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The Importance of Fuel Injector Valve to Support Main Engine Performance Ship MV. Meratus Medan I

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ABSTRACT

The injector functions to atomize the fuel into the engine's pressurized combustion chamber with a control mechanism that allows regulation of the amount of fuel atomized into the combustion chamber. Incomplete combustion of the injector is indicated by the appearance of black smoke in the chimney. The research method used in this thesis is qualitative. Data sources were obtained from primary and secondary data collection. Data collection techniques through observation, interviews, literature study and documentation. The data analysis technique used in this research is the shell method. They were testing the validity of the data using the triangulation method. The research results stated that the factors causing less than optimal performance on the injector were the discovery of crust on the tip of the nozzle, the nozzle and spring being damaged, the working hours on the injector had exceeded the limit, the quality of the fuel was not good, and there was water and mud content. The efforts include checking and testing the injectors, always carrying out a planned maintenance system according to the manual book, and improving the fuel quality from the presence of water and mud content by running a purifier.

1. Introduction.

The fuel injector valve constitute essential elements in marine propulsion systems, exemplified by those on the MV Meratus Medan I, where they precisely govern fuel admission into the combustion chamber, thereby influencing efficiency, output power, and pollutant levels. Their criticality is evident in design features, performance metrics, and the ramifications of injection dynamics on engine operation. Notably, injector configuration and functional spesifications profoundly shape combustion effectiveness and exhaust characteristics.

Optimal fuel atomization into a fine spray is indispensable for efficient combustion. Sudarma et al. underscored the pivotal role of injection pressure and timing in modulating engine efficacy and emissions, with precise nozzle calibration mitigating exhaust opacity and bolstering performance (Sudarma, 2020). Moreover, injector responsiveness, particularly in common-rail configurations, is paramount for superior operation. Chiu noted that piezoelectric actuator innovations enable rapid actuation, vital for refining combustion in diesel powerplants (Chiu, 2021).

Nevertheless, injector functionality encounters hurdles. Xu and Zhang examined phenomena like injection latency and cavitation - induced erosion within hydraulic circuits, which precipitate erratic fuel metering, impairing engine output and emissions (Zhang & Xu, 2022). Ren et al. expounded on flow dynamics and cavitation effects, highlighting their bearing on fuel efficiency and emission mitigation (Ren, 2022). Thus, sustained injector reliability across diverse conditions is indispensable for marine diesel efficacy.

Additionally, systematic injector servicing yields marked enhancements in engine metrics. Aziz and Fahmi demonstrated that elevating injection pressure via refurbishment augments brake power and thermal efficiency while curtailing specific

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fuel use (Aziz & Fahmi, 2022). These insights affirm the necessity of routine injector oversight to sustain peak operation.

Fuel injector valves are indispensable for marine diesel performance on vessels like the MV Meratus Medan I, with their engineering, parameters, and upkeep pivotal to efficiency, power, and emissions control. Ongoing technological progressions in injectors and diagnostics will further elevate reliability in marine propulsion.

The primary propulsion unit denotes the core internal combustion engine generating mechanical thrust for vessel propulsion (Aji, 2021). The main engine usually uses Marine Fuel Oil (MFO) or High-Speed Diesel Oil (DO) to generate power. To support engine performance, especially in the fuel combustion process, one of the main engine components that must be considered and maintained regularly is the fuel injector valve. The function of the fuel injector valve is to atomize the fuel into the pressurized engine combustion chamber with a control mechanism that allows the amount of fuel atomized into the combustion chamber to be regulated (Ridwan et al., 2020). This allows control and adjustment of the fuel rate required by the ship's engine according to needs when operating at various speeds and loads. An injector that has good performance is one whose fuel spray speed is relatively high, namely being able to reach (250-350m/sec) and its atomization pressure reaches 300 bar. The author is very aware that injector maintenance is crucial because it can have very fatal consequences if routine maintenance is not carried out, and there are no periodic checks as recommended in the manual book in terms of checking each part of the injector. Is the injector still working optimally, or has its fogging decreased and its parts become damaged? Checking the injector parts includes cleaning the nozzle from dirt that sticks using marine diesel oil or using a special fluid to clean dirt or crust that sticks (Gabdrafikov et al., 2019), testing the injector according to the pressure recommended in the manual book, and the importance of cleaning the injector seat from dirty oil makes injector maintenance very necessary (Susanto & Khaeroman, 2023). The goal is to maintain injector performance and prevent ship damage that may occur during operation. If this maintenance is not carried out according to the manual book, the components in the engine will likely experience decreased performance due to the accumulation and blockage of dirt that enters the engine system (Khusniawati & Palippui, 2020). If the injector condition experiences this, the combustion quality will decrease and result in low cylinder performance. To overcome this problem, it is crucial to carry out maintenance or replacement of damaged components. However, sometimes the machinist faces constraints due to the limited supply of spare parts, and so they may be forced to use components that are no longer optimal to ensure the engine continues to operate.

