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Marine Diesel Engine Fixed and Moving Parts

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ABSTRACT
Marine diesel engines are mostly preferred for its reliability and fuel efficiency. To understand the function of marine diesel engines, the identification and description of its parts are necessary for its proper maintenance. Component parts of the marine diesel engine are divided into fixed and moving parts. These parts are described in detail. Recommendations for identifying and understanding the different classification schemes should gain increased familiarity with the nature of the specific parts as well as the approaches to the repair and maintenance.

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I. INTRODUCTION

Diesel engines have a significant role in the shipping industry. Aside from the reliability and high torque output of diesel engines, the relative safety of diesel fuel also provides its advantages. Moreover, the almost total absence of carbon monoxide in the exhaust has proven to be of significant advantage. Diesel engines have been commonly regarded as a better type of engine compared to other types in the marine industry. To ensure that the maximum advantage is derived from its effects, its proper maintenance require the understanding of the machinery's components and their individual nature and functions. In this regard, this paper presents an identification and description of the components of marine diesel engines. The parts are classified into fixed and moving parts so that an understanding of the engine's mechanism is developed as to the nature and function of each of the parts. In some of the parts, suggested maintenance procedures are provided.

Marine engines

Diesel engines can be classified in different ways. These classifications involve speed, usage, operation and cylinder arrangement. In terms of speed, diesel engines can be categorized as high, medium and slow speed. While in terms of operation or operating cycle, engines can be 2-stroke, 4-stroke, single acting or double acting. In the marine industry, 2-stroke and 4-stroke engines are used (Stonecypher (a), par. 4). For propelling regular ships, the slow speed 2-stroke engines are normally used. Those requiring auxiliary power commonly use 4-stroke engines for greater speed. Figure 1 presents pictures of both 2-stroke (left) and 4-stroke engines (middle and right). Slow speed engines operate up to 300 revolutions per minute (rpm). However, large 2-stroke slow speed diesel engines run below 120 rpm. For very long stroke engines, the maximum speed is about 80 rpm. The biggest, most powerful engines are slow speed, 2-stroke and crosshead diesel engines. Meanwhile, operating speeds between 300 to 1000 rpms are medium speed. A large number of 4-stroke medium speed operate at about 500 rpm. Engines operating beyond 1000 rpm are high speed. In terms of usage, the engines can be identified as either automotive, locomotive or marine engines. It should be distinguished from this classification that marine engines are those used in water vessels. Based on cylinder arrangement, diesel engines can either be horizontal, vertical or vee radial. Engines can also be classified in terms of their construction. They can either be a crosshead, trunk or opposed piston. Majority of the large merchant vessels have slow speed, 2-stroke and crosshead engines or medium speed, 4-stroke and trunk engines. A number of the smaller boats use high-speed engines.

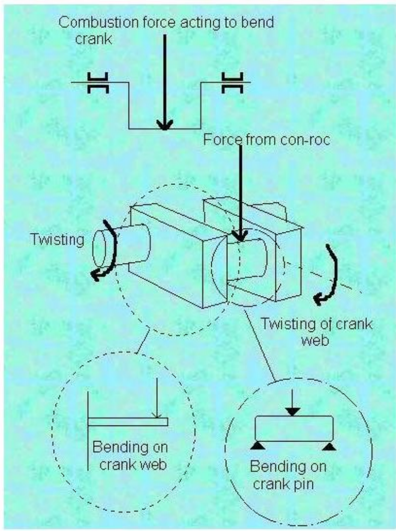
Figure 1. 2-stroke and 4-stroke engines

Diesel engines are also technically referred to as compression ignition engines.This is a type of engine characterized to operate using internal combustion like those of diesel engines. The ignition consequently happens due to the increase in temperature brought about by the mixture compression in the cylinder (Collins English Dictionary, par. 1).

Marine propulsion is the term which describes the mechanism utilized to generate thrust to move the ship across water. Steam engines were first used in marine propulsion. Later, they were replaced by two-stroke or four-stroke engines. Other types of engines include outboard motors and gas turbine engines on swifter ships. Steam-producing nuclear reactors thrust warships and icebreakers. For increased energy-efficient propulsion, electric motors with battery storage are proposed to be used for submarines and electric boats (NTNU 3). Gradually recognized is the use of liquefied natural gas (LNG) due to lower costs and lower emissions. In most modern ships, reciprocating diesel engines are preferred because of their operational simplicity, robustness and fuel economy unlike other types of propelling mechanisms. Electric motors or engines are used to turn a propeller. Pump jets or impellers are also less frequently used.

