TOWARDS THE CONCEPTION OF A UNIVERSAL MULTIMEDIA TOOL FOR THE DESIGN OPTIMIZATION OF THE FIN

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ABSTRACT

The multimedia tool has become a global reality in our own decade. ICT have been imposed in the area of training (e-Learning) and industry. It is a process of distance learning based on resources and multimedia support. The work presented here falls within the context of creating these tools. We will therefore describe in the following the features of this tool.
A multimedia aid both dedicated to educational and industrial heat transfer with an application to small fins was conducted.
It will allow students to learn about the domain of fins, and industry engineers to select and scale their fins in an optimal manner without tedious calculations. A simulation of the phenomenon of heat transfer along the wing is established. The most commonly used shapes of the fins used in the industrial world were listed and studied. The most common boundary conditions were taken into account. A mathematical model based on different equations governing the transfer of heat along the different fins with adequate boundary conditions was developed. Flowcharts are established for every type of fin. An interface is made to manage and “multi mediate” "the simulation program in order to have a tool with either an educational aim (applicable to e-Learning) or industrial vocation. The user will so be able to choose between two options:

- a predefined fin
- a form of fin to be optimised

For the first case, the dimensions of the fin being defined, the user will then be able to determine the total flow generated by the fin, its effectiveness, changes in temperature and flow dissipated according to its length.
For the second case, the user will be able to determine the length and the optimum thickness of the fin to have a clearing of optimum heat as well as the complete flow cleared by the fin, its effectiveness, the variation of its temperature and of the cleared flow according to its length.
This interface, very easy to use, is developed in Java language and PHP and is placed on website accessible to every user.

Key words**:** e-Learning, fin, optimal form, Heat transfer, Flowchart, Interface, Java language, PHP.

1. Introduction

The fin has as function to amplify exchanges of heat between a wall plan and an external fluid. The transfer between the fin and the wall is made by conduction, while exchanges with external fluid take place by convection. The improvement of the performances of machines is conditioned by the quality of the thermal transfer. To reach this target, two ways can be adopted:

- Improvement of the properties of heat transfer of the absorbent whose thermal conductivity is greater.
- Improvement of the exchange surface between the outer wall and the absorbent by using fins playing so the role of thermal bridge between the heating wall and the reactive environment.

This way can be driven from an analysis coming from the mathematical modelling of the process and an optimisation based on numerous techniques. Several researchers have studied the problem of design and optimisation of the shape of the surface fin [1]. As part of the increase of the heat transfer effectiveness, the reduction of dimensions, of the weight of the systems of heat dissipation and as well as their volumes has become a necessity in the industry [2].

In the field of electronics [3], microtherm [4] and compact exchangers [5], very important flows of heat must be cleared for miniaturized components and this through much reduced exchange surfaces.

Parabolic, triangular, trapezoidal, curled profiles have been proposed for longitudinal fins. Several of them have shown their effectiveness to clear heat under certain conditions [8] [9], but unfortunately in some situations, the final solution in the optimisation problem of fins profile has not yet been found. The design and optimization of fins is a topic that receives much attention from researchers and industrialists. These are the reasons that led us to design a multimedia tool that will allow the user (both industrial and e-Learning students in the field of heat transfer) to:

- Calculate the characteristics of the geometrically predefined fin (total flow exchanged, efficiency, evolution of the temperature and the flow throughout the fin).
- Optimise the shape of the fin to be conceived

2. The multimedia education (e-learning)

Nowadays, access to knowledge has become interactive. The massive introduction of information and communication technology (ICT) in the worldwide educational system has changed the way of teaching [1] and permits to all people the access to knowledge and continuing and permanent education (motto of UNESCO for this 21st century).

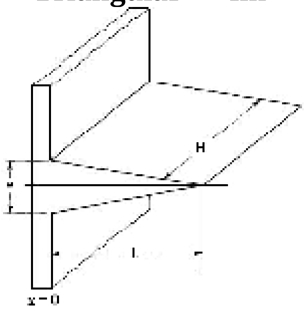
Multimedia education (e-Learning) aims to improve teaching practices on a daily basis, it also ensure high quality monitoring to engineering students in training. The main purpose is well to improve the quality of learning and not to be a substitute for traditional modes of learning. Research of very developed techniques were made around ICT and new teaching methods have been created [2].The e-Learning is a process of distance learning using multimedia resources. These used multimedia supports can combine text, 2 or 3D graphics, sound, image, animation and even video. These materials allow revolutionising pedagogic approach, by using playful methods where interactivity plays an important role. For that we think about developing a multimedia tool common to both educational and industrial needs. It is about a tool allowing the access to the world of fins.

