Studying The Effect Of Drag Reducing Agents (DRA) In The Cooling Pump Performance Used In Marine Diesel Engine.

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Abstract

Marine diesel engines are used to produce the mechanical energy to drive the propeller of ships. The energy is produced from air – fuel burning inside the cylinder. The air temperature increases during the compression stroke above the self-ignition temperature of the diesel fuel. Then, the fuel is injected and burn inside the cylinder during power stroke. Due to high combustion temperature in the cylinder, primary coolant must be flowed over the cylinder jacket to cool the cylinder. Fresh water is considered the primary coolant. The primary coolant inlet temperature is around 60°C while the outlet temperature is around 85°C. So, a centrifugal pump is used to circulate a certain quantity of sea water "secondary coolant" to cool the primary coolant to a proper inlet temperature. One of the most common problems in sea water usage is the corrosion and fouling scales that contaminate the suction and discharge pipes of the circulating pump. Drag reducing agent is used to coat the inner surface of the pipe to decrease the fouling, contamination scales, reduce the primary losses against the circulating pump, decrease consumed power, and increase pump efficiency. Small dosing pump is used to inject the drag reducing agent with different concentration in part per million. The pump flow rate, developed head, consumed power, and primary coolant temperature after heat exchanger were measured and compared with free DRA case. It was concluded that 15 ppm of drag reducing agent is the most proper concentration in order to decrease the pump power by 18.4%, decreased the friction head by 18.2%, and keep the same primary coolant temperature at the exit port of the heat exchanger.

Keywords: *Marine diesel cooling, drag reducing agent, centrifugal pump, pump performance, pipe roughness, heat exchanger fouling*
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1. Introduction

Diesel engine is an internal combustion engine that used to generate mechanical work represented in rotating motion from the chemical energy. The chemical energy comes from the air compression inside the cylinder which causes increasing in its temperature above the self-ignition temperature (~540 ^{o}C) of the diesel fuel. Power freight trucks, large tractors, and marine vessels are the most common applications of the diesel engine.

The diesel engines are classified into two stroke and four stroke engines. The diesel engine induces the air into the cylinder during the intake stroke while the fuel is injected in the power stroke as shown in (figure 1).

