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University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

SOFTWARE FOR COMPUTING THE FORCE TRANSFER RATIO

Ion GROZAV, Tünde NICOLI

Abstract: *In the paper is presented software that helps the designer to compute the force transfer ratio of a clamping mechanism, especially in the case of the workholding. For the calculus of the force transfer ratio was used an original method named Force Separation Method (FSM). This method is simple, precise and gives the possibility to observe easy the reserve of the auto-blocking and auto-braking of the clamping mechanism. There are presented the cases of planar clamping mechanisms with n = 3 or n = 4 contact points. In the case n = 3 are included wedge, lever and circular eccentric like amplifying elements. The paper includes also a planar model for computing the screw force transfer ratio. In the case n = 4 was included the plunger.*

Key words: *software, force transfer ratio, clamping mechanism, workholding, design.*

1. INTRODUCTION

The clamping mechanism of the workholding has some tasks to do. One important of them is to acting upon the workpiece with the right clamping force. For this is important the force transfer ratio sometimes named the transfer function. Acting upon clamping mechanism with a force, it will amplify the force and this will be applied upon workpiece like a clamping force. The workpiece was positioned in the workholding by the positioning mechanism and by clamping force this position will be keep and during the manufacturing process.
Usually the entrance force in the clamping mechanism is: manual actuating, pneumatic, hydraulic, electromagnetic actuating, etc. During the manufacturing process upon workpiece will act process forces that can modify the workpiece position, so will appear the manufacturing errors. To keep right position must applied certain clamping force. For increasing the entrance force of the clamping mechanism will be used some amplifying elements. Sometimes the clamping mechanisms include only one amplifying element, case when the computing of the force transfer ratio is a little easier [1, 2, 4, 5]. When the force transfer ratio is not sufficient then will be use more amplifying elements. In these cases the amplifying elements will be put in cascade (series).

There are many methods to compute the force transfer ratio. Some of them are rough or laborious. More precise and easy to applied are Moment Separation Method [3, 4, 5] and Force Separation Method (FSM) [1, 2]. The last one will be used in this paper. This method can compute precise the force transfer ratio if the friction coefficients are rightfully estimated.

2. THE CALCULUS OF THE FORCE TRANSFER RATIO

This method can be applied at planar clamping mechanism, case when every amplifying element can be moved in plan, having three degree of freedom. Two degree of freedom will be taken by the contact of element with the body of the clamping mechanism and the last degree of freedom will be raisable by the static equilibrium of the element upon which will act two forces, called principal forces [1, 2].

In Fig. 1 is presented the general case of an amplifying element with n = 4 contact points and 4 forces acting upon it, the principal forces R_1, R_2 and the secondary forces R_3, R_4.

The FSM separate the principal forces, which are using for calculate the force transfer ratio, from the secondary forces that appear like reaction forces at the contact with the mechanism body.

Principal force transfer ratio of the amplifying element is [2, 1]:

$$i_{Rp} = \frac{R_2}{R_1} = \frac{\sin\varphi_1}{\sin\varphi_2}. \qquad (1)$$

In the same manner can be finding the secondary transfer ratio:

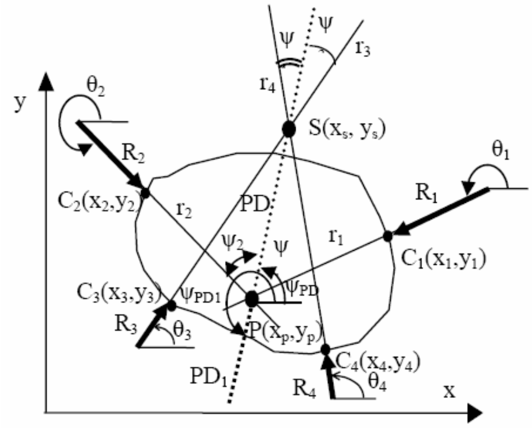

Fig. 1. Force Separation Method (FSM).

$$i_{Rs} = \frac{R_4}{R_3} = \frac{\sin \varphi_3}{\sin \varphi_4} . \qquad (2)$$

Using these relations has been made software for computing the force transfer ratio. For do this is necessary to introduce the initial data. The designer has to introduce the number of the forces that acting upon the amplifying element, coordinates of the amplifying element contact points with the adjacent bodies and the fiction coefficients in the contact points.

