load variability led to a reliability improvement achieved by reducing the variability in the chain load through revising the tolerances for the sprocket tooth profile. This work demonstrates the efficiency of the process and the usefulness of computer simulation in achieving reliability and robustness enhancement while reducing design and development time and costs. In this paper, CAE tools and FEA techniques are used for computing chain loads. The study of the manufacturing process showed that this variability could be considerably reduced by tightening the tolerances.

Hiroshi Takagishi and Atsushi Nagakubo [26], in this work, on the longitudinal model the load prediction accuracy was inadequate. Accordingly, a link-by-link model was created, allowing transversal vibration to be taken into account. As a result, the features of a chain system using a blade tensioner were clarified, thus enabling the chain load and behavior to be predicted with a higher degree of accuracy than before. The results show that it was possible to predict the behavior of the chain and the chain load more realistically and with higher accuracy, clarifying the features and limitations of a chain system that uses a blade tensioner

INTRODUCTION

Chain tensioners are mechanical devices used to maintain proper tension in a chain drive system. In various mechanical applications, especially in machinery and automotive engines, chains are employed to transmit power from one rotating shaft to another. However, chains can experience slack or looseness over time due to factors such as wear, stretch, or variations in load. Chain tensioners address this issue by applying a controlled force to the chain, ensuring optimal tension for efficient power transmission and minimizing wear on chain components.



■Tension Adjustment Method

By inserting a Ø6 rod in a hole of the eccentric pin and rotating, tension adjustment of max. 50mm can be obtained. Fix base plate so that idler and chain engage each other at a position of max. tension tolerance (Fig. 1), and tighten the eccentric pin nut in chain driving direction.

■Chain Tensioner Position

Install a chain tensioner on the loose side as shown in the figure below.

(Note) Do not use the Chain Tensioner under the conditions where it is located on the side of adjusting tensions, such as forward reverse rotary drive.

Figure 1: Chain Tensioner position

This paper proposes a design of the manual chain tensioner which optimized design in which it surface gear system is added that can be used to adjust the idle point of the chain tensioner and also can be used to lubricate the internal parts of the chain tensioner. Reverse engineering is used to design the chain tensioner

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MANUFACTURING PROCESS OF CHAIN TENSIONERS

The manufacturing process of chain tensioners can vary depending on factors such as the type of tensioner, materials used, and specific design requirements. However, here is a general overview of the typical manufacturing process for chain tensioners:

- **Design and Engineering**: The process starts with the design and engineering phase, where engineers develop detailed specifications and drawings based on the requirements of the application. This phase involves determining factors such as the type of tensioner, materials to be used, dimensions, tolerances, and functional requirements.
- **Material Selection:** Once the design is finalized, appropriate materials are selected for manufacturing the chain tensioner. Common materials include steel, aluminum, various alloys, and polymers. The choice of material depends on factors such as strength, durability,
- **Raw Material Preparation:** Raw materials are sourced and prepared for the manufacturing process. This may be weight, corrosion resistance, and cost.
- involve cutting, shaping, or forming the materials into the desired shapes and sizes using processes such as casting, forging, machining, or extrusion.
- **Machining:** Machining processes such as turning, milling, drilling, and grinding are used to shape the raw materials into the specific components of the chain tensioner. CNC (Computer Numerical Control) machines are often employed to ensure precision and accuracy in machining operations.
- **Assembly:** Once the individual components are machined, they are assembled into the final chain tensioner assembly. This may involve processes such as welding, brazing, riveting, or adhesive bonding to join the components together. Additionally, other elements such as springs, hydraulic mechanisms, seals, and bearings may be incorporated into the assembly as required.

- **Surface Treatment:** Surface treatment processes such as heat treatment, plating, coating, or painting may be applied to improve the surface properties of the chain tensioner. These treatments can enhance corrosion resistance, hardness, wear resistance, and aesthetics.
- **Quality Control:** Throughout the manufacturing process, quality control measures are implemented to ensure that the chain tensioners meet the required specifications and standards. This may involve dimensional inspections, material testing, functional testing, and visual inspections to identify and rectify any defects or deviations from the desired quality standards.
- **Packaging and Shipping:** Once the chain tensioners pass the quality control checks, they are packaged according to customer requirements and shipped to their destination. Packaging may involve protective measures to prevent damage during transit, such as cushioning materials and secure packaging.