Several issues can arise due to damage to the injector in the main engine, leading to delays in other ships and longer journeys, which are detrimental to various parties, both the owner and the company (Sariffudin et al., 2021). For the owner, additional costs are incurred at the port due to delays in sending and receiving goods. Meanwhile, the company will experience losses, including increased fuel consumption, increased oil consumption, and being charged a late fee at the port called demurrage. This delay can be caused by several factors, including slow unloading, slow loading, and damage to the main engine injector on the ship.

On the voyage that was carried out on the MV Meratus Medan I ship with the Surabaya-Bitung route, there was a decrease in engine speed on the main engine. The emergence of black smoke from the chimney indicates that the combustion in the engine is not perfect. This is because the injector performance is not optimal; in this case, the fuel spraying has decreased spraying speed, only reaching 190m/sec, and the atomization pressure only reaches 220 bar, which does not match the manual book. Based on the problems above, this study aims to determine the effect of less than optimal spraying caused by the fuel injector valve and to determine how to handle less than optimal fuel injector valves.

2. Methodology.

2.1. Research Approach.

This study uses a qualitative method. The characteristic of qualitative research methods is the collection of descriptive and more open data to understand the views and experiences of the subjects of the study (Bungin, 2018). The data sources for this study are primary data and secondary data collected using data collection techniques. According to Sugiyono (2018:271), data collection techniques are an approach used to obtain information and data needed for research to provide answers to the problems that have been taken.

The research was analyzed using the SHEL method. The SHEL model is a framework related to humans and focuses on the relationship with environmental resources, shipping systems, and human elements (Miller & Holley, 2018). This model presents a shift in how Software, Hardware, Environment, and Liveware (users) interact and affect each other.

The study was also validated using the triangulation method. Triangulation is a data collection technique that combines various available techniques with various existing data sources (Mamik, 2015). Triangulation implies the process of examining data from various sources using various techniques and times. Three types of triangulation are generally applied: source triangulation, data collection technique triangulation, and time triangulation (Noble & Heale, 2019).

2.2. Experimental Setup.

The data collection techniques for this study are observation, interview, documentation, and literature study techniques. For observation, monitoring of the object of this study is carried out. Interviews are conducted with the relevant sources. Documentation is carried out by obtaining documents in the form of manual books, engine logbooks, and planning maintenance systems. For the literature study method, it is carried out by obtaining books, literature, notes, and reports related to the research.

The research instruments used are obtained from interview guidelines and field notes. According to Hardani (2020), to become a more effective instrument in the research process, the author needs to be more careful in understanding how to carry out qualitative research so that they can dig up a deeper understanding of the topic being studied.

3. Results and Discussion.

3.1. Constraints That Cause the Performance of the Injector on the Main Engine to Be Less Than Optimal.

3.1.1. Encrustation at the Nozzle Tip.

Nozzle tip deposits arise from deficient atomization, fostering dribble and accumulation, worsened by substandard fuel and purifier inefficacy, which permit contaminants into the system (Stepień et al., 2017; Lacey et al., 2011). Nozzle-spring wear from neglected servicing erodes spring resilience and needle integrity, disrupting combustion and elevating emissions.

