

Improving the Internal Combustion Engine Performance as a Driven Pump with a Modified Cooling System

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Abstract: An irrigation system that uses a pump to channel water through pipes requires a stable pump performance influenced by the internal combustion engine's driving performance. The performance of an internal combustion engine is influenced by several things, one of which is the quality of the cooling system. The cooling system on the Yanmar TS190R diesel engine has a weakness with little cooling water, so it cannot be used continuously. The rice fields in Mojopuro Wuryantoro Wonogiri are rainfed rice fields, highly dependent on water supply through pumps in the dry season. The pump will work for a minimum of 10 days non-stop to irrigate 60 hectares of rice fields and require human resources to supervise around the clock. The research of the cooling system of the elevated water temperature was carried out on a Yanmar TS190R, water-cooled, diesel engine and Ebara 150 SQPB pump 15 kW, 2 m³/min capacity. The studies were conducted for the engine speed 500, 1000, 1500, 2000 rpm without circulation (initial) and with modified water cooling circulation. The flow rate of cooling water to the radiator depends on the pump's engine speed. A modified cooling system that combines a pump as a cooling water supply driven by an internal combustion engine can reduce the average radiator temperature from 96 to 76°C. Lowering the radiator temperature allowed the diesel engine-pump system to operate for several days (more than ten days non-stop) without being supervised by workers.

Keywords: Cooling system, internal combustion engine, driven pump, irrigation system

Introduction

The rice fields in Mojopuro village, Wuryantoro district, Wonogiri regency are rainfed rice fields, highly dependent on water supply through pumps in the dry season. An irrigation system that uses a pump to channel water through pipes requires a stable pump performance influenced by driving, namely the internal combustion (IC) engine. The use of an IC engine as a driving force for irrigation water pumps is different from an internal combustion engine in the automotive sector. The difference lies in the length of operation of the machine; in



general, automotive engines are used continuously for less than 24 hours, while the water pump driving machine works for several days non-stop. Based on field observations, the pump will work for a minimum of 10 days non-stop to irrigate 60 hectares of rice fields and require human resources to supervise around the clock.

Thirty to forty percent of the energy from the fuel is lost in the form of exhaust heat, and 30% is in the coolant on IC engines (Patowary & Baruah, 2018). The cooling liquid, which offers a more consistent temperature around the combustion chamber than direct cooling air, is the most common and widely utilized type of cooling in IC engines. The cooling water's qualities, however, limit the maximum temperature. Krakowski (2013) found the pressure in the system; hence the temperature of the liquid could be maintained at the expected level for a more extended amount of time. The cooling intensity was changed by controlling the flow of the water pump and switching the coolant flow between small and large cooling systems. Therefore, adjusting the water pump's flow rate is one technique to enhance cooling intensity. A cooling water system is widely utilized in IC engines to maintain a steady thermal condition throughout a wide range of load and speed. A circulating pump forces water through the jacket of the cylinder block and the cylinder head in a closed water circulation system with a radiator (Qasemian, & Keshavarz, 2016). The radiator receives the hot water from the engine. Water runs through tubes with fins on the outside. The engine drives a fan that pulls air over the finned tubes, lowering the water temperature passing through them. The circulating water pump receives the cooled water from the radiator (Hidayat, Setiawan, Arif, Afnison, 2020).

A radiator is the essential component of an engine's cooling system. It comprises three fundamental components: an inlet tank, an outflow tank, and a core. In most cases, the engine cooling system uses two operating fluids. They are air and coolant, respectively. The primary function of the air is to remove heat from the hot coolant and ensure that it circulates in a cold state throughout the engine block (Yadav and Singh, 2015). The air will flow freely over the radiator, reducing the coolant temperature from 95°C to 92°C (Dhiraviam, Prabhu, Suresh, & Prabhu, 2015). Because of their low thermal conductivities, traditional heat transfer fluids like water are frequently constrained. Enhancing heat transfer in a diesel engine radiator can save energy, save process time, increase the thermal rating, and extend the equipment's operating life. With pure water coolant in the engine cooling system, the exhaust temperature reached 585 K (311.85°C), and the cooling water temperatures (in-out) on the radiator reached between 336 and 371,1 K (62.85 to 97.95°C) (Erkan, Tüccar, Tosun, & Zgür, 2021). Thus the volume of water in the radiator will decrease due to evaporation.

