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THE NUMERICAL CALCULATION MODULE FOR PISTON RINGS

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Abstract

The piston with piston rings and bearing surface is a self-contained and highly complex tribological system. One of the most widespread global friction pairs traversed by reciprocating a pair of ring - cylinder liner piston - rings - cylinder internal combustion engine. Group PRS combustion engine is the solution generating considerable friction. Various researchers estimate the share of friction losses, per node piston rings - cylinder liner, at 19 to 60% of the total friction losses in the combustion engine. This paper describes part of a larger program to reduce wear the set working parts (piston, piston ring and bearing surface). The project is implemented through the development of new designs of piston rings with anti-wear coating that contains synthetic diamond in the form of loose embedded in a coating of chromium (PRS). The aim of the authors was to present the methodology used to compute characterized by a particular procedure. In practical use FEM software is used and the FVM. Developed and implemented Piston Rings Calculation Module is compatible with the idea of numerical computational methods is to say: functionally consists in carrying out a calculation of the desire to achieve the exact solution (the nearest is real) by conducting and receiving intermediate solutions (the next).

Keywords: *tribology, piston ring, bearing surface, simulation, combustion engines*

1. Introduction

This paper describes part of a larger program to reduce wear the set working parts (piston, piston ring and bearing surface). The project is implemented through the development of new designs of piston rings with anti-wear coating that contains synthetic diamond in the form of loose embedded in a coating of chromium (PRS). The main purpose of coating is to reduce ring wear while maintaining or reducing wear cylinder sleeve. Application for said part of the research is EMD 645 engine. The engine used in this study was manufactured by the Electro-Motive Division of General Motors Corporation (EMD). This engine is available in both naturally aspirated and turbocharged configurations, and in V-8, V-12, V-16, and V-20 configurations.

It is popular for locomotive applications in North America, as well as in marine, industrial and power generation applications. For this program, the EMD 12-645-E engine was chosen because it is commonly found in switcher and road-switcher locomotive applications in North America, in power ranges from 750 kW to 1,500 kW. Roughly, 3,000 of these switcher locomotives are in operation in North America. Fig. 1 shows an EMD GP38-2 road-switcher locomotive, which is equipped with an engine like the one tested in this program.

Specifications for the EMD 12-645-E engine are given in Tab. 1. The EMD 645-E engine is a uniflow-scavenged, two-stroke, direct-injected diesel. Fig. 2 shows a power assembly from the EMD 645-E engine. Fig. 2 shows that the power assembly has four compression rings on the piston crown and two oil control rings at the piston skirt. Prior to INNOTECH testing at UW, the model engine was rebuilt, equipped with a set of commercially available power assemblies, and broken in for 85 hours of operation.

Fig. 1. EMD GP38-2 road-switcher locomotive

Tab. 1. EMD 12-645-E engine specifications [2]

Engine Model EMD 12-645-E	
Cylinders	V-12
Bore	230 mm
Stroke	254 mm
Displacement/cylinder	10.6 dm^3
Compression Ratio	16:1
Power	1,100 kW
BMEP	5.9 bar @ 900 rpm
BSFC @ rated power	254 g/kW-hr
Air Charging	Gear driven roots – blower
Fuel Injection	Cam driven unit – injectors
Crankcase Ventilation	Crankcase fumes are returned into the blower
Engine Condition	About 100 hours break-in upon complete engine overhaul
Emission Certification	EPA Tier 0 – switcher Cycle 2

2. Finite-element simulation

Finite element as such is a simple geometric shape - flat or spatial, for which are set out special points called nodes, and certain functions of interpolation, called functions shape. The nodes are located at the vertices of the finite element may also be placed against its sides; this is called the higher order components. If the nodes are only the vertices of the finite element is called a linear component or element of the first row. The Government of the element is always equal to the rank shape function, while the number of functions in a single component shape corresponds to the number of its nodes [2, 8, 9]. All finite elements and nodes must be numbered, usually seeks to ensure that the numbering will guarantee a minimum bandwidth of non-zero coefficients matrix of equations [2, 8, 9]. FEM concept assumes that any quantity, for example, stress or strain described by a continuous function, approximated discrete model. Discrete model is composed of a set of continuous functions defined in a finite number of subdivisions called elements, to which divided the region [2, 8, 9].