Such encrustation hinders atomization, impeding air-fuel admixture, yielding incomplete combustion, fuel waste, emissions spikes, and black smoke. Progressive blockage distorts spray geometry, exacerbating deficits.

Figure 1: Encrustation at the nozzle tip.

Source: Authors.

From a hardware vantage, nozzle tip deposits compromise cylinder-head combustion, curtailing atomization efficiency and prompting exhaust opacity.

3.1.2. Excessive Operational Hours.

Surpassing design life degrades atomization and combustion pressure, undermining performance (Li et al., 2018). Omission of Planned Maintenance System (PMS) protocols accelerates wear (Cheng et al., 2014). Scheduled interventions are vital for parameter adherence and combustion optimization. Prolonged service without oversight yields erratic metering, combustion inefficiency, power loss, fuel escalation, and emissions. Adhering to PMS extends utility and efficacy.

3.1.3. Insufficient Onboard Spare Parts.

Assured spares availability underpins propulsion continuity; procurement latencies compel improvisation with legacy or rehabilitated elements, courting unreliability (Pandian & Das, 2023). Personnel acumen in stewardship is germane; lacunae therein foment downtime proliferation.

Augmented competency development in inventory governance is advocated. Contingent reutilization harbors latent hazards to systemic coherence, necessitating prioritized stockpiling of premium spares and proficient cadre deployment.

3.1.4. Deteriorated Fuel Specifications and Aqueous / Sedimentary Contaminants.

Fuel adulteration with detritus and moisture congests filtration media, hampering pump-injector synergy and hastening erosive degradation. Proactive filter regimens and purifier vigilance are cornerstone mitigations for qualitative uplift and engine thrift. Such impurities attenuate atomization, catalyze corrodibility, and inflate operational costs alongside emissions. Disciplined purification cascades yield contaminant abatement and performance restitution.

3.2. Proactive Measures for Fuel injector Valve Optimization Aboard MV Meratus Medan I.

3.2.1. Systematic Injector Scrutiny and Performance Validation.

Manufacturer directives prescribe evaluations at 500-1000 hour junctures, commencing with macroscopic appraisal for occlusions, succeeded by ameliorative lavage (diesel or WD-40 equivalents). Subsequent assays validate spray morphology and nebulization fidelity against normative criteria, with longitudinal logging furnishing prognostic intelligence. This regimen fortifies engine resilience and longevity.

3.2.2. Rigorous Adherence to Planned Maintenance System - (PMS) Protocols.

PMS architectures systematize anticipatory interventions, incorporating lunar cadences (Prasetyo, 2020), substitutive heuristics, and archival traceability (Li et al., 2018; Cheng et al., 2014). This paradigm preempts degradations, enshrines operational primacy, and provisions redundancy via spares.

3.2.3. Fuel Conditioning through FO Purifier Engagement.

Purificatory cascades excise aqueous and sedimentary fractions, preconditioning service tanks and filter matrices, thereby insulating injectors from adulteration (Pandian & Das, 2023). This praxis assures immaculate feedstock, combustion rectitude, emission parsimony, and ecological congruence.

3.3. Multifaceted Analysis of Injector Performance: Technological, Ambient, and Anthropocentric Lenses.

3.3.1. Software Dimensions.

1. Lack of implementation of planned maintenance system. The upkeep and servicing of fuel injectors necessitate adherence to prescribed protocols outlined in the manufacturer's manual, including routine inspections to assess

the operational integrity of the injector components. This check includes that the running hours on the injector have not exceeded the limit, checking for the absence of crust on the nozzle tip, and testing the injector. When testing the injector nozzle tip did not experience any leakage or seepage and the components on the injector were not damaged. This procedure must be observed and carried out routinely by Machinist II the person responsible for the main engine.

One solution to overcome the lack of implementation of engine maintenance against the manual and planned maintenance system is to carry out maintenance according to what is stated in the manual book and follow the established maintenance schedule. Engine maintenance should not only be carried out when the engine experiences problems or damage but must also pay attention to the working hours of the components so that the results of the injector maintenance are more optimal.

