Design Tool for a Didactic Project Related to Internal Combustion Engines

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ABSTRACT

Referring to the content of a semester or a graduating period project during the Mechanical Engineering studies, two types of activities are to be highlighted: the first one is to approximate the assembly components dimensions and to check the stress values they are confronted to and the second one is to give them the final shape with all their details, whether or not opposing to the operating efforts. In order to obtain a better project is necessary that this process develops under multiple iterations, consecutively modifying certain dimensions and visualizing the resulting geometry.

Starting from these considerations the authors have projected a calculation and visualization system of the geometry of the components forming the mechanism of an internal combustion engines. This system contains data and model files under a parametric form with reciprocate connection to visualize the resulting form after each dimension modification and its verification to the efforts. This method allows to stream as numerous as necessary iterations in identifying the right dimensions and the appropriate forms.

Keywords: Design System, Computational and Visual Tool, E-Learning, Internal Combustion Engines.

INTRODUCTION

The process of designing an internal combustion engine is a complex task for any company or research group. This consists in defining a lot of the engine characteristics, from its use, possible destination, class belonging, acquisition price etc. From the point of view of its definition the basic design activities cover the in-cylinder thermodynamic processes and the sizing of the main parts of the engine (Racovitza and Negreanu, 2008). First category to be used relies on the thermodynamics criteria and equations and the second one applies the elements of the strength of materials (Racovitza, 1996).

Describing the thermal processes from the cylinder inside (Stone, 1992), this is an extremely complex domain, in terms of gas exchange, air-fuel mixture formation, combustion and heat release and emissions genesis. Concerning a didactic project, especially dedicated to realize the shape of the main engine parts and less supposed to solve the engine thermodynamics, despite the existence of some very performing and highly professional soft packages, such as AVL Soft Programs™ ("AVL BOOST"), or AMESIM Numerical Code™ (“AMESIM”), a more schematic evaluation has been chosen by using classic transformations of the involved work agents.
The starting project requests correspond to the engine rating power and speed and therefore the student needs to complete a reference study upon similar releases on the market. These data allow him to proceed to the design method itself (Racovitza, 2009).

The program running the procedures of the components sizing and their calculation to strength has been implemented using Microsoft EXCEL™ ("EXCEL MICROSOFT OFFICE"). This soft, together with its Visual Basic for Application™ ("VISUAL BASIC") extension allow the creation of the special frames, adopting the initial data and visually presenting the results by performing non-tabled calculations. An important benefit in this case is the fact that all the data are listed in the calculation sheets, which allows an easy control of the system.

**STRENGTH CALCULATION**

In this design domain two working methods could be mentioned:

- In the first case, when the work starts from the adopted material type and their maximal efforts, the geometric form can be then defined.
- In the second case the piece dimensions are first chosen by the designer, followed by the calculus and the comparison between the effective found and the maximal admissible efforts values.

Because it has been decided to work upon the first scenario, the engine mechanism dimensions could be first chosen from the statistic range values. Usually, these statistic data are listed as a function of the cylinder bore (D), which is presumed to be found by the thermal calculus (Apostolescu and Chiriac, 1998 and Heywood, 1988).

As a given example, for the engine piston, its dimensions are showed in Figure 1 (Zatreanu 1980 and Gaiginschi and Zatreanu, 1995). These values could be chosen by the operator under relative reference to the cylinder diameter (bore).

![Figure 1: The main dimensions of the engine piston](image)

In order to make easier the picking up process of the above mentioned length and diameter values some windows have been generated in order to input the data as a ratio to the bore value. Help keys have been also provided, to offer information on the admissible range values (see Figure 2). These frames can provide also information functions concerning the adopted materials, similar to radio keys, allowing choosing a certain material from a given list. The input data are grouped in
dedicated zone of the EXCEL™ work sheet, reported to the bore or in absolute form, as seen in Figure 3.

After the initial data input using the described windows the user can directly modify the chosen values inside the worksheet. The project design contains a sheet especially dedicated to the optional data choosing, in which the user can perform anytime his modifications. The effective dimensions should be established only after the multiplying factor set according to the cylinder diameter value (see Figure 4). In order to set acceptable geometric values, from case to case these could be rounded up.

Figure 2: Operational window to choose the piston main dimensions

| Piston materials |
|------------------|
| ○ Hypereutectic alloy |
| ○ Eutectic alloy |
| ○ Hypereutectic Malleable 118 alloy |
| ○ Hypereutectic Malleable 224 alloy |
| ○ Z alloy |

geometric data are in *geom Sheet

![Table Image]

**Figure 3: Various input data for the piston**
The force and the torque values appearing in the motor mechanism will be established in the first part of the project, in which the basic characteristics of the engine are set. They depend on the pressure diagram, adding the system inertial solicitations. Therefore, it appears necessary to evaluate the motioning weights, starting also from the existing statistic sources. Thus, everything being set, the user can pass to the pieces strength calculation chapter (Figure 5).