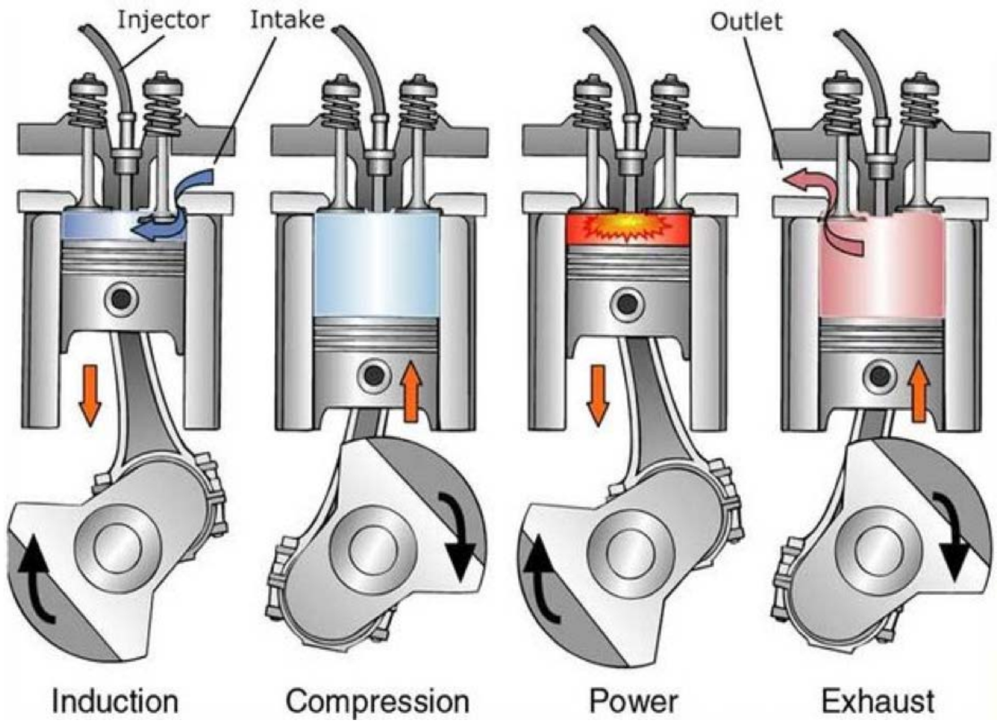

Fig. 1. Diesel engine stroking

Marine diesel engines are used for electrical power generation in ships in addition to turning the propeller that is responsible for moving the ship. Both of two or four stroke diesel engines are used as marine engine. The four stroke diesel engine is used for power generation while the two stroke is used for turning the propeller.

Primary coolant is used to cool the diesel engine. The usual primary coolant used is fresh water due to its high specific heat. Sea water cannot be used as a primary coolant because it is corrosive fluid. Freshwater is used as the primary coolant to cool machinery directly, whereas seawater is used to cool freshwater passing through a heat exchanger as shown in (figure 2).

A pump is used to circulate the primary coolant cool the cylinder jackets, heads and turbo-blowers in closed loop. The cylinder jacket cooling water after leaving the engine passes to a sea-water-heat exchanger and then into the jacket-water circulating pump again.

Another centrifugal pump is used to pump the seawater through the heat exchanger with adequate quantity to cool the primary coolant to its proper inlet temperature. The original cycle is represented in schematic diagram as shown in (figure 3).