There are three force amplifying elements categories. They are different according with the number of the contact points n, respectively with the number of the forces that acting upon the element. The categories are:

- force amplifying elements with $n = 4$ contact points and 4 forces that acting upon the element, two principal forces R_1 and R_2, respectively two secondary forces R_3 and R_4;
- force amplifying elements with $n = 3$ contact points and 3 forces that acting upon the element, two principal forces R_1 and R_2, respectively one secondary forces R_3;
- force amplifying elements with $n = 2$ contact points and 2 forces that acting upon the element, two principal forces R_1 and R_2.

For the case $n = 2$ is not necessary to compute force transfer ratio because in this case it will be equal with one. These elements are using only for transmitting the forces or for changing the direction of the forces, not for amplifying them.

This software was made only for planar clamping elements with $n = 3$, respectively $n = 4$ contact points.

In the first stage of the software the designer has to introduce the number of the contact points in a form like in Fig. 2. It brings in focus that only three and four contact point is admissible.

If it was introduced $n = 3$, the next stage is to select one of the cases with $n = 3$ contact points for computing force transfer ratio. The designer must pick on a selecting button from the form presented in Fig 3.

Fig. 2. Number of contact points.

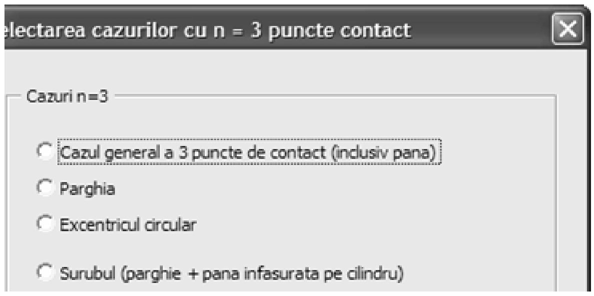

Fig. 3. Selecting the case n =3.

In the general cases of the amplifying elements with three contact points are include the wedge like amplifying element.

In these cases must be given the coordinates of the principal contact points C_1 and C_2, the direction of the normal forces (α_i angles) in all the contact points, the friction coefficients μ_i in all contact points and the directions of the friction forces that appear due to relative movement in the contact points. The sense of the friction force will generate the increase or decrease the angle of the resultant forces R_i ($i = 1, 2, 3$).

The increase of the R_i angle will be take by choosing the sense + (plus) for friction force, respective – (minus) for decrease of the R_i angle, how it is presented in Fig. 4.