3. Design of mathematical models

The majority of the fins used in the industry have been listed (extended surface). A classification of fins was made in accordance with their geometric shapes in:

- Longitudinal fins
- Radial fins
- Spines (fin-shaped spines)

3.1 Triangular fin (Longitudinal fin)



The differential equation governing the temperature along a triangular fin is:

$$x.\frac{d^2q}{dx^2}+\frac{dq}{dx}-m^2.L.q=0$$

With $q(x)=T(x)-T_\infty$ and $m=\sqrt{\frac{2.h}{l.e}}$

The general solution for this equation is

$$q(x)=C_1.I_0\left(2.m\sqrt{L(L-x)}\right)+C_2.K_0\left(2.m\sqrt{L(L-x)}\right)$$

We notice that: C_2 should be zero because at $x=L$, $K_0(0)$ is equal to infinity, thus:

$$q(x)=C_1.I_0\left(2.m\sqrt{L(L-x)}\right)$$

One condition is necessary:

- $x=0 \quad T=T_0 \quad q(0)=T_0-T_\infty$

3.1.1 Variation of the temperature

$$\frac{T(x)-T_\infty}{T_0-T_\infty}=\frac{I_0\left(2.m\sqrt{L(L-x)}\right)}{I_0(2.m.L)}$$

3.1.2 The overall heat flow

$$q_f=l.s.\left.\frac{dT}{dx}\right|_{x=0} \qquad \text{with } s=e.H$$

$$q_f=\frac{2.h.H.(T_0-T_\infty).I_1(2.m.L)}{m.I_0(2.m.L)}$$

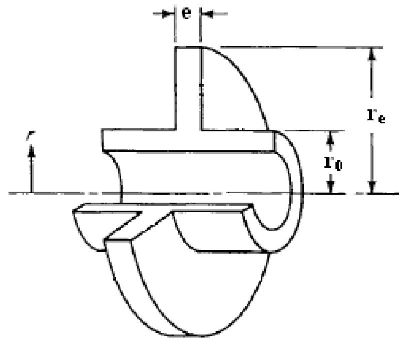
3.1.3 The efficiency

$$q_{id}=2.h.L.H(T_0-T_\infty)$$

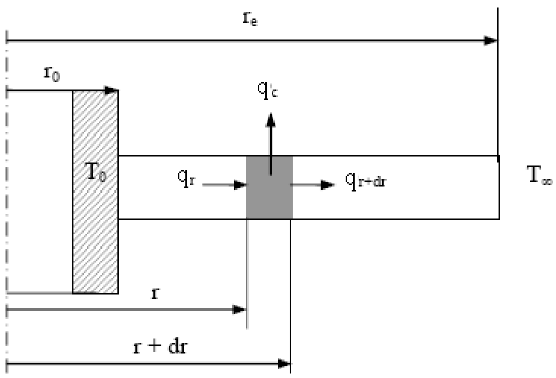
$$h=\frac{2.h.H.(T_0-T_\infty).I_1(2.m.L)/m.I_0.(2.m.L)}{2.h.L.H(T_0-T_\infty)}$$

$$h=\frac{I_1(2.m.L)}{(m.L).I_0(2.m.L)}$$

3.2 Radial fin of rectangular profile



Let us conduct a review of energy on the system composed of the portion of the disc between r and r+dr.



3.2.1 Thermal balance

The balance sheet of energy is written:

$$q_r=q_{r+dr}+q_c$$

q_r : Heat flow transmitted by conduction to radius r: $q_r=-l.2.p.r.e\left(\frac{dT}{dr}\right)_r$

q_{r+dr} : Heat flow transmitted by conduction to radius r + dr:

$$q_{r+dr} = -l.2.p.(r+dr).e.\left(\frac{dT}{dr}\right)_{r+dr}$$

q_c : Heat flow transmitted by convection on the fin surface between r and r + dr

If l is independent of radius r, we get:

$$\frac{1}{r}.\frac{(r+dr).\left(\frac{dT}{dx}\right)_{r+dr} - r.\left(\frac{dT}{dx}\right)_{r}}{dr} = \frac{2.h}{l.e}.[T(x)-T_\infty]$$

Or still : $\frac{d^2q}{dr^2} + \frac{1}{r}.\frac{dq}{dr} - \frac{2.h}{l.e}q$
where $q = T - T_\infty$

It is a BESSEL equation whose solution is written in the form:

$$q(r) = C_1 I_0(m.r) + C_2 K_0(m.r)$$

Where $m = \sqrt{\frac{2.h}{l.e}}$

C_1 and C_2 are determined by the boundary conditions. For the radial wing, two types of boundary conditions are proposed.

3.2.2 Type-1

The fin is assumed long and the temperature at its end is equal to the fluid temperature.

