DETERMINE FORCES ACTING ON BEARING AND VEHICLE SUSPENSION SYSTEMS

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Abstract: *the article analyzes the forces that arise in the carriage and suspension by the example of a motorcycle. There is the determination of forces that arise in the carriage and suspension in the early stages of design. The algorithm is proposed to be used to determine the forces. This algorithm is based on the program writing in the programming language Python. Input data for the determination of forces are geometric dimensions of a vehicle, weight of a vehicle, characteristics of a ground and a driving mode of a vehicle.*
Keywords: *suspension, carrying system, carriage system, determination of forces, motorcycle, Python 2.7.*

ОПРЕДЕЛЕНИЕ СИЛ В УЗЛАХ НЕСУЩИХ СИСТЕМ И НАПРАВЛЯЮЩЕГО УСТРОЙСТВА ПОДВЕСКИ ТРАНСПОРТНЫХ СРЕДСТВ

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Аннотация: *в статье анализируются реакции в узлах конструкций несущих систем и направляющего устройства подвески на примере мотоцикла. Рассматривается метод определения реакций в узлах конструкций несущих систем и направляющего устройства подвески на ранних этапах проектирования. Для определения реакции предлагается воспользоваться алгоритмом, на основе которого в качестве примера написана программа на языке программирования Python. Исходными данными для определения являются геометрические размеры транспортного средства, масса транспортного средства, характеристики опорной поверхности и режима движения транспортного средства.*
Ключевые слова: *подвеска, несущая система, несущая система, определение сил, мотоцикл, Python 2.7.*

Arising in the carriage and suspension forces, geometric dimensions and weights of elements or the entire vehicle must be determined for making the strength test of vehicle and selecting the section that will be arisen by these forces. The strength calculation can be made only after these actions.

In the initial stages of the design of vehicles, we face the problem with lacking of information to select the section for making design calculations.

Approximate geometric dimensions, places of fastening parts of the vehicle and the characteristic points with the suspension are known in their initial design but it does not allow making full calculations.

The existing methods of calculation were based on the CAD / CAE-systems that require a high power of the computing machinery, a large amount of input data (for example, 3D model), the ability of creating the correct constructions of 3D models and making the CAE calculations. However, it takes a lot of time.

The way of solving the problem is using the program writing in the programming language Python [1].This program helps to determine the force that arise in the carriage and suspension.

This program includes the algorithm for determine the forces from the elements of the carriage by solving a system of linear equations.

This is the following information that needs to be known for making the program:

- Geometric dimensions of a vehicle, carriage and suspension;
- Mass of a vehicle or of all elements of a vehicle;

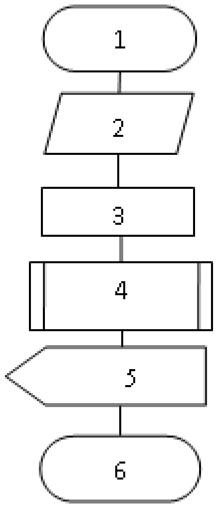

Fig. 1. The block diagram of the program

- Characteristics of support surface and a running mode of vehicle [2].

Figure 1 (the block diagram of the program): 1. Beginning of the program; 2. Task matrix coefficient; 3. Solution of the system of linear equations; 4. Set results into database; 5. Output results to the screen; 6. The end of the program.

First, the initial data is entered into the program. There is the wheelbase, the wheel track, the position of the center of gravity, the traction coefficient, the place of application of a force from elements of the mechanism and vehicle components, the running mode.

Further, the system under consideration is divided into groups. At this time the forces and mass moments of elements of vehicle are applied to the groups and forces between groups of elements are exchanged by reactions. All of these groups have special points. These are checkpoints that help to state static equations.

$$\sum \boldsymbol{M_o} = 0$$
$$\sum X_o = 0$$
$$\sum Y_o = 0$$

After determining static equations, all known forces are taken in the opposite side of equations.

The matrix system of reactions must have the same number of equations as variables, that is, the coefficient matrix of the system must be square. Otherwise the system will generate an error [1, c. 36]. The coefficients of the system of linear equations are standing before the reactions. If there are no reactions the matrix coefficients of these are zero.

The matrix coefficients of the unknowns will take this form: $\mathrm{x_1} \quad \dots \quad \dots \quad \mathrm{x_n}$

$$M(a) = \begin{pmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \dots & \boldsymbol{a_{in}} \\ \boldsymbol{a_{12}} & \boldsymbol{a_{12}} & \dots\boldsymbol{a_{(i+1)n}} \\ \dots & \dots & \dots & \dots \end{pmatrix} \begin{matrix} 1. \sum X_o = 0 \\ \dots\dots\dots\dots \\ n. \sum \boldsymbol{M_i} = 0 \end{matrix}$$

Matrix with known values will take the form:

$$\mathrm{M(b)} = (\mathbf{b_1} \quad \dots \quad \mathbf{b_n})$$

Each value in the matrix M(b) contains all of the known values of the equation.