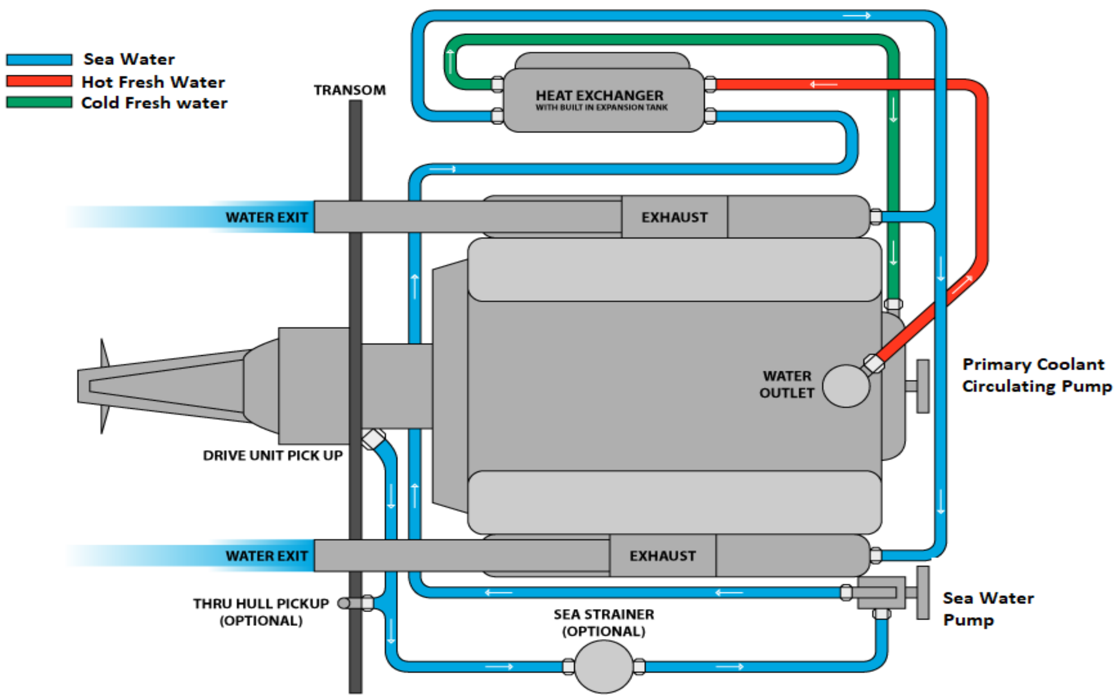

Fig. 2. Cooling Cycle for Diesel engine

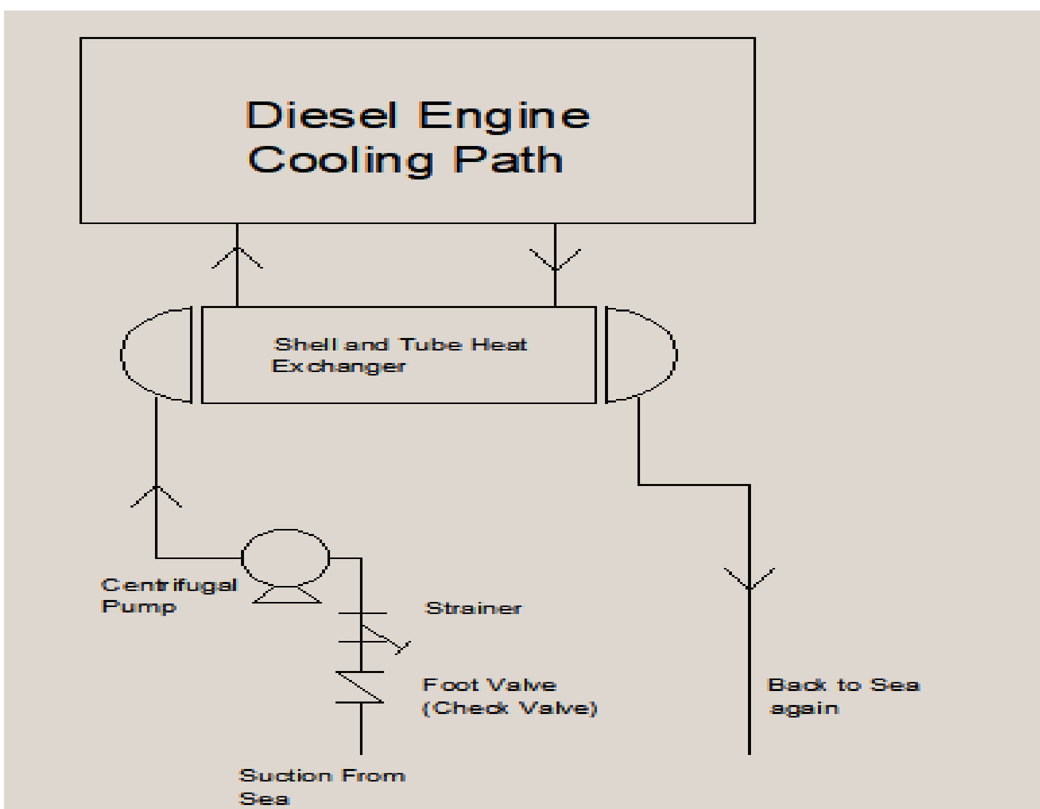

Fig. 3. Schematic drawing of Secondary Cooling Cycle

Sea water is one of the most common corrosive liquids that have several negative effect of the cooling cycle as a secondary coolant of marine diesel engine:

- High contamination scales in the suction and discharge pipes of centrifugal pump
- Cause pump parts corrosion.
- High fouling effect in the heat exchanger

For long trip of the marine diesel engine; more and more scales will be deposited on the inner surface of the suction and discharge lines of the sea water pump. Hence, the developed head by the pump will be increased to overcome the new resistance and the produced flow rate will be decreased. Consequently, the engine coolant temperature will be increased gradually to alarm set point.

Drag reducing agent is one of the most recent techniques that used to decrease the scales adhesion in the suction and discharge pipes. This material is made out of high molecular weight polymers that decrease turbulence in the pipes as shown in (figure 4). This decreases the pumping power, increases the flow and decreases the losses head.

