FAMU/FSU College of Engineering
Department of Mechanical Engineering

Operations Manual

Marine Keel Cooler Optimization Tool

EML 4551C Senior Design

Team 3

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Abstract

This report defines the operations manual for the Marine Keel Cooler Optimization Tool. 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 has been conducted to obtain adequate knowledge with regards to keel cooled systems and the design parameters needed to keep in mind. The following report includes an overview of the schedule being followed in order to complete the project. The overall plan, methodology and project approach decided upon by the team will ensure deliverables are met on time and an accurate product is delivered to the sponsor.

Acknowledgements

The team would like to acknowledge our advisor, Dr. Van Sciver for his insight and direction. The team has been given the opportunity to meet with Dr. Van Sciver weekly in order to talk about the science involved as well as the methodology the team should follow when approaching this project. He has provided the insight needed in order to ensure success in the project ventures. The team would also like to acknowledge the Senior Design instructor, Dr. Gupta who also has met with the team weekly to discuss schedule and make sure the team covers the project scope appropriately. The team would also like to extend an acknowledgement to Frank Ruggiero for the opportunity to work on a project for the Marine Application Engineering group as well for the sponsorship and technical support of this project.

1. Introduction

The Marine Keel Cooler Optimization tool will be a great development and upgrade from the current tool available to Cummins Marine. It has a bold new look, feel and functionality allowing the Application Engineer, technician or boat builder to validate the sizing of a keel cooler given a broader range of input parameters. 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.

Throughout the design process there are three underlying motivations: manufacturability, reliability, and economy. When designing a product for manufacture there is an implicit obligation to make the manufacturing process as efficient as possible. Having this foresight during the design stage will make for an easy transition to production later. Once manufactured though, how consistent will the product be and for how long? This is typically determined by the intended application and is ultimately limited by cost. This leads to the final motivation: economy. It is important to consider cost when designing a product and how these costs may limit the overall design. If there are similar products on the market, it would be beneficial to design a product at a competitive price. These concepts will help streamline all processes from concept generation all the way to post-production. Our team made every effort to include these motivations into the design of our Keel Cooler Optimization Tool.

2. *Functional Analysis*

The goal of the keel cooler optimization tool was to develop a more functional and user-friendly user interface with more feedback to replace Cummins current Keel cooler validation software. This is done by performing thermal calculations that measure heat dissipation of a proposed keel cooler design with the necessary heat dissipation of a desired engine. In order to achieve the best possible user experience and to increase the accessibility of the program, a web-based application was developed. The program can be divided into three main components, the front-end interface, the server frame-work, and the back end python code. The front-end user interface was designed using html, css, and JavaScript. The Python Web framework that was used was Django, which is free and open source and provided a pre-made template for rapid web-development. The program language used was python due to its relative ease to use, and its commonality in modern web-development.

The program by itself is structured by dividing its components into classes which carry out various functions. The manage.py class runs the server and relays information between the server and client to provide a web host. Within the program, the settings.py class establishes databases, authorizes users, hosts, and adds templates. The urls.py class handles url requests from the webserver. This class tells the program when an address is entered and sends it to the views.py class. The views.py class accepts requests and processes the user inputs. When a url request is made, the views.py class sends the user to their requested page.

The thermal analysis that evaluates the user's data takes place within the views.py class. The class is composed of a division of several sub functions that perform calculations or obtain values based upon the user's inputs on the html page. The functions can be categorized as data-collecting and data-processing. Data-collecting functions are conditionally accessed based upon the user's inputs on the html page. The html page contains several different types of selection options which translate to calculation parameters in various ways. The engine selection, shown in figure 1, uses a bubble selection in order to decide which parameters to use. When the user selects the QSK19 Engine, the html page sends the value 1 to the views.py class which uses an if-else statement to access the QSK19 function that fills various thermal parameters unique to that engine.