The decision matrix is produced at the end of its creation.

$$\mathrm{M_x} = \mathrm{M(a)} \cdot \mathrm{M(b)}$$

Guide to Linear Algebra is used for the decision matrix.

The resulting values will take the form:

$$M_x = (\boldsymbol{x_1} \quad \dots \quad \boldsymbol{x_n})$$

The result is displayed by using the exit instruction.

The result of equation solving is the values of forces that are acting on the structure under consideration.

For the determination of forces that arise in carriage and suspension systems of motorcycle this example of program was created that is writen in the programming language Python.

The carriage and suspension systems are divided into groups. There is a general group (Fig. 2), a steering shaft (Fig. 3), the carriage (Fig. 4), powertrains (Fig. 5) and a suspension arm (Fig. 6). The relationships between these groups replace reactions. The equilibrium equations are written for each group. The forces between groups of elements are exchanged by reactions. The balance equations for each group are written below.

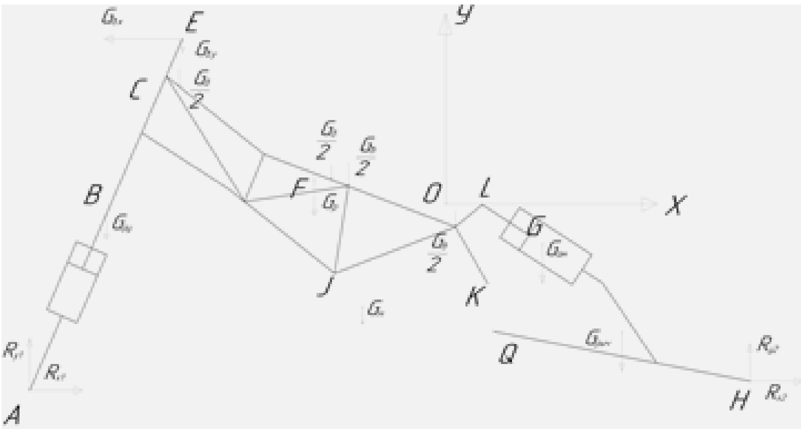

Fig. 2. The general group

There are balance equations for the general group:

$$-r_{x1}\cdot l_{rx1}+r_{y1}\cdot l_{ry1}-r_{x2}\cdot sin11^{\circ}\cdot l_{rx2}-r_{y2}\cdot cos11^{\circ}\cdot l_{ry2}=$$
$$=G_{py}\cdot hG_{py1}+G_{vn}\cdot sin15^{\circ}\cdot hG_{vx1}+G_{vn}\cdot cos15^{\circ}\cdot hG_{vn1}+G_{b}\cdot 0.5\cdot hG_{bn1}+G_{b}\cdot 0.5\cdot hG_{b31}+G_{vp}\cdot 0.5$$
$$\cdot hG_{vn1}-G_{vp}\cdot 0.5\cdot hG_{v31}+G_{m}\cdot hG_{m1}+G_{p}\cdot hG_{p1}-G_{am}\cdot hG_{am1}-G_{pich}\cdot hG_{pich1}$$
$$r_{x1}-r_{x2}=G_{vn}\cdot sin15^{\circ}$$

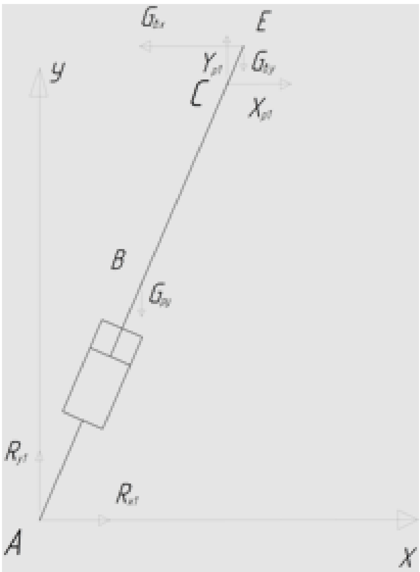

Fig. 3. The steering shaft

$r_{y1}\cdot sin15^{\circ}+y_{p1}=G_{vn}\cdot cos15^{\circ}r_{y1}+r_{y2}=G_{py}+G_{vn}\cdot cos15^{\circ}+G_{b}+G_{p}+G_{vp}+G_{m}+G_{am}+G_{pich}$

There are balance equations for the steering shaft:

$$x_{p1}\cdot l_{xp1}-y_{p1}\cdot l_{yp1}=G_{vn}\cdot sin15^{\circ}\cdot hG_{vx}+G_{vn}\cdot cos15^{\circ}\cdot hG_{vy}-G_{py}\cdot hG_{py}$$