In reciprocating diesel engines, rotating crankshafts can be directly attached to the propellers of slower engines. This attachment can be done either through the reduction gearbox in medium- and high-speed engines or through an alternator and electric motor. Crankshaft rotation is linked to the camshaft or hydraulic pump in intelligent diesel engines. Gearboxes are not generally necessary with modern ships' propellers since they are at their most efficient operating speed – that is for slow speed engines. Commonly, there are either one or two propeller shafts in propulsion systems. Individually, it has its own direct drive engine. There may be one, two or more propellers for ships operating at medium or high speed diesel engines. One or two of the engines drive the individual propeller shaft using a gearbox. If there is more than one engine geared to one shaft, a clutch is used to drive each engine. This lets the unused engine to be disengaged from the gearbox while the other engines are operating. This allows for upkeep for the engines as they may be far from the port.

Components of a diesel marine engine



In this section, the parts of a diesel marine engine is described and illustrated under fixed or moving part classification. The function, specifications and inspection and care for each component are also provided. There are 21 components identified in this paper.

1. Moving parts

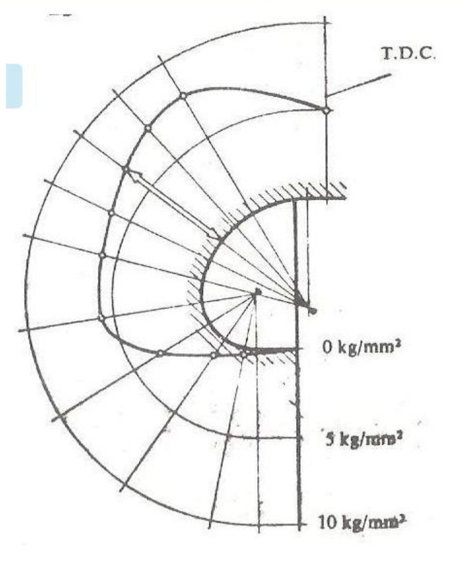
A marine diesel engine's moving parts comprise of the following – the crankshaft, the pistons and piston rings and piston skirt, fuel valves, air start valve, exhaust gas valve, inlet valve, fuel injectors, turbo blowers,connecting rod, crank pin, camshaft, push rod and rocker arms, crosshead, crosshead guide and fuel pump. Each of these parts are individually described in this section.

Crankshaft. This component converts the up and down movement of the pistons of the cylinder into constant rotary motion. This then moves the propeller shaft. The crankshaft operates as the outlet of power from the engine which supplies the propeller that moves the ship forward. It receives oscillating motion from the connecting rod and gives a rotary motion to the main shaft. This also drives the camshaft which actuate the valves of the engine. Figure 2 shows the parts of the crankshaft, shown on the left.

There are different types of forces as the crankshaft operates, which can be hinted from the illustration in Figure 2. There are different bending and twisting forces performed by this part. Forces may be attributed to the piston weight, combustion load, axial load and compressive loads of webs on journals, to name a few. Majority of these forces observe exchanging patterns which lead to fatigue. Thus, these materials require considerable Ultimate Tensile Strength (Stonecypher (b), par. 5). The material also needs to be wear resistant, with tensile strength and ductile. The speed of the engine must also be considered in selecting the material for constructing the crankshaft. Slow speed engines use plain carbon steel with approximately from 0.2 to 0.4% carbon. For vessels with comparatively higher speed, alloy sheets are used for the engines.

Figure 3 presents a stress diagram of a crankshaft. This illustrates the stresses in a web fillet in a Sulzer RND 10 crankshaft.

Figure 3. A sketch of the stress in a crankshaft



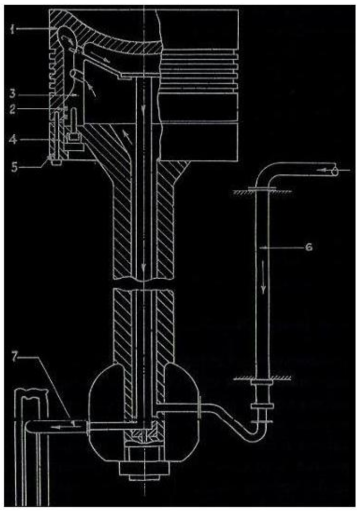
Pistons and piston rings. Before power is transferred to the crankshaft, the piston generates power in the combustion chamber and conveys this energy from here to the other parts. The piston compacts the air amidst the cylinder head and the piston crown (Marine Diesel EngineBlogspot, par. 17). The piston is the fundamental link as to how to-and-fro motion is converted into constant rotary motion (Stonecypher (i), par. 2). Marine piston operate basically as in any piston. The only thing that differentiates this is its size. Figure 4 shows how big a marine piston is. The ceiling and wall height in the picture should give an idea of its size.

