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ANALYSIS OF SELECTED CONTACT ALGORITHMS TYPES IN TERMS OF THEIR PARAMETERS SELECTION

Robert Panowicz

Military University of Technology them. Jarosław Dąbrowski
Department of Mechanics and Applied Computer Science
Gen. Sylvester Kaliski Street 2, 00 – 908 Warsaw 49, Poland
tel.:+48 22 6837348, fax: +48 22 6839355
e-mail: rpanowicz@wat.edu.pl

Abstract

The analysis of many engineering problems involves not only deformation of the considered system, but occurrence of the interaction between the individual separate elements of the system as well. The occurrence of friction is the most common phenomenon occurring during this interaction. In the case of intense friction, the heat released in this process is also important. In computer methods of mechanics, the process of interaction between bodies is carried out using special algorithms. The most frequently applied are: the penalty method, the barrier method, direct elimination of constraints, the Lagrange multiplier method, the perturbed Lagrangian method, the augmented Lagrangian method, Nitsche method. Owing to its easy implementation process, an approach based on a penalty function is often applied. In this approach, the contact between the bodies can be identified with the presence of the spring between the elements of the bodies in the contact. The stiffness of the spring depends on: material bulk modulus, face area, volume or shell diagonal and a numerically selected scale factor.

The article will present the results of analyses that will allow fast and easy selection of its value. In the analyses there were presented the results considering the basic types of contacts: node to surface, surface to surface and surface to surface mortar.

***Keywords**: finite element method, contact, penalty method*

1. Introduction

Almost every technical engineering or scientific - research issue deals with the contact of separate components of the system under consideration.

Two basic elements can be distinguished in the contact process. The first one is connected with deformation of the interacting bodies. The magnitude of this deformation depends on intensity of an interaction and mechanical properties of materials. The other one is strictly connected with the contact. It depends on physical properties of contacting surfaces and the shape of bodies.

Depending on the properties of the contacting surface, we can distinguish the following physical phenomena that play an important role during the contact:

- friction,
- adhesion,
- heat transfer between interacting bodies,
- heat secretion during friction on the surfaces of interacting objects.

The latter phenomenon can be considered as part of the friction phenomenon. However, it is significant only in selected cases (for example, the phenomenon of interaction between the bricks and the brake disc, friction stir welding [1, 2], high speed machining [3]) therefore it has been included separately. In other cases, it is not considered due to a small influence of heat on the course of the phenomenon.

Each of above mentioned phenomena is described by appropriate mathematical-physical models which reflect their most important characteristics. In computer methods of mechanics, specific, additional algorithms are responsible for implementation of the contact. These algorithms are responsible for detecting the contacting surfaces or their parts (for example, the individual finite elements). They are also responsible for implementation of a numerical model of the physical phenomena occurring during the contact process. A physical – mathematical – numerical algorithm applied to calculate the contact phenomenon should:

- reflect correctly the physical phenomena occurring during contact,
- not limit the stability condition of a calculation scheme and should not affect the time step,
- not cause a significant increase in computation time,
- be able to implement calculations in various configurations of contacting surfaces (surface – surface, line – surface, node – surface, line – line, node – line).

The most commonly used algorithms are: the penalty method [4, 5], the barrier method [6, 7], direct elimination of constraints, the Lagrange multiplier method, the perturbed Lagrangian method, the augmented Lagrangian method, Nitsche method [6, 8].

An approach based on a penalty function is often used owing to its easy implementation process. In this approach, the contact between the bodies can be identified as the presence of the spring between the elements of the contacting bodies (Fig. 1).

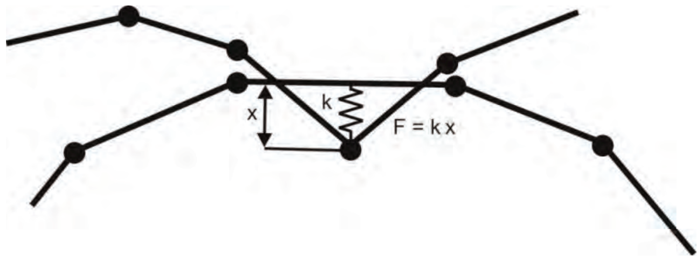

Fig. 1. Contact elements - penalty method; x – penetration, k – penalty terms, F – contact force

The stiffness of the spring depends on: material bulk modulus K, face area A, volume V or shell diagonal and a numerically selected scale factor f [5]:

$$k = f\,\frac{KA^2}{V}\,. \tag{1}$$

The article presents the results of analyses that will allow fast and easy selection of a contact value – scale factor f. In the analyses, there were presented the results considering the basic types of contacts: node to surface, surface to surface and surface to surface mortar.