Fig. 2. EMD 645-E power assembly [2]

Individual continuous functions of the subdivisions are determined by the value of the primary functions of a finite number of points called nodes. To obtain a discrete model should therefore:

- distinguish a finite number of nodes,
- nodes to determine physical quantities, subject to approximation – such as stress or displacement,
- divide the area in question on a finite number of elements:
  - approximate size of the physical elements using polynomial approximation, for example, ranks, or strings. [1]. Now that the finite element method is used widely, there are many types and kinds of finite elements. In order to determine the type of finite element makes the following basic criteria characterizing featured item: [2, 8, 9]
  - dimension of the element: one-dimensional – 1D, two-dimensional – 2D, three-dimensional – 3D,
  - geometric shape,
  - the degree and type of shape function adopted,
  - number of nodes in the element,
  - constraints imposed on the item. [2, 8, 9].

Due to the size of finite elements can be divided into one-dimensional, two-dimensional and three-dimensional, exemplary diagrams of data elements are presented below [2, 8, 9]. Of the three-dimensional elements, which describe the three-dimensional space, we can distinguish volume elements such as TETRA, PENTA, HEXA, and elements axially - symmetrical. Due to the geometrical shape can distinguish the following finite elements [2, 8, 9].

In some cases, the mapping area of the curved lines uses elements with curved contours – isoparametric elements. For ease of description of the geometry of the curved elements is transformed to the geometry of the core. We can distinguish 3 classes of curved elements:

- isoparametric,
- super parametric,
- sub parametric, 8, 9].

By constraints imposed on the finite element meant to receive the possibility of movements in different directions points that belong to this element. The element arises field strains and stresses. In the space generally occurs 6 degrees of freedom, while the number of degrees of freedom of the finite element is presented below [2, 8, 9].

- rod elements 2D and 3D {ux, uy, uz},
- Beam Elements 2D and 3D {ux, uy, uz, αx, αy, αz,},
- membrane elements {ux, uy},
- disc elements {ux, uy, αz},
- plate elements {u, αx, αy} or {u, αx, αy, αxy}
- coating elements {ux, uy, uz, αx, αy, αz,},
- volume elements {ux, uy, uz} [1].

During the execution of the task No. 1 titled Strength calculations band of piston rings during the period from 01.06.2014 to 31.08.2014 works were carried out in order to calculate the state of stress in the piston rings whose method of implementation and the scope can be reduced to:

1. Develop calculation module piston rings (Fig. 3).
2. Carry out calculations for the three engines of the Rings: EMD 645, I0470, according S359 of Computing Module Piston Rings.

Developed and implemented Piston Rings Calculation Module is compatible with the idea of numerical computational methods is to say: functionally consists in carrying out a calculation of the desire to achieve the exact solution (the nearest is real) by conducting and receiving intermediate solutions (the next). Shown in Fig. 3, a block diagram of a computing unit piston ring contains the names of the functionality of each of the stages in the quest to achieve the final effect, which is to define the geometry and material of piston rings. Presented a block diagram of computing unit piston rings (Fig. 4) has a sub-module implemented in the rump. 2 pt.: „load calculation in the model assembly TPC combustion engines using the MES“. Said sub-module is marked in red and will be described in the task no. 2.

Spreadsheet – Data input at this stage, collected all available data measurement in the piston ring grooves and measurements of the diameters of cylinders, as well as data on the materials from which the consortium member FPT „Prima“ SA can make piston rings. Then made estimates based on empirical formulas and pre-defined geometry and material of piston rings. The pre-processor – Construction geometry at this stage been set in the previous step geometry w / w rings. The construction geometry was carried out in the pre-processor to the program Ansys CFD, construction geometry was based on coordinates of points then combined their curves, which were spread on surfaces which were then sealed in volume and given boundary condition „solid“. Geometric correct – at this stage was inspected by checking whether the geometry of the virtual rings is located in annular grooves of the pistons. Pre-processor – Discretization computing space, at this stage in the software Ansys CFD made discretization or the distribution of geometry into a finite number of elements, choosing cubic higher-order elements (Fig. 4).

