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## MODELING OF THE DEFORMATION OF ELASTIC PADS FOR RAIL FASTENINGS

**Summary.** Rail fastenings are one of basic elements of the top structure of a track. Elastic pads are the important element of the rail fastenings. Definition of their elastic characteristics is necessary for the subsequent studying of the dynamic interaction between the track and the rolling stock.

## MODELOWANIE ODKSZTAŁCENIA PRZEKŁADEK SPRĘŻYSTYCH DO PRZYTWIERDZEŃ SZYN

**Streszczenie.** Przytwierdzenia szyn do podkładów są jednym z podstawowych elementów nawierzchni kolejowej. Sprężyste przekładki są ważnym elementem konstrukcji przytwierdzeń. Wyznaczenie ich parametrów sprężystości jest niezbędne do dalszej analizy współpracy dynamicznej pomiędzy torem a pojazdem szynowym.

### 1. INTRODUCTION

Rail fastenings are one of the major elements of the top structure of the track. Traffic safety of the trains depends on their reliable work. They carry out the function of connection between the trackway and the tie array. They carry out function of the primary amortization for dynamic interaction between a track and a rolling stock. Rail fastenings carry out also the important function of fixation long-welded tracks at the temperature influence on the rails. And, last, rail fastenings carry out the function of the electric isolation between trackways.

There are many designs of intermediate rail fastenings. In the monograph [1] it is considered three basic types of fastenings: inseparable, separate and mixed. Their difference is reduced to a way of fastening of the rail to the tie. Except that distinction in designs are brought also by the type of used ties: wooden or ferro-concrete. More various designs of the rail fastenings are described in the book [2]. The analysis of these and other references shows, that both on railways of Central Europe and on railways of the former USSR countries rail fastenings of separate type prevails. On the Polish railways for wooden and ferro-concrete ties are used the fastenings of K-type. Their analogues on railways of the former USSR countries used KB-type fastenings for ferro-concrete ties and D2-type fastening for wooden ties. In work [1] it was noticed, that the specified fastenings have a number of essential lacks, such as rather a considerable quantity of parts, their raised material capacity, the increased wear of nonmetallic elements that demands of their additional repair. And, nevertheless, considerable advantages of fastenings of such type exceed their lacks and do by the most widespread on a network of railways in different countries.

Because designs of the specified rail fastenings are similar, we will stop in considered work on a rail fastening of the KB-type. Its design provides use of two elastic pads. One is lied between a base of the rail and the tie plate, the second is between the tie plate and the tie. Both pads carry out the functions of elastic dumping elements, and also the isolating functions. In this connection their importance for the analysis of the mechanical system the track – the vehicle is great enough. However it was not possible to find mechanical characteristics of the specified pads in references and in the Internet. Taking into account that modern computing means allow to model the dynamics of the specified system, for creation of such model it is necessary to set parameters of pad elasticity. In considered article attempt on the basis of experimental data is made to estimate the specified parameters.

## 2. GEOMETRICAL MODELLING AND FE-MESH GENERATION

AutoCAD means had been used for geometrical modeling of the rail fastening. On fig. 1 the design of the rail fastening of KB-type is shown. For drawing simplification the tie and the elements of fastening of the tie plate to the tie are not shown.

