ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2012
Seria: TRANSPORT z. 76 Nr kol. 1865

Alzbeta SAPIETOVA[1], Vladimir DEKYS[2], Martin BUDINSKY[3]

UTILIZING OF SENSITIVITY ANALYSIS IN PREPARATION OF OPTIMIZING PROCEDURE

Summary. Speed and efficiency of an optimizing algorithm can be a function of used number of variables. Before optimization of dosing mechanism parameters, sensitivity analysis was performed. Choice of the design variables was the output from this analysis. The article deals with this analysis and interpretation of its results.
Keywords. Sensitivity analysis, optimization, structural parameters, contact force.

WYKORZYSTANIE ANALIZY WRAŻLIWOŚCI W PRZYGOTOWANIU PROCESU OPTYMALIZACJI

Streszczenie. Szybkość i efektywność algorytmów optymalizacyjnych mogą być funkcjami zastosowanej liczby zmiennych. Przed optymalizacją parametrów mechanizmu dozującego została przeprowadzona analiza wrażliwości, której efektem był dobór proponowanych zmiennych. Artykuł jest poświęcony tej analizie oraz interpretacji jej wyników.
Słowa kluczowe. Analiza wrażliwości, optymalizacja, zmienne konstrukcyjne, siła styczna.

1. INTRODUCTION

A correct choice of the optimizing variables significantly affects the speed and effectiveness of the solution. We start from the fact, that not all of the optimizing variables have the same influence on selected objective functions. The goal of the article is to present sensitivity analyses which will exclude optimizing variables with lower influence and point out to parameters which will serve as design variables in subsequent optimizing analysis.

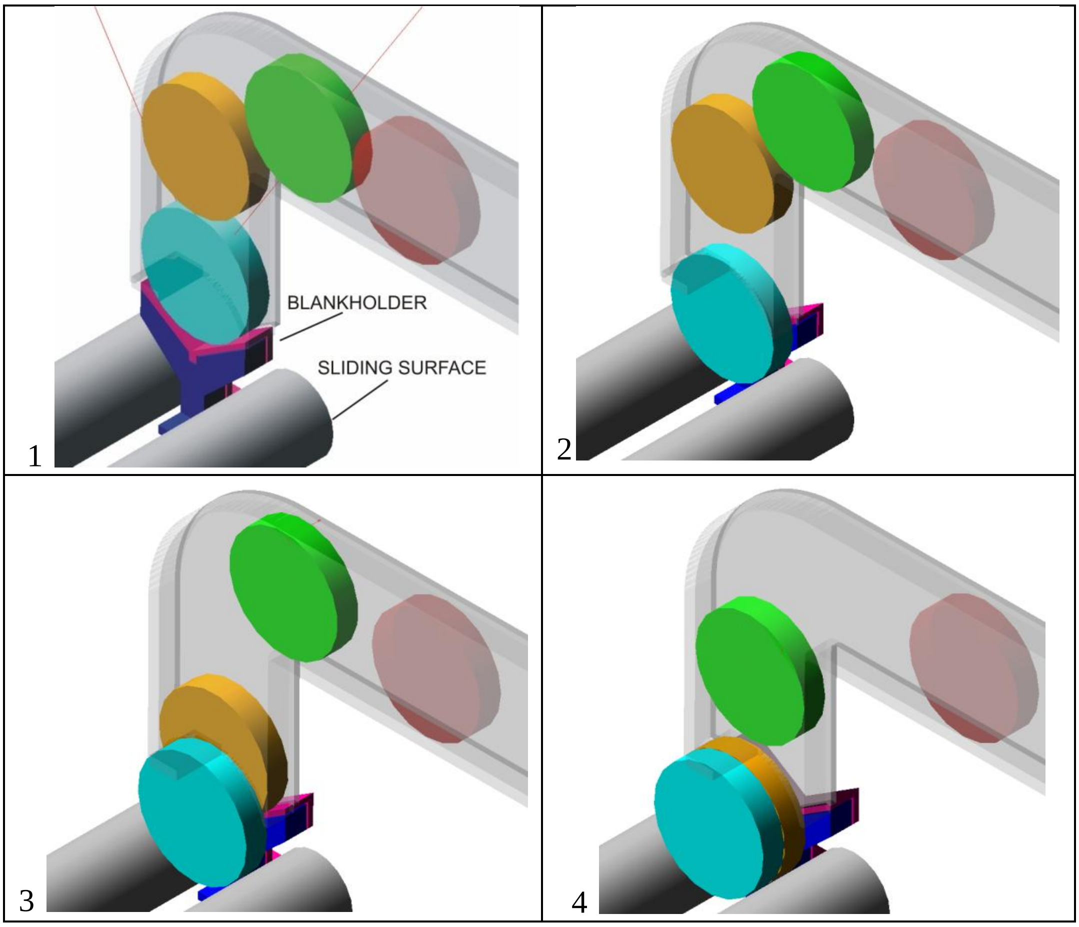
Sensitivity analyses are performed on a virtual prototype (VP) of dosing mechanism for cylindrical components (CC) in environment of ADAMS/View - program for multi-body dynamics.

