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MATHEMATICAL STUDY OF CYLINDRICAL-PISTON WEAR GROUPS BY THE METHOD OF BOUNDARY ELEMENTS

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Referring to American companies such as CRISS, VICON MARIO, WABCO and TEREX, which pay more attention to rationally improving the traction of heavy-duty dump trucks than to increasing the specific power of the engine by reducing friction in the cylindrical-piston group, I chose a topic that coincides with the program "Tacis" in the study of this area.

Tacis is a program developed by the European Union for the New Independent States and Mongolia to accelerate the development of harmonious and mutually beneficial economic and political ties between the European Union and these countries.

In 1995, within the framework of the Tacis program, it was decided to take global actions in the energy sector of Ukraine aimed at conserving energy.

In 1996, fuel consumption in Ukraine amounted to about 6.4 million tons of oil equivalent. This figure could increase 2.5 times and reach a value of approximately 16 million tons in 2010, if the forecasts of energy consumers are confirmed. Thus, moving to a free market economy, Ukraine needs to overcome additional economic difficulties caused by significant additional energy costs to the detriment of the trade balance.

Therefore, Ukraine has begun reforms in the energy sector, based on: the application of a pricing policy that reflects the true cost of energy; adoption of the Law on Energy Conservation in 1994; creation of the State Committee for Energy Conservation.

In addition, a project was launched in April 1996 under the Tacis program: the development of measures to improve fuel efficiency in the motor vehicle sector. It aims to assist the Ukrainian government in developing an appropriate framework for the implementation of energy saving actions targeted at commercial transport collective enterprises and private owners cars.

One of the areas of efficient fuel use is to improve the design of the engine, ie reduce the cost of friction in the cylindrical-piston group. It is known that the costs of friction in the cylindrical-piston group make up most of the other costs of the internal combustion engine. This is due to significant mechanical and thermal loads. It should also be borne in mind that the pistons moving in a straight line in the cylinders are subjected to alternating loads, which lead to wear of both cylinders and pistons in longitudinal and cross section. This indicates that the piston and cylinder of the internal combustion engine has an ovality and taper. The ovality of the cylinder is observed when during operation it is subjected to significant transverse forces that press the piston to the mirror of the cylinder. As a rule, the ovality occurs along the axis perpendicular to the axis of the piston pin.

Applying a mathematical model using the method of boundary elements, I developed a program (Appendix A), which I used to determine the stress-strain state of the elements of the cylindrical-piston group.

The program for the two-dimensional method of fictitious loads was transformed from Fortran to Turbo Pascal. The calculations were performed in five steps:

1. Determining the location of the positions of all boundary elements and the task for each of them boundary conditions in displacements or stresses.
2. Calculation of limiting coefficients of influence and construction of the corresponding system of linear equations taking into account boundary conditions on each element.
3. Solving a system of equations.
4. Calculation of displacements and stresses on each boundary element.
5. Calculation of coefficients of influence for the points set in the considered area and calculation of displacement and stresses in these points.

Construction of calculation schemes. Description of boundary contours. All boundary contours are approximated by rectilinear segments adjacent to each other. Each boundary segment (or part of a segment) is divided by NUM under segments - boundary elements. The locations of the elements are specified by specifying the coordinates x, at the start (XBEG, YBEG) and end (XEND, YEND) points of the segment, as well as the value of NUM (NUM $\geq$ 1). Based on this data, the program automatically calculates the coordinates of the centers, lengths and orientations of the boundary elements.

The number of boundary segments is denoted by NUMBS. The program involves the use of no more than 50 limit elements. In general, the best results are obtained when all boundary elements have approximately the same length.

When setting the coordinates x, at the ends of the boundary segment it is necessary to take into account the rule of bypassing the boundary; a closed loop is bypassed counterclockwise if the area under consideration lies outside the circuit, and clockwise if the area under consideration lies inside the circuit.

Field points are given within the considered area of the point, ie points not on the boundary in which the displacements and stresses are calculated. Field points that are equidistant from each other along a straight line are specified by specifying the coordinates x, at the beginning of XBEG, YBEG and the end of XEND, YEND of this line, as well as the number of intermediate points NUMPB along the line. The number of rectilinear segments used to specify fieldpoint locations is denoted as NUMOS. The program does not contain any restrictions on the number of NUMOS, and therefore the number of field points is arbitrary. At the same time, the program is designed so that it skips field points lying at distances less than the length of one element from the center of the boundary element, because at such distances the calculated results are inaccurate.