2. Loads scheme

The simplest analyses of the contact process can be carried out on the basis of loads schemes shown in Fig. 2a.

In the case, shown in Fig. 2a, there are two cuboids A and B. The upper surface of A body is loaded locally with F force while the lower surface of B body is supported pivots bearing. It was assumed that the value of the distributed loads is so small that the two bodies are in the elastic range. The contact was defined between the interacting surfaces.

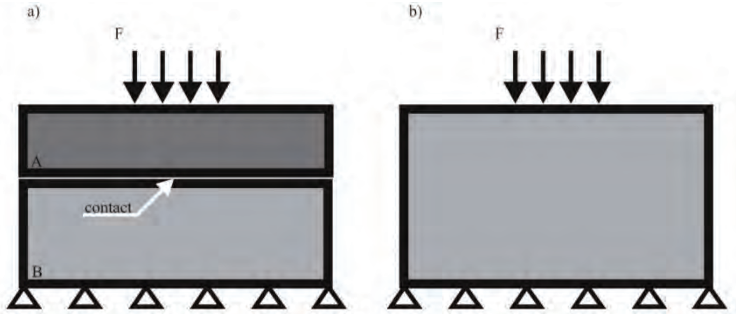

Fig. 2. Loads schemes; A i B – bodies in the contact, F – loads

3. Analysis of results

Both bodies has been described as linearly elastic and characterised with Young modulus E = 207 GPa and Poison ratio v = 0.3, i.e., parameters corresponding to properties of steel. The results of loads corresponding to the first situation (Fig. 2a) will be related to the case of a body (Fig. 2b, 3).

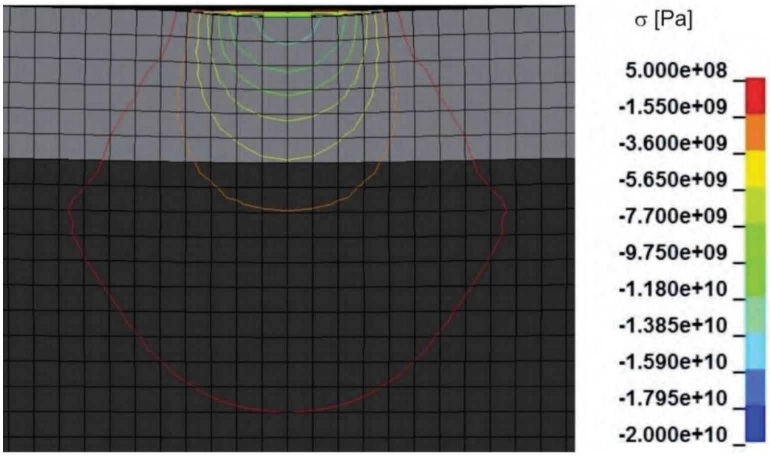

Fig. 3. Distribution of main stress perpendicular to surface – single body

Figures 4 – 10 present the graph of stresses perpendicular to the surface of contact in the plane of symmetry of the presented system as a situation which allows the best analysing of contact conditions between interacting bodies.

In all analyses, in the case of its lowest value of scale factor equal to 1, there occurred great differences (Fig. 4, 5, 6), and calculation time was significantly longer or the contact was broken – penetration of bodies in contact.

The results of analyses, in the case of contact of a node – surface type, were presented in Fig. 4 depending on the value of parameter defining contact stiffness. The subsequent Fig. 5 present the results concerning a surface – surface type. The latter group of Fig. 6 concerns contact of a mortal type. These Fig. and 7 - 10 show analyses for cases with different mesh density. The inserted results concern 1:1, 2:1 (Fig. 7 and 9) and 3:1 (Fig. 8 and 10) meshes.