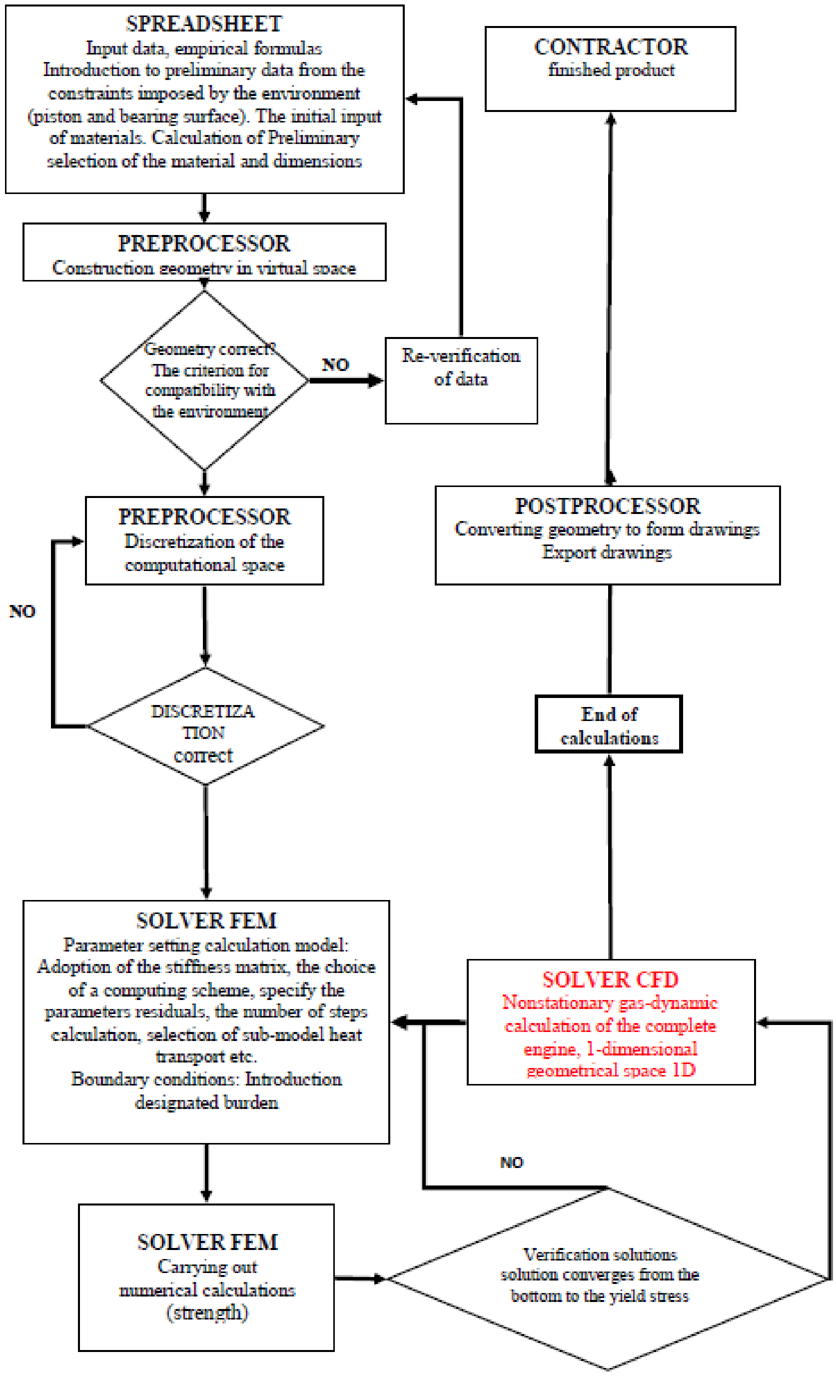

Fig. 3. A block diagram of the computing unit of piston rings

Discretization correct – at this stage was made to verify the quality of discrete area of scanning all the elements of the criterion: volume differences, differences in diagonals, differences in lengths of the sides. SOLVER FEM – Abaqus, at this stage, carried out all the necessary steps to build a numerical model of the above / in the system; adoption of stiffness matrix, the choice of a computing scheme, specify the parameters of convergence, the number of steps calculation, selection of sub-model heat transport etc. One of the most important things was the introduction of boundary conditions through proper task force vector. Verification solution – at this stage completed the task of receiving the first targets as a result of stress in the rings under two conditions of load: compression (Fig. 5) and stretching (Fig. 6) for each of the rings. After the analysis for each of the rings to give the results. In Fig. 5 and 6) has been included distribution of stresses and displacements for the individual rings.