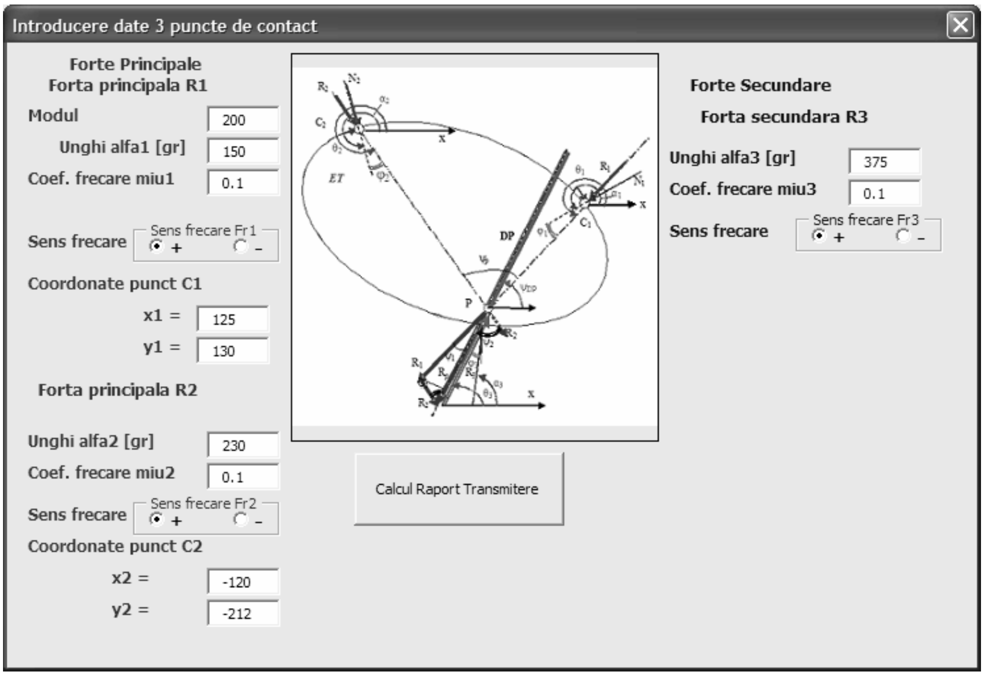

Fig.4. Input data for the case n =3.

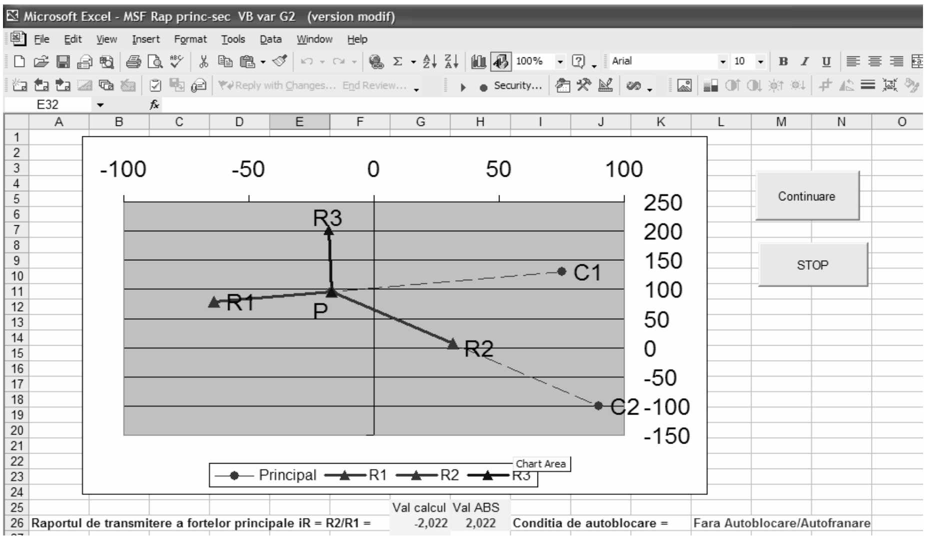

Fig. 5. Graphical representation of the resulting forces.

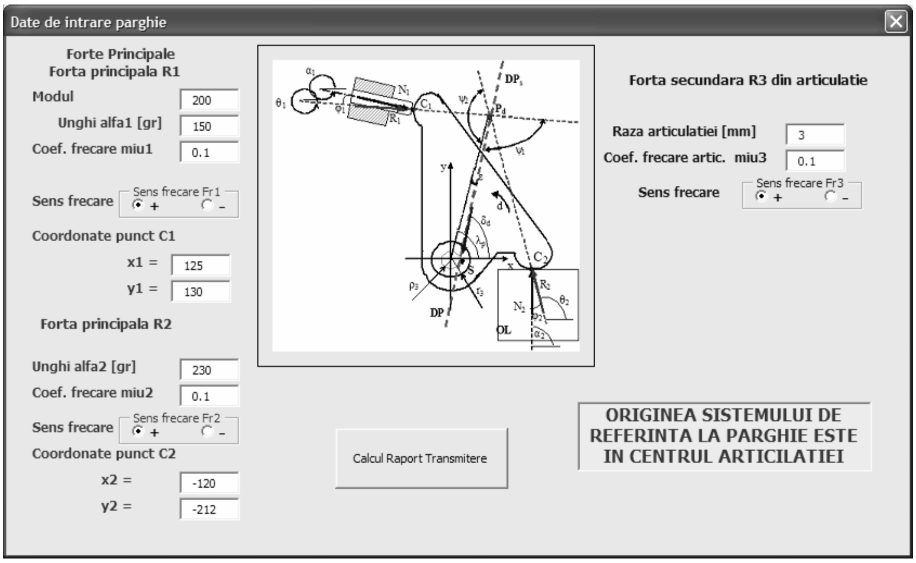

Fig.6. Input data for lever.