Although the traditional cooling system has shown to be adequate for many decades, there is still an opportunity for improvement in terms of efficiency, fuel consumption, and other significant losses. Better temperature control and efficient engine operation (Shenoi, Sivan, Vamsi Krishna, Lakshmikanth, & Ganesh, 2018). The effect of geometrical adjustments on the liner's surface and the improvement in heat transfer rate over the initial model. Because of the turbulence caused by the increased surface area, heat exchanges between the liner and the coolant jacket have improved. As a result of the changes, the heat transfer coefficient increased by 18%, resulting in a higher heat transfer rate (Shenoi, et al., 2018). When the temperature rise of the coolant from the intake to the outlet is considered, this increase in the heat transfer coefficient is optimal. The cylinder head coolant jacket has a mean velocity of 0.85m/s (Qasemian, & Keshavarz, 2016). The area around the exhaust is one of the most hazardous zones because of the high exhaust gas temperatures and the thin bridge between the two exhaust valve seats. However, the flow velocity of the valve bridge over the exhaust channel is slightly slower, at roughly 0.6 m/s, and has to be enhanced. In comparison, the mean velocity of the coolant jacket in the cylinder block is 0.72 m/s. Different coolant

flow rates and velocity at similar cylinder positions may cause certain regions to be overcooled while others are undercooled (Qasemian, & Keshavarz, 2016).

A multiblade axial fan is part of the cooling system of the Yanmar TS190R diesel engine. The radiator and the sub-tank are integrated, which removes the need for time-consuming cooling water addition and improves cooling efficiency. A hopper cooling system consists of a hopper core and a baffle board. A thermo-siphon cooling system is constructed and connected to the engine via tubing when the hopper cooling system is used for an extended period. The cooling water is then circulated by convection. The cooling water is chilled at higher temperatures as it spreads to and from the sub-tank, eliminating the need for water resupply. The disadvantage of the thermo-siphon system is that it requires a big sub-tank to circulate enough water (7–10 times the hopper volume). The purpose of this research is to develop an alternative cooling system for a diesel engine used as an irrigation water pump driver that can offer enough water as a cooling medium without requiring the addition of a water supply tank.

Methodology

The cooling system research of the elevated water temperature was carried out on a Yanmar TS190R (1200 cc), 19 HP maximum power at 2200 rpm, water-cooled, one cylinder, 4-cycle diesel engine. The pump-driven Ebara 150 SQPB pump has a 15 kW maximum power at 2000 RPM, a 21.5 m head, and a 2 m³/min capacity. K-type thermocouples of 0.3 mm wire diameter, 1 mm probe diameter, and 20 ms response time were used to measure the coolant inlet and outlet temperatures. Three thermocouples measure the water inlet and outlet temperatures in the radiator, and the other three measure the water outlet temperature from the engine. A thermogun is also used to measure the temperature at several predetermined spots (Figure 1) to assist the representation of temperature distribution data. The studies were conducted for the engine speed 500, 1000, 1500, 2000 rpm without circulation (initial) and with modified water cooling circulation. The flow rate of cooling water to the radiator depends on the pump's engine speed. The radiator's temperature was measured at a specified moment after the diesel engine had run for 10 hours (when the radiator water started to decrease) and then compared to the temperature after the radiator was adjusted by circulating water from the diesel engine's pump. Figure 2(a) shows a configuration of a diesel engine and the pump it operates, with a circulation pipe running from the pump to the diesel engine's radiator. The circulation pipe nozzles (inlet-outlet) are located as shown in Figure 2(b).

