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THE OPTIMIZATION OF CAR ENGINE PISTON-ROD BY NUMERICAL METHOD

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Introduction

During car engine with expanded working volume designing or racing car preparing for a competition, the details of engine usually need to be basically underworked. The aim of underworking – is the light-weighting of moving details (decreasing the weight of rotating and reciprocating masses) and respectively fitting their weight (all pistons and piston-rods must be the same weight) in order to allow engine achieve frequent turnovers with the minimum loses because of friction. Making rotating masses light-weighted allow engine to be more dynamic.

The piston, piston finger and from 25 to 30% weight of piston-rod are related to the reciprocating details. The weight reducing of all these details leads to the fact, that on frequent turnovers the crank piston-rod's inertial force is reducing and as a result decrease the mechanical loses. In this case it's important to equivalent the pistons , piston-fingers and piston-rods' weight, in order to avoid different stresses on crankshaft journals and, therefore, diminish the dynamic burden from torsional vibrations.

The aim of the work is an optimum size ratio selection of simplified piston-rod model, providing the construction volume reducing and, as a result, the masses within allowable stress limits. The algorithm of the optimization was released in finite element package of Ansys software.

Main purpose of the article

Taking into account the connecting rod symmetry only one half of construction is considered.

The geometric model includes lower and upper head in the form of half-rings (Fig. 1, a), connected by the edge with a T3 thickness and a wall with a T4 thickness. Despite of thicknesses T3 and T4 properties, the connecting rod model includes 6 more design properties (the thickness of lower and upper head – Dt1, Dt2, the angles of orientation of the edge — Ug11, Ug21, Dug1, Dug2), which are in optimization process vary in set restriction limits. Letter designations (T, Ug, Dt) are used for parametric programming of the values, which are used in calculation.

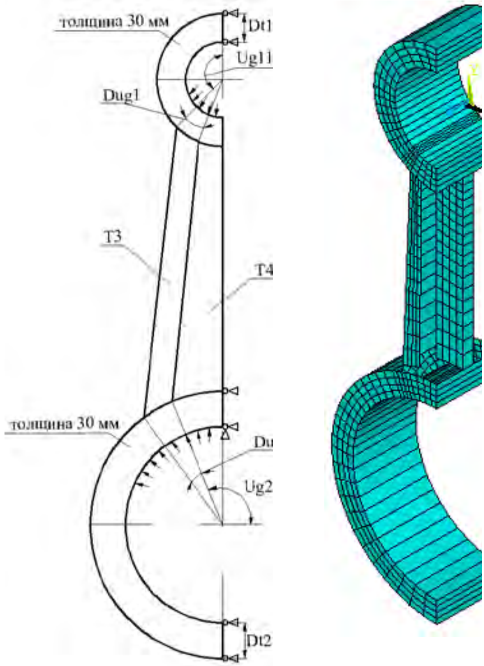

Fig. 1. Calculated scheme and parameters to be optimized (a),
finite element connecting rod model (b)

There is a carried out loading effect on the connecting rod, gone out of the gas tension forces from combustion chamber and crankcase sides, viewed in this work. In order to simplify, it's assumed, that on lower and upper head there is a equable tension of 60 C degrees in bow limits. The tensions, acting on upper head are selected that way so to make the summarized loading equal the summarized force, that's acting on lower head. The mounting of the bundles towards X axis creates the symmetry condition. One of the bundles is mounted towards Y axis in order to compensate small difference in summarized loads, acting on the lower and upper head.

The piston-rod finite-element model consists of 368 elements like Solid45 and 445 bundles. For the calculation it was used a regular scheme of separating into finite elements. The material of the model is a an elastic modulus $E = 2{\cdot}10^5$ MPa and the Poisson's ration μ – 0,28.

After the stress-deformation connection rod model state analysis with given boundary conditions there is its optimization process. The main issue of the optimization in this work is an elastic edge orientation and the thickness of ridges between the edges.

In ANSYS program there are two methods of optimizations: the method of approximation and the first explicit method.

The approximation method – is a method of zero-explicit that provides the effective solving of the majority of design problems. The first-explicit method is based on project sensibility evaluation to certain factors and best fit for solving problems requiring high accuracy. [1]. In this case, the best results were given by first-explicit method.

In the Ansys program texts, written on the parametric programming language APDL, set limits on construction parameters and the variable state. [2] As a variable state it was used an equivalent stress, corresponding Huber-Mises criterion. The minimizing object variable was the weight of the structure.

As a result of done optimizations the program displays a message box with a number of best parameters set. In the presented work the convergence was reach at 5 iterations. The equivalent stresses increased from 140 MPa до 157 MPa that is actually located in allowable limits. The changing of the connection rod dimensions after the optimization are shown in the table.

Table. - Optimized parameters' values

Parameter of optimization	Before the optimization	After the optimization	Parameter changings
Piston-rod volume, mm^3	69597,8	59018,9	Decreasing on 15,2 %
Thickness of the edge, mm	20	17,6	Decreasing on 12 %
Thickness of the wall, mm	5	4,82	Decreasing on 3,6 %
Thickness of upper head, mm	10	8,9	Decreasing on 11%
Thickness of lower head, mm	10	10,1	Increasing on 1 %

Results

Summing up the results of the study we can conclude the following:

-Currently the geometric parts' shape of crank piston- rod group is usually chosen by using common recommendations, which don't consider the working condition of definite detail and requirements, addressed to it;

-The light weighting of rotating masses allow engine to reach high turnovers faster;

-The using of modern software systems reduces time and financial costs for manufacturing or modification of one or another detail of automobile engine;

-The proposed approach allows to optimize the details of automobile engines with absolutely different complexity shape, that makes new possibilities for designing, meanwhile the shape of the part is determined sourcing from ensuring it's best performance.

Summary

In this work it's performed how the selection of optimum size ratio of car engine piston-rod simplified model was done, in order to reduce the volume of construction with the acceptable values of tensions. The conducted research has shown that rational designing using modern software systems reduces time as well as physical and financial expenses for manufacturing or modification this or that motor-car engine detail.

References

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