# Design and Analysis for the Improvement of Electric Kettle Performance

M. A. Hassan, R. Daud, S. N. S. Jamaludin
Faculty of Mechanical Engineering,
Universiti Malaysia Pahang, Lebuhraya Tun Razak,
26300 Gambang, Kuantan, Pahang
Phone: +609-5492205, Fax: +609-5492244, Email: masszee@ump.edu.my

***Abstract* – *This paper presents the new design of kettle coil and the analysis of heat transfer rate in order to improve the performance of current electric kettle. The main purpose of this study was to analyze the performance of new coil design and compared it with the current design in order to examine their effects on different parameters of ecological performance such as heating performance and electricity consumption. Mainly, there are three coil designs were proposed and all designs concept is done using Solidworks software. Then, each of the coil designs will be analyzed and simulated using COSMOSFlow Works software. The analysis will be based on the coil geometry and the heat transfer rate of each design due to different design of the electric kettle coil may result in different water heat transfer rate. After all the data were gathered, the comparison between these new coil designs is done and the best design concept is selected. In order to show and prove that improvement in the current electric kettle has been achieved, the comparison between the boiling rate of the selected design coil and the current design is done. As the result, the new concept of coil design is proven to produce better heating performance with the minimum boiling rate of 600 milliliter per minute, which is more economical and about 34% of energy saving compared to current design.***

***Keywords*** – Analysis, Heat transfer, Kettle coil, 2-D design, CFD

## I. INTRODUCTION

This paper examines the design analysis of low-complexity of electrical consumer products during their daily use. In the domestic domain, these products are such as electric kettle, food processor and coffee machine. However, for the present study, the electric kettle are chosen as a model products since it is a frequently and widely used appliance and is characterized by considerable electricity consumption during operation which is up to 3 kWh.

The used of electric kettle nowadays is not limited for inside the kitchen only but also available in the office pantry, coffee bar and any other places that for people refreshment. Widely used of this electrical consumer product because of easy-to-use and time saving in boiling water for making hot tea or coffee. However, improvement in the electric kettle design still can be done in order to achieve highly quality products which consume less electricity and increased the boiling rate in the kettle [1-9]. Furthermore, the current kettle coil is easily exposed to corrosion which can cause hazardous to consumers when drinking from corroded kettle coil [2].

Therefore, to achieve the most saving electric kettle in order to reduce the consumption of both energy and resources, kettle coil is the important component to be design and analyzed. The successful design of a kettle coil requires knowledge of the heat transfer mechanisms that dominate within it, and knowledge of how these mechanisms are affected by the interaction with the fluid consumed.

This study was undertaken to investigate the change in the heat-transfer performance observed in an electric kettle when current design of kettle coil was replaced with the new coil design. Focus will be given in designing the kettle coil geometry using Solidworks software and later analyzing the kettle heating performance by using Computational Fluid Dynamics (CFD) methods. The water consumed in this study was 600 milliliters at constant power supply of 2kW.

## II. LITERATUREVIEW

Before the existence of electric kettle, all the earliest design was had the element in a separate chamber under the water, maintaining the heat beneath the water in the traditional boiling vessels. As the time travel, people begin to think that the separation of water from the element (fire or heat) made the kettle become inefficient to use and expensive to run [1].

Then, a faster boiling was achieved by placing the element in a metal tube, directly into the water chamber. Later, more improvement on the electric kettle were done such as, some manufacturers employed a cut-out or patented safety ejector mechanism which disconnected the electrical supply if tea kettles boiled dry and also provide a spare fuse inside the handle cavity. After that, the kettle caught up with the iron by appearing in a fully-automatic form. A controller jet of steam from the boiling water is used to cut the power supply via a fast-acting bimetallic strip. This invention was the last stage in development of the modern kettle until the plastic jug kettles were introduced in today’s market [2-4, 11].

### *A. Product Development Process*

In the design of electric kettle, there a number of risks and opportunities that required effective judgment over technology, market and time. Although there are many methods in order to improve the design of a product, but reverse engineering is still the best method in doing it. Through reverse engineering, new concepts can be explored and changes can be made such as thickness in geometry of components or changes in material used. Alternatively, the component of existing product can be replaced or placed in different topologies in the functional model. In addition to redesign the electric kettle, concept generation plays the important role. A functional decomposition may be used to generate form solution to each of the product functions in order to overcome problems arise when dealing with electric kettle [3, 5, 11]. Previous researches also have made several guidelines in developing a new design and redesign the existing products [3, 9]. The steps can be review in Figure 1.

Fig.1. The redesign product development process [5].

### *B. Heat Transfer Concept as Heating Element*

Based on literature research, heat will transfer when a temperature gradient exists in a stationary medium which maybe a solid or a fluid. For example, in electric appliances such as in electric kettle, heat conduction occur as the energy transfer from more energetic to less energetic particles of a substance due to interactions between the particles [6].

Previous researchers conclude that several aspects must be taking into consideration in order to improve heat conductivity in the electric kettle, there are varying the coil face area, varying tube size and varying the number of circuits. They also suggested that to enhance the heat transfer surfaces the arrangement of the tube pattern through the fin surface and the distance between each tube may vary the air turbulence and the amount of heat transfer area. This subsequently will affect the coil’s thermal performance. These enhancements will increase the thermal capacity of a coil but the drawback is they will affect the medium pressure losses through the coil during heating occurred [7, 8].

According to Cornwell et al research, the optimization of layer thickness for kettle coil starts with a single-layer tool. This layer is then split into a greater number of layers with respects to geometrical deviation parameters in repetitive steps, until the condition of allowable geometrical deviation is achieved. The limit of geometrical deviation is given for individual parts in order to indicate the different between the prescribed and actual design geometries [13].