PROBLEM STATEMENT

Using the traditional methods of manufacturing we face many problems while designing and manufacturing processes while manufacturing complex designs. And we need to calculate the values required

But by using Reverse engineering we can manufacture by using the product that is already manufactured. There will be no need to design the new product and there is no need to calculate the value for the product. Instead, we will scan the product that is already manufactured and optimize the design according to the requirement

METHODOLOGY

The methodology of reverse engineering typically involves the following steps:

- **Planning:** Identify the product or system that needs to be reverse-engineered and define the goals and objectives of the product
- **Information gathering:** Collect as much information as possible about the product or system, such as technical specifications, documentation, schematic, and other related materials.
- **Disassembly:** Physically disassemble the product or system to gain a better understanding of its internal components, mechanisms, and processes
- **Analysis:** Use various techniques such as visual inspection, testing, and measurements to analyze the product or system and determine its functionality, behavior, and interactions.
- **Reconstruction:** Use the information obtained from the analysis to create a model or prototype of the product or system, which can be used for further testing and development.
- **Documentation:** Document the entire process of reverse engineering, including the results. Finding and conclusions.

REVERSE ENGINEERING

Reverse engineering or backward engineering is the process of deconstructing a product to see how it works. A company can reverse engineer a product for various reasons, including fixing, testing, or recreating it. If you have an interest in working in the engineering or manufacturing industry, knowing everything about reverse engineering can help you build a rewarding career. In this article, we answer, 'What is reverse engineering?', explore its benefits, outline the steps to reverse engineer a product and provide a few examples of reverse engineering.

REVERSE ENGINEERING OF CHAIN TENSIONER

Calibry Nest is a desktop software, which comes with a 3D scanner in an unlimited number of licenses and allows the user to post-process the raw data captured by Thor3D scanners.

The main window of Calibry nest consists of the following sections:

1. The Toolbar is the primary panel of instructions used for processing scans;
2. Side Toolbar shows a combination of tools varying depending on the stage of processing and the type of data opened;
3. Files Panel (aka Project panel) Shows the scans and all results generated during post-processing;
4. Editing area shows the data of a currently selected project. Here the data can be edited;
5. Scanner panel shows scanner controls as well as a list of all scans stored on the current PC/Laptop;
6. The Status bar shows the progress of any process, its level of completion, and some additional status data;

7. The Memory monitor opens a small window where RAM and VRAM usage is shown.

After scanning is finished all captured frames are saved in a file with an .ascan extension These files are saved on a PC/laptop a scanner is connected to. These files can then be processed either on the same computer or be transferred to any other computer to be processed in Calibry Nest

There are several ways of opening a scan in Calibry Nest :
1. By using the open button on the main toolbar
2. By choosing open in a file menu
3. By dragging a scan from a folder and dropping it into the Calibry Nest Window
4. By double-clicking on a scan file in its location folder
5. By double-clicking on a scan in the list of scans on the Scanner Panel
6. By selecting a scan from the list on the scanner panel and clicking the open button
7. By using the Ctrl+O hockey shortcut and picking a scan for processing

Registration of scan

When unprocessed scans are opened in Nest the data may look noisy and layered it is normal especially if the scan was made without activating the live 3D mode Registration analysis of the frames and trying to fit them together in the best possible way think of it as assembling jigsaw puzzle

Registration can be started in the following ways:
- Long-press the start Non-Textured button and select Registration from the drop-down menu
- Right-click the Start Non-textured button and select registration from the drop-down menu
- Press Ctrl+1 hotkey shortcut (Hotkey can be changed if needed)
- Go to Files-------> Start--------->Stages---------->Registration
-

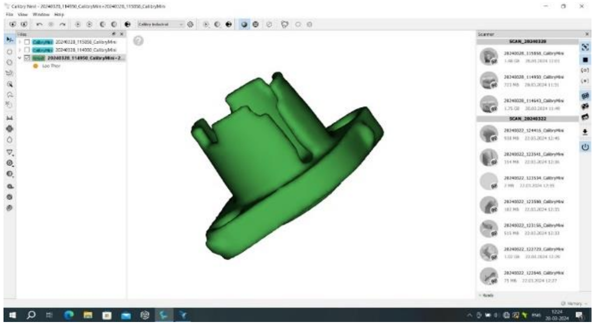


Fig: After Registration of Scanned Image

- Press the Registration button on the process stages panel (This panel is hidden by default. Right-click the Main Toolbar and pick process stages to see it.)
- Press start Non-Textured Button to run registration and finalization in sequence
- Press F5 to run registration and finalize in sequence

ASSEMBLING OF 3D MODEL

A special case is an alignment of scans made in Marker Tracking mode. If the following conditions are met, such scans can be aligned without specifying common points (markers themselves will be used for this purpose)