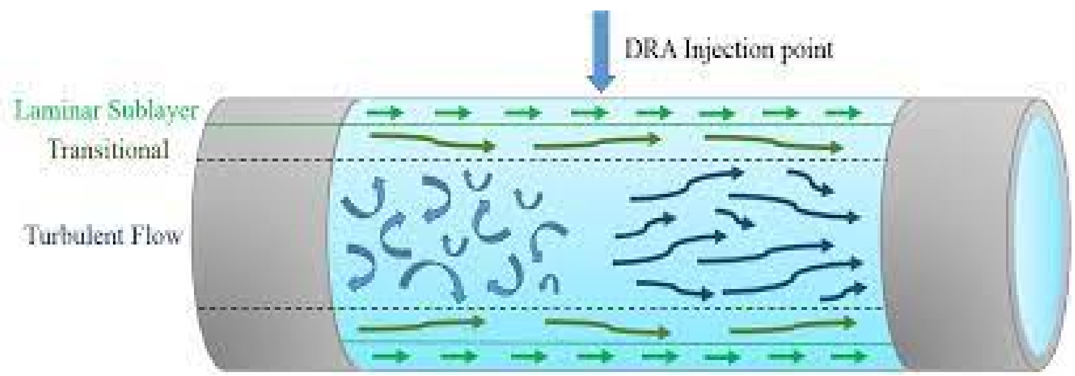

Fig. 4. DRA effect in flow turbulence reducing

This study deals with using drag reducing agent in the injection port of the secondary coolant to increase the pump reliability, decrease pumping power, increase cooling efficiency, increase pump life time, and performance

2. Material and Methods

2.1 Fabricated Test Rig

Now, drag reducing agent will be added to the sea water discharge line toward the heat exchanger. The experiments will be carried out for diesel engine "Caterpillar model no. 3406C". The DRA will be injected by an injection (dosing) diaphragm pump from the injection port. The modified cooling cycle is as shown in (figure 5).

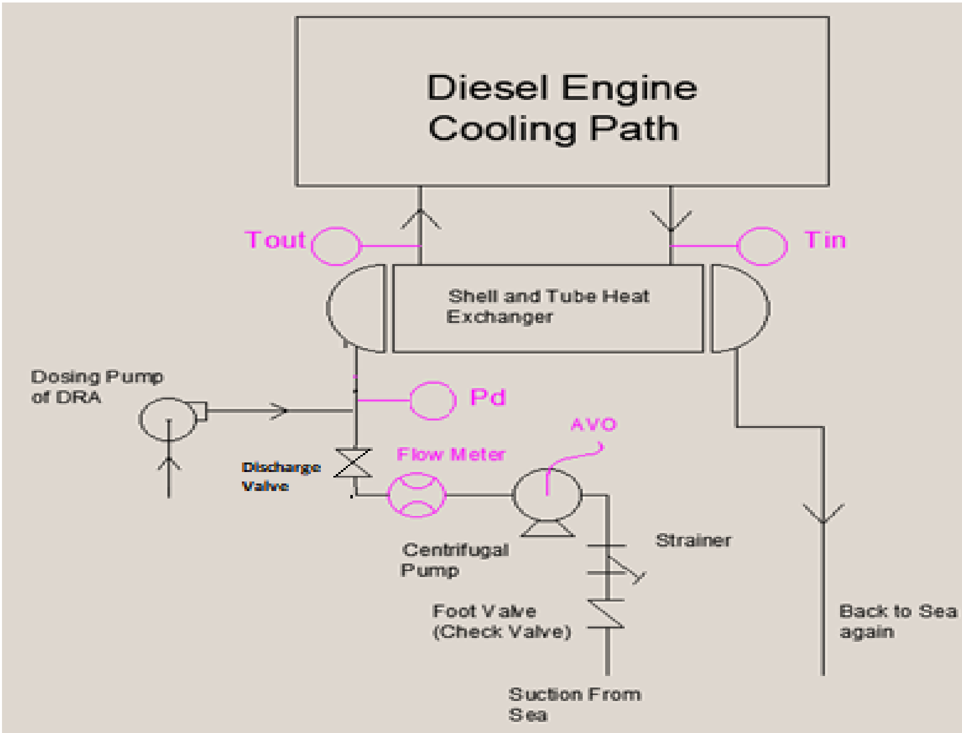

Fig. 5. DRA Dosing pump and Instruments Used

2.2 Pump Specifications and Instrument Used

Circulating pump was installed to circulate the sea water toward the shell and tube heat exchanger "tube side" and back again to the sea. The pump specifications are shown in table 1:

