FAMU/FSU COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

TEAM 3 | MARINE KEEL COOLER OPTIMIZATION TOOL

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Needs Assessment

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Abstract

Cummins Marine is in need of a better tool which would enable the Marine Application Engineers to ensure proper validation of the marine keel cooler. The current tool was developed in the early 1980's and is limited to only steel keel coolers and only provides a pass/fail output to the user. The team is then faced with the creation of a new tool which will not only test the pass/fail cooling capability of the keel cooler but the tool will also be able to calculate box channel, half round and full pipe sections in steel or aluminum. It will evaluate an existing keel cooler system and be able to recommend other sizes which would optimize the cooling per vessel/engine installation. Such tool will allow the Marine Application Engineer to validate the keel cooler not only in extreme conditions but in different climates as well since most commercial vessels will navigate across international waters.

To ensure tool accuracy, research is currently being conducted to obtain adequate knowledge with regards to keel cooled systems and the design parameters needed to keep in mind. Once confidence of knowledge of the system is achieved the group will move towards writing the program and constructing a sea channel to validate the tool. After proper testing of the tool with the sea channel is completed, the group will be awaiting the schedule of a docked keel cooled vessel to conduct the final validation test.

1. Introduction

Modern ships and boats rely upon high-powered propulsion systems in order to successfully navigate through their respective environments. The delivered power of engines for typical commercial marine vessels ranges between 230-2700 hp (169-2013 kW)[1]. In order for these vessels to function properly, heat must be dissipated effectively in order to achieve the optimal efficiency for sailing conditions.

There are two main types of cooling systems for marine engines; the first is known as a raw water system and the second is known as the freshwater (closed) cooling system. In a raw water system, surrounding water is drawn from the outside of the ship and is circulated through the engine block and then expelled from the exhaust. This is hazardous to the system in both salt- and fresh-water application due to the corrosiveness of salt on the water pump impellers and the risk of foreign contaminants which could lead the system to foul. The engine components risk early failure and may lead to an engine overhaul before the vessel operator’s expected to.

The second type of cooling system is known as a closed cooling system. These systems do not employ water as a direct cycling fluid rather, rather piping is used to separate the coolant and the surrounding medium. Some systems function similar to the radiator in automobiles where coolant is pumped through one side of a heat exchanger and raw water is pumped through another in order to dissipate heat. Another type of closed cooling system removes the need for a heat exchanger by employing an external set of pipes which protrude from the bottom of the vessel to exchange heat directly with the surrounding water. Keel coolers operate by taking advantage of the surrounding water as an endless heat sink for a vessel’s heat transfer fluid. Due to the risk of

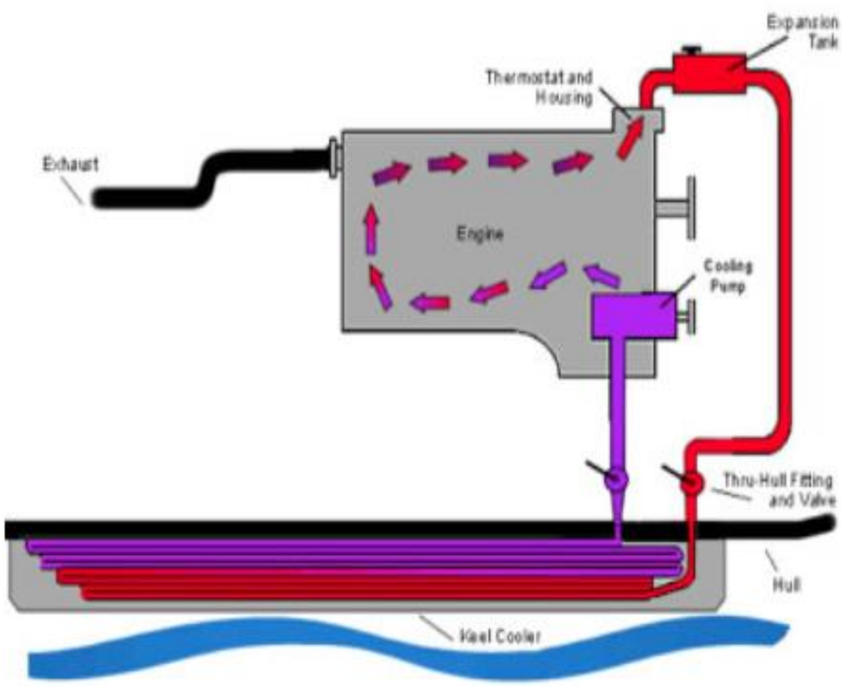

Figure 1: Simple diagram of a typical keel cooler system

fouling from various contaminants contained in the water medium, these coolers typically do not run ocean water directly through the power cycle, but rather exchange heat via convection through external tubing between the engine coolant and the surrounding medium. This process is illustrated in *Figure 1*, explaining just how this process takes place. A pump draws coolant from the thermostat and sends it through and expansion valve, which sends coolant into the keel cooler at the bottom of the vessel. The heated fluid moves through a series of highly conductive pipes which remove the heat via convection with the heat sink. The cod coolant is finally pumped back into the engine via a cooling pump. This process eliminates the need for a heat exchanger, and other components vital for closed cooling systems.