- r = r$_o$ $q = q_0 = (T_0 - T_\infty)$ from where $q_0 = C_1.I_0(m.r_0) + C_2.K_0(m.r_0)$
- r = r$_e$

$$q = 0 = C_1.I_0(m.r_e) + C_2.K_0(m.r_e)$$

$$C_2 = \frac{q_0.I_0(m.r_e)}{K_0.(m.r_0).I_0.(m.r_e) - K_0.(m.r_e) - I_0(m.r_0)}$$

$$C_1 = \frac{-q_0.K_0.(m.r_e)}{K_0.(m.r_0).I_0(m.r_e) - K_0.(m.r_e).I_0.(m.r_0)}$$

Therefore

$$q(r) = \frac{q_0.[K_0(m.r).I_0(m.r_e) - I_0(m.r).K_0(m.r_e)]}{K_0(m.r_0).I_0(m.r_e) - K_0(m.r_e).I_0(m.r_0)}$$

From where:

The variation of the temperature:

$$\frac{T(r)-T_\infty}{T_0 - T_\infty} = \frac{K_0(m.r).I_0(m.r_e) - I_0(m.r).K_0(m.r_e)}{K_0(m.r_0).I_0(m.r_e) - K_0(m.r_e).I_0(m.r_0)}$$

The overall heat flow:

$$q_f = -2.p.r_0.l.e.\left.\frac{dq}{dr}\right)_{r=r_0}$$

$$q_f = 2.p.r_0.e.l.m.(T_0 - T_\infty).\frac{K_1(m.r_0).I_0(m.r_e) + I_1(m.r_0).K_0(m.r_e)}{K_0(m.r_0).I_0(m.r_e) - K_0(m.r_e).I_0(m.r_0)}$$

The efficiency:

$$q_{id} = 2.p.(r_e^2 - r_0^2).h(T_0 - T_\infty)$$

$$h = \frac{2.r_0}{m(r_e^2 - r_0^2)}.$$
$$\frac{K_1(m.r_0).I_0(m.r_e) + I_1(m.r_0).K_0(m.r_e)}{K_0(m.r_0).I_0(m.r_e) - K_0(m.r_e).I_0(m.r_0)}$$

3.2.3 Type-2

The fin is isolated at the end

- $r = r_0$ $q = q_0$
- $r = r_e$

$$q_0 = C_1.I_0(m.r_0) + C_2.K_0(m.r_0)$$
$$I_0'(x) = I_1(x)$$

$$0 = C_1.I_1(m.r_e) - C_2.K_1(m.r_e)$$
$$K_0'(x) = -K_1(x)$$

Variation of the temperature

$$\frac{T(r)-T_\infty}{T_0 - T_\infty} = \frac{K_1(m.r_e).I_0(m.r) + I_1(m.r_e).K_0(m.r)}{I_0(m.r_0).K_1(m.r_e) + I_1(m.r_e).K_0(m.r_0)}$$

The overall heat flow:

$$q_f = -2.p.r_0.l.e.\frac{dq}{dr}\bigg)_{r=r_0}$$

The minus sign is placed, because the temperature gradient decreases with increasing r.

$$q_f = 2.p.r_0.e.l.m(T_0 - T_\infty).\frac{I_1(m.r_e).K_1(m.r_0) - K_1(m.r_e).I_1(m.r_0)}{I_0(m.r_0).K_1.(m.r_e) + I_1(m.r_e).K_0(m.r_0)}$$

The flow along x axis:

$$q(x) = 2.p.r_0.e.l.m(T_0 - T(x)).\frac{I_1(m.r_e).K_1(m.r_0) - K_1(m.r_e).I_1(m.r_0)}{I_0(m.r_0).K_1.(m.r_e) + I_1(m.r_e).K_0(m.r_0)}$$

The efficiency:

$$q_{id} = 2.p.(r_e^2 - r_0^2).h(T_0 - T_\infty)$$

$$h = \frac{q_f}{q_{id}} = \frac{2.r_0}{m(r_e^2 - r_0^2)}.\frac{I_1(m.r_e).K_1(m.r_0) - K_1(m.r_e).I_1(m.r_0)}{I_0(m.r_0).K_1.(m.r_e) + I_1(m.r_e).K_0(m.r_0)}$$

4. Flowchart of calculations and applications:

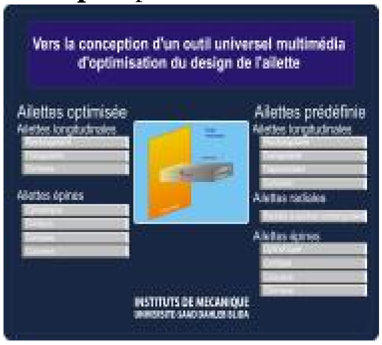
A series of flowchart is established to make the necessary calculations. The work was divided in two main parts. The first one will concern the case where the fin dimensions are imposed. In this case, the choice will first focus on the form and afterwards on the type of boundary conditions. In the second part, it will be a question of finding the optimum dimensions for a maximum clearing of heat of the fin towards surrounding middle. The choice will be made on the shape of the fin and the boundary conditions.