Table 1. Pump Specifications

Parameter	Value / Description	Unit
Pump Type	Centrifugal	
Impeller Type	Closed Impeller	
Casing Type	Volute - vertically split	
Impeller Material	Treated Cu alloy	
Casing Material	Cast Iron	
Flow rate	0 – 10	m^3/hr
Head	0 – 25	m
Rated power	0.75	Kw
Fluid Density	1000 – 1040	Kg/m^3
Pump Speed	1500 – 3000 VFD	RPM

The pump performance was measured by measuring the following parameters:

- Pressure indicators are used at the discharge pipe to measure the developed head by the pump.
- Vortex flow meter is used to measure the pump flow rate.
- AVO meter is connected series on one phase of the motor cable to measure the actual consumed current.

Moreover, temperatures indicators are installed on the inlet and outlet of primary coolant of heat exchanger to indicate the effect of DRA on the cooling capacity. All the instruments are indicated on the schematic drawing as shown in (figure 5).

2.3. DRA description and Test Methodology

Polyisobutylene is a polymer type that used as drag reducing agent in the range of 5-35 ppm (part per million) in the test section. DRA concentration will be controlled by changing the injection pump stroke. As increasing the stroke length of diaphragm plunger, the DRA quantity increases and vice versa.

The DRA concentration will be varied at the same sea water pump flow rate. Comparison will be applied for each DRA concentration to determine the effect of the DRA in the following parameters:

- Pump power
- Developed head
- Primary coolant temperature

Hence, comparison will be applied to determine the most proper DRA concentration in the secondary coolant which enhance the pump performance and keep the engine cooling cycle efficiency.

3 Results and Discussion

To study the DRA effect on the pump performance the following procedures were followed:

- DRA was injected using the injection pump with a certain flow rate.
- The sea water pump flow rate was kept constant during DRA injection. To keep the same flow rate at different DRA injection, the pump speed was decreasing due to decreasing the discharge pipe loss head.
- Measure the developed head, power, and primary coolant exit temperature at the same flow rate and different DRA concentration.
- All measured data were recorded and compared as below

3.1 Pump RPM changing to keep the flow rate

As increasing the DRA concentration in the discharge line, the friction loss was decreased against the pump and the flow rate was increased according to H-Q curve of the centrifugal pump. So, the pump RPM was decreased to keep the same flow rate "7.5 m^3/hr" as shown in (figure 6).
On (figure 6), point (1) represents the original operating point without using drag reducing agent. While point (2) represents the new operating point after using DRA and decreasing the head loss.
Each DRA concentration deal with new pump rotational speed as shown in (figure 7).