Cummins Marine is one of the different specialized markets of Cummins Inc. which specializes in the “Marinization” of engines and the design of new components to allow the current Cummins engine line survive in marine applications. Customers often times ask the Application Engineers to ensure the engine selected will work properly with the vessel it is going to be installed in. This includes the sanity check of ensuring that the keel cooler will provide the correct cooling for the engine. These factors are important to consider since the vessel must pass an Installation Quality Assurance Review in order to meet warranty. In order to meet customer’s requirements, Cummins Marine makes use of a web-based optimization tool which allows the Application Engineers to predict whether or not a particular keel cooler design will successfully meet the vessels’ requirements. The program operates on user-inputted parameters such as keel size, engine power, and temperature range. These values then predict whether the cooler will pass or fail based on extreme operating conditions. Although the tool has been in service for a long time, it has several limitations. The tool only predicts keel cooler systems which are made from steel and does not offer an option to optimize the design. The program lacks feedback and is outdated as a user interface. The goal of the Keel Cooler Optimization Tool Senior Design Project is to create a tool that adds feedback alongside the pass-fail conditions. The program will suggest improvements in the design of the keel cooler based on a thermodynamic analysis. Such improvements can range from material selection, pipe configuration as well as an optimal temperature range of operating conditions. The successful implementation of this tool will result in an increase in company profit and customer satisfaction. With a program which successfully predicts improvements in keel cooler design, boat builders will be able to build the keel coolers with confidence knowing it will be more efficient and optimize the performance of their engine and work in different nautical waters.

To achieve this goal, extensive background research must be conducted on the variables important to the design of a keel cooler. Once the group has a full understanding of the analysis process, the method for creating this tool must be decided upon; this includes the programming language, program structure, user interface and a means for testing the accuracy of the program. The group must show sufficient understanding of the thermal design process and develop a product that is user-friendly, intuitive and provides meaningful feedback to the end user.

2. Project Definition

2.1 Background Research

A current model of this program exists and is used by Cummins. The program is used to evaluate the current and future keel coolers which will be installed in the vessels[3]. The current system of evaluating the keel coolers is done by looking at the engine which will be installed on the ship, the total hear generated by the engine, design speed of the vessel, maximum water temperature the vessel will face and currently only evaluates keel coolers made out of steel. This current program does not provide the user with suggestions on how to design a more efficient keel cooler and has been in commission since the early 1980’s and is in dire need for an update.

Cummins Keel Cooler program was only developed to test keel coolers after production and would only determine as pass or fail given worst case scenarios. The new program will not only determine a pass of fail, it will suggest an optimal keel cooler size, design and material. The program underdevelopment is meant to be easily transferable and shared between users and eventually be converted to a web based program. The new program will most likely ask for the same input parameters as the previous program, but will be more accurate to ensure the keel coolers are properly sized and fitted for the vessels. The ease of evaluation needs to stay constant as well since the easier the program is to use, the more likely it will be utilized. The current design is web based, therefore the new design will need to be converted to a web based system once it is completed.

A keel cooler works as a radiator or heat exchanger attached to hull of the ship. One such textbook which will be referred to for future equations, charts, and tables on heat flow from a high temperature to a low temperature would be "Fundamentals of Thermal fluid Science's". For possibly making suggestions for better keel cooler designs the group would possibly need to suggest the addition of aluminum to the material selection. To do so, material properties would need to be known to allow proper suggestions. The group will possibly be referencing the materials book "Materials Science and Engineering an Introduction".

There is no opposition for this product due to it being geared towards Cummins engines to ensure that installed engines will work properly on the vessels without overheating. This program will be licensed by Cummins for its own use. The only program that would compete with this end product would be the current program the Marine Application group has been utilizing.

2.2 Needs Statement

The Senior Design Project for Group 3 for the Marine Keel Cooler Optimization Tool is sponsored by Cummins Marine. The tool currently utilized by the Marine Application Engineers is severely outdated and only returns whether or not the user inputted parameters will result in a passing or failing keel cooler design. The program does not provide any feedback to the designer or operator. This limits the overall design process and does not validate the keel cooler design on the vessel for other nautical water climates.