Figure 4. Marine diesel engine piston

Due to its significant size and the stresses it undertakes, much effort is required to design the piston so that it should withstand the forces and is expected to perform a long time (Stonecypher (e), par. 5). Pistons are subject to thermal stresses. It takes on much heat as this is located near the combustion chamber. The piston crown, or the upper part of the piston, is the part subjected to high temperatures reaching up to 450 centigrade. Thus, this must be cooled properly. Compressive and inertial forces also stress the piston particularly during the up-and-down motion of the piston.

Figure 5 is a sketch of a piston where parts are numerically labeled. These parts are identified to include the following: piston crown (1), sealing ring (2), cast iron insert (3), skirt (4), clamp ring (5), cooling oil inlet pipe (6) and cooling oil outlet pipe (7). The illustration also shows directional arrows where the cooling oil enters and exits the piston. The cooling oil helps bring down the temperature of the piston to 110 centigrade at the ring zone.

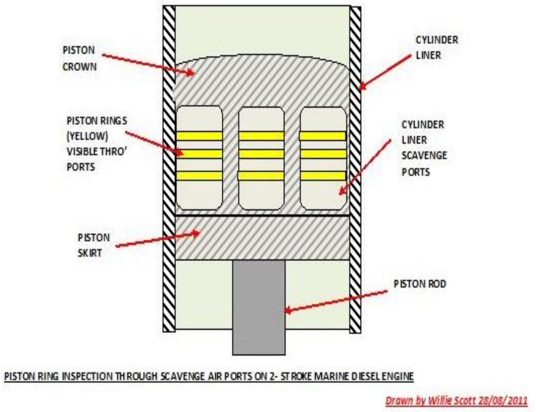
Figure 5. Sketch of a piston and its parts



Pistons can either be oil-cooled or water-cooled. Since water absorbs heat greater than oil, oil-cooled pistons are preferred in marine diesel engines. This also helps in the carbonization of oil. Also, in water-cooled pistons, water contaminates the crankcase and causes problems. Oil leaked into the crankcase does not provide this negative effect since there is already oil in the crankcase sump (Stonecypher (f), par. 7). Water also increases the probability of corrosion and attacks the surface of the piston.

The piston rings are considered to play a very significant role in the compression combustion ignition system (Stonecypher (g), par. 1). Its care and maintenance is vital to the overall functioning of the piston. The compression rings function as a seal against the liner. This prevents leaking high temperature combustion gases. These also oils the rings to remove the lubricating oil from the cylinder after the lubrication. This prevents the excess oil to mix with the charge.On the one hand, oil or scraper rings remove the excess lubricating oil in the cylinders. Build-up of carbon at the rings and piston crown is prevented. Figure 6 shows where the piston rings are located along with the other parts of the piston. This figure also indicates a piston skirt which carries the gudgeon pin and rub against the liner.

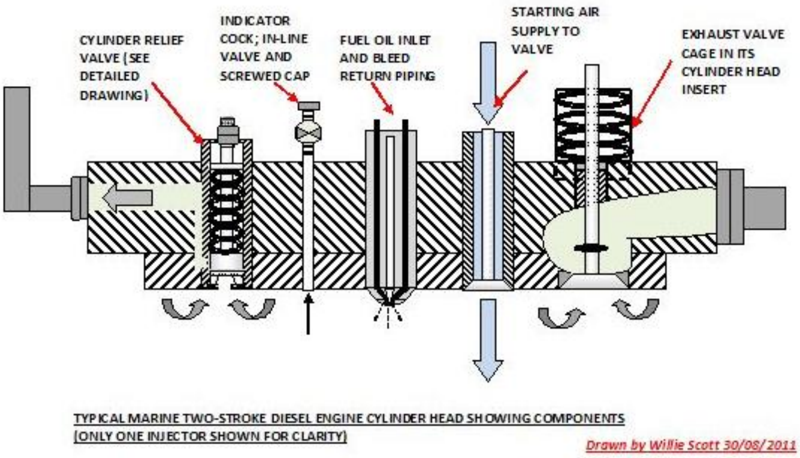
Figure 6. Location of piston rings and other parts of the piston