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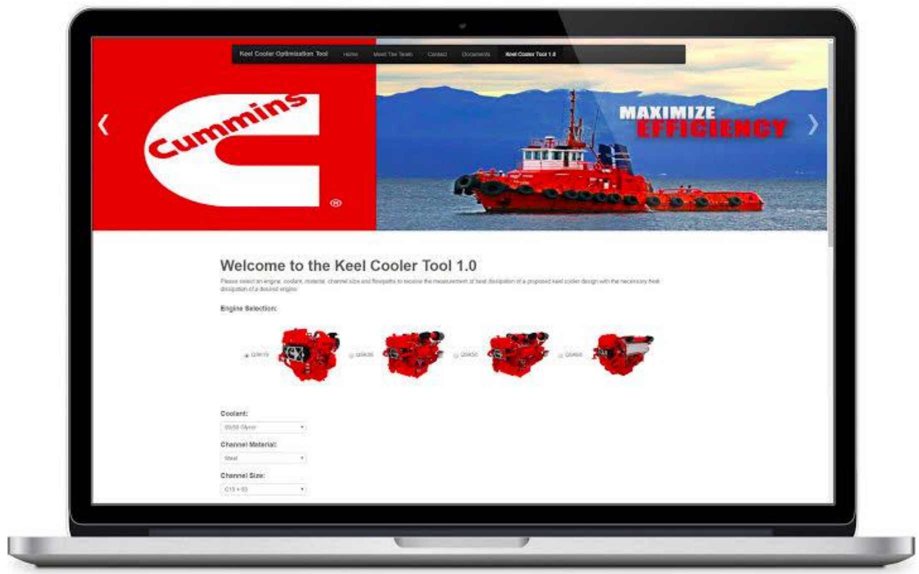

Figure 1. Engine Selection View to user

A similar type of information processing is used by the drop-down box which prompts the user to select a standard channel size. The program does not actually make calculations based on the name that is selected, rather it references the selections order in the drop-down box. For example, when the C15 x 33.9 channel size is selected, the program receives the number 3, which corresponds to the third value in the channel size drop-down box. This value is used to access the depth, area, thickness, and thermal conductivity of that channel size.

Once the user inputs their value for the engine selection, coolant type, channel size, number of flow paths, and selected length, the program takes those stored values and uses an array corresponding to length values to compute the minimal length required to dissipate the required heat for the engine. The minimal keel cooler length is displayed along with a pass or fail condition based on whether the analyzed length met the minimal required length standard.

In order to generate a result, all data fields must be inputted correctly. The user has the option of inputting their own number of flow paths but the value must be a valid integer number. Decimal values, symbols, and other non-numerical characters will return an error prompting the user to make a valid selection.

3. Project Specification

The project should cover all marine engines offered by Cummins, both current production and out of production which will/are installed in keel cooled vessels. The tool is to be used not only to validate the keel cooler system but also suggest the optimal keel cooler design to the boat builder. The tool must be able to calculate and predict how the cooling system will behave under different engine loads and water ambient temperatures. This tool will then be validated through testing on a sea channel constructed by the team and depending on boat builder availability, it will be tested on a current installation.

Program:

- Web Framework – Django
- Programming Language – Python
- Web Development Languages – html, CSS, JavaScript

Calculations:

- Engines evaluated: QSK19, QSK38, QSK50, QSK60
- Coolants Evaluated: 50/50 Glycol, Water/EDC
- Materials Evaluated: Aluminum, Steel

4. Operation Instruction

To use the keel cooler optimization tool to its full capacity, the user must have some information gathered which pertain to the vessel being worked on. The user will select whether to use the validation aspect of the program or the design aspect. If the user selects the option for keel cooler sizing validation the important parameters to have on hand are: engine model, coolant type, keel cooler channel material, channels size and the number of flow paths. In order to properly evaluate your application requirements, the user must first select which engine you will be using.

Figure 2. The first information the user will be prompted to enter.

The user will then make an engine selection by simply clicking the engine to which the user wants to use, as shown above in *Figure 2*. Once the user completes the engine selection, as shown in *Figure 3*, the user will be prompted to select which type of coolant the engine will be using from the drop-down list. (Note: Only the coolant types shown are compatible with this tool. No guarantees can be made if another coolant type is used, since only the specified coolant constants have been accounted for).

