Optimization and Numerical Anlysis of Mechanical Properties of Connecting Rod in the Internal Combustion Engine

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The paper presents the process of optimisation of geometry of connecting rod used in the automotive industry. This connecting rod is used in a sports car with a high power engine, where high torque values can damage individual components. Three numerical, geometric models of 40HNMA structural steel connecting rods were made for optimisation. Statistical analysis of strength properties using the finite element method was carried out, and results for the models were compared. The simulation and calculations were performed in SolidWorks.

Keywords: Optimization, crankshaft, FEM, SolidWorks, internal combustion engine

It was started planning and solving engineering issues, which required earlier much more consuming time, together with the progress of civilisation, evolution of computer subassemblies and discovery of new technologies [1-7]. Usage of the computer allows creating a real model, performing computer simulation, analysis of heat distribution, estimated deformation and aerodynamic researches [8-13]. Thanks to these above mention issue a company does not need to pay for useless costs of production, which in fact will not satisfy basic assumptions [14-27]. Especially it is obvious in the process of car engines production, heavy industry, military, aerial and related industries, which needs many financial expenses for creating prototypes of machinery. The connecting rod, as the element which connects a piston with a crankshaft, moves forces which influence on the piston surface and a crank pin of a crankshaft engine [28-32]. It is required, to a connecting rod has a suitable strength allowing for long and failure-free work, because at the moment of damage might lead to the destruction of the whole engine [33-36].

Experimental part

Methodology

The first model is based on the actual model used in the automotive industry, while the other two models present a proposal for construction solutions. The connecting rod is used in a 1.6-litre petrol engine and is the base for all models. The connecting rod was purchased on its own and then manually dimensioned using professional measuring tools (fig.1). The designed part is a connecting element between the piston and crankshaft. It is also responsible for the transmission of forces from the piston to the crankshaft junction.

The simulation and calculations were performed in SolidWorks. The software has enabled three models to be developed, the best solution to be initially estimated, the necessary corrections to be made before the calculations are performed and the best model to be selected. The numerical analysis made it possible to choose the best model suitable for use in the automotive industry for a specific combustion engine. The developed model is an excellent basis for creating a prototype solution, and thanks to maintaining original base dimensions, the element will be ready to be tested in a specific car engine.

Figure 2 shows an isometric view of the three models of connecting rods. Despite the different shaft geometry, the dimensions remained unchanged. The inside of the head is considered to be a fixed geometry as a contact point with the crankshaft in the simulation. A force of 40 kN was applied to the inner part of the head, simulating the maximum forces acting during heavy engine operation, each crank handle has been immobilised in the internal part of the head (fig. 3). Static analysis with a three-wall mesh static analysis was performed during modelling. The net has been compacted to ensure maximum accuracy of

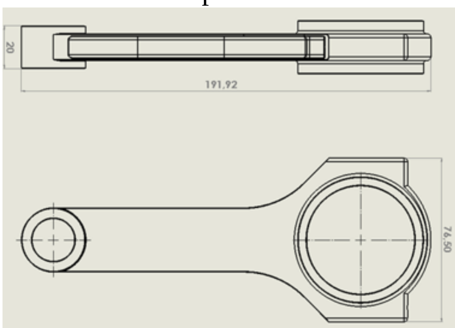

Fig. 1. Geometrical model

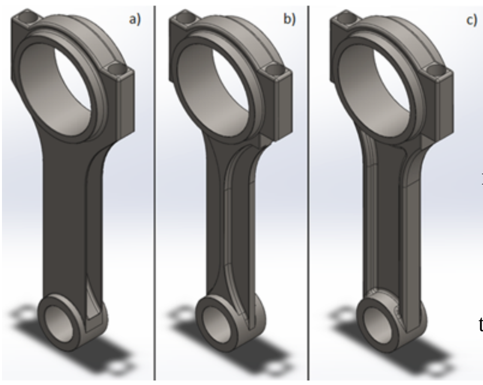

Fig. 2. Connecting rod models manufactured. a) genuine model, b) model with a side notches of the shank, c) model with a notch in the middle of the shank.

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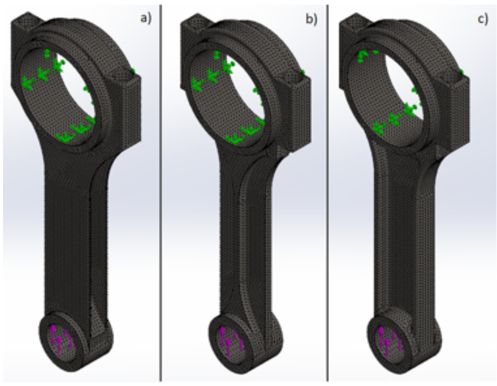

Fig. 3. The analysed model with generated mesh and the boundary conditions a) genuine model, b) model with a side notches of the shank, c) model with a notch in the middle of the shank

Results and discussions

Figure 4 shows the stress distribution in the test connecting rods. The actual model (a) has evenly occurring stresses, concentrating around the centre of the shaft. The maximum value of these stresses is between 420-515 MPa.