## III. METHODOLOGY

The procedures begin with a survey on the user needs when dealing with the electric kettle. The survey was done among the regular kettle users, who are student population of Universiti Malaysia Pahang (UMP). About hundred participants took parts in this study and all the information obtained will be used in modeling the desired electric kettle.

After that, details study on the current product design was implemented and a full scale measurement on the product was done. All the required data were gathered such as types of coil used, boiling time and boiling rate in heating 600ml of water. As mentioned before, all the analysis of the current design and new design were analyzed using CFD methods and comparison of kettle coil performance will be done after the simulations are completed. The setting for power supply, amount of water boil and material used was fixed during the simulation.

Then, the concept designs for the new kettle coil are generated using the Solidworks software. Since the main focus in this study is to analyze the boiling rate produced by the kettle coil, the concept generation will be on kettle coil design only. After completed modeling all the coils, analysis will be performed on each of coil designs using CFD methods. For the material selection in modeling these coils, one specific material is chosen that is copper alloy.

It is fixed for all coil designs for the ease during simulations and comparison purposes. Furthermore, based on literature review copper alloy was the suitable material in making the kettle coil since it is corrosion resistance and last long than other steels [2, 12].

Based on the data gathered, comparison will be done in order to choose the best coil design for the new electric kettle. Lastly, the assembly modeling of the chosen design with the other parts of electric kettle was drawn for future development. The flow chart in Figure 2 shows the summary of all the procedures involved in this study.

Fig. 2. Flow chart outlining the analysis steps undertaken.

## IV. RESULTS AND DISCUSSION

### *A. Analysis of the Survey on Customer Needs*

According to the information collected through the questionnaire survey conducted among hundred participants in UMP, 93% of the responses were agreed that electric kettle is an important appliance for their daily use (refer Figure 3). This data also indicates that responses usually use electric kettle for typical uses such as making a cup of hot coffee or tea, cooking an instant noodles and other reasons. However, above of all purposes, most of the respondent frequently used electric kettle to boil water for hot drinks. These facts can be seen in the Figure 4.

In order to improve the current design of the electric kettle, several aspects of what customers will considered before they used or buy this product must be analyzed in details. Based on the survey, there are four important aspects that customer will take into considerations before buying the products, such as good ergonomics, high performance, provided with safety factors and less electricity consumed.

Fig. 3. The pie chart shows the respondent feedback on the use of electric kettle.

Fig. 4. The bar chart shows the typical used of electric kettle.

By referring to the survey done, 74% of correspondent agreed that it is a must to have safety factor in this electrical consumer product. These feedbacks are expected when most of the respondents prefer electric kettle with an automated function in kettle design such as automatic switch-off. By providing this feature, safety precautions can be increase for instance, it can prevent from short circuit. More or less, this feature also can support the user in reducing energy consumption by eliminating prospective memory failures of forgetting to switch off the appliance [4]. Besides that, 75% of users also think this product should have technical efficiency when boiling a certain amount of water. The survey results are shown in Figure 5.

Fig. 5. The four important aspects customer considered in using/buying the electric kettle.

*B. Conceptual Design of the Kettle Coil*

At this stage, the design concept for the electric kettle coil is generated. By using all the data and information which had been collected before, three ideas are managed to gain. The main purpose in designing the kettle coil is to increase the contact area of the coil with the water in the boiling chamber, while reducing the material and manufacturing cost of the coil. Figure 6 shows three different shapes of the kettle coil together with the heating chamber.

Fig. 6. The proposed designs for kettle coil.

However, to determine the heating performance of each kettle coil, simulation on the thermal transmission using COSMOSFlow Works is done. By setting the heat source at constant value of 2kW, the simulation results obtained are as shown in Table 1.

Table 1. The simulation results for each design coils.

Based on the results, the red colour indicates the area where all the water flows into the heating chamber at temperature 100°C. Table 1 also shows that design B have the highest velocity of water, 0.18cm$^3$/s during the heating operation started compared to other designs. In design B, a simple helix shape of coil was applied in order to ease the thermal to spread inside the heating chamber. Since, design B showed the best performance, it is then selected for the new concept of electric kettle. As predicted, design B also showed better performance compared to current coil design. This refers to Figure 6 when the comparison of data proved that design B able to boil water at 600ml per minute, faster than current design which is only 450ml per minute. The red contour in Figure 7 also indicates that the heat is distributed more fairly in design B.

Fig. 7. The comparison of heating performance between the design B and current design.

## V. CONCLUSION

The results showed that the proposed design of the kettle coil had achieved better heating performance compared to the current design. Based on the results, the reduction of the energy used for about 34% can be obtained when using the new design of electric kettle coil. The achievement showed that by improving the kettle coil design, users can experience better performance of electric kettle and save more energy and time consumed. This is because of the effectiveness of the new kettle coil design had influence a lot in the performance improvement in the electric kettle use.

For the future empirical studies, further product features of high relevance to ecological performance may be worth examining. For examples, an adjustable set point that provided to the electric kettle may be helpful since it allow user to switch off the kettle according to temperature levels they required. Alternatively, a temperature display may support the user in deciding when the appliance needs to be switched off. This is because some beverages require temperature levels well below boiling point such as instant coffee and green tea. This will continue intensification further in the need to reduce both water and electricity consumption.

Finally, it is also important to take into consideration the additional environment impact and manufacturing cost of implementing design-based measure. It has to be demonstrated that the benefit of increasing ecological performance during product utilization is not outweighed by undue increases in the product's environmental impact during other phases, such as manufacturing or product disposal. This weighing up of the environmental impact across different phases of the product's life cycle is a critical activity for ecological design of consumer products [4, 9].


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