By performed *Design study* sensitivity analysis the change of one variable on one objective function is verified. Simulation was controlled by a simulation script which has ensured refining of the solution step at the impact of CC on the blankholder and this script controls an accurate calculating of the reaction.

[1,2,3] Faculty of Mechanical Engineering, Zilinska univerzita v Ziline, Zilina, Slovak Republic, e-mail: alzbeta.sapietova@fstroj.uniza.sk, vladimir.dekys@fstroj.uniza.sk, martin.budinsky@fstroj.uniza.sk

2. VIRTUAL PROTOTYPE OF DOSING MECHANISM FOR CYLINDRICAL COMPONENTS

Fig. 1 shows the VP of the dosing mechanism for CC in particular phases of the working cycle. In Fig. 1.1 the cylindrical components are passing through the trench and impacting on the blankholder. In Fig. 1.2 the blankholder is pushing out from under the components which will impact on the sliding surface. In Fig. 3 the blankholder is going back into its initial position and by that shifting the blue component. Then the yellow component will impact on the blankholder. In Fig. 1.4 the blankholder is returning back. The yellow CC falls behind the blue one and the green one will impact on the blankholder. This procedure repeats as many times as how many CCs are required in a dose.



Rys. 1. Pompa wolumetryczna dozownika elementów cylindrowych
Fig. 1. VP of the dosing mechanism for cylindrical components

At the impact of a CC on the blankholder the contact forces arise, especially at higher weights. These forces have negative effect on a CC and device of the machine. The goal is to minimize magnitudes of these contact forces by constructional modifications of the selected parameters.

3. REACTION FORCES UNDER STATIC LOADING

A conveyed CC in proposed mechanism impacts on the blankholder and sliding surface so that it is in contact with them on two surfaces. For that reason this state is analyzed in term of a static loading before the dynamic sensitivity analyses will be performed.

In Fig. 2 free body diagram of CC in contact surface of the carrier is illustrated. Fig. 3 shows the dependence of the reaction forces R_A, R_B in the blankholder on α angle. The blue curve ($R_A = R_B$) denotes the dependence without considering friction forces T_A, T_B and the purple (R_A) and green (R_B) curves denote the dependence with considering friction.

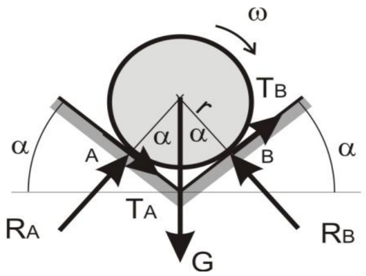


Fig. 2. Free body diagram of cylindrical component in V-shaped contact surface
Rys. 2. Uwolniony element cylindrowy w przestrzeni ładunkowej o kształcie V

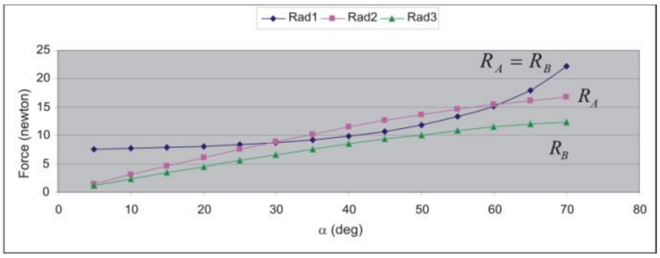


Fig. 3. The dependence between the angle α and the reaction forces
Rys. 3. Zależność między kątem α a efektami reakcji

In the analytical solution in term of static loading (Fig. 2 and 3) we have found that contact surface of the carrier will have the shape of "V" if we want to ensure a stable placing of a CC in the carrier. The static analysis shows that when increasing the value of the angle α, the reaction forces also increase (Fig. 3).