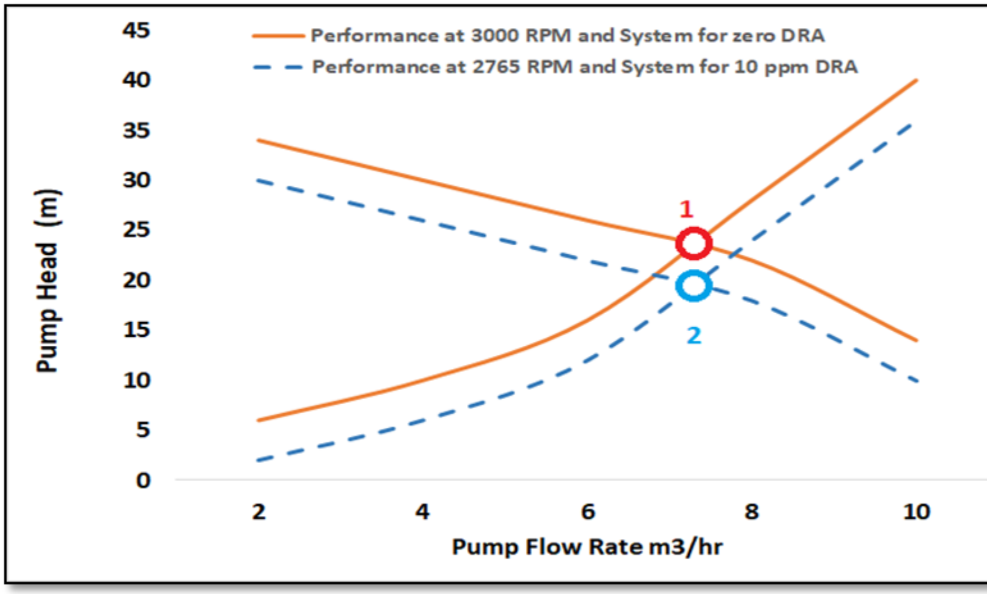

Fig. 6. New operating points at different Pump RPM

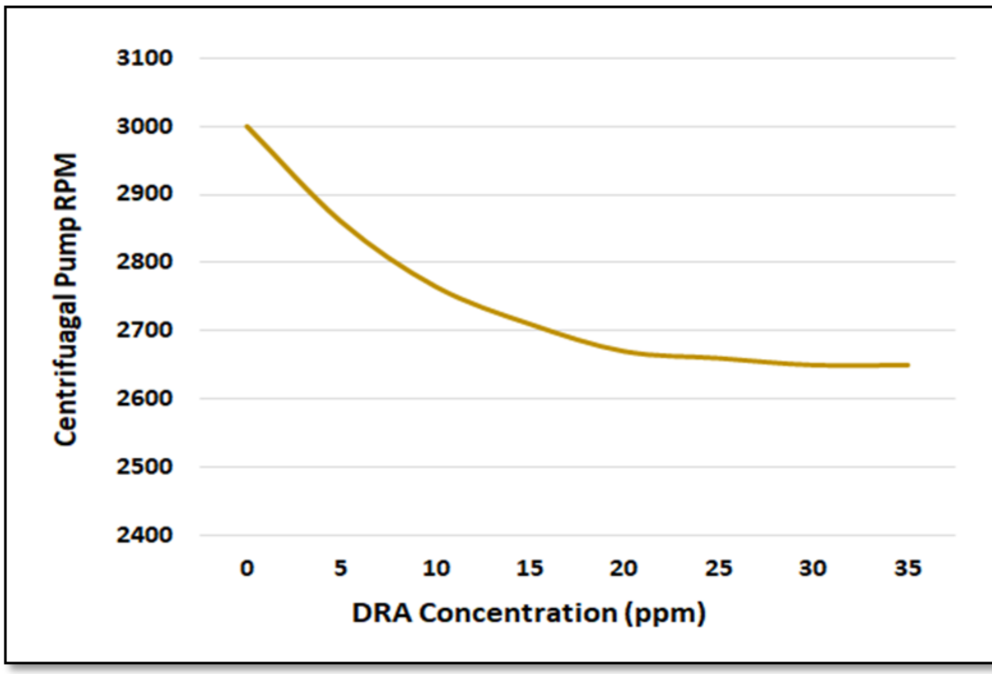

Fig. 7. Pump changing RPM with DRA concentration

3.2. Developed head with DRA concentration

From (figure 8), it is shown that the pump developed head was decreased with increasing the DRA concentration up to 15 ppm. While from 15 to 35 ppm; there is no significant effect of DRA existence in the pipe. At 15ppm DRA, the head against the pump was decreased by 18.2% compared with free DRA.