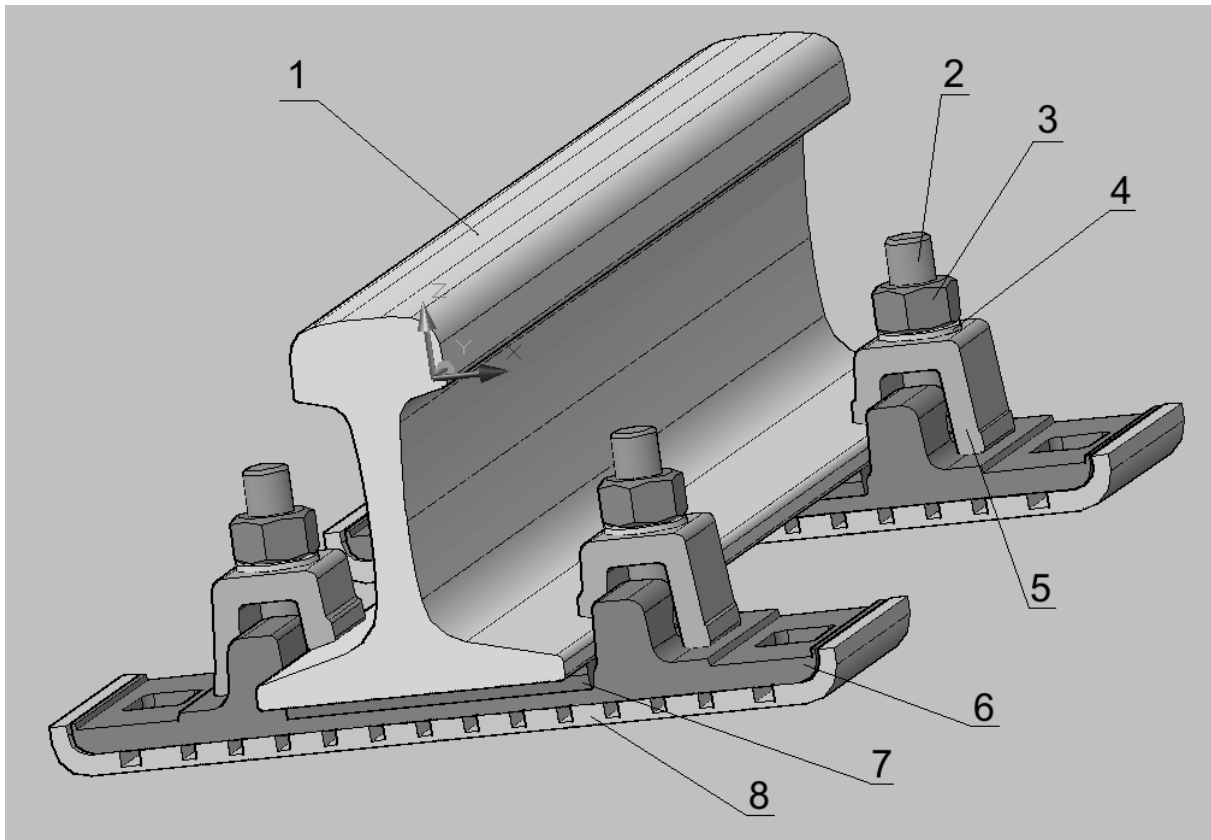


Fig. 1. Rail fastening of the KB-type  
Rys. 1. Przytwierdzenie pośrednie typu KB

Rail fastening is executed in such a manner that the rail 1 press to the steel tie plate 6 by means of the clips 5. The pressing force on the clips is created by the bolted joint, which consists of the T-head-bolt 2, the nuts 3 and the spring washers 4. Between a rail 1 and a tie plate 6 there is the elastic pad 7. One more elastic element in a design of a rail fastening of KB-type is the elastic pad 8 between a steel tie plate and the tie. According to the railway nomenclature it has designation CP-328. Its geometrical model is shown on fig. 2.

