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THEORETICAL INVESTIGATIONS ABOUT THE INFLUENCES OF THE PISTON PIN STRESS ON THE COMBUSTION ENGINE PERFORMANCES

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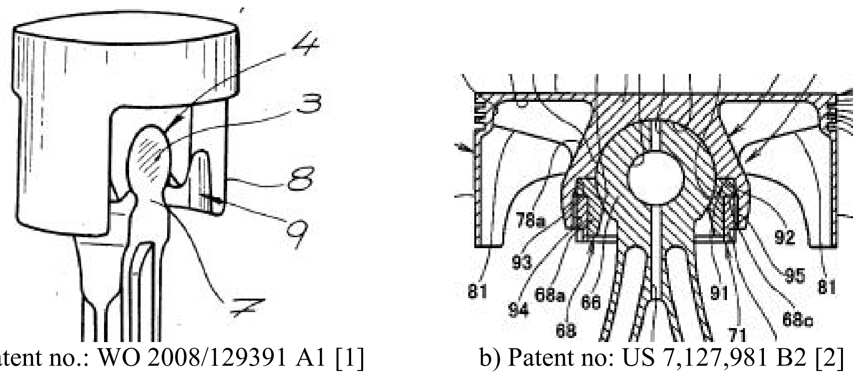
Abstract: *The engine piston pin stress is done by the action of exhaust gases pressure forces, forces of mass inertia, constructive shapes, material and thermal treatment. The performances of the combustion engine are in direct relationship with those of the piston pin. The theoretical investigations in this paper are focused on the variant of semifloating piston pin (fixed into the connecting rod foot). The theoretical aspects which were analyzed are linked to the mass decreasing influence, to the optimized distribution of material and to the optimization of constructive shape. The aim of the researcher is to realize a better behavior in case of real loadings and, finally, to improve the performances of the combustion engine.*
Keywords: *piston pin, stress analysis, theoretical investigation, optimization*

1. INTRODUCTION

The piston pin is one of the most loaded parts of the combustion engine. The best economical and technical shape for this part is the cylindrical model. There are some investigations to change this shape but, despite their patented protection, they have not been successful variants because of the disadvantages. We can see some examples in figure 1:



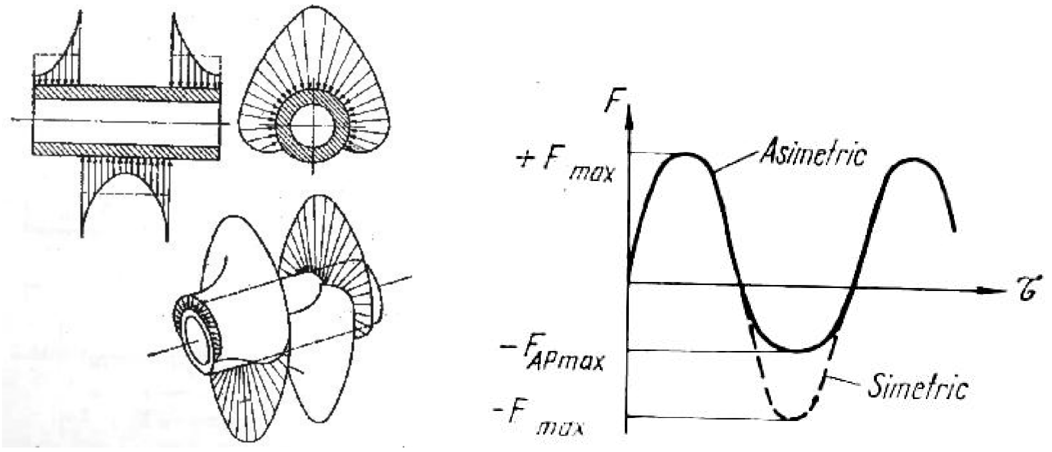
a) Patent no.: WO 2008/129391 A1 [1] b) Patent no: US 7,127,981 B2 [2]

Figure 1: Pinless connection between piston and connecting rod

These achievements are interesting first of all as theoretical idea. The cinematic link between the connecting rod and the piston without piston pin is not a new idea and some variants can be seen in figure 1. The practical manufacturing is very complex with many linking components which have to replace the piston pin and to ensure a stable connection and perfect functionality. This paper tries to present some theoretical aspects about the influences of the piston pin (with classical shape - exterior cylindrical shape) loadings on the combustion engine performances for the semifloating pin variant. This theoretical investigation consists of a new constructive shape analysis, of some research about the decreasing of mass as compared to the floating pin variant and of the influences on the twist vibrations.