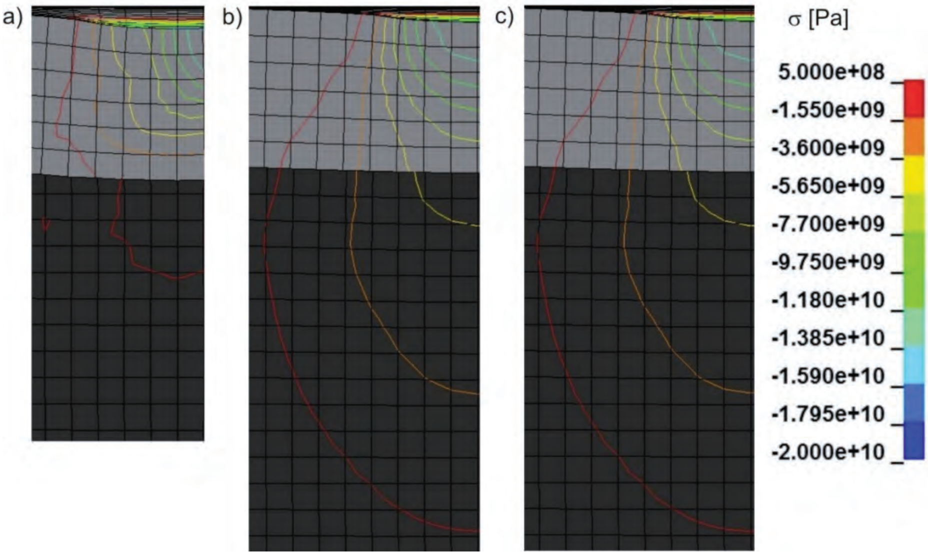

Fig. 4. Distribution of main stress perpendicular to contact surface – node to surface contact for different scale factor; a) f = 1, b) f = 100, c) f = 1000

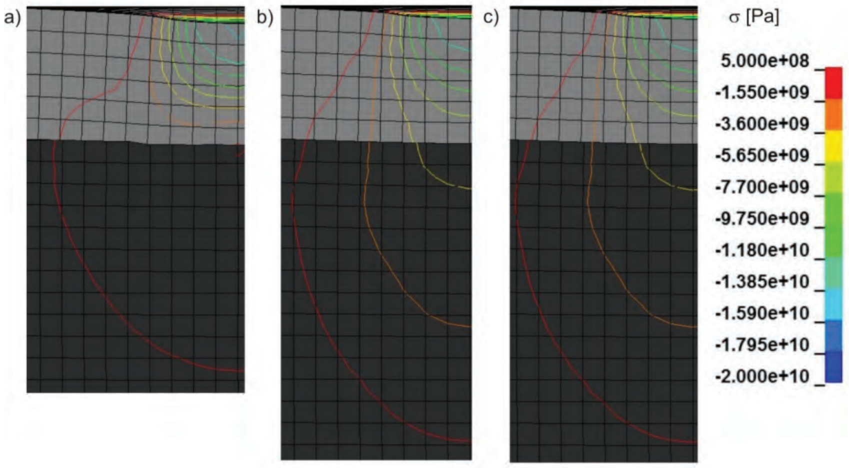

Fig. 5. Distribution of main stress perpendicular to contact surface – surface to surface contact for different scale factor; a) f = 1, b) f = 100, c) f = 1000

Increasing the contact stiffness through increasing the parameter value to 100 significantly improved accuracy of results with the real situation. The accuracy is increasing with the increase of the parameter to 1000.