By selecting the button „Calcul Raport Transmitere" will be calculate the force transfer ratio, called sometimes and transfer function, according with relation (1) [2, 1]. The result of the calculus is presented in Fig. 5. In this figure can observe that secondary force R_3 is between the principal forces R_1 and R_2. These positions of the forces are desired in the clamping action to avoid the self-blocking of the amplifying element. In the case of unclamping the element will not have self-braking. The self-blocking always must be avoided in the construction of clamping mechanism. The self-braking is desired for the clamping mechanism. The self-braking assures to keep the output force (clamping force) even the input force doesn't act. This property for keeping the clamping force is very good in the case of manual acting of the clamping mechanism, when after clamping the operator stop the action of the input force. For the other drives the self-braking is an assurance in the case of drive fall.

How much the angle ψ_1, between R_3 and R_1, is greater and the angle ψ_2, between R_3 and R_2, is smaller so the force transfer ratio will be greater and there is a great amplification of the element.

The compute force transfer ratio is presented in Fig. 5. The negative value of the force transfer ratio show the absence of the self-blocking in the clamping action, respectively of the self-braking in the unclamping action. The graphical representation of the forces gives the possibility to see the reserve of the self-blocking / self-braking. This is very useful for the designer because is well know that the estimation of the friction coefficients are doing with some approximations. This approximation, in the critical domains, will make to have some undesired effects like self-blocking of the clamping mechanism or absence of the self-braking. The form with final results (Fig. 5) has a command button for continuing the computing in other cases of amplifying elements, and the other one for stopping the calculus. By selecting the command button "Continuare" the form (Fig. 2) for selecting the number of the contact points will appear. In this form can be written number 3 and by selecting the command button "Start" will appear the form from Fig. 3. By selecting the optional button of lever will appear the form for input data in lever case, like in Fig. 6.

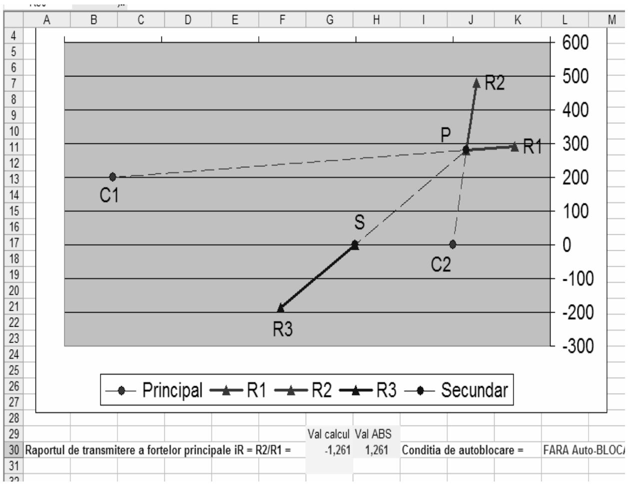

Fig.7. The results for lever.

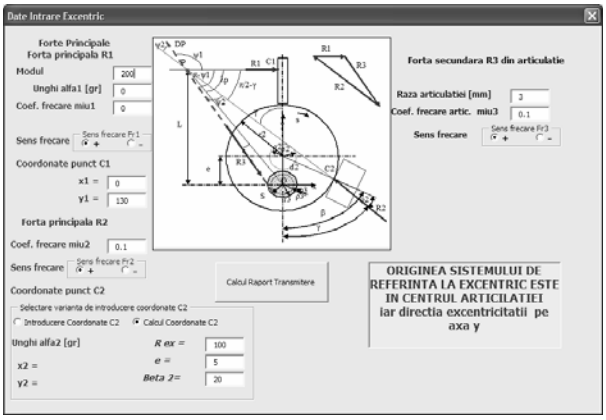

Fig. 8. Input data for circular eccentric.

In the lever case the origin of the reference system must be in the center of the cylindrical articulation. The rule for input data are the same like was presented previous.