"The current Cummins keel cooler design tool provides no feedback on a particular design and is limited in its capability"

2.3 Goal Statement & Objectives

"Design a more versatile design tool which generates feedback and provides a more user friendly interface"

Objectives:

- Successfully predicts the heat dissipation, efficiency, as well as the optimal operation temperatures for a particular design
- Suggests useful design alterations that would increase the efficiency of the design
- Validate the keel cooler system in scenarios where the vessel is at low idle or relocated to a different body of water (different ambient water temperature)
- Must be user friendly and intuitive

2.4 Constraints

Constraints:

- Budget of $6,000
- Project completion by Spring 2016
- Must be accurate in accordance with Cummins industrial standards
- Must provide feedback to the user
- Must include a wider material selection than current tool option

2.5 Methodology

Prior to in depth design of the Keel Cooler Optimization tool is undertaken, research on the distinct parameters and design variables must be done to fully understand the keel cooler system and functions. Once this is done, the team will be able to start designing the program as well as manufacture a sea channel to test and validate the program. The team is to keep into consideration of completing the project as well as the validation sea channel by Spring 2016

After research has been conducted and a general overall knowledge has been achieved the group will decide on the programming language which will be most optimal for developing a future web-based tool. As this is underway, the group will construct a sea channel with various bends to validate the program. Once the program has been validated on the prototype sea channel, the tool will be scheduled to be tested on a current installation to validate the keel cooler of a vessel.

2.6 Schedule

The schedule puts dates to the groups proposed plans. As a standard the group will utilize Gantt Charts to ensure deliverables are met by a certain date. This year, the group requires MS Project for Gantt Charts as seen in *Figure 2*. For more information Lynda.com offers a training course as far as required. Once the key components for this project is determined, the Gantt chart will be updated to reflect the group's deliverable schedule.

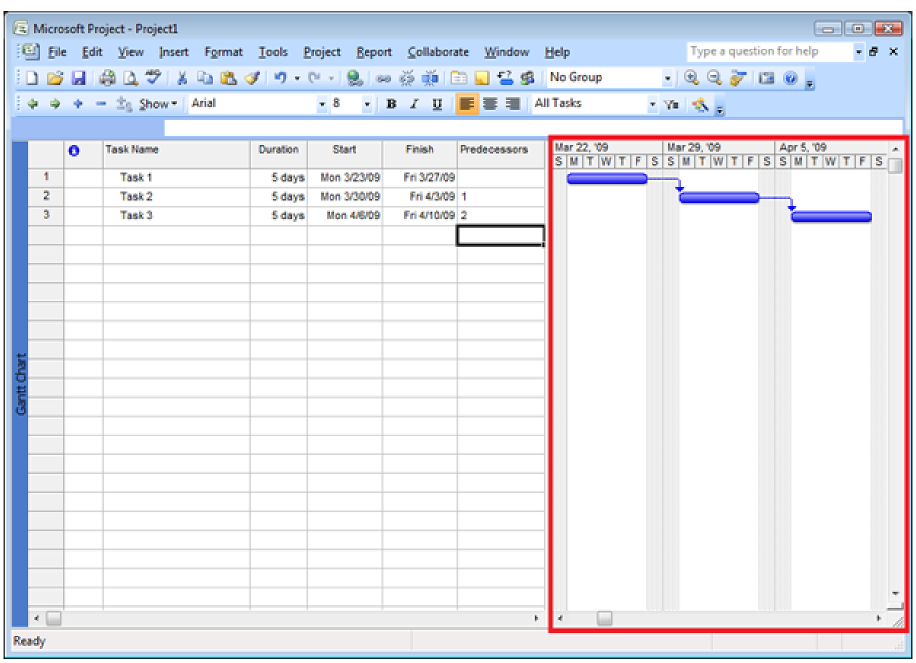

Figure 2: Example of Gantt Chart from online source

3. Conclusion

The Marine Keel Cooler Optimization tool hopes to meet the needs of Cummins Marine in providing an up to date tool that is user friendly and reliable. In order to meet these requirements the group is faced with familiarization of keel cooled engines and how systems operate. The current tool Cummins Marine utilizes was commissioned in the early 1980's and only outputs a pass/fail response for the user. Cummins Marine is in need for an updated tool which would allow recommendations on improving the design of the keel cooler, validating the keel cooler not only in extreme conditions but as well as in normal operating conditions and in conditions where the vessel would be at wide open throttle at 0 knots (in cases such as a tug boat pushing a boat). The group will achieve such program by researching more information about keel cooled systems to serve as a foundation for designing the tool. The group will also implement the knowledge from thermodynamics and thermal fluids classes to ensure the tool is not only efficient but accurate. As the program is written, the group will work on a validation sea channel to test the accuracy of the tool. Once the tool seems to be operating as it should, it is the goal for the team to test the tool on a current vessel installation.

References

1. Shaw, Courtney. "Cummins Marine Propulsion." *Cummins Marine*. Web. 23 Sept. 2015. <http://marine.cummins.com/>.
2. "Marine Keel Coolers for Heat Dissipation." *Marine Keel Coolers for Heat Dissipation*. Web. 23 Sept. 2015.
3. *Cummins Keel Cooler Sizing Tool*. Computer software. Vers. 2.0. Cummins, n.d. Private Web. 23 Sept. 2015.