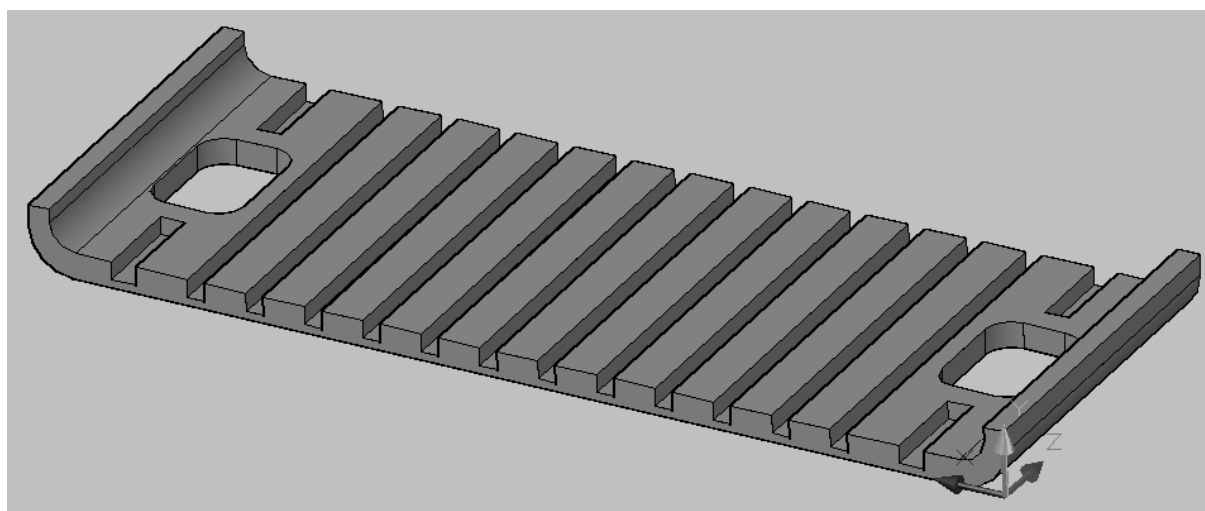


Fig. 2. Geometrical model of an elastic pad under the tie plate

Rys. 2. Geometryczny model sprężystej przekładki pod podkładką zębową

The specified elastic elements carry out the important function of reduction of dynamic rigidity of the track, that finally leads to decrease of the level of contact forces in the wheel – rail pair. In the article [3] for modeling of quasi-static interactions in the described assembly have been used the finite element method (FEM). FE-generation of the FE-mesh with the use of software package MSC.NASTRAN for Windows where the FEMAP module is using as preprocessor was the feature of the given approach. Created thus FE-mesh was exported further to the MSC.MARC program where the problem solution was carried out, and also the analysis of the received results was carried out. Such approach allowed to save essentially time for creation of the FE-mesh. However the received meshes were not optimum on the structure and the subsequent solution of nonlinear contact problems with use of package MSC.MARC was carried out with big difficulties which caused considerable processor time of the solution concerned, and in some cases created FE-meshes in general were rejected by MSC.MARC package.

For elimination of these lacks of the previous approach it was accepted decision to carry out the generation of the FE-mesh with use of means of the MSC.MARC package. The meshes created as a result of such FE approach at the subsequent solution of the problem allowed to accelerate solution process about 10 times. On fig. 3 as an example the FE-mesh of an elastic pad under the rail is resulted. The given pad in a design of a rail fastening of the KB-type has designation CP-356 or CP-318. On fig. 3 it is shown in the turned shape. On its bottom working surface 21 not continuous holes is executed.

### 3. A PRELIMINARY CHOICE OF MATERIAL CHARACTERISTICS OF THE PADS

Enough rigid rubber or polyurethane can be a material for the given pad. In article [4] the history of a material choice for the given pads is described. As it is clear from the described text here, the question of a material choice for pads is difficult enough and opened now. At various times as material, wood, pressed plywood, polyethylene and other materials were used. Now for pads the rubbers of various modifications are used. There carry out also exploration tests for perspective materials. The specified factors influence that the data describing the mechanical characteristics of the pad materials are absent in the literature.

The technical information [5] published on WWW page of the manufacturer (Ural Factory of Rail Fastenings) can give data necessary for calculation. In particular, here diagrams of dependence of pressing force on the clips to a rail as a function of displacement of a rail surface in the zone of the specified clip – rail contact for various designs of rail fastenings are shown. Among the specified diagrams only two curves which concerns the KB fastening (fig. 4) are chosen. The greatest question

causes, that on these diagrams are shown. According to the quoted information, it is «dependence of force in the point of contact of the clip and the rail as the function of the deformation in this point». Specified "deformation" is designated by letter  $f$  and measured in mm. If not to consider the formal discrepancy, that dimensionless deformations should not be measured in mm and replace a word "deformation" with more correct word "displacement" all the same here there are questions. Curve 1 corresponds to use case a two-turn spring washer with cross-section 8x10 mm, and the curve 2 similar for use three-turn washers of the same section. Then if the loading on a rail in a zone of clip contact and displacement of the same place is considered, how the washer choice influences on the deformations in the specified zone of the contact? The second reasonable question consists that according to diagrams specified displacement can reach almost 13 mm! It thus, that the thickness of an elastic pads makes only 7 mm.