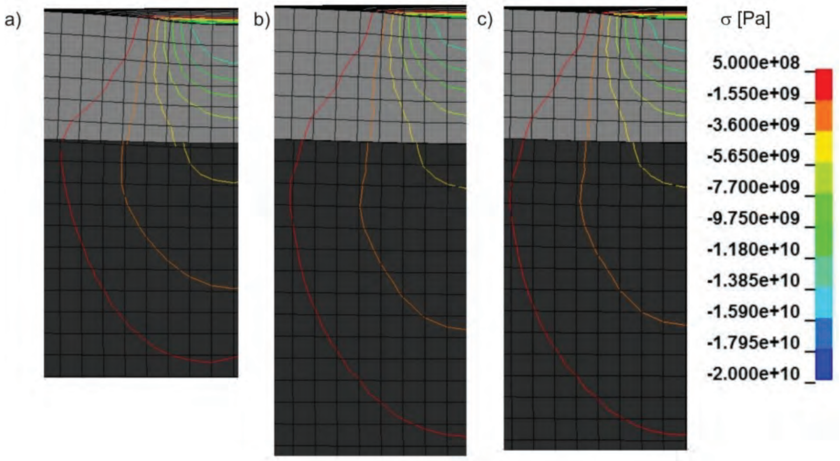

Fig. 6. Distribution of main stress perpendicular to contact surface – mortar contact for different scale factor; a) f = 1, b) f = 100, c) f = 1000

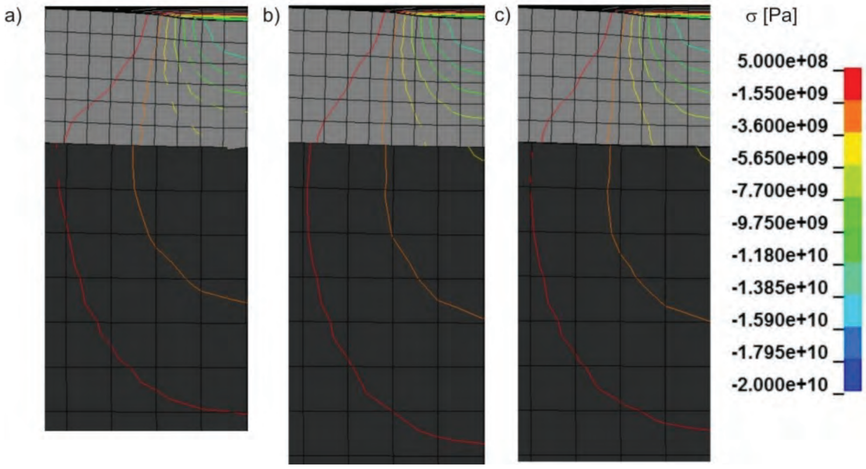

Fig. 7. Distribution of main stress perpendicular to contact surface – mesh density 2:1, scale factor f = 100, for different contact; a) node to surface, b) surface to surface, c) mortar contact

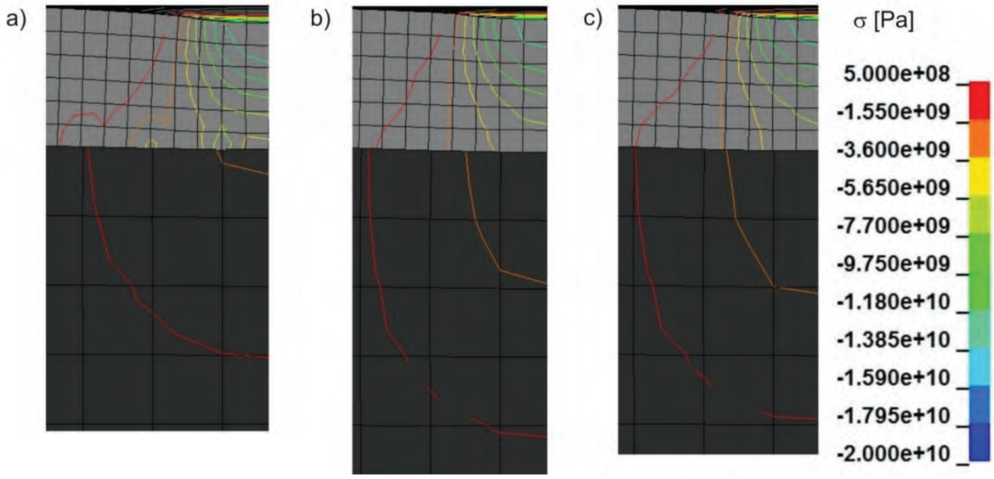

Fig. 8. Distribution of main stress perpendicular to contact surface - mesh density 3:1, scale factor f = 100, for different contact; a) node to surface, b) surface to surface, c) mortar contact