The designer has to judge the friction forces sense in the contact points and to select the friction signs + (plus) or – (minus) according with the previous rule. By selecting the button „Calcul Raport Transmitere” will be calculate the force transfer ratio. The results are presented in Fig. 7. In the previous form, by selecting the command button “Continuare”, inputting the number 3 in the form (Fig. 2) and selecting the case of the circular eccentric in the next form (Fig. 3), will appear the form for input data in this case. The input data form is presented in Fig. 8. The data for circular eccentric will be input similar like in the case of the lever. Supplementary in this case there is the option for computing the coordinates of the principal contact point (output contact point) C_2. The designer can introduce himself the C_2 coordinates by selecting the optional button “Introducere coordonate C_2”, or to input other characteristics of the circular eccentric and will be compute the C_2 coordinates. For doing that the designer must select the optional button “Calcul coordonate C_2” (see Fig. 8).

The results of the computing in the unclamping case of the eccentric are presented in Fig. 9. In this figure can be seen that the force transfer ratio is positive and so there is the self-braking. More, in Fig. 9 the secondary force R_3 is outside of the minimal angle between R_1 and R_2, which show the same that existence of the self-braking. The existence of self-braking shows that the eccentricity has been chosen properly for the eccentric.

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The screw is a combination of wedge with lever. The wedge is wound on a cylinder (see Fig. 10). The screw is not a planar amplifying element. Has been made a new planar model of the forces which acting upon the screw for applying the Force Separation Method. In this model there is an inconvenient, the friction force, which appear upon the screw end, has been consider that is acting on the medium radius of the screw thread. This approach makes that compute force transfer ratio to be a little smaller than in reality. This thing is like an assurance factor, the clamping force created with the screw being greater. For using the software in the case of the screw will be selected the case $n = 3$ (see. Fig.2), then will be selected the screw case (see. Fig.3). In the next form presented in Fig. 10 will be input the data for screw.

By selecting the button „Compute Transfer Ratio” will be calculate the force transfer ratio for the screw. The results of the calculus are presented in Fig. 11. In the same Fig. are presented and the force transfer ratio compute with a relation that take in account the real friction radius for the screw end.

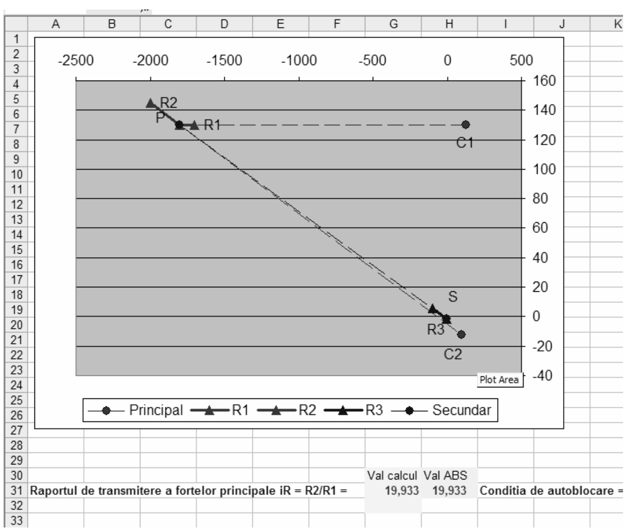

Fig. 9. The results for circular eccentric.