To provide for the mechanical properties of piston rings, these are made from an alloy of cast iron and other elements. The two-stroke engines' piston rings are formed from a base metal of pearlitic grey iron mixed with molybdenum, chrome, vanadium and nickel (Stonecypher (g), par. 7). In modern engines, a greater amount of titanium and vanadium is used to produce hard carbides together with the alloy constitution. A pot casting technique is used in the production of the oval casting. Individual rings are formed from this and they are machine, parted off and with edges rounded. The main properties of piston rings include: the inherent hardness of wear resistance, low friction and self-lubricating, corrosion resistance, load bearing and good heat transfer. Inherent hardness allows longer periods of replacement for the piston rings. Less friction and self-lubrication support efficiency since fuel and lube oil use are reduced. The rings also need to be tough to resist the extensive forces and shock loads occurring during the internal combustion process. Resistance to corrosion protects the piston ring from corrosion due to the high sulfur content. The piston rings are also expected to transfer heat instantly. At the same time, they have to be resistant to the high heat of the combustion process. Aside from these mechanical properties, the piston rings must also have thermal expansion. This last property allows the piston to retain its optimum clearances within their subparts.

Although the cylinder head or cover is a fixed part of the engine, its various valves are moving. More common cylinders come as a single piece produced in cast steel. These cylinders include the following parts – fuel valves, air start valve, exhaust gas valve and indicator clock. Fuel valves introduce heavy fuel and diesel oil in the form of a mist into the combustion chamber. Air start valve starts the engine in the astern rotation by infusing compressed air into the relative cylinder (Scott (a), par. 8). The inlet valve in a 4-stroke engine allows the fresh charge of air fuel mixture to enter the cylinder bore. Also in a 4-stroke engine, the exhaust valve permits the burnt gases to escape from the cylinder at the proper timing. Meanwhile, the exhaust gas valve is placed at the middle of the cylinder and caged attached to an insert of the cylinder head. This valve is operated using hydraulics. The cage is cooled with water. A fin is attached to the valve stem to decrease the wear on the seat of the valve. The indicator clock, on the one hand, reveals the condition of the engine. As the clock is left opened while the engine is on, the clock allows blowing out of dirt or water gathered after the machine is closed down or renovated. The indicator clock is however included in the moving parts although it is a fixed structure in the valves. Figure 7 shows a labeled cylinder head indicating the various valves and inserts into the head.

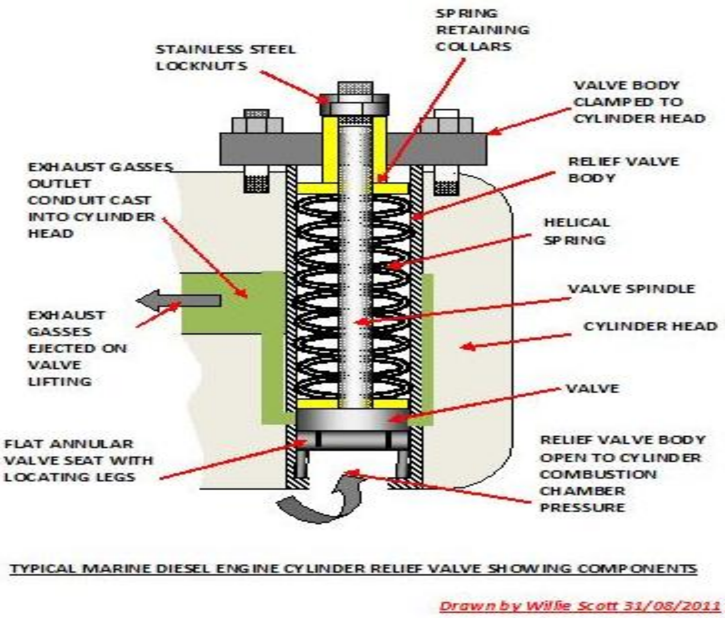
Figure 7. Cylinder Head indicated with valves and inserts



Cylinder Relief Valve. This component protects the cylinder head from combustion forces. One among the several valves in the diesel engine, this valve helps reduce the pressure in the combustion area and expels the gas into a flanged pipe out to the deck of the vessel (Scott, (a), par. 4). This valve lifts up to release the pressure. The valve is constructed by enclosing this within a cast iron casing and is attached to the cylinder head using threaded studs and hex nuts (Balu, par. 6). This valve consists of a helical valve spring and the valve and stem.

