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Design of simple valve spring compressor for maintenance of the cylinder head of tugboat engine

M F Jauhari[1,2]*, R S Maryati[1] and Raihan[1]

[1] Department of Automotive Engineering Technology, Politeknik Negeri Banjarmasin, Banjarmasin, Indonesia
[2] Center of Research and Community Services, Politeknik Negeri Banjarmasin, Banjarmasin, Indonesia
*Corresponding author email: firdaus.jauhari@poliban.ac.id

Abstract

The Top Overhaul stands as the initial phase of maintenance and repair involving the cleansing, inspection, measurement, analysis, or replacement of all components within an engine. Among its components, the cylinder head is a crucial element, and this research represents a step towards designing a simple valve spring compressor, a specialized service tool intended for the upkeep of tugboat engines. Methodologically, a combination of literature review and direct field observations was employed to gather supportive data for this design. The SolidWorks 2020 software facilitated the design process and enabled the analysis of its static load. Alloy steel was selected as the material for this specialized tool, with parameters such as von Mises stress, strain, displacement, and factor of safety serving as measures of the design model's strength. The valve spring compressor was structured as an assembly of multiple parts, allowing for adaptability in size to suit varying engine dimensions. Simulation results indicate that the working forces exerted on the design model remain below the material's yield strength threshold, thereby affirming its operational safety.

Keyword

Design, Simple valve spring compressor, Tugboat engine

Introduction

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One method for the maintenance and repair of engines involves periodic maintenance, which entails executing preventive maintenance tasks periodically based on calendar time or working hours, referring to the manual instruction book. Through regular and planned maintenance, the potential for damage leading to the inoperability of a vessel can be prevented and minimized. The Top Overhaul constitutes the initial phase of maintenance and repair for cleaning, inspection, measurement, analysis, or replacement of all engine parts/materials undergoing overhaul [1]. One component of the top overhaul is the cylinder head. The cylinder head is a crucial engine component, serving firstly as the site for the generation of pressure and the explosion resulting from the efforts of each engine cylinder. Its secondary function is to house all other vital parts/equipment involved in the top overhaul process. A critical aspect within the cylinder head area during top overhaul activities is the complete valve gear [2]. This section encompasses the rocker arm bush, pin, bolts, cotter valve, retainer, valve spring, and valve seal. All these constitute small parts that undergo significant movement in facilitating the opening and closing of exhaust and intake valves, thereby experiencing considerable friction leading to uneven wear. Consequently, maintenance with an adequate and smooth lubrication system is essential.

This research represents a step in the design of a specialized tool used in the maintenance procedures of tugboat engines, specifically in the Top Overhaul process based on industrial internship activities at PT. Sinar Alam Duta Perdana. A tugboat is a vessel primarily employed for maneuvering, especially towing or pushing other vessels in ports, open seas, rivers, or canals. Tugboats are also utilized for towing barges, damaged vessels, and other equipment [3]. Despite their size, tugboats possess substantial power.

Several citations indicate that designing various special tools for different cases can yield diverse functionalities and operational methods. A special tool is proposed for the removal and installation of cylinder rod units in HD Dump Trucks [4]. The tool was devised to lift and hold the rod cylinder to prevent elongation, thus expediting the removal and installation process, reducing unit downtime, and offering advantages in terms of saving costs related to manpower, lead time, and production loss. Another paper outlines the design of a tool used in the process of removing calliper pistons during car brake maintenance [5]. Innovation was implemented using pneumatic power at 300 psi, resulting in accelerated process times, exhibiting higher efficiency compared to processes without the use of the special tool. A valve spring compressor design for assembling cylinder heads is also documented in a patent [6], presenting a C-shaped frame tool adjustable to define two opposing jaws. The first jaw incorporates adaptable feet to engage the spring retainer and move past the valve stem end. An actuator, assisted by manual control, is housed in the second jaw, forming an integrated handle. Other related patents include a utility model for a valve spring compressor. Valve springs are used for disassembly and assembly; the valve spring compressor mainly consists of a mounting base, a clamping device, and a lifting-type mounting device, where the clamping device and the lifting-type mounting device are arranged on the mounting base [7]. A similar patent with a different configuration comprises a main shaft, a base plate arranged at one end of the main shaft, a number of connecting holes formed in the base plate, and a rotating arm arranged at the other end. Through the valve spring compressor, the valve spring can be easily compressed, allowing for the straightforward removal or installation of the anti-release cone key on the valve stem [8].