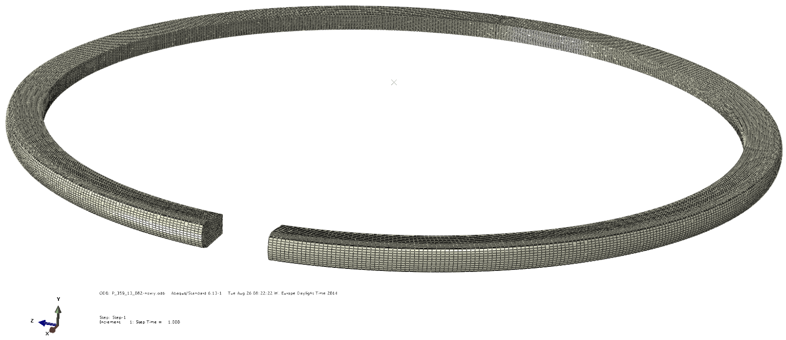

Fig. 4. The discreet form a ring geometry of an exemplary EMD 645E - mesh FEM

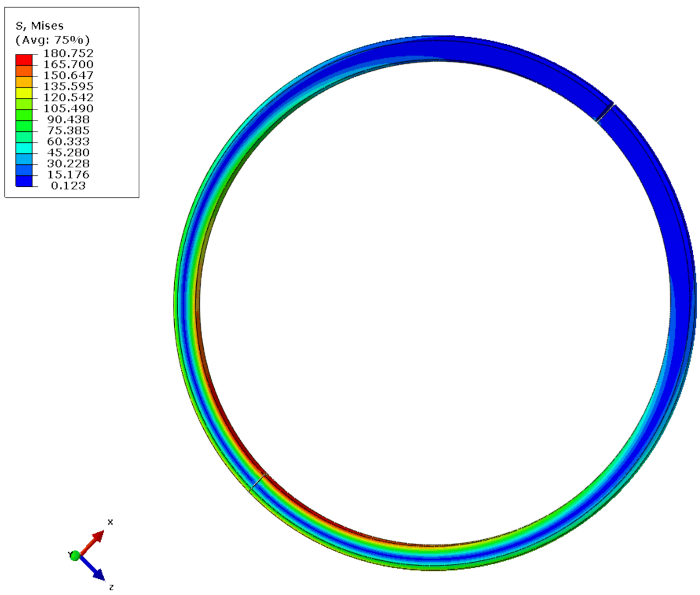

Fig. 5. View of the state of stress in the compression ring engine EMD645

The state in which the rings are shown in the figures k = 1.2 for the material. Noticeable is the accuracy of the highest stresses experienced during assembly („expansion“ of the ring) are found in the most remote from the slot assembly, a similar tendency appears in the case of compression to close the lock.

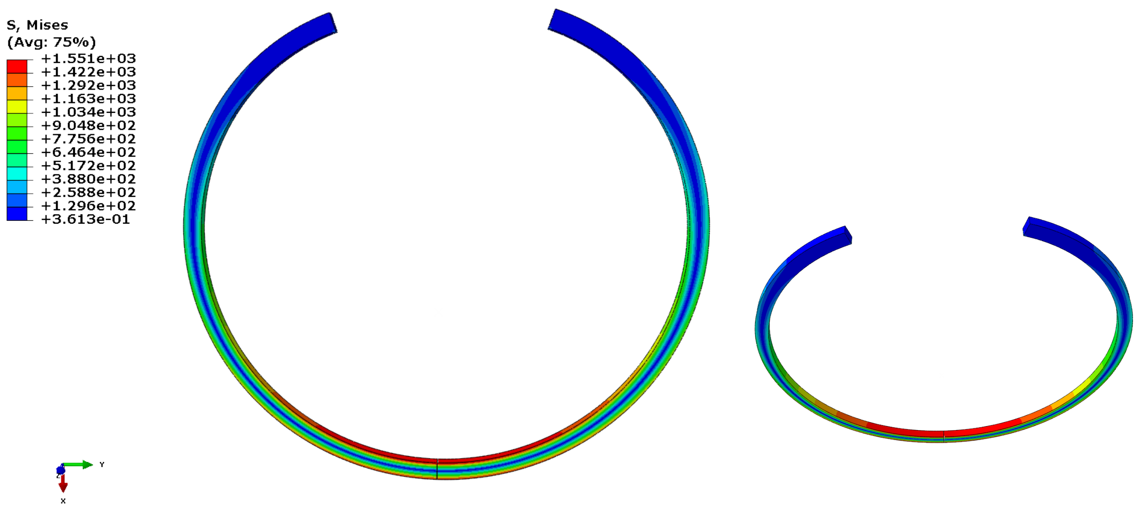

Fig. 6. View of the state of stress in the tension ring exemplary engine EMD 645E

3. Conclusion

In conclusion obtained maxima strain ring, which comes to maximum stress. On this basis it was concluded that the rings meet designed in terms of strength required Formed during both compression and installation pistons.

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