Air Start Valve. In large engines, compressed air starts the motor. These valves are mounted onto the cylinder head. These admit the starting air into the cylinder and then seals when the engine collects speed and runs on fuel oil as the valve is outfitted with its own distributor and Ahead-Astern cam. Depending on the firing order of the machine, the cams adjust their opening times to guarantee overlapping for uninterrupted cylinders. Every cylinder has a starting valve which housing is molded unto the bottom portion of a two-piece cylinder lid. Figure 8 shows a diagram of the air start valve, which includes its steel casing with spindle, guide piston, store spring and other parts.

Figure 8. Air start valve



Fuel Oil Injector. The fuel injector delivers fuel in fine spray under pressure. Injectors come in two types: cooled or uncooled. In cooled injectors, water is distributed around usually in closed circuit systems and is placed in a separate pump and cooler system (Scott (a), par. 9). For uncooled injectors, the fuel oil is circulated using atomizing nozzles to regulate the temperatures. Injectors operated on hydraulics are molded into 2-stroke engines.

Exhaust Valve. There is only one exhaust valve in the main engine. The valve uses the same operating principle found in smaller 4-stroke engines. However, the structure and operation are quite complex.

Found at the center of the cylinder head, this valve acts as an outlet and receives the waste combustion residues. In smaller 4-stroke engines, a conventional tappet-cam structure comprises the set of exhaust valves. For 2-stroke engines, those found on ships, the valve is hydraulically driven. A pneumatic structure moves the spring action. Figure 9 illustrates a schematic description of the valve on the left side of the diagram; while on the right, the parts are indicated. Oil is colored yellow in this diagram. The oil allows the valve to open. This oil comes from the oil system of the diesel engine and brought to this area through a hydraulic pump which is assisted by the engine cam. The air, on the other hand, helps in valve closure and is responsible for the spring cushioning effect (Stonecypher (h), par. 6). A small amount of the lubricating oil is incorporated with air. This air also keeps the valve guide cool. To get an idea of its size, the exhaust valve's actual size is placed next to a person of average height as illustrated in Figure 10.

Figure 9. A schematic and parts diagram of an exhaust valve

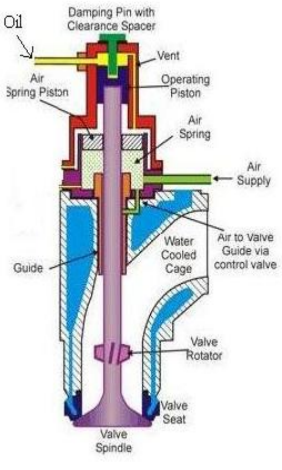
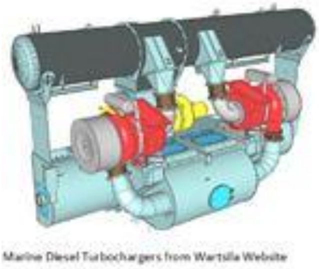


Figure 10. Relative size of the exhaust valve

Turbo Blowers. These parts supply scavenge air in a 2-stroke diesel engine. It rotates via the exhaust gases, drives the compressor on the chute where cool air is drawn and heated, and then enables the complete combustion of diesel or fuel oil. The pressurized air having passed through a cooler and then drawn by the compressor has to be cool first to allow for efficient combustion (Scott (b), par. 5). The turbocharger uses the energy of the exhaust gases emanating from the engine to constrict the air going inside the engine (Marine Diesel EngineBlogspot, par. 21). Figure 11 shows an image of a turbocharger.

Figure 11. Turbocharger



Pyrometers and gauges are used to monitor the condition of the engine. They are molded in the exhaust gas streams since the gases that come out from the here are extremely hot.

The other moving parts of the engine include the following – connecting rod, crank pin, camshaft, push rod and rocker arms, crosshead, crosshead guide, fuel pump, gudgeon pin, governor, scavenger ports and the push rod. The connecting rod alters the reciprocating motion of the piston into rotary motion at the crankshaft. It also diffuses power created at the piston to the crankshaft. The crank pin moves power and motion released from the piston to the crankshaft using a connecting rod. The cam shaft takes driving force from the crankshaft through the gear chain. It operates the inlet and exhaust vales with the assistance of the cam followers, push rod and rocker arms. The crosshead is a beam that connects the piston rod to the connecting rod. The crosshead guide allows the crossheads to only move in the same direction as the piston travels. The fuel pump delivers a metered amount of fuel into the cylinder through fuel delivery pipe and the fuel injector.The gudgeon pin in a 4-stroke engine connects the piston with the small end of the connecting rod. The governor controls the speed of the engine at different loads by regulating the fuel supply in the diesel engine.The scavenge ports in 2-stroke engines pushes exhausted gas-charge out from the cylinder. It also draws in fresh air for the next cycle.Push rod in a 4-stroke engine pushes the rods sitting on the cam shaft when the engine is running. They also move up and down in a timed sequence. This moves along with the rocker arm, which opens and closes the inlet and exhaust valves.