2. THEORETICAL BACKGROUND

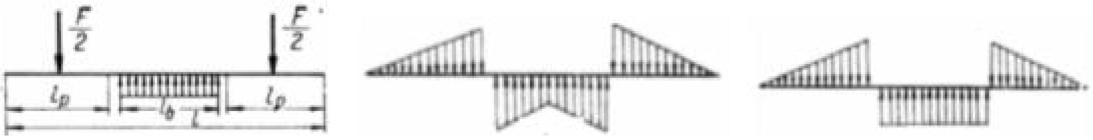
The piston pin loadings are complex and they induce a suitable shape of tensions distribution. This kind of status is presented in figure 2. The piston pin is considered a fixed right beam. Its tensions, as a result of loading, are presented in figure 1 a) and the loading cycle is presented in figure 1 b). The loading cycle of the semifloating pin is asymmetrical and for the floating pin it is even more disadvantageous (symmetrical) because the medium fiber will be stressed to the maximum deformation in both senses of direction.



a) b)

Figure 2: Load force distribution a) and load cycle in piston pin [3] [4]

An idealization special for analytic calculus was necessary in order to make a shift from the real loading spatial status to a special mathematical model. The scheme is presented in figure 3. Figure 3 a) represents the real loading status. The gases pressure force is halved distributed (F/2) on the two points of piston bosses. This does not describe a realistic situation. Figure 1 b) represents a distribution closer to the real model and it is more rational because it matches the wear distribution along the piston pin. That is why the modeling from figure 3 is considered more suitable. It could be easily assimilated to an analytic calculus.



a) **b)** **c)**

Figure 3: Diagram of the load idealization modell [4]

The most loaded area of the piston pin is between the extremity of connecting rod small end and the beginning of the piston boss. The phenomenon that occurs, the double shear stress, is due to the effect of the forces from that area: the opposite forces of maximum values. The calculus formula (Jurawski's formula) of maximum tension on the shear stress [5] is:

$$\tau = \frac{0{,}85F(1+\alpha+\alpha_2)}{d_{eb}^2(1-\alpha^4)}, \tag{1}$$

where:

$\alpha = d_{ib}/d_{eb}$.

Thus, finding an optimized shape of the piston pin is a challenge for project engineers. The shape of the piston pin must meet the necessary functional and constructive requests and it must have a better functionality and a lower mass. The exterior cylindrical shape has to be kept because of the assembly particularities, first of all because of the connection with the connecting rod small end and piston boss. The possibilities to optimize this exterior cylindrical surface are limited because of mounting constructive details with the exception of improving the quality of the surface by fine and superfine machining and hardening thermal treatment. The extremities and the cylindrical internal area are the areas that can be analyzed in order to determine the optimization possibilities with geometrical changes. The lateral extremities can be optimized by milling in order to decrease the stress. Further, an optimized model of semifloating piston pin will be presented.

3. MATERIALS: COMPOSITES

The composite materials [6] represent the main direction for the researchers. They hope that in the future these types of materials will become more important for the automotive industry. There is the possibility to use them for some elements from the structure of vehicles, for example the mixed laminated materials from the simple or multistratified sandwich layer, consisting of metal-plastic materials. The material consisting of Al/Al_2O_3 and Mg/ Al_2O_3 has high rigidity, high wear and temperature resistance. The metallic composite materials are usually used in automotive industry for some parts of engines, of suspension and braking and steering systems. The mobile equipment (the connecting rod, the piston and the piston pin) and the thermodynamic and fatigue stressed parts are made from these types of materials. According to [6], the physical characteristics of composite materials can be described using the formula:

$$P_c = \sum P_i w_i , \qquad (2)$$

where:

P_c represents the properties of the composite material

P_i represents the properties of composite material components

w_i represents the volume percent of the composite material components

In order to take into consideration the mechanical properties, the equation (2) has to include the parameters which take into account the dimension of particles of the filling material, of orientation, of wrapping geometry, of the specific interaction between matrix and the filling material and of the effects along the interface. Therefore, it is clear that physical and chemical properties of the composites can not be described through an unique equation. [6]

Figure 4 presents a licensed invention [7] which consists of a piston pin made from a composite material. There can be seen, into the detailed right figure, material fibers arranged in layers which have different directions, ensuring the internal consistency of the piston pin. The cylindrical external surface is realized by vapors coating or by pressing the metallic bushing (piston pin bush).