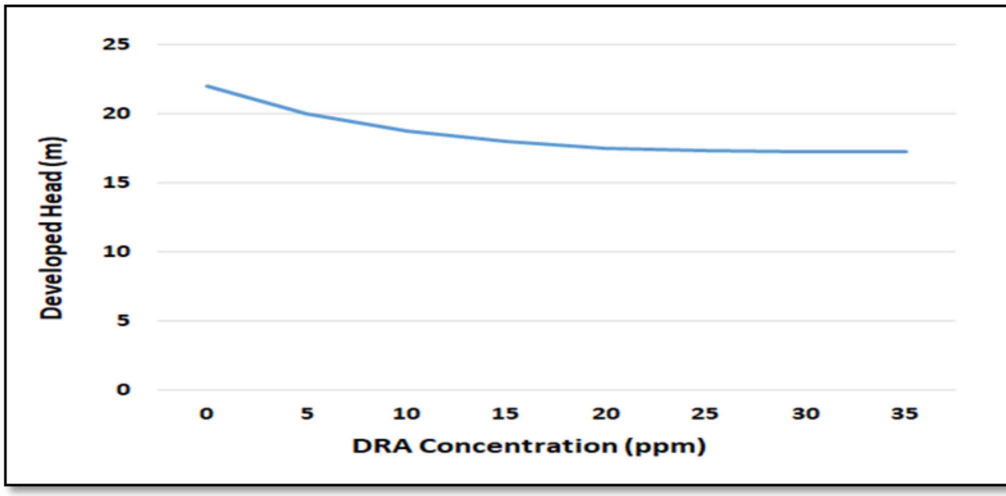

Fig. 8. Developed head changing with DRA concentration

3.3. Consumed power with DRA concentration

From (figure 9), it is shown that the pump consumed power was decreased with increasing the DRA concentration up to 15 ppm. While from 15 to 35 ppm; there is no significant effect of DRA existence in the pipe. At 15ppm DRA, the pump consumed power was decreased by 18.4% compared with free DRA.

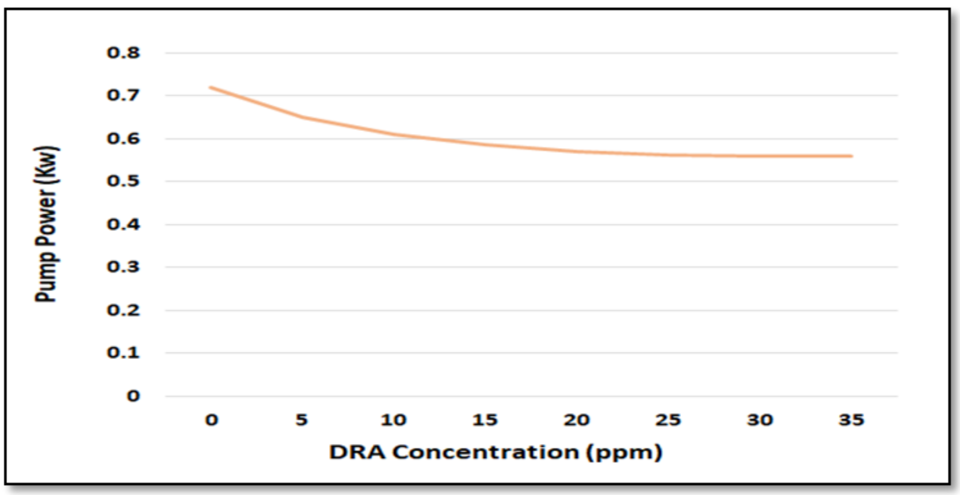

Fig. 9. Developed head changing with DRA concentration

3.4. Primary coolant temperature with DRA concentration

From (figure 10), it is shown that the primary coolant temperature that exit from the shell and tube heat exchanger was increased with increasing the DRA concentration. This is back to the existence of DRA polymers in the heat exchanger which have a low heat transfer coefficient. This is the main cause of decreasing the heat transfer in the heat exchanger and raises the exit temperature with increasing the DRA concentration.

Hence, DRA cannot be used above 15 ppm due to its negative effect on the heat exchanger.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 5, May 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