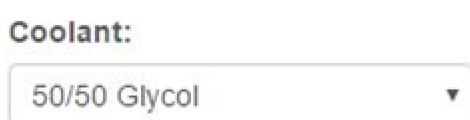

Figure 3. Example of Coolant selection

The user will then select which material the keel cooler will be made from. This is important since steel and aluminum have different thermal properties. This program allows the user to select between steel and aluminum, a new validation parameter introduced due to the voice of the customer.

Once the material for the keel cooler is selected, the channel size must be selected. The program uses the American Standard Steel and Aluminum which includes the most common used channel sizes which frequent many boatyards. This ensures accuracy in the validation calculation. Following this step, the user will enter the number of flow paths in the design of the keel cooler. (Note: The number entered must be an integer). If an integer value is not entered the tool will generate an error message in red located at the bottom of the window.

Figure 4. Channel Material, Channel Size, and Number of Flow Paths selection.

Once the user has entered all of the information, the user must click the submit button and the relevant data will be produced under the “RESULTS:” heading. Here the user will find data which evaluates the proposed keel cooler specifications and provides relevant feedback (ie. pass/fail, recommendations for meeting the cooling requirement). If the user’s selection criteria is unable to effectively cool the engine, additional suggestions will be provided. If the selection criteria is satisfactory for the intended application, the tool will display an “APPROVED” notification at the bottom of the window. (Note: only the parameters that are provided are eligible for evaluation. The use of any other configurations other than those provided by this tool cannot be guaranteed.)

5. Troubleshooting

The program has been tested stringently so that there is no need for troubleshooting the program itself. The program responds to errors in in data input by displaying an error message. If after inputting the data for a validation result, an error message will appear. Make sure that all fields are filled and that they have the correct data inputs. The lone open text box for inputting number of flow paths will only accept integer values. Other character types will generate an error message prompting the user to input a valid integer.

6. Regular Maintenance

In order to stay up to date with the latest engine catalogs, the persons in charge of website oversight should add or remove additional functions with new engine types along with their respective specifications to the views.py class as well as the keelcooler.html script. The thermal analysis will not change therefore the remainder of the code will stay valid.

Other updates to the program will have to be made in the future to ensure it continues to be relevant as Cummins develops more engine models and releases new fuel ratings. This final step is important since it will ensure continuity, reliability, and accuracy. The tool developed for Cummins will allow for such updates and will continue to serve the Application Engineers, technicians and boat builders for many years to come.

7. Conclusion

The Marine Keel Cooler Optimization tool hopes to meet the needs of Cummins Marine in providing a tool that is up to date, user-friendly, and reliable. The current tool utilized by Cummins Marine was commissioned in the early 1980’s, is limited in its ease of use, and only provides a pass/fail output for the user. Cummins Marine is in need of an updated tool which not only validates a proposed design (pass/fail), but can also provide additional design requirements and specifications that will ensure proper cooling performance in the application environment. The team is tasked with writing a program that will utilize these features and provide accurate results. The group has been (and will continue throughout the duration of the project) researching general information and implementing the knowledge from thermodynamics, fluid mechanics, and heat transfer in order to successfully achieve the project goal. In addition to writing the program, the team will build a testing apparatus that will be used to model and evaluate the differences in performance for various design configurations, i.e. number of flow paths, types of materials, orientation, etc., and can also be used to verify the accuracy of the program. The parts for the hardware side that are hardest to obtain have been ordered, such as the pump, heating tank/element, and thermocouples and the keel cooler has been assembled. Since the main script (framework) of the program has already been written, it is only a matter of ensuring the proper engineering principles are employed when fleshing out the rest of the program. This is a crucial step because if the tool does not provide correct data to the end user, the design could cause catastrophic engine failure once it is implemented on a production vessel. Once the program has been coded, it can be verified for accuracy by using both data obtained from our testing rig and with data provided by Cummins regarding successful systems that are currently in use. Following the customer requirements defined by the Sponsor the team expects the keel cooler optimization tool will surpass current expectations while meeting all of the customer needs.

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