If there are symmetry conditions in the problem under consideration, then the amount of input data required for this problem can be reduced. To set the symmetry conditions, the KSYM parameter is used, which is determined based on the following conditions:

- KSYM = 1 means that the conditions of symmetry are absent or not imposed;
- KSYM = 2 means that the line x = XSYM, parallel to the x-axis, serves as the axis of symmetry;
- KSYM = 3 means that the line y = YSYM, parallel to the y-axis, serves as the axis of symmetry;
- KSYM = 4 means that both lines x = XSYM i y = YSYM serve as axes of symmetry.

If the problem has one axis of symmetry KSYM = 2 or KSYM = 3, the boundary elements should be defined only for half of the boundary contour; symmetrically arranged reflected elements are generated and taken into account in the program automatically according to the procedure described in the program. Similarly, if the problem has two symmetry axes KSYM = 4, the elements should be defined only for the quarter contour.

The program has two limitations associated with the location of boundary elements in problems with symmetry: boundary elements can not lie along the line of symmetry and can not cross it. For example, if one end of an element lies on a line of symmetry, then the other must lie outside that line. Field points, however, can be selected along the line of symmetry.

The program allows you to work with any sequential system of units, such as in the SI system. The input values for the limit displacements, if any, must be given in the same units used to specify the coordinates of the points, and the input values of the boundary stresses and initial stresses, if any, are given in the same units in which the Young's modulus is given. The calculated values of displacements and stresses will then have the appropriate units.

The program is built in such a way that all the necessary input data is entered through a text data file or directly into the specified line of the program. Data file "DATAN. txt "is created using any text editor capable of saving the file in the format" *. txt ». One line of the file should contain only one value of the source data. The data are entered in the following order:

1. In line "118" of the program it is necessary to set the following control parameters:

- NUMBS - the number of rectilinear boundary segments, each of which contains at least one boundary element used to define boundary contours;

- NUMOS - the number of other segments, not on the boundary, along which the displacements and stresses are calculated:

1 - symmetry conditions do not overlap,

2 - x = XSYM serves as an axis of symmetry,

3 - y = YSYM serves as an axis of symmetry,

4 - x = XSYM i y = YSYM serve as axes of symmetry.

2. At the beginning of the program it is necessary to set the elastic constants in line "5" and the position of the axes of symmetry, if any, line "118".

• PR - Poisson's ratio,

• E is the Young's modulus,

• XSYM - position of the axis of symmetry, parallel to the x-axis, XSYM is ignored if KSYM = 1 or 3;

• YSYM - the position of the axis of symmetry, the parallel axis y, YSYM is ignored if KSYM = 1 or 2.

3. In line "118" of the program it is necessary to set the initial voltages, if any, in the considered area. PXX = σxx, PYY = σyy, PXY = σxy.

4. Specified in the data file "DATAN. txt »information characterizing the problem under consideration (problem name), position and boundary conditions on boundary elements, positions of internal points, areas in which displacements and stresses are calculated:

• NUM - the number of evenly spaced boundary elements along a straight line segment; all elements within the segment must have the same boundary conditions,

• XBEG - coordinate x of the beginning of the segment;

• YBEG - coordinate at the beginning of the segment;

• XEND - coordinate x of the end of the segment;

• YEND - coordinate at the end of the segment;

KODE=
1 - if specified σ_s i σ_n ,
2 - if specified u_s i u_n ,
3 - if specified u_s i σ_n ,
4 - if specified σ_s i u_n ,

• BVS - total tangential stress σ_s or tangential offset u_s,

• BVN - full normal voltage σ_n or normal offset u_n.

The input of this data is repeated cyclically to describe the boundary conditions of all elements of NUMBS rectilinear segments.

The positions of the inner points of the region in which the displacements and stresses are calculated characterize the parameters:

• NUMPB - the number of equidistant points between the specified first and last points.

• XBEG - coordinate x of the first point on the line;

• YBEG - coordinate at the first point on the line;

• XEND - coordinate x of the last point on the line;

• YEND - coordinate at the last point on the line;

The data is entered until the entire number of NUMOS segments along which the displacements and stresses are calculated is described.

The program contains the main program and three subroutines. The main program controls all input and output operations, and also contains logical operations necessary to determine the position of the boundary element, build a system of algebraic equations and calculate unknown boundary parameters, displacements or forces, as well as displacements and stresses at all internal points through components of dummy loads. all boundary elements.

The calculations of the displacement and stress factors for the limit fi of the internal field points are implemented in the COEFF subroutine, and the results are used in the main program. The INITL subroutine is used at the beginning of these calculations in cases where the symmetry conditions are taken into account, so that the imaginary boundary elements are generated within the program. Operations with imaginary elements occur by sequentially referring to the COEFF subroutine after the appropriate determination of coordinates and orientation of imaginary elements. The SOLVE subroutine solves a system of algebraic equations built in the main program. The solution procedure is based on the Gaussian exclusion method without selecting the leading element.

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