$r_{x1}\cdot cos15^{\circ}-x_{p1}=G_{vn}\cdot sin15^{\circ}$

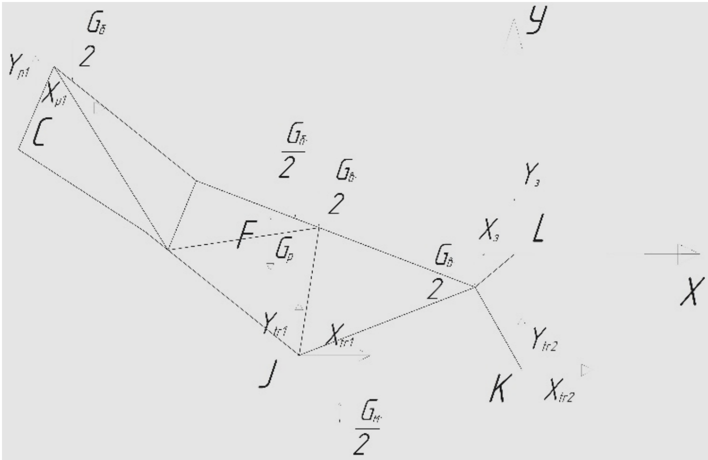

Fig. 4. The carriage

There are balance equations for the carriage:

$$x_{p1} \cdot l_{x1} - x_{tr1} \cdot l_{xt1} - x_{tr2} \cdot l_{xt2} + y_{p1} \cdot l_{y1} + y_{tr1} \cdot l_{yt1} - y_{tr2} \cdot l_{yt2} =$$
$$= G_b \cdot 0.5 \cdot hG_{bn} + G_b \cdot 0.5 \cdot hG_{b з} + G_{vp} \cdot 0.5 \cdot hG_{vn} + G_{vp} \cdot 0.5 \cdot hG_{v3} +$$
$$+ G_m \cdot hG_m + G_p \cdot hG_{p1}$$
$$x_{p1} + x_{tr1} + x_{tr2} + x_3 \cdot sin30° = 0$$
$$y_{p1} + y_{tr1} + y_{tr2} + y_3 \cdot cos30° = G_m + G_p + G_b + G_{vp}$$

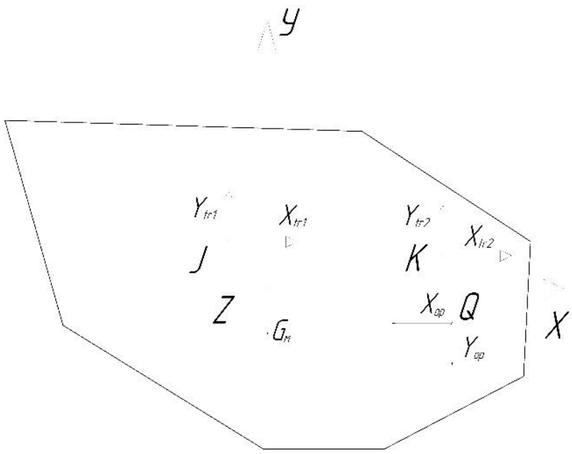

Fig. 5. Powertrains

There are balance equations for powertrains:

$$x_{tr1} + x_{tr2} + x_{op} = 0$$
$$y_{tr1} + y_{tr2} - y_{op} = G_m$$

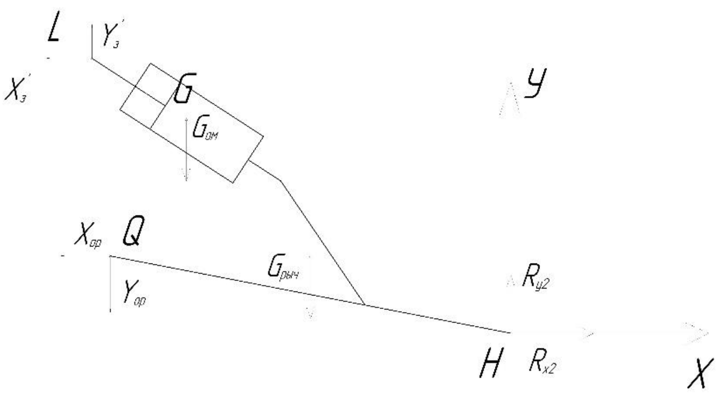

Fig. 6. The suspension arm

There are balance equations for the suspension arm:

$$-x_3 \cdot sin30° \cdot l_{x3} + y_3 \cdot cos30° \cdot l_{y3} - y_{op} \cdot l_{yop} - x_{op} \cdot l_{xop} =$$
$$= G_{am} \cdot hG_{am} - G_{pich} \cdot hG_{pich}$$
$$-x_{op} - x_3 \cdot sin30° + r_{x2} \cdot sin11° = 0$$
$$y_3 \cdot cos30° + r_{y2} \cdot cos11° - y_{op} = G_{am} + G_{pic□}$$

All the known forces are taken in the opposite side of the equations.

Summary

The result is displayed in the form of a matrix with the values of reaction forces, which are then used for the selection of a bearing and suspension systems. According to the obtained values the most loaded seat are determined and tested.

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