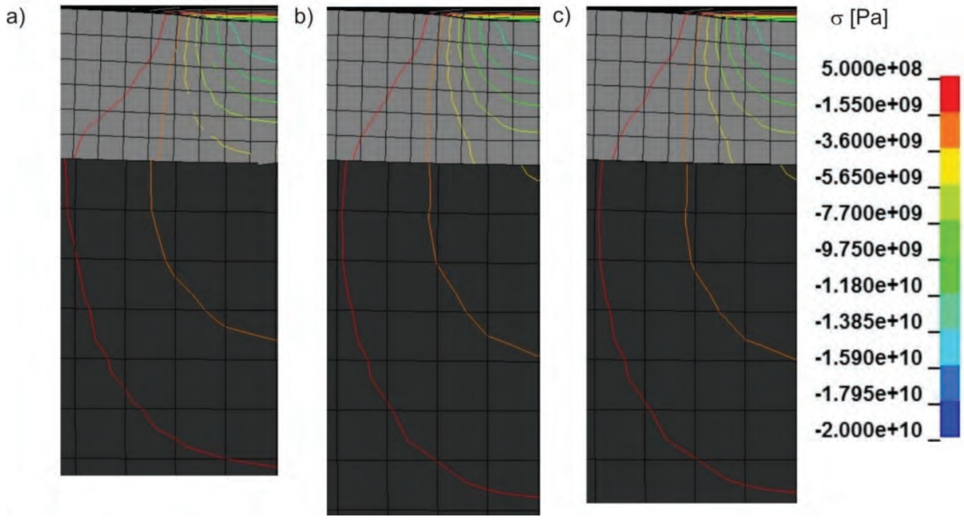

Fig. 9. Distribution of main stress perpendicular to contact surface – mesh density 2:1, scale factor f = 1000, for different contact; a) node to surface, b) surface to surface, c) mortar contact

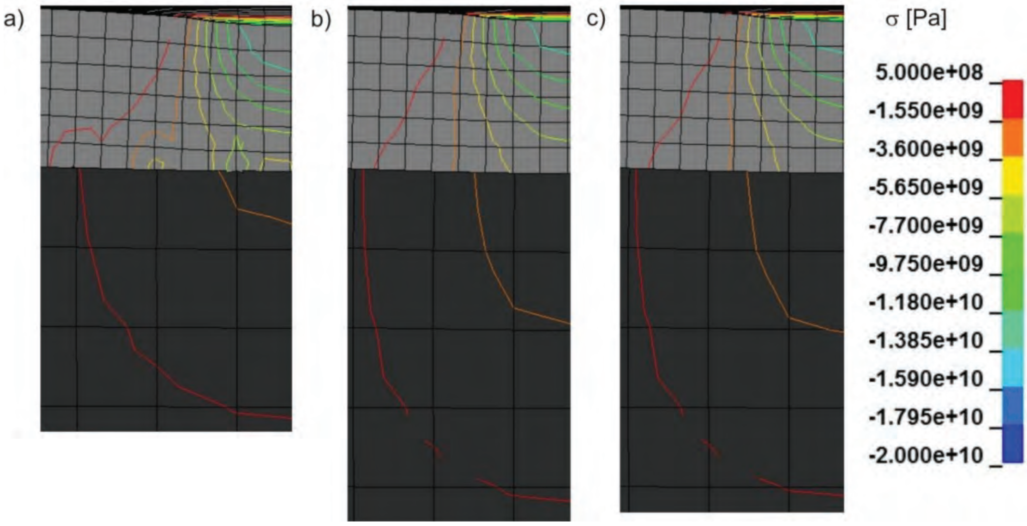

Fig. 10. Distribution of main stress perpendicular to contact surface – mesh density 3:1, scale factor f = 1000, for different contact; a) node to surface, b) surface to surface, c) mortar contact

3. Summary

In the analyses, there were presented the results considering the basic types of contacts: node to segment, segment to segment and mortar contact in terms of scale factor selection. There was also studied the influence of finite elements dimensions of bodies in contact.

It turned out that scale factor parameters default values defining contact stiffness applied in Ls-Dyna software are not sufficient enough.

In order to reflect real contact parameters the difference in dimensions of finite elements should not be greater than 3.

It turned out that the best of the considered types of contacts for penalty method is mortar type contact.

Acknowledgements

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