Table 1
THE WEIGHT OF CONNECTING RODS MODELS

Model	Weight [g]
a)	394g
b)	431g
c)	430g

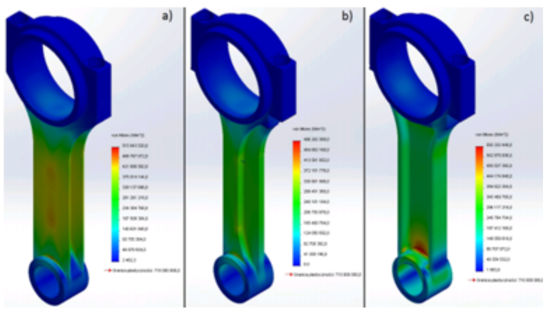

Fig. 4. Stress distribution-isometric view. a) genuine model, b) model with a side notches of the shank, c) model with a notch in the middle of the shank

For model b) with side notches of the shank, the stress distribution is evenly distributed over the entire surface of the shank. The maximum values are 413-496 MPa and are located at the junction of the shank with the connecting rod head.

The model (c) with a cut-out of the middle of the wide part of the shank shall have a stress build-up in the joint between the shank and head. The maximum stress is between 540-590 MPa. The stress concentration in the model c) is caused by a lack of support in the central, thinnest part of the shank. This can be prevented by modifying the model by adding a layer of material that causes this stress to spread over a larger area. At the highest stress points, the material may crack and accelerate component wear and, in the worst case scenario, vehicle engine failure and damage may occur.

Figure 5 presents distributions of displacements which were done on the influence of given force. The simulation shows that the smallest displacements occur in a model with lateral indentation (b), where the central part of the shaft transmits the stresses in the largest area. The displacements for the actual model (a) and the model with lateral indentation (b) shall be even over the entire surface area, except for the model with indentation in the middle of the shank (c) which, in the middle part of the head, exhibits the largest displacements which could lead to a failure.

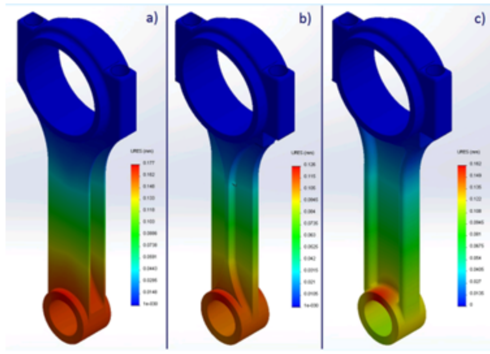

Fig. 5. Displacements - isometric view. a) genuine model, b) model with a side notches of the shank, c) model with a notch in the middle of the shank

The largest displacements do not exceed 0.18mm for all models, which is a very small value. The lowest loads are found in the model with side indentation (b), where uniformity of displacements and their maximum size is 0.13mm, suggesting the highest durability.

For the connecting rod, it is important to emphasise the total weight of the component, which should be as low as possible to reduce the energy losses caused by the connecting rod inertia. The amount of displacements caused by the applied pressure does not have a big influence on the work of the connecting rod, but for the first optimised model these displacements are 29% lower with 8% weight increase. Smaller displacements allow the desired rigidity of the connecting rod to be achieved. Figure1 presents the total weight of modelled elements.

Conclusions

Juxtaposition the weight together with the results suggests, that the real model (a), in spite of less precise results of stress analyses and displacement, will be more useful in a car engine. Reducing the weight to the level of 9.5% maintaining uniformity of stresses and displacements confirms assumptions concerning using a real mode (a)l as the prototype model. But if the goal is obtaining the highest level of car engine reliability with increased efforts of the elements- the model with a side notches of the shank (b) will be the best alternative.

The following conclusion can be drawn:

-A real model with a side notches of the shank has a suitable ratio of weight to resistance.

-The first alternative model with a side notches of the shank allows increasing the power of the engine without loss of resistance and risk of its damage

-For a model with a notch in the middle of the shank, the highest stress occurs in the place of connection of a head with a connecting rod shaft.

-In the case of the density of the finite element mesh, it is possible to obtain detailed results, but its influence on the prolongation of calculation time concerning the results of the simulation.

-Displacements caused by pressure do not influence a rod shaft work, but in the case of the model with a notch in the middle of the shank, displacements might be caused accelerated use and damage of element.

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