This research focuses on developing a specialized tool design utilized to compress the valve spring when installing or removing cotter valves on the cylinder head of a tugboat type S6R2-MTK3L. Cotter valves function to secure valves with springs through the retainer component. These cotter valve components are also commonly referred to as valve keepers, valve cotters, or valve locks. Installing or removing these parts is challenging, necessitating a specialized tool to perform the task easily without damaging other components

Method

The methodology employed in this research encompasses a series of detailed stages. Firstly, an in-depth survey addressing issues related to the maintenance of the cylinder head in tugboat engines was conducted. Subsequently, a literature review was undertaken to comprehend the designs and functionalities of existing valve spring compressors, serving as the foundation for designing a simpler tool. The subsequent step involved crafting a prototype tool using SolidWorks 2020 software for 3D modeling to ensure the accuracy and effectiveness of the design. The design of the valve spring compressor underwent testing in SolidWorks using static loads applied to the pressing components (push rod and attachment). The selection of materials for this special tool was tailored according to the static analysis imposed on the fabricated structure, ensuring a safe value for tool users. The flowchart for the design of the simple valve spring compressor is depicted in Figure 1.

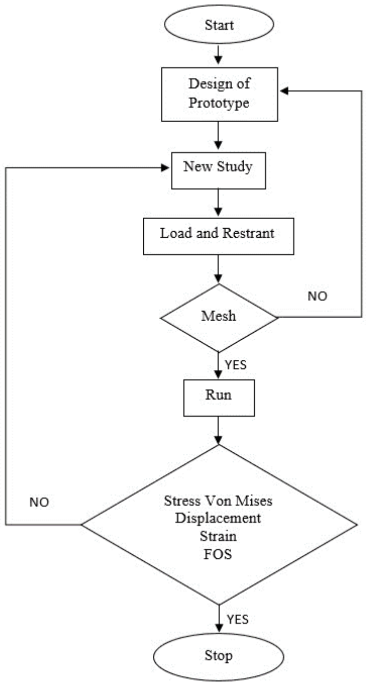


Figure 1. Control flow of valve spring compressor design

The first step of this research is making the design of a simple valve spring compressor with type material for good Safety Factor value, Alloy Steel shown in Figure 2. The second stage is to ascertain the kind of analysis used in this new study menu. The third stage involves loading and restraint, which requires the special tool design to determine fixtures and loads. The next stage is the meshing process, where we divide model's geometry into many elements used by the solver in creating a control volume. After that, the process known as Run is performed to obtain analysis results such as von Mises stress or displacement; strain and factor of safety are also determined for products made by this design.

1. The von Mises stress method is a procedure for determining the value of the stress within some material under load. This technique plays a crucial role in SolidWorks load analysis, which is used for predicting location and magnitude of stress within part of modeled structure or design [9]. The von Mises method is based on the theory that a material will fail if its equivalent stress exceeds the yield strength for such a material. Here the stress occurrence at different points within a material, is compared using its equivalent calculated stress.
2. In solid works load analysis, strain is the relative change in size or shape of an object caused by applied loads. This is an important parameter in evaluating how a material responds to forces or pressures applied upon it. Strain analysis: determination of dimensional changes or deformations in parts of the model. This allows users to understand how much distortion is taking place at different sections within the structure [10].
3. In SolidWorks load analysis, displacement is movement or transfer of a point or section within the model caused by applied loads and forces. Analyzing a loaded model or structure, the software records on how parts of the model move from their initial position as they are under applied loads. Displacement can also be represented as a vector, in both direction and magnitude of point displacement within the model.
4. The Factor of Safety (FoS) is the ratio between a structure or component's maximum load-bearing capacity and actual applied left on that structure [11]. In a SolidWorks load analysis, FoS is used to evaluate how safe or robust the design is under those loads. A higher FoS means a greater degree of safety.

(a) (b)

Figure 2. Cylinder head of tugboat engine (left) and design of valve spring compressor (right)

Result and Discussion

Finite Element Methods (FEM), a major technique in both the modeling and analysis of structures, is included in many software such as SolidWorks. The FEM concept, hidden within SolidWorks, allows designers to represent physical objects simply as interconnected sets of little elements. By treating complex objects as simple elemental parts aggregated together, FEM allows for very detailed structural responses to be examined. With this approach, we can designate all kinds of material properties, constraints, and loads. Afterwards, FEM theory is used to calculate the structural responses resulting from these factors. In this way, an understanding of how a given structure will respond to specified loads can be achieved even before the physical construction of that structure. With FEM within SolidWorks, simulations can be carried out as close to real conditions as possible. One is then able to estimate deformations; stresses and other structural responses. This allows the testing of a design before it is integrated into mass production, so that mistakes can be prevented and high costs avoided [12-13].