Marker positions should not be changed during the entire scanning session

Scans marked for alignment should have a reasonable amount of common markers

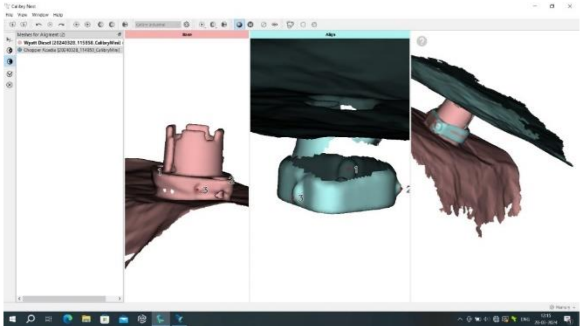
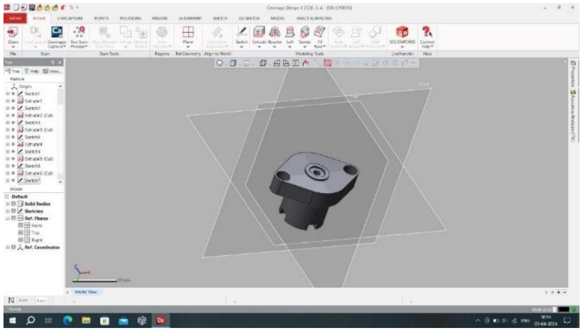


Fig: Final Result After Merging the several scans

Optimization of Scanned Model

Geomagic Design X is an innovative new software solution that allows engineers to create fully parametric CAD solids and freeform surfaces from 3D scan data and polygon mesh data with a best-in-class user interface. In addition to its ability to create parametric CAD solids, Geomagic Design X differentiates itself from existing reverse engineering software by offering a design process that utilizes the skill sets that engineers already possess. The result is a software solution that requires minimal training, reducing the time necessary to process 3D scan data. Users are provided with high-quality results that are unavailable through other current reverse engineering options. Geomagic Design X enhances the functionality of both 3D scanning technology and existing CAD applications by sharing common technologies and processes. Geomagic Design X features powerful tools such as:

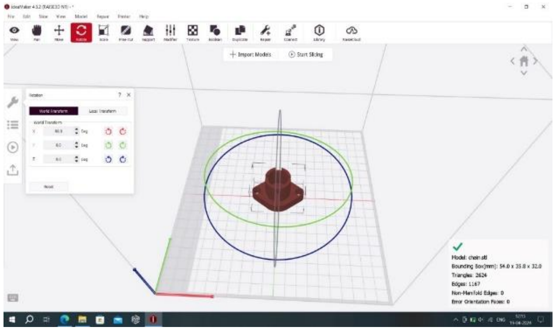
- Redesign Assistant
- Accuracy Analyzer
- True Hybrid Modeler - Solid, Surface & Mesh
- Align Wizard
- Best-in-class Mesh Operations
- Sophisticated Curve/Sketch Tools
- Scan-to-CAD Synchronization
- Quick Mesh-to-Surface
- Seamless Data Transfer
- Mesh Cleanup



3D PRINTING OF CHAIN TENSIONER

The basic procedure for printing a model in Ideamaker software includes

1. Importing the Model
2. Adjusting the Model on the Platform
3. Pre-processing of model
4. Selection of material
5. Adjusting Temperatures, density, speed, and



Model: chain.stl
Bounding Box(mm): 54.0 x 35.8 x 32.0
Triangles: 2624
Edges: 1167
Non-Manifold Edges: 0
Error Orientation Faces: 0

RESULTS

Reverse engineering can be valuable for understanding how products and systems are designed and manufactured, and for identifying ways to improve them or resolve disputes related to intellectual property. The resulting prototype is shown below obtained by the process of reverse engineering.

It is easy to design the complex design using reverse engineering and a 3D printed chain tensioner with an optimized design that includes supporting holes for the spring to maintain the idle point.

In this project, gears are created so that they can be used to adjust the idle point of the chain tensioner these gears can also be used for lubricating the spring and internal parts of the chain tensioner

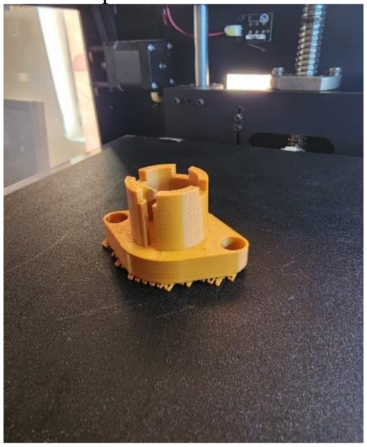


Fig: Final printed product

CONCLUSION

In conclusion, reverse engineering is a valuable process that allows for the recreation or enhancement of existing objects, such as a chain tensioner, through the utilization of modern technologies like 3D scanning and printing. By following a series of systematic steps including scanning, point cloud processing, mesh creation, CAD modeling, functional analysis, and iterative improvement, engineers can effectively reverse-engineer a physical object and generate a digital representation suitable for manufacturing.

Through reverse engineering, manufacturers can achieve various objectives, such as product customization, performance optimization, and the development of innovative designs. This process enables the replication of complex geometries, the identification and resolution of design flaws, and the exploration of new possibilities for improvement. Ultimately, reverse engineering plays a crucial role in driving innovation, efficiency, and competitiveness across industries by bridging the gap between physical objects and digital design environments.

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