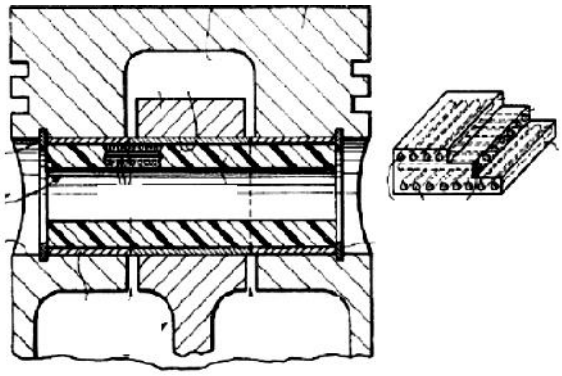


Figure 4: Composites piston pin [7]

The placing of the composites in the piston pin assemble is a usual technological process, continuously developing. Its aim is to optimize the constructive and functional characteristics.

4. SIMULATION

The computer simulation [8] was done in order to establish the behaviour of the part under the action of the load forces and to appreciate the movements. At the same time the areas where the shear stress has maximum values are observed and new optimization possibilities can be suggested, based on simulation results. The geometric dimensions which were used for the model are the characteristics of Dacia 1289 cm^3 (810-99) engine piston pin. This engine used to be made on the Dacia Factory from Pitești, Romania.

The applied loading was considered to be 50 [daN/cm^2]. It was uniformly distributed into the piston bosses. It was considered better to model the conjugate ensemble piston-semifloating pin-connecting rod in order to better reproduce the real conditions. The applying of loading will be done as in reality on the piston and the sending of force flow is done through the piston boss and the semifloating pin to the connecting rod. Finally, the semifloating pin is separated and the results can be interpreted. To model and to make a simulation of the piston pin is less recommended because it is necessary an idealization which is too different from the reality: it is false to consider the contact area with the connecting rod small end as a point without moving (fixed area). Figure 5 presents some details of the jointed assembly simulation.

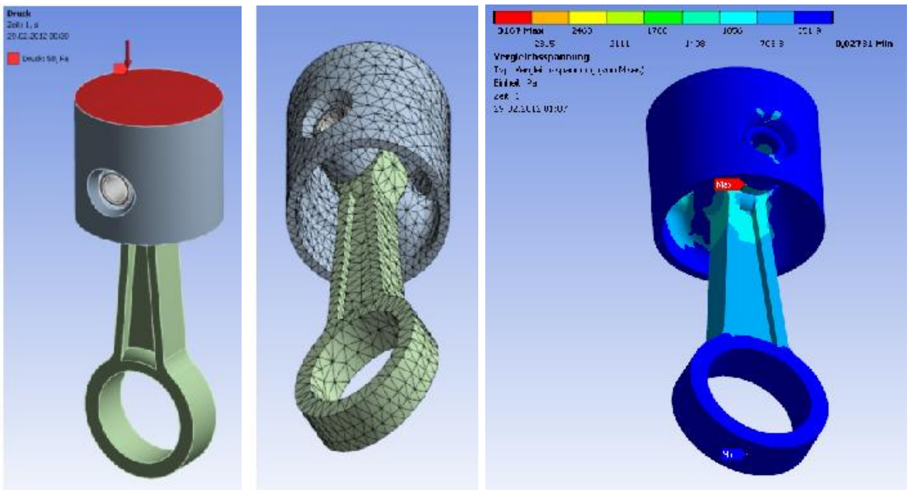


Figure 5: Simulation results of the connected components (semifloating pin, piston, connecting rod) [8]

The results of the simulation (Figure 6) for the semifloating pin, after it was isolated in the above assembly:

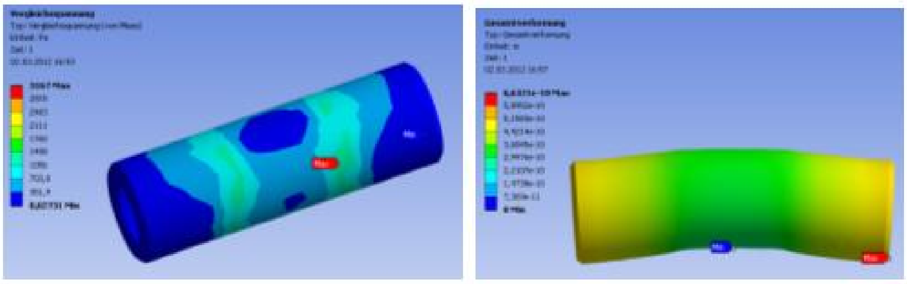


Figure 6: Simulation results of the isolated semifloating pin [8]:
Stress distribution (left) and deformation (right)