4. REACTION FORCES UNDER DYNAMIC LOADING

In this chapter an influence of the selected structural parameters on the contact forces at the impact of CC on the blankholder in term of dynamic loading is presented. If bodies are in contact when modeling the VP, the function CONTACT allows you to create or modify it in the environment of ADAMS/View. Under *interrupted (impulse) contact*s coming in many short time intervals, the ADAMS/Solver makes an estimation of the contact forces by modeling an evolution of local deformation. Energy decrements during the collision are represented by the damping force with corresponding damping coefficient or coefficient of restitution [1].

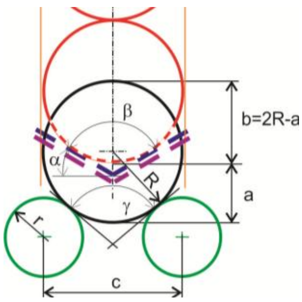


Fig. 4. Structural parameters α, a and c
Rys. 4. Zmienne konstrukcyjne α, a oraz c

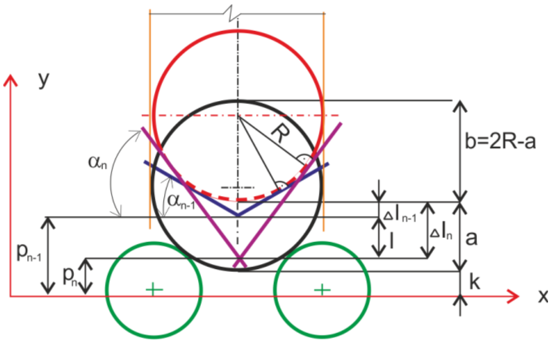


Fig. 5. Parameters of the analysis
Rys. 5. Parametry obliczenia

The Fig.4 illustrates the structural parameters which have an influence on magnitudes of the contact forces:

— blankholder angle α, which is a function of the angle β: $\alpha = (180 - \beta)/2$.

— position of the blankholder a, which can change in the range of the diameter of CC ($2R$).

— distance between the contact surfaces of the sliding surface c, which is a function of the angle γ.

4.1. Sensitivity analysis of the change of the blankholder angle

If we want to know the influence only of the angle α on the reaction forces, a CC must fall from a constant height. In analyses of the change of the blankholder angle we will position the blankholder so that the absolute coordinate of CC $a+k$ will be constant. The parameter k is random. This implies that if change the angle α, we have to shift the blankholder about a value of l, relations (1), (2) and Fig. 5, which is:

- displacement of the n-th position against the previous (n-1) th position - relatively,

$$l = \frac{R}{\cos\alpha_n} - \frac{R}{\cos\alpha_{n-1}}, \qquad \alpha_n > \alpha_{n-1}, \tag{1}$$

- or the n-th displacement always against the selected constant origin ((n-1)-th position) - absolutely

$$l = \frac{R}{\cos\alpha_n} - R, \quad ak \quad \alpha_{n-1} = 0, \tag{2}$$

where the position of the blankholder a (Fig. 3)

$$a = p_n - k + \Delta l_n, \tag{3}$$

and the parameter
$$\Delta l_n = \frac{R}{\cos\alpha} - R. \tag{4}$$

For the verification of the relations (1) and (2) a simulation with equal values of the blankholder angle and angle of the sliding surface, i.e. $\alpha = \gamma$, and with $a = R$ was performed. Fig. 6 illustrates the results of the simulation, in which the parameters change in terms of the above mentioned relations. Values of the contact forces are equal. This confirms the propriety of the mentioned relations. Analysis was performed for a CC with diameter of 30 mm.