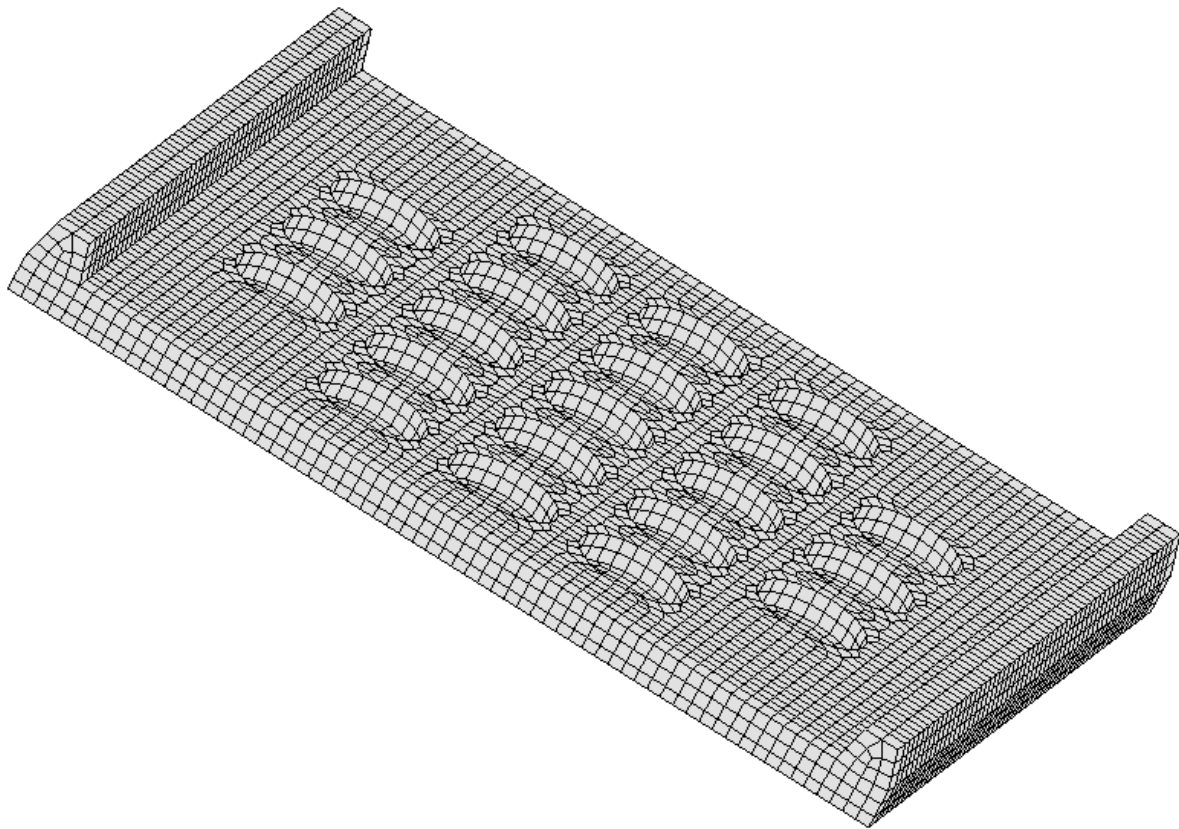


Fig. 3. The FE-mesh of an elastic pad under a rail created with using of the MSC.MARC program  
Rys. 3. Siatka MES sprężystej przekładki pod szynę opracowana w oprogramowaniu MSC.MARC

Answers to the questions can be only that displacement could be measured in other places. For example, vertical displacement of a nut was measured. It is obvious, that in this case it is essential, what is chosen a washer. Indirect acknowledgement of the specified assumption is that on one of article [5] drawings (fig. 3.8) such letter  $f$  has been used for a designation of "washer deformation».

The question of rigidity of the specified connection is ambiguous also. In article [5] the concept «rigidity of the pad» is entered and it is underlined, that for KB-65 fastening for pressing force from 4 to 6 kN such rigidity is equal to 1,43 kN/mm in the case of use of the three-turn washers. If the two-turn washer is used, such rigidity is equal to 1,54 kN/mm. The specified concept is not absolutely correct. If to consider the clip as the elastic element executed from steel, its rigidity will be on some orders above. If rigidity of the clip connections is considered it is necessary to take into account, that here there are various elastic bodies. Some of them have a high compliance (spring washers, an elastic

pad under a rail) and also more rigid bodies (a tie plate, a clip, a bolt, a nut and a rail) which have considerable rigidity, however under the influence of force in the bolted joint are also deformed.