5. Steps to create the interface

1 - Installing a local server on the computer (necessary for an HTML application).
2 - Installing the software Cpanel of dynamic website administration.
3 - Integration of a Template adapted to the interface of the application.
4 - Customizing the Template (changes of menus and homepage).
5 - Creating modules and buttons for all situations (type of data and fin).
6 - Integration of JavaScript programs previously established for each type of fin.

6. User's Guide of the interface

1st step: Open the main menu.



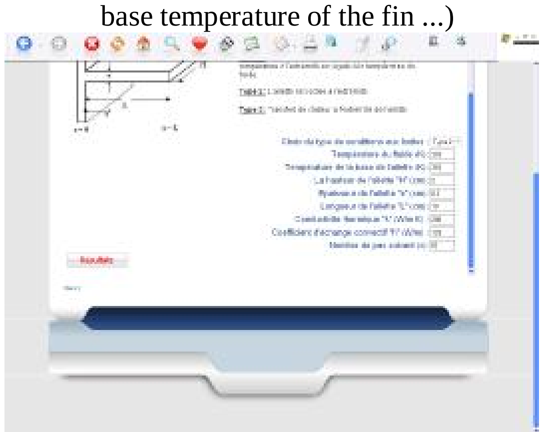
2nd step: Select the desired practice in the menu, namely:

- Fin predefined
- Fin to be optimised.

3rd step: The case of the longitudinal predefined fin with rectangular section will be given as an example. The user will then have to choose the form of the desired fin.

4th step: the user should:

- Opt for a type of boundary conditions
- enter the required data (length, thickness, thermal conductivity, coefficients of convection of surrounding fluid, fluid temperature, base temperature of the fin ...)



5th step: Click on the results button.

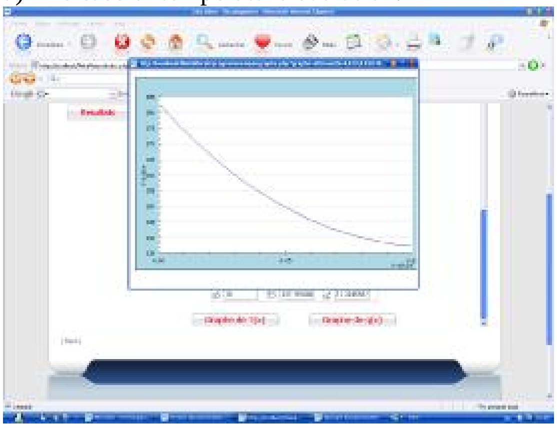
6th step: display of results, namely:

- Total flow generated by the fin.
- The efficiency of the fin.

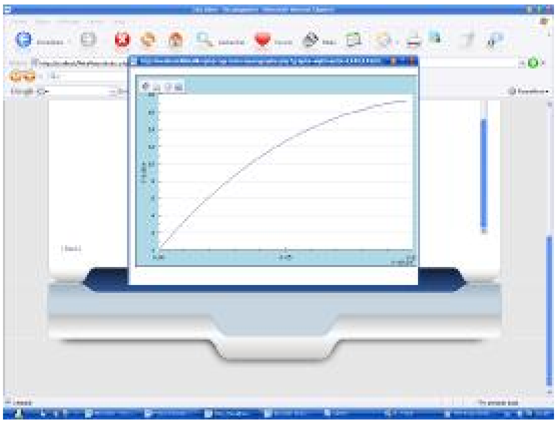
- The flow evolution along the fin.
- The temperature evolution along the fin.

7th step: Choose viewing the changes in temperature or flow.

a) The case of temperature evolution:



b) The case of flow evolution along the fin:



7. Conclusion

In this work a multimedia tool with application, to both educational (in the field of e-Learning) and industry, was developed. The work was based initially on techniques and tools used in e-Learning, followed by a study on the feasibility of its use as an industrial tool. It will allow students to be initiated to the field of fins, and industrial engineers to choose and scale their fins in an optimal manner, without tedious calculations. A simulation of the phenomenon of heat transfer along the fin is established. An interface is set to multi mediate this simulation. This interface is significant because of its ease of use.

There is a possibility in the future to install this interface on a website and enrich it with other work along the same line of research

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