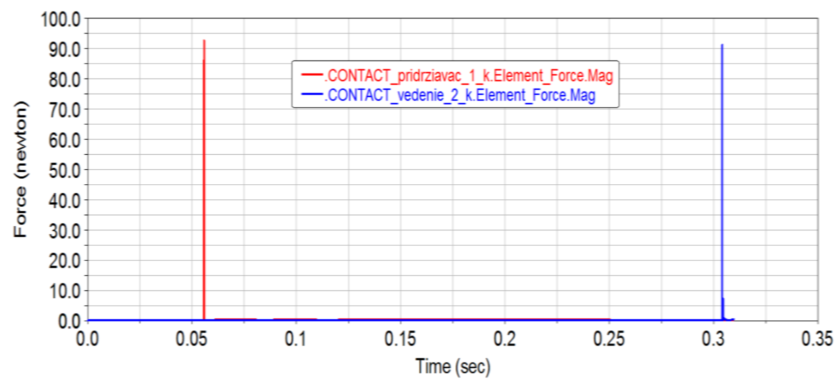
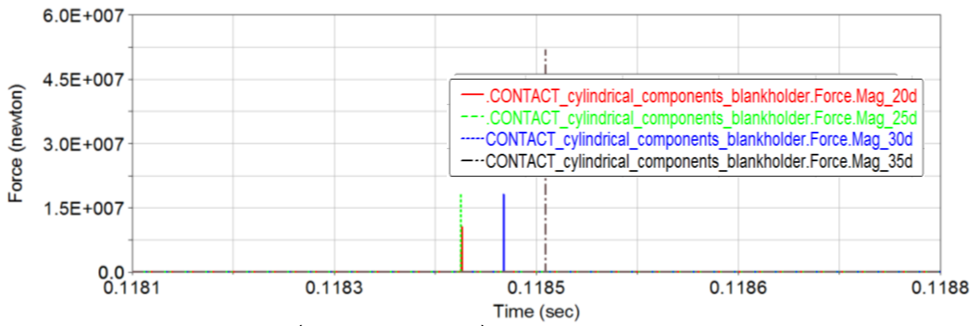


Fig. 6. Contact forces on the blankholder and the sliding surface
Rys. 6. Siły styczne na uchwycie a przewody

Sensitivity analysis of the influence of magnitude of the contact force on the blankholder angle was realized for a CC with diameter of 120 mm. Results in Fig. 7 confirms the fact resulting from the static analysis, that when increasing the value of the angle α, the reaction forces also increase.



Rys. 7. Analiza sił stycznych, $\alpha \in \{35, 30, 25, 20\}$deg oraz $a = R$

Fig. 7. Analysis of the contact forces, $\alpha \in \{35, 30, 25, 20\}$deg and $a = R$

4.2. Sensitivity analysis of the blankholder position

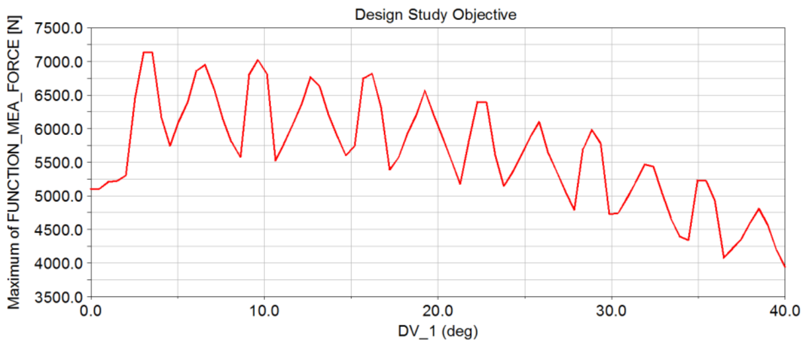


Fig.8. Change of the contact force depending on the height of the impact

Rys. 8. Zmiana siły stycznej w zależności od wysokości wpływu

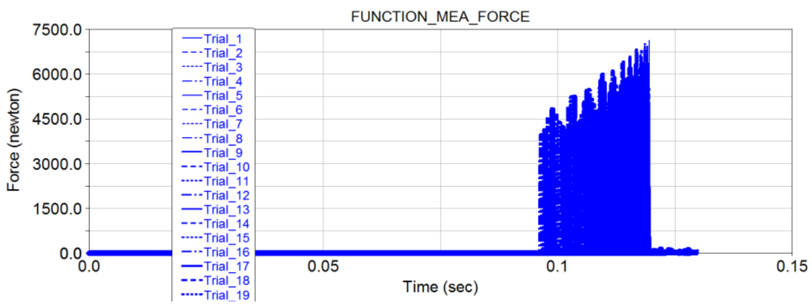


Fig. 9. Magnitude of the contact force depending on the height of the impact

Rys. 9. Wielkość siły stycznej j w zależności od wysokości wpływu

When changing only the degree α (without changing the blankholder position), height of the impact of CC on the blankholder changes (Fig. 5) too. Figs. 8 and 9 show the results of the measu-rement performed by Design Study method. The angle $\alpha \in \{0,40\}$deg is optimizing variable and reaction force at the impact of CC on the carrier is objective function. This force increases with increasing height of the impact. The measurement shows that height of the impact has non-negligible effect on the reaction force during the elemental ope-ration. Range of the reaction force is from 3900 N to 7100 N.