2. Fixed parts

The fixed parts of the diesel engine includes the bedplate, the cylinder head, the thrust block, the propeller shaft and the stern tube, aside from other fixed parts included here.

Bedplate. Any structure requires a solid foundation. Since marine diesel engines can be huge structures and sustain a lot of forces from the movement of pistons, aside from the engine's weight, a solid base is very important. A durable support is needed to sustain such load and force. This is the function of the bedplate, which houses the large crankshaft. The bedplate also supports the cylinder block. In both longitudinal and transverse directions, the bedplate must be able to support strongly the engine (Stonecypher, par. 5).To appreciate the need for a sturdy bedplate, figure 12 below shows the magnitude and size of the marine diesel engine. The encircled portion in the picture highlights the size of a man as against the enormity of the engine.

Figure 12. Magnitude and size of the marine diesel engine

Bedplates come in different sizes and design which varies along with the type and size of the engine. Figure 13 below is the bedplate of Doxford 58J4 placed on a 15 thousand ton deadweight vessel. Moreover, bedplates consist of the following parts: a cast transverse girder, a long box girder, a limit stop and the chocks. To fasten the bedplate to the tank top and the limit stops, foundation bolts are used.

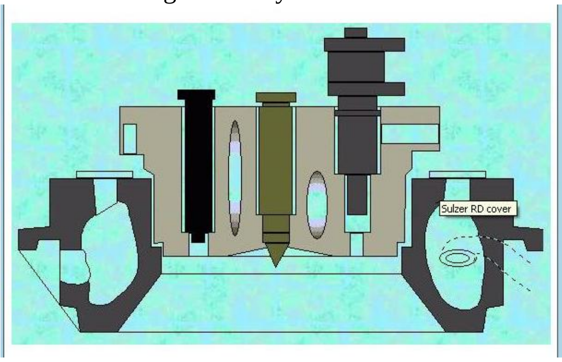
Figure 13. Bedplate of Doxford 58J4

Regular inspection of the bedplates must be conducted. Flaws at its various parts including the cross girders, welded seams and bolts must be detected. Cross girders, for example, are exposed to heavy cyclic loading because of gravity and inertia forces (Stonecypher, par. 6). These also experience tremendous vibrations. If these parts are not properly placed, the crankshaft may be misaligned and lead to large damages.

The Cylinder Head. This acts as the cover of the cylinder liner, which was why it is also called as the head as it is located on the top portion. This encloses the combustion can and thus it is exposed to intense levels of mechanical and thermal stresses. Several mountings are used and vary based on the engine's make and model (Stonecypher (g), par. 3). Some of these mountings include air, fuel and relief valves among others. These covers are carefully designed to allow the proper combustion to occur as they decide the shape of the combustion chamber. Production and operation of the cylinder is a challenging task (Stonecypher (g), par. 7). In a 4-stroke engine, the cylinder head holds the inlet and exhaust valves. An injector is also mounted on here.

Figure 14 illustrates a cylinder head for a Sulzer RD marine diesel engine. Its different valves like the air starting valve, fuel injector and cooling water passages among others are included. The passage of the cooling water is fixed with zinc rings which protects versus corrosion. The cylinder head is secured onto the cylinder block using bolts that should hold up different intensities. The bolts aid in the transformation to gases getting on the cylinder head to the bedplate through the cylinder block. The gas forces then come up at the ship's hull. This action is referred to as uniflow scavenging.Those without exhaust valves have exhaust ports instead. This design is referred to as loop scavenging engines.

Figure 14. Cylinder Head



Corrosion, scaling and stud formation are among the possible defects a cylinder head is subject to. The severe working conditions expose the cylinder cover to these defects and it is impossible to eliminate them completely (Stonecypher (g), par. 8). However, the life of the cover can be extended through proper cooling water treatment, prevention of fouling of cooling spaces and clean combustion techniques.