The obtained result is expressed by some safety coefficients, emphasizing the ratio between the admissible and the effective values. It is obvious that these coefficients should be greater than 1, ideal case when both are equal. The undesirable situation when calculating this ratio under 1 leads to an unsatisfactory result and to the message that the procedure should be resumed with other initial data.

For each part of the engine mechanism a special zone for dimensions choosing and efforts calculation has been created. The results have been listed in tables which could be at the time insert in the project (Figure 6).

| Piston results |
|----------------|
| **Geometric data** |
| **Dhead**  | 89.37 mm |
| **Dcyl**   | 89.88 mm |
| **L**      | 57 mm   |
| **Hc**     | 41 mm   |
| **Lm**     | 68.5 mm |
| **d**      | 8 mm    |
| **H1**     | 7 mm    |
| **H**      | 2.5 mm  |
| **H2**     | 3 mm    |
| **A**      | 3 mm    |
| **B**      | 9 mm    |
| **AAV**    | 0 mm    |
| **delta**  | 0.405 mm|
| **G coated** | 4 mm |
| **d out (greasing)** | 0.2 mm |
| **No**     | 8       |
| **Stroke** | 77.4 mm |
| **d shoulder** | 31 mm |
| **d piston** | 24.5 mm |

Figure 4: The effective dimensions for the piston
To highlight in three dimensions the item which should be designed the CATIA System is using ("CATIA V5R20"). The procedures of this system are very accessible, the created models could be given in a parametric form and the system itself is widely spread among the design companies. The mechanism components have generally a similar form from one engine to another. Their dimensions have been expressed as a function of the cylinder bore (calculated applying the thermodynamics calculation) and depending on the engine type, which influence the values of the
coefficients. Thus, families of items appeared, containing similar geometry, based on certain dimensional values related to the options given by the project. For the piston, the generating parameters are listed in Figure 7. They will contribute to the piston modeling and its image, projected by these values is showed in Figure 8. In Figure 9 is presented the first iteration with the values for a piston of a Diesel engine. So that it could be better explained the capabilities of the working algorithm, one extreme case is listed for which one of the checking values does not correspond, the safety coefficient resulting under the limit 1. To solve this situation means for example to increase the total length of the piston, as seen in Figure 10. This is just an example witness how easy these modifications could be made. After all these iterations concluded by the user meaning that the primary form of the component is defined, the second part of the designing process has to be assumed, to reach the final status of the project. All the previously obtained results should remain and the rest of the characteristic operations must be accessed. For example, the piston should have defined its combustion chamber and the rest of the chamfering and rounding operations will approach the primary model to the final requested form. Finally, the student is supposed to present a project containing all the elements of pieces sizing the checking calculations and the drawings for all the items.

Figure 7: The modeling parameters of the piston
Figure 8: The engine piston

| Type       | Position | Mechanics | Thermal | Sum  | Safety Coefficients |
|------------|----------|-----------|---------|------|---------------------|
| radial     | center   | 250.57    | -48.05  | 162.53 | 3.06               |
|            | edge     | 376.80    | -46.04  | 330.75 | 1.51               |
| tangential | center   | 250.57    | -38.05  | 162.53 | 3.06               |
|            | edge     | 124.34    | 37.95   | 162.30 | 3.08               |

Rings Zone

| omega      | Thrusts  |
|------------|----------|
| 1577.92    |          |

| Position | Coefficient |
|----------|-------------|
| 135      | 3.69        |
| 1        | 558.17      |

Figure 9: First iteration for the piston

Figure 10: The second iteration for the piston
CONCLUSIONS

The presented paper is highlighting a sizing and checking system for the efforts and the deformations of the engine mechanism components (piston, connecting rod and crankshaft) equipping an internal combustion engine. In this analyzing phase, one module to geometrically shape the constructing elements is also included in order to correlate the design and the computation results, allowing to generate the primary form of the verified items.

There are followed two goals: achieving of correct checking calculations based on the theoretical courses methodology and the analysis of the elements shape obtained by sizing choices.

The use of the designing tool proposed by the authors is strictly didactic. It permits an easier way to calculate the strength elements of the materials forming the engine components and is more orientated on the shape definition.

The main quality of the method is the link between the geometry chosen by the user and the check calculation together with the final structure of each item. The old versions of this work consisted in sizing and checking calculations involving some sort of software with loosing then this connection between geometric data and the real form when passing to the drawing.

The possibility to easily conduct multiple iterations is a policy to obtain high quality didactic projects, with a better approach to the existing commercial engines. It also becomes quite accessible to predict the influence of certain dimensions on the checking calculations and what dimensions could be chosen without affecting the safety coefficients.

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