4.3. Sensitivity analysis of the influence of the distance between the sliding surfaces c.

A dosed CC falls from the carrier and impacts on the sliding surface (Fig. 1). The goal of the following sensitivity analysis is to compare, how the reaction force will form the sliding surface changes by changing the parameter "c" (Fig. 4). Reaction forces were tracked for the values of the parameter c=100, 110, 120, 130 and 140 mm. Contact force increases with increasing value of the parameter "c". The differences between contact forces do not have high influence on the solution, because these differences are negligible in term of

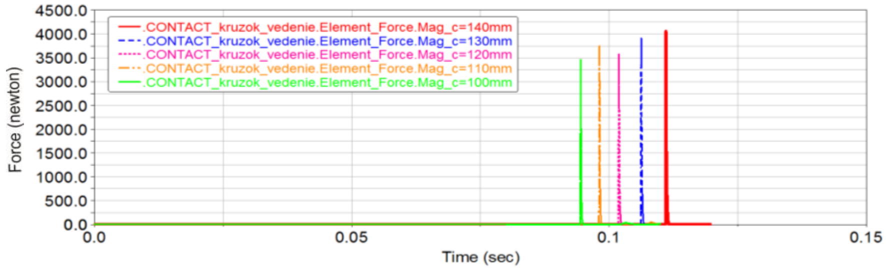


Fig. 10. Analysis of the contact forces depending on the distance between the sliding surfaces

Rys. 10. Analiza sił stycznych w zależności od odległości przewodu

the magnitude of the contact forces. Reaction force values for given inputs lies within the interval of (3541, 4198) N (Fig. 10). The dimension "c" is chose as c=120 mm for the reason of constructional demands (foil winding at packing of CCs) and demands for using the sliding surface for bearings with different bearing numbers.

5. CONCLUSION

Starting from the mentioned sensitivity analyses, the position a and the angle α will serve as optimizing variables for subsequent optimizing analysis. Contact forces on the blankholder and sliding surface will serve as objective function. Optimal values of the structural variables are a function of minimal values of the contact forces. By doing so we try to reduce a loading on a conveyed component, i.e. eliminate its damage. Lower contact forces decrease a noisiness of the device and form the environment which is better for health of workers. The article deals with the issue of selecting optimization variables prior to the optimization solution. Were presented SW modules of the MSC / ADAMS, which supports this approach. The paper belongs to the field of optimization, contact problems, dynamics and mechanics of body which is solved in Department of Applied Mechanics of the University of Zilina [2-5].

Acknowledgments *The work has been supported by the grant project VEGA 1/1000/12 and 1/1259/12.*

Bibliography

1. Palčák F.: Integračné prostredie programu ADAMS. In Informačné listy. ISSN 1212-43892002, 2002, roč.2 , č. 3. s. 17-21, in Slovak.
2. Vaško M., Saga M.: Solution of Mechanical Systems with Uncertainty Parameters using IFEA, Communications-Scientific Letters of the University of Zilina, vol. 11, No. 2, 2009.
3. Zmindak M., Saga M.: Structural Optimization of Trusss Structures for Deterministic and Nondeterministic Lodas Using MATLAB, In: Proceedings of the VII th International Conference on Numerical Methods in Continuum Mechanics, High Tatras, 1998.
4. Jakubovičová L. et all: Contribution to discrete optimising of beam structures subjected to fatigue damage, Transactions of the Universities of Košice, No. 2, 2011, p. 137-142.
5. Sága M. et all: Identification of the hysteretic material model parameters and application on energy fatigue curve, Machine Dynamics Research, Warsaw University of Technology, 2010, p. 79-87.
6. Kaššay P., Homišin J., Grega R., Krajňák J.: Optimization of pneumatic flexible shaft couplings parameters/ 2011. In: Napędy maszyn Transportowych: 8 Naukowo-techniczna konferencja: 17-19 listopada 2011, Ustroń, 2011, p. 1-13.