Thrust Block. The thrust block is responsible for the efficient transmission of power to the propeller. It also warrants the control of the torque and propeller shaft alignment from this part to the stern tube. This component is also referred to as the tilting pad bearing or the Michellbearing. Amidst the thrust block and stern tube is the propeller shaft. This propeller shaft is sustained by several shaft bearings placed along the shaft's length. Meanwhile, the stern tube comprises of supports and seals for the propeller shaft.

Steel plates and I-beams hold the structure of the thrust block. The thrust block is made of a housing with several wedge-shaped metaled pads with helical oil grooves. These pads are positioned and patched up throughout a steel support. Overheating and premature wear of the pads should be prevented which is facilitated by the fluid film of oil amid the pads and the collar (Scott (c), par. 7). Because of the drive shaft's rotation, the oil becomes self-pressurized. An oil basin is placed at the foot of the housing which holds oil-cooling oil. Seawater is flowed in this area. Figure 15 is an illustration of the thrust block together with the other parts described here.

Figure 15. Thrust block and adjoining parts

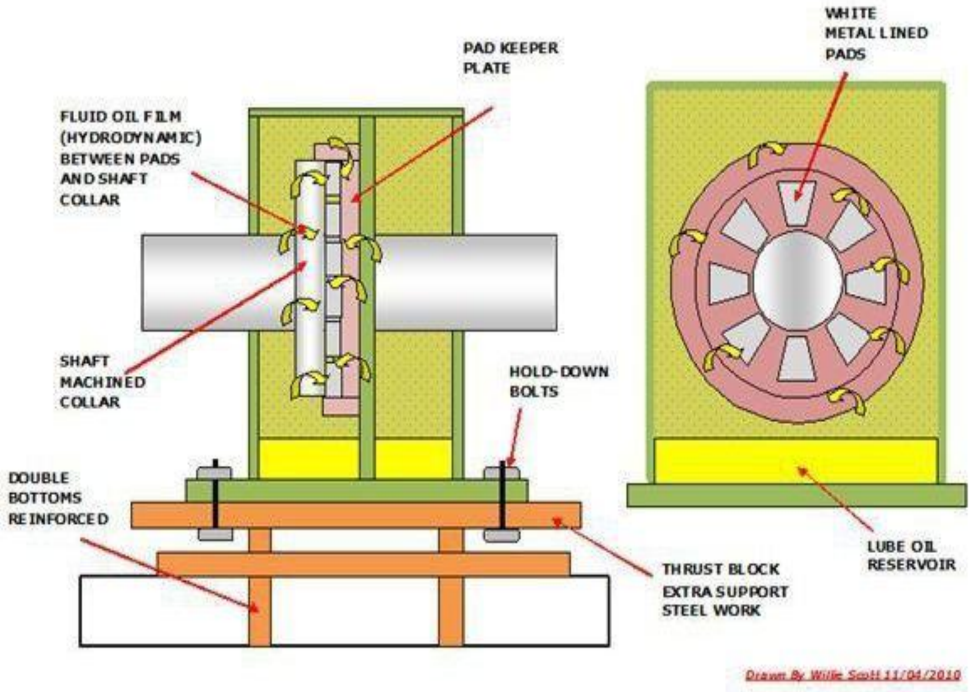
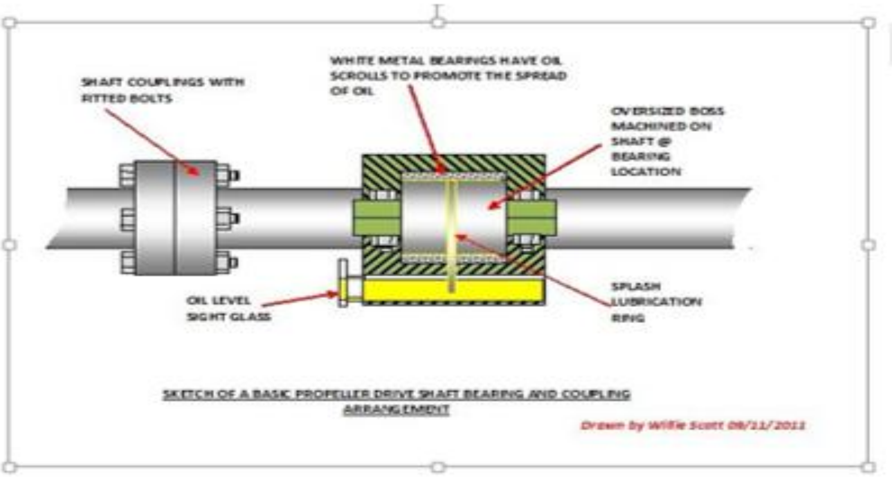