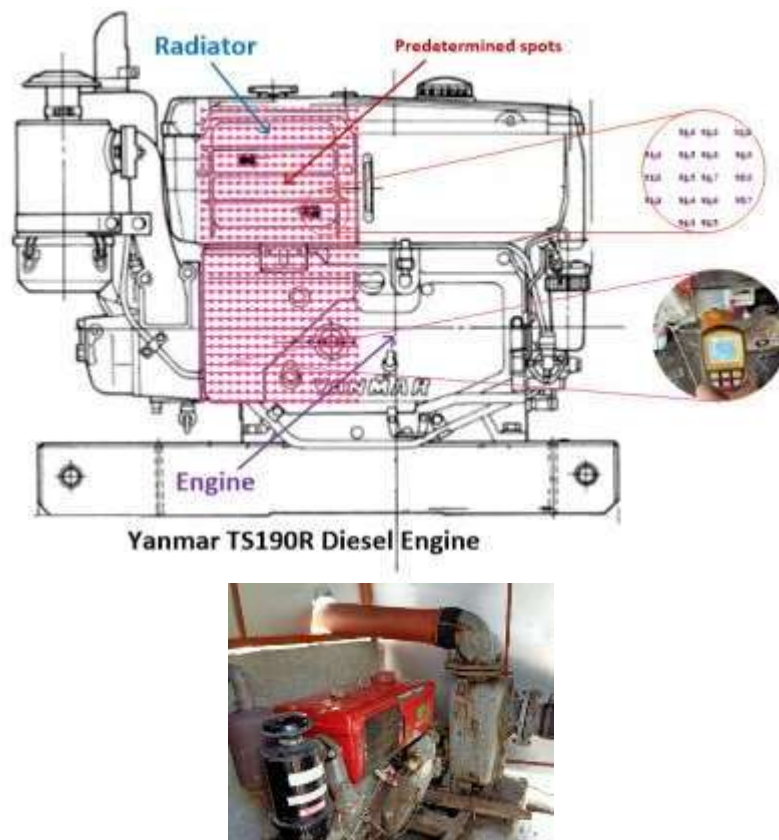


Figure 1. Predetermined spots on radiator and combustion chamber.

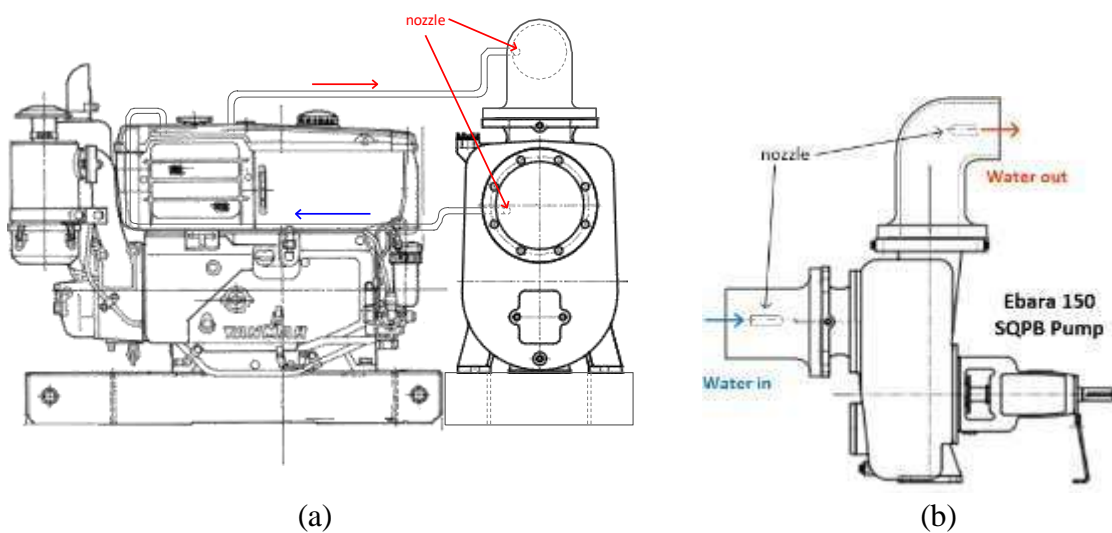


Figure 2. Configuration diesel engine and pump.

Result and Discussion

The temperature at the radiator (indicated by coolant outlet temperature) was measured for ten hours and found to range from 90.6 to 96.8°C (depending on engine speed), indicating a significant reduction in water volume. The variation of temperature coolant outlet versus the engine speed at initial and modified circulating water is shown in Figure 3. The figure shows that the engine speed increases the cooling temperature due to the increased engine temperature (combustion chamber) for the initial model. Figure 3 also indicates a reduction in coolant outlet temperature as engine speed increases due to the pump discharge increasing (flowrate) in conjunction with engine speed, supplying more water to the radiator (modified cooling system).