In figure 6-left the shear stress maximum area can be seen very clearly. The deformation status can be seen in figure 6-right. Taking into consideration these results, we can conclude that the proper area should be strengthened (the area where the shear stress has maximum value) and the section from unsolicited areas can be reduced (the extremities). The practical investigations [8] confirmed these aspects and they are presented in figure 7:

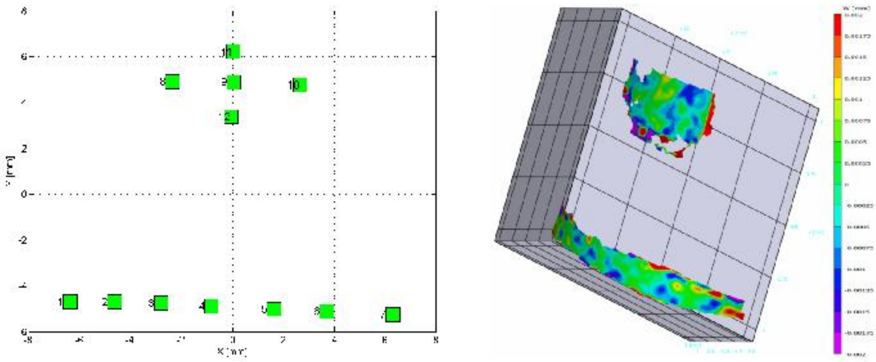


Figure 7: Experimental results of displacement measurement for the
most solicited area of the semifloating pin [8]

A suggestion for an optimized shape is presented in figure 8. The outer section, which corresponds to the forces sent through the piston bosses, will have a uniform strength beam shape. In consequence, at the exterior the section will be reduced (less pressure forces) and the internal the section will increase (because the transmitting forces are bigger). The next section, which corresponds to the intermediary area between piston bosses and connecting rod foot, the section where the shearing stress has maximum values, will have maximum dimension. The third area, the middle one, could be considered as to be integral to the connecting rod foot (because the piston pin-connecting rod foot tightening is very strong) and ,combined with the decreasing of loadings from the central area, can allow a circular milling. Thereby, the section will be weaker but it will be compensated by the section of the connecting rod foot section which is integral.

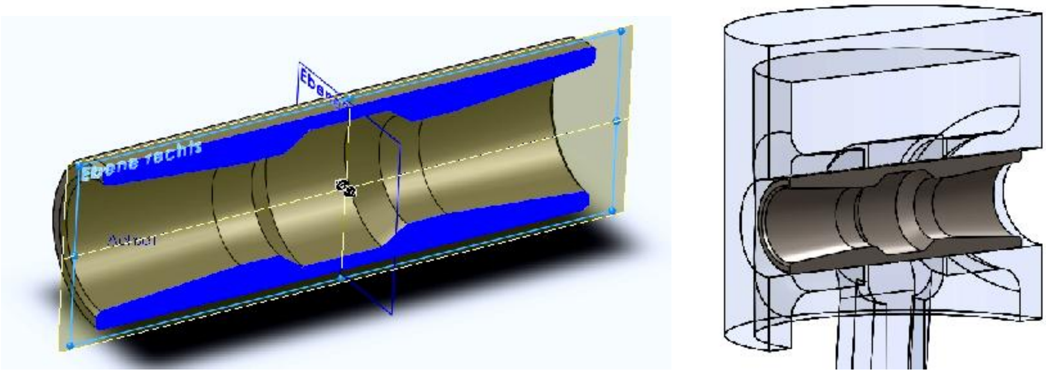


Figure 8: New optimised section for semifloating pin proposed in [8]

5. CONCLUSION

The theoretical research about the influences of piston pin loadings on the combustion engine performances have to be done taking into consideration the construction and assembling method influences on the conjugated parts and on the functional ensemble they belong to. The theoretical and experimental independent analysis and a unilateral simulation can not lead to results very close to reality.
The interesting examples which were presented, licensed protected, suggest the engineers' inventiveness and their focusing on an optimizing direction. They also have to take into consideration the practical and technological aspects. Without these particularities the ideas will be only some simple written projects. We could generalize this idea and it could be said that no component can be projected without taking into consideration these aspects , mainly because nowadays there are a lot of restrictions which can not be enforced without following them, with only one purpose: the optimization.

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