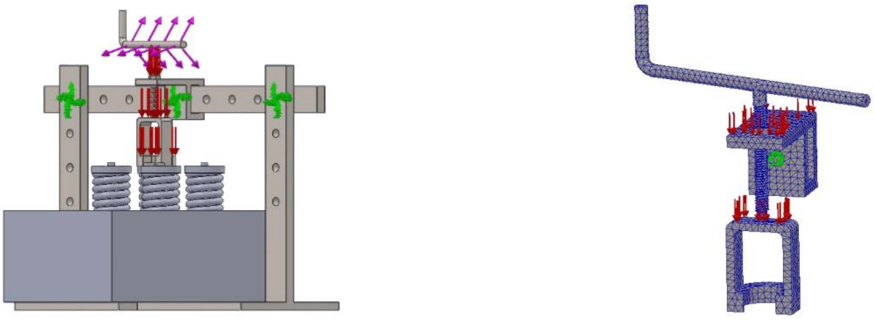
The researcher used SolidWorks 2020 software to design the simple valve spring compressor and conduct static load analysis. Before the analysis, what kind of material it was--Alloy Steel--was decided by discussions held with technicians at PT. Sinar Alam Duta Perdana. The mechanical properties of the alloy steel material are presented in Table 1.

Table 1. Mechanical properties of alloy steel materials

Property	Value	Units
Elastic Modulus	0.28	N/mm²
Poisson's Ratio	21000	N/A
Shear Modulus	79000	N/mm²
Mass Density	7700	Kg/m³
Tensile Strength	723.8256	N/mm²
Compressive Strength		N/mm²
Yield Strength	620.422	N/mm²
Thermal Expansion Coefficient	1.3e-05	/K
Thermal Conductivity	50	W/(m.K)
Specific Heat	460	J/(kg.K)
Material Damping Ratio		N/A

The results of static load simulation on the valve spring compressor design indicate a consistent response to the applied force of 250 Newtons. The force is applied to the push rod, transmitting stress in the form of compressive force to the attachment, directly pressing the spring component. This allows for easy and rapid valve release with minimal risk of damage (Figure 3a). For this simulation, the pillar and bridge sections are assumed as rigid structures excluded from calculations, and the sliding clamp uses a fixed geometry fixture. The static load analysis focuses on the sliding clamp, push rod, and attachment components, as they receive and transmit forces to the valve spring in the tugboat engine (Figure 3b).

The resulting von Mises stress provides insights into critical points susceptible to structural failure, with a maximum stress of 6,063,770 psi well below the material's yield strength (Figure 4). Meanwhile, the strain analysis offers a depiction of potential material deformations (Figure 5). Detected displacements offer information about anticipated movements or shifts in this design, indicating conditions within safe limits (Figure 6). All obtained data serve as key indicators to assess structural reliability expressed through the safety factor (Figure 7) with values > 1, representing a comparison between material strength limits and applied loads, offering a comprehensive overview of the safety and reliability of this valve spring compressor design [14–16].



(a) (b)