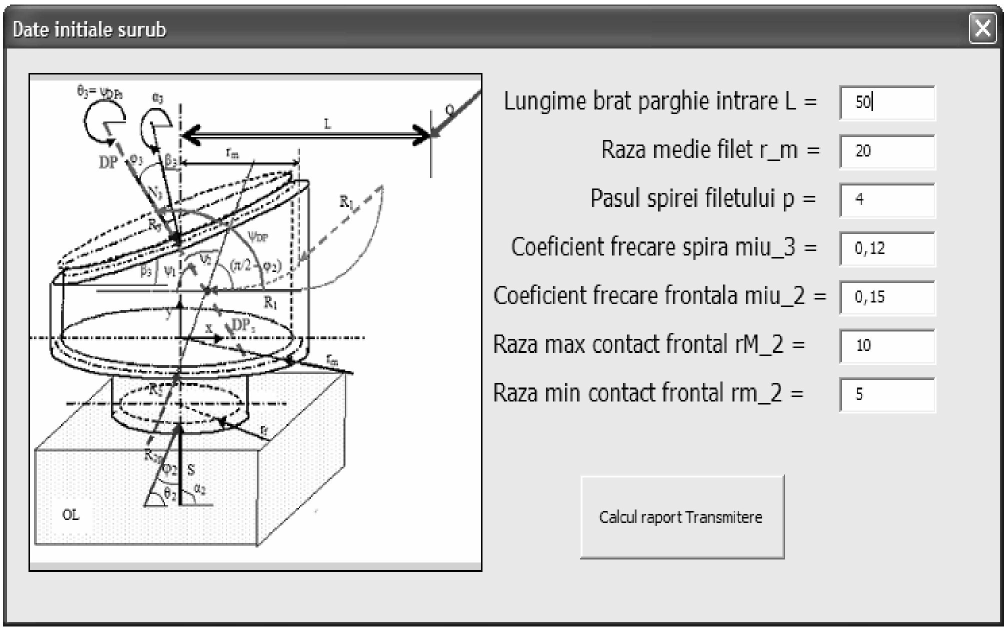

Fig.10. Input data for screw force transfer ratio.

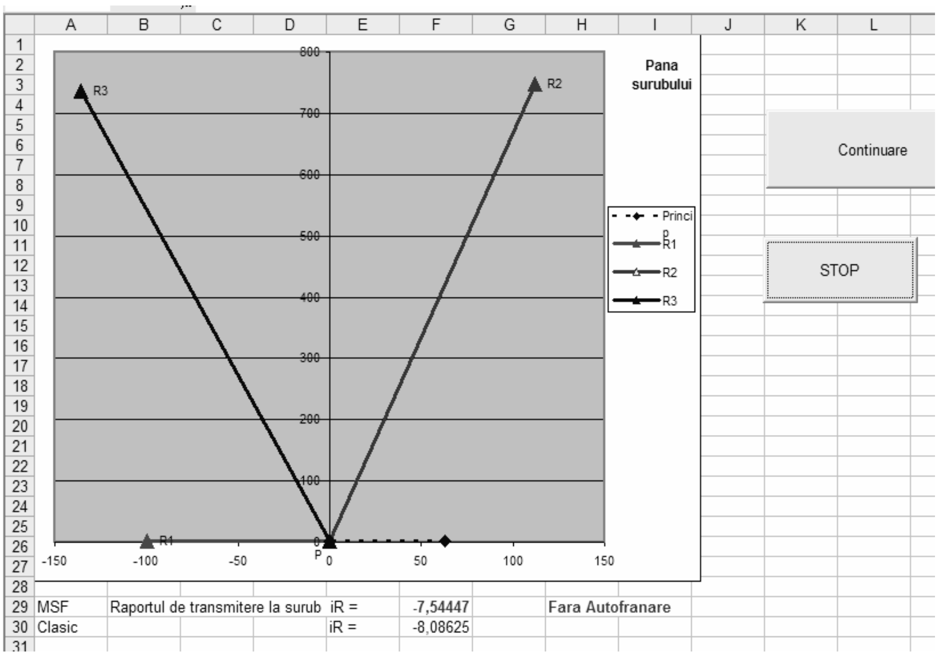

Fig.11. The force transfer ratio for screw.

The software can compute the force transfer ratio for the amplifying elements with 4 contact points (see Fig. 2). By writing number 4 in text box will appear the form for input data in that case, like in Fig. 12. The input data is similar like in the case $n = 3$.

The results of the computing are presented in Fig. 13. In this case can be compute and the force transfer ratio for the secondary forces (see Fig.13).

3. CONCLUSIONS

In the design activity is important to know the real value of the force transfer ratio for clamping mechanism. So is possible to apply the desired clamping force and will be avoid the clamping forces greater that are necessary for a properly positioning. To big forces will generate to great elastically and contact deformations. These deformations will have a negative influence upon the position of the worpiece during the manufacturing process and so will appear the manufacturing errors. A quick computation of the force transfer ratio will help the designer to find the best solutions for clamping mechanism of workholdings.

In the design activity of the clamping mechanism is important to know the reserve of the self-blocking of the mechanism to avoid the situations when the clamping mechanism not running in the clamping direction.