2. Requests for spare parts are experiencig delays in delivery.

   The impact of inadequate provision of spare parts on board includes a number of problems that arise due to the scarcity and incompatibility of available spare parts. The author conducted interviews with the Chief Engineer and Machinist I revealing that these problems mainly impact the ship's main engine. To overcome the limited spare parts on board, efforts were made to conduct more detailed data collection and integrate it into software. This approach aims to ensure that the need for spare parts on board can be better managed and requested appropriately from the company, avoiding shortages of spare parts and ensuring smooth ship operations.

3.3.2. Hardware.

Hardware is a physical and non-human element of a system or device. Factors that can cause hardware damage can cause a decrease in injector performance. The following are factors that can cause the injector to work less than optimally, including interference with the combustion system in the cylinder head due to crust on the tip of the nozzle, and damage to the spring on the injector. So that the combustion process is disrupted by being marked by black smoke coming out of the chimney. For this reason, it is important to test the injector before testing, if you find crust, first clean the crust that sticks to the tip of the nozzle so that the resulting atomization is more optimal and it is important to replace the damaged components.

3.3.3. Environment.

Factors that impact the less-than-optimal performance of injectors in terms of the environment involve inadequate fuel quality. Poor quality fuel can cause dirt particles to pass through the filter and reach the injector, causing crust to form on the nozzle tip. This poor fuel quality is triggered by the inoperability of the fo purifier due to damage so that the water and mud content of the fuel is not separated and the lack of fo purifier spare parts to replace damaged components. This condition causes dirt and water to enter the combustion chamber, inhibiting the optimal combustion process. Handling this problem involves routine cleaning of the filter or strainer screen and replacing dirty filters with new ones. This aims to reduce the amount of dirt entering the combustion system, prevent the formation of crust on the nozzle, and maintain optimal injector performance.

3.3.4. Liveware.

The sub-optimal performance of the injector in terms of human resources (liveware) can be influenced by several factors. One of them is the lack of awareness of the ship's crew about the importance of carrying out machinery maintenance by the planned maintenance system and instructions from the manual book. This lack of understanding can result in negligence in carrying out maintenance procedures, which can cause problems with machinery components, including injectors. In addition, the limited number of spare parts on board is also a factor that affects injector performance. The unavailability of adequate spare parts requires the crew to use used spare parts to replace damaged components. However, the use of these used spare parts cannot always produce optimal performance, because their quality may have decreased and is not comparable to new spare parts.

To overcome the lack of awareness of the crew regarding machine maintenance, the steps that can be taken are to increase their understanding and awareness of the importance of carrying out maintenance by the planned maintenance system and manual book. This can be done through training and counseling so that the crew is more aware of maintaining machinery and preventing the same damage from happening again.

3.3.5. Relationship between liveware components.

a. Liveware - Software.

   Lack of awareness of the engine crew regarding the need to carry out maintenance by the planned maintenance system and the manual book is the main factor that causes problems in the function of the machinery, which ultimately hampers the operation of the ship.

b. Liveware - Hardware.

   The working hours of the injector have exceeded the limit and no maintenance and repairs have been carried out, resulting in less than optimal injector performance.

c. Liveware - Environment.

   No repairs were made to the fo purifier so that the fuel did not go through separation first, which caused water and mud content to enter the combustion system. This could cause the performance of the injector to be less than optimal.

d. Liveware - Liveware.

   The importance of communicating between the ship's crew and the company is key to ensuring the smooth flow of requests for spare parts needed on board. This has a significant impact because quick approval of the provision of spare parts will make it easier to carry out maintenance and repairs to machinery components without having to rely on the use of used spare parts

Conclusions.

The obstacles that cause the performance of the fuel injector valve to be less than optimal on the MV. Meratus Medan 1 ship is the discovery of crust on the tip of the nozzle, the nozzle and spring have been damaged, the working hours on the injector have exceeded the limit, the quality of the fuel is not good and there is water and mud content. So that this does not happen again, an inspection and testing must be carried out on the injector, always PMS (Planned maintenance system) according to the manual book, and improve the quality of the fuel from the water and mud content by running a for purifier.

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