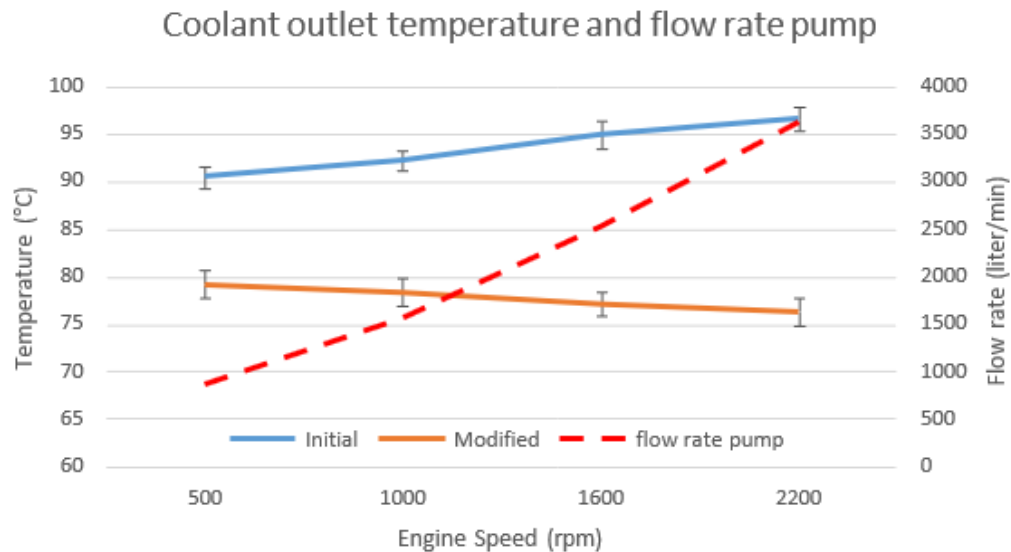


Figure 3. Coolant outlet temperatures initial and modified cooling system and flowrate pump.

Circulating water to the radiator affects the speed of coolant distribution (120 l/min) in the cavities around the engine block and lowers the temperature (Qasemian, & Keshavarz, 2016). The rate of water flowing through the inlet nozzle at the pump (from 44 l/min (500 rpm) to 180 l/min (2200 rpm)) influences coolant distribution, which is controlled indirectly in this study by engine speed. As indicated in Figure 4 (b), the radiator and engine temperatures gradation from low (inlet) to high (outlet) differs dramatically from Figure 4 (a).

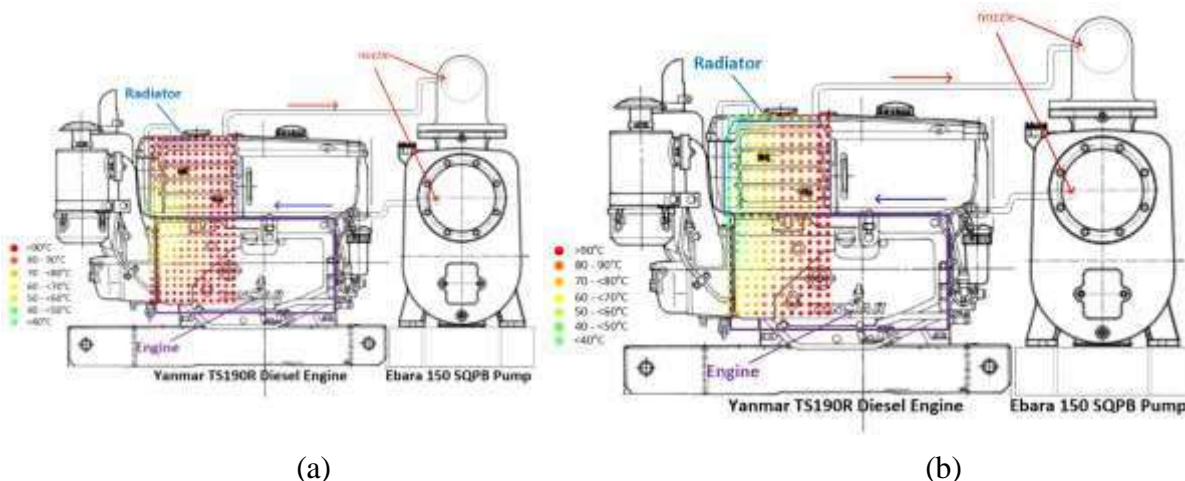


Figure 4. Engine and radiator temperatures at (a) initial and (b) modified cooling system.

As shown in Figure 4(b), the temperature distribution on the radiator and engine shows a decrease in temperature at the bottom of the radiator and the top of the engine, ranging from 40 to 70°C. This result is in line with the research conducted by Said *et al.* (2019), which reduces the temperature by using nanofluids coolant to 70°C. This redesigned cooling system still has a shortcoming, particularly the regulation of water entering the radiator because the pump spin increases as the engine speed increases. An excessively high rate (180 l/min at 2200 rpm) of water entering the radiator has the potential to harm the radiator's fins (in contrast to the type of hopper that does not have fins). It is essential to install a nozzle opening regulator that is controlled by the radiator's temperature.

However, the use of circulating water from the pump (with a predetermined inlet and output water nozzle) has been successful in lowering the radiator temperature, allowing the diesel engine-pump system to operate for several days (more than ten days non-stop – based on application in the field). It has minimized labor costs by eliminating the need to add water to the radiator every three hours.

Conclusions

A modified cooling system that combines a pump as a cooling water supply driven by an internal combustion engine can reduce the average radiator temperature from 96 to 76°C. Lowering of the radiator temperature, allowing the diesel engine-pump system to operate for several days (more than ten days non-stop) without being supervised by workers.

The nozzle opening regulator should be controlled automatically. It is better to use an automatic control in the cooling systems of internal combustion engines to improve the thermal management system's operation.

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