In unclamping direction many times are desired the self-braking for keeping the clamping force even than the input force not acting. In theses cases is important to know the reserve of the self-braking. Using the presented software is easy to know all the data above mention.

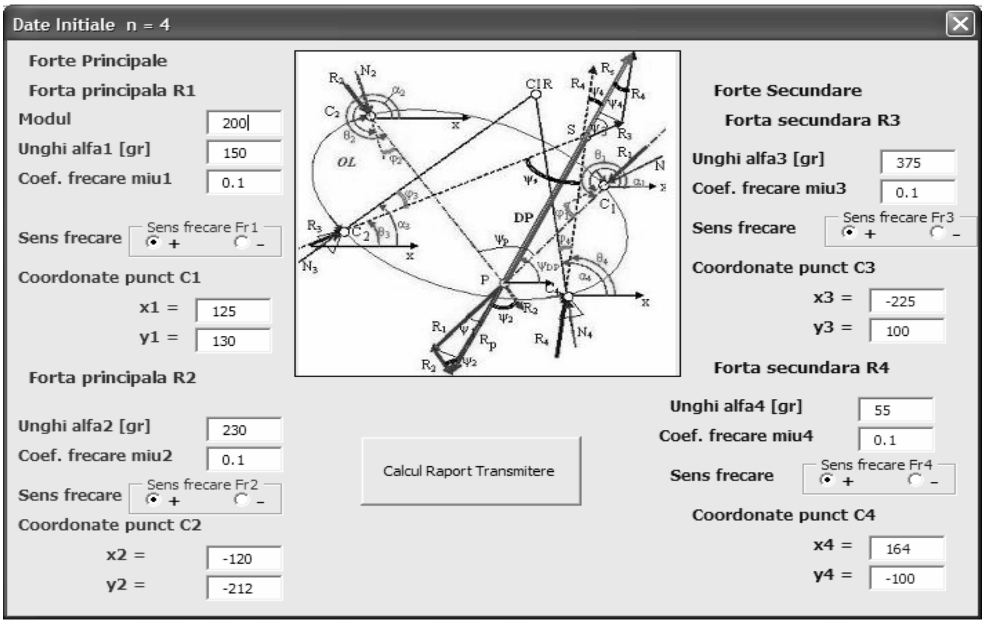

Fig.12. Input data for *n* = 4 contact points.

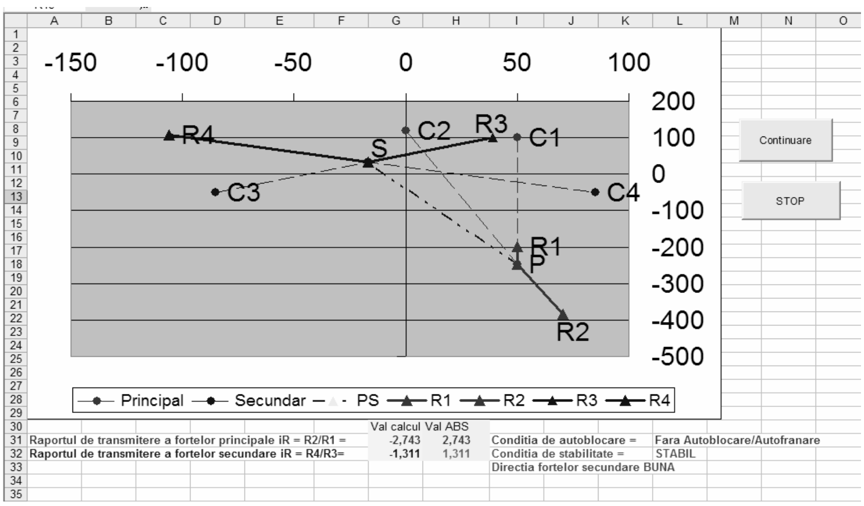

Fig.13. The results for the case *n* = 4 contact points.

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Authors:

Dr. Eng., Ion GROZAV, Associate Prof., POLITEHNICA University of Timisoara, Material Engineering and Manufacturing Department,
E-mail: igrozav@eng.upt.ro.
Eng., Tünde NICOLI, Prof. Gr. 1, Scholar Group ELECTROTIMIS-Timişoara, Mechanical Department,
E-mail: nicolitu@gmail.com.