Figure 3. Simulation of static loads and meshing on the model

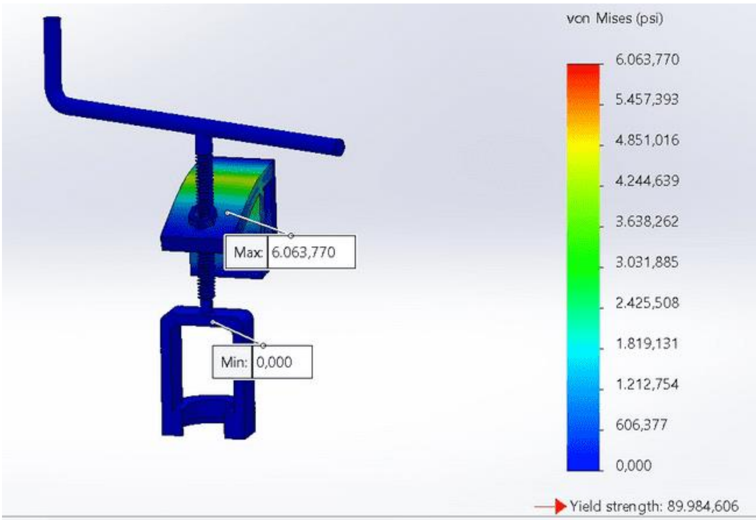


Figure 4. Von Mises stress analysis

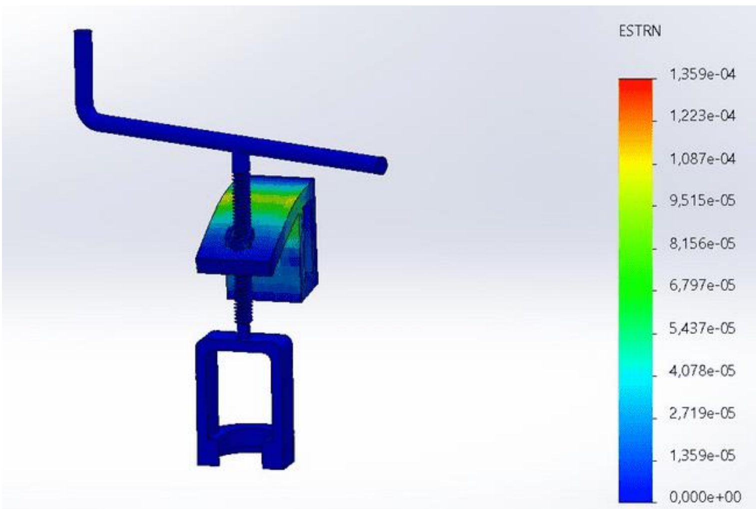


Figure 5. Strain analysis

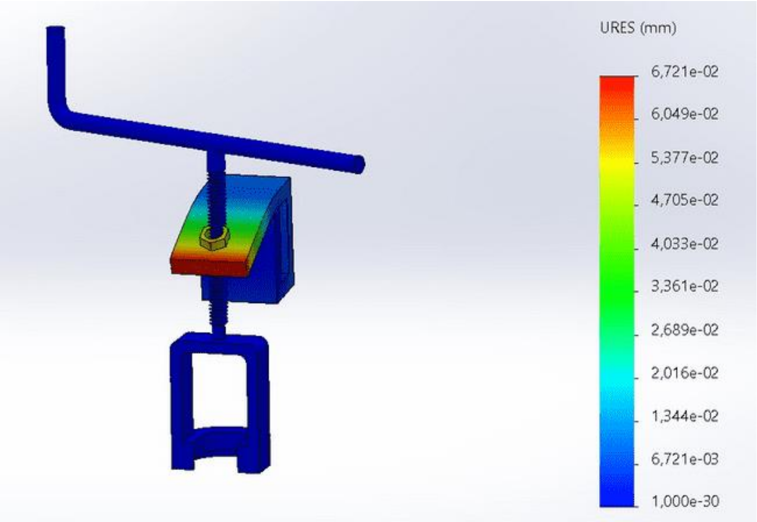


Figure 6. Displacement analysis

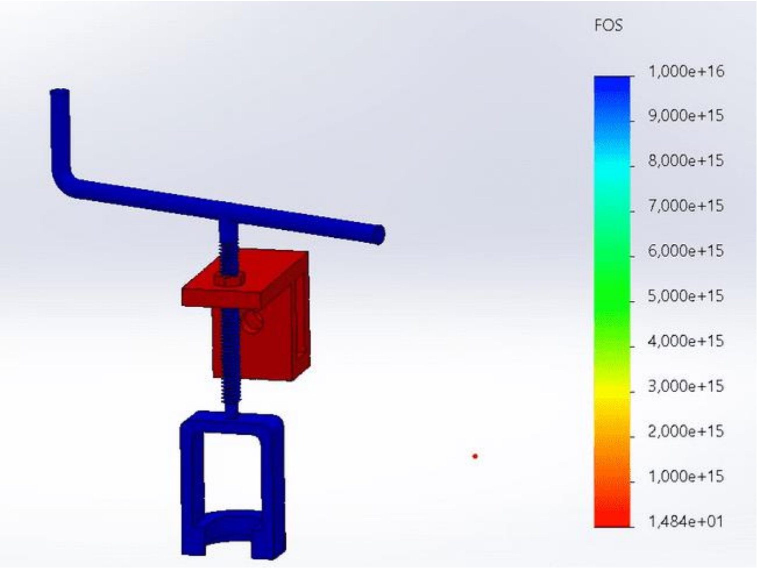


Figure 7. Analysis of safety factor

The analysis results depict that the valve spring compressor design exhibits good tolerance towards the applied static load. The recorded von Mises stress in the simulation indicates that the components possess adequate strength margins against the applied forces. Based on the calculations from the computer simulation program, the von Mises stress reveals that the maximum stress experienced by the tool under working conditions is lower than the yield strength of the material used. Therefore, it can be concluded that the construction of the simple valve spring compressor is safe for operational loads.

Conclusion

Based on the results of the design and load analysis of this simple valve spring compressor, the design of the simple valve spring compressor for the S6R2-MTK3L tugboat engine comprises an assembly structure consisting of five main parts: pillars (right and left), a bridge, a sliding clamp, a push rod, and an attachment. The material used for the simple valve spring compressor is alloy steel with a mass density of 7700 kg/m^3, a tensile strength of 723.8256 N/mm^2, and a yield strength of 620.422 N/mm^2. The simulation results of the loading demonstrate the structural feasibility with deformations and stress levels well below the material's allowable limits. The high safety factor also indicates the design's reliability in withstanding the predetermined loads. These outcomes provide a foundation for further development to validate the reliability of this design in handling applied static loads.

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