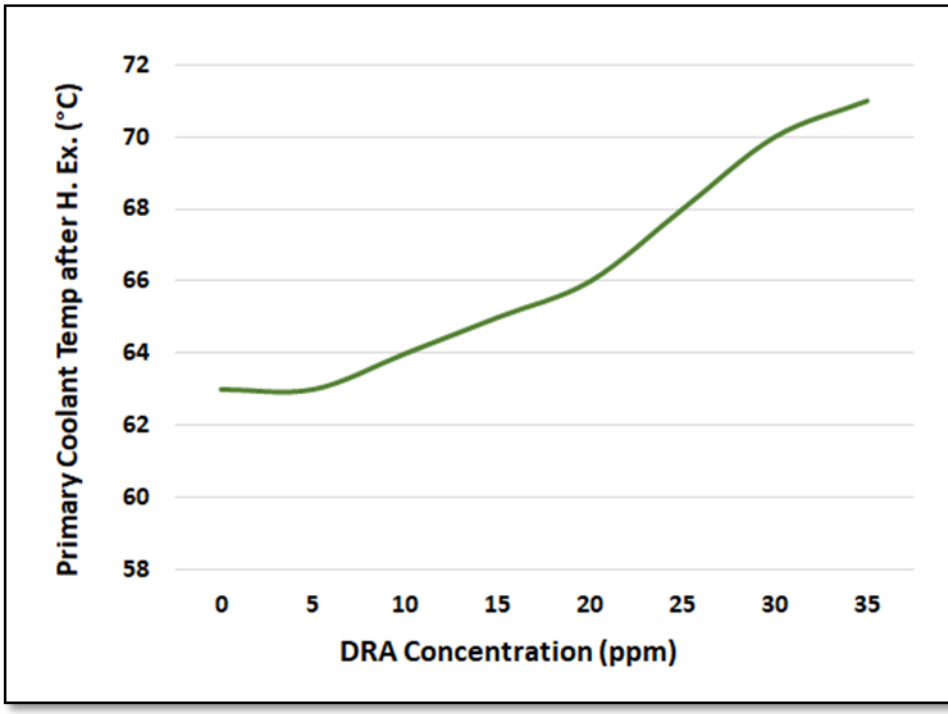

Fig. 10. Primary coolant temperature exit from heat exchanger changing with DRA concentration

From before, drag reducing agent with 15 ppm is very useful in pump performance enhancement of marine diesel engine model no. 3406C. The enhancement represented in 18.2% decreasing in head, 18.4% decreasing in power, 9.6% decreasing in pump RPM, and keep the heat exchanger cooling efficiency as shown in (figure 11). Decreasing the pump rotational speed increases pump reliability and lifetime.

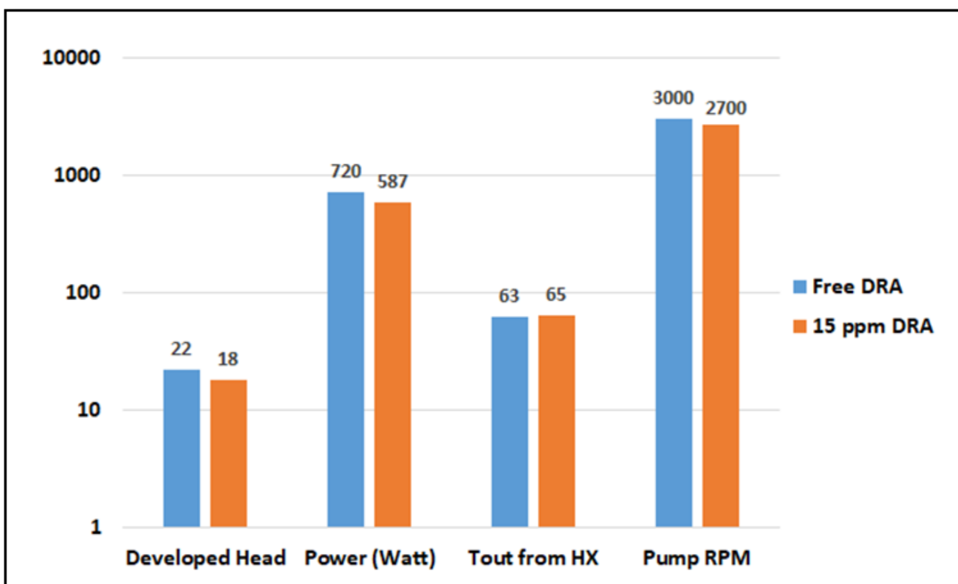

Fig. 11. Comparison between all parameters in case of free and 15ppm of DRA

4. Conclusion

It was concluded that the most proper DRA concentration is 15 ppm used in diesel engine "Caterpillar model no. 3406C" to increase the pump performance according to the following:

- The pump RPM was decreased by 9.6%
- The pump developed head was decreased by 18.2%
- The consumed power was decreased by the 18.4%

All these parameters will increase the pump reliability and lifetime. Moreover, it will decrease the fouling and contaminated scales deposition probability.

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