Figure 16. A common propeller shaft

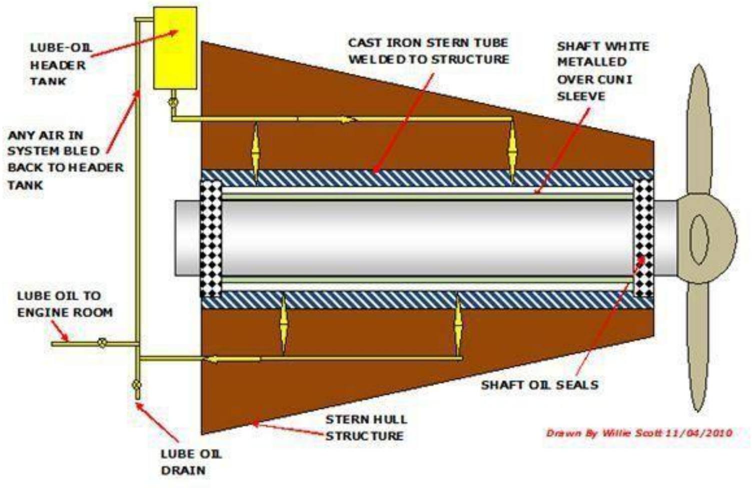


Propeller drive shaft. This shaft is fastened to the main engine flywheel. It goes through the thrust block and then to the shaft tunnel. Shaft bearings hold the propeller drive shaft. Produced from forged steel, the propeller drive shaft is coupled with flanges. It is affixed providing a sufficient diameter from the shaft bearings. This portion of the engine needs fine finishing so that it can run smoothly within the white metal bearing (Scott (c), par. 9). The flanges, on the other hand, have to be precisely structured and the bolt holes piled to insert the fitted bolts. High tension bolting fastens them together. They are intensified by a hydraulic tensioning gear. Bearings which support the shaft are formed in two halves and are commonly lined with white metal. Oil scrolls distributes the lubrication in this section. Figure 16 shows a propeller shaft with its labelled parts.

The propeller shaft contains copper nickel alloy and Babbitt metal is smeared on this. This provides the bearing surface amidst the propeller shaft and the stern tube. This contraption is lubricated and cooled by lube oil. To protect the shaft from the access of oil to the seawater and the aft bilge, the adjustable gland seals of the propeller shaft ensures this.

Stern tube. This part of the engine supports and seals the propeller shaft. It is produced from cast iron tube and attached into the stern frame. Various arrangements of stern tube bearings exist. There those which conform to the descriptions provided here while others contain an additional eater-cooled strut bearings secured externally to the vessel's hull particularly those found on warships (Scott (c), par. 9). This tube holds the shaft up to the propeller. Figure 11 shoes an illustration of the stern tube with its parts labelled.

Figure 11. An illustration of a typical stern tube



The other fixed parts of the engine include the following –cylinder block, cylinder liner and the stuffing box. The cylinder block clutches the engine parts such as pistons, cylinders, crankshaft and oil pump. It secures the crankshaft which converts rotational motion into reciprocating motion. The cylinder liner retains the lubricant within the cylinder cover and acts like a sliding surface for the piston rings. This also takes in the combustion heat from the piston and its rings and then conveys the heat to the coolant. This also stops the compressed and combustion gases from seeping. The stuffing box prevents the fluids from seeping inside of the engine's parts.

II. CONCLUSION AND RECOMMENDATIONS

The structure of the marine diesel engine is something to marvel at considering its size and inner workings. The identification of the different components and their classification into moving and fixed parts help develop an understanding of their functions. Repair and maintenance of the parts are also aided since the description of how they operate is provided and better understood.

Learning that there are different classifications of marine diesel engines, it is recommended that familiarity with the specific types of machines in its various schemes of classification be developed. Classifying the parts as to moving and fixed does not seem to provide a comprehensive identification of the components of the marine diesel engine since there are parts existing and functioning differently in 2-stroke or 4-stroke engines. Their basic differences must be identified to distinguish the specific functioning of each of the parts. Also, the nature of the types of machines be understood so that the approaches to repair and maintenance be established for every kind of marine diesel engine.

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