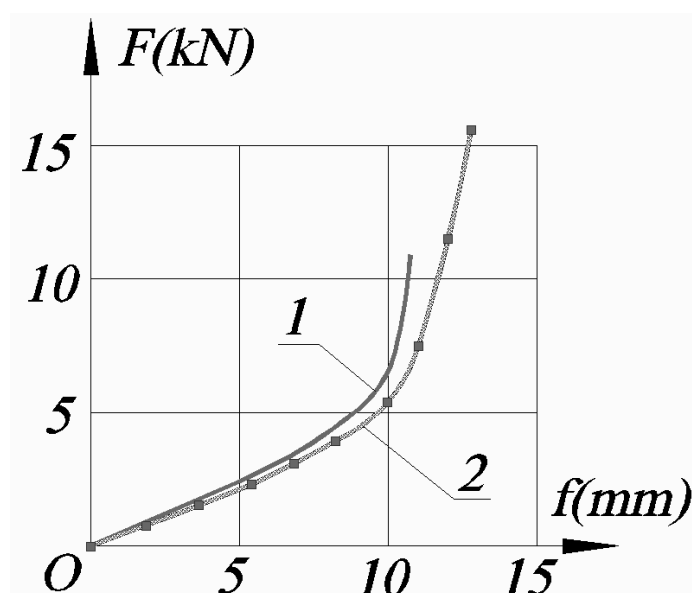


Fig. 4. Dependence of pressing force on the clip as function of the contact zone displacement according to [5]  
Rys. 4. Zależność wartości siły nacisku klamry od przemieszczenia strefy kontaktu według [5]

About that researches of the rigidity characteristics of elastic pads for rail fastenings is a question that actual can testify publications in various articles of authors from different countries. In particular, in article [6] characteristics of elastic pads of ZW 700 type which are product by the company Saargummi (SGW) are considered. It is obvious, that elastic characteristics of the rubber used for given pads are nonlinear. Same fact is caused that there is no uniform approach to definition of rigidity of such pads. Here the static secant rigidity can be considered. This parameter defined as a tangent of an inclination angle of the secant drawn through two certain points on the diagram of the dependence of pressing forces on a pad as function of the vertical displacement on its working surface. The static tangential rigidity, defined as a tangent of an inclination angle of a tangent line in one of points of the above-stated diagram, can be considered also. Besides it can be considered also dynamic rigidity of pads. From the resulted researches it is visible, that if a static secant rigidity of the pads is a constant equal approximately of 50 kN/mm, then static tangential rigidity can change depending on a point of drawing of a tangent line. In the paper [6] as static tangential rigidity was accepted its value at average loading.

A similar approach is used in the information [7] for definition of static rigidity of pads of various types. Apparently from the resulted information a static secant rigidity of pads used on the European railways is in interval from 8,5 kN/mm to 120 kN/mm. Apparently, the specified characteristic shows distinction in used materials. Nevertheless, rigidity of pads defined according to the ways specified above will be considerable above, than which can be defined on a basis fig. 4. It proves only the fact, that fig. 4 mismatches the real characteristics of elastic pads of the KB fastening and is the integrated characteristic of all clip joint.

Thus, the choice of the characteristics of elastic pads is actual enough. The solution of this question depends on use of experimental data for each used material. FEM programs allow to consider nonlinear properties of a material. Nevertheless, in the given work as the first approach the pad material was considered linearly elastic, that corresponds to an initial phase of loading. The modelling of the clip joints can help with a choice of elastic characteristics of pads. As the first step it is offered to consider interaction of FE models of the rail, the clips, the pad under a rail and the tie plate.

#### 4. FINITE ELEMENT MODELING OF A RAIL FASTENING

On fig. 5 it is presented FE model of a rail fastening. Here the "cut out" site of rail R65 together with a tie plate and an elastic pad is considered. Each of considered parts declares as "a deformed contact body" - MSC.MARC terminology. Thus on fig. 5a the rail is called as a body 2, an elastic pad - a body 1, a tie plate - a body 3.

Displacements of the nodes on the bottom surface of a tie plate are excluded by boundary conditions. Loading is set by vertical displacement of "clips". They are modeled by rigid surfaces which are declared by contact bodies 4 (fig. 5b). As it was specified above, generation of FE meshes for all considered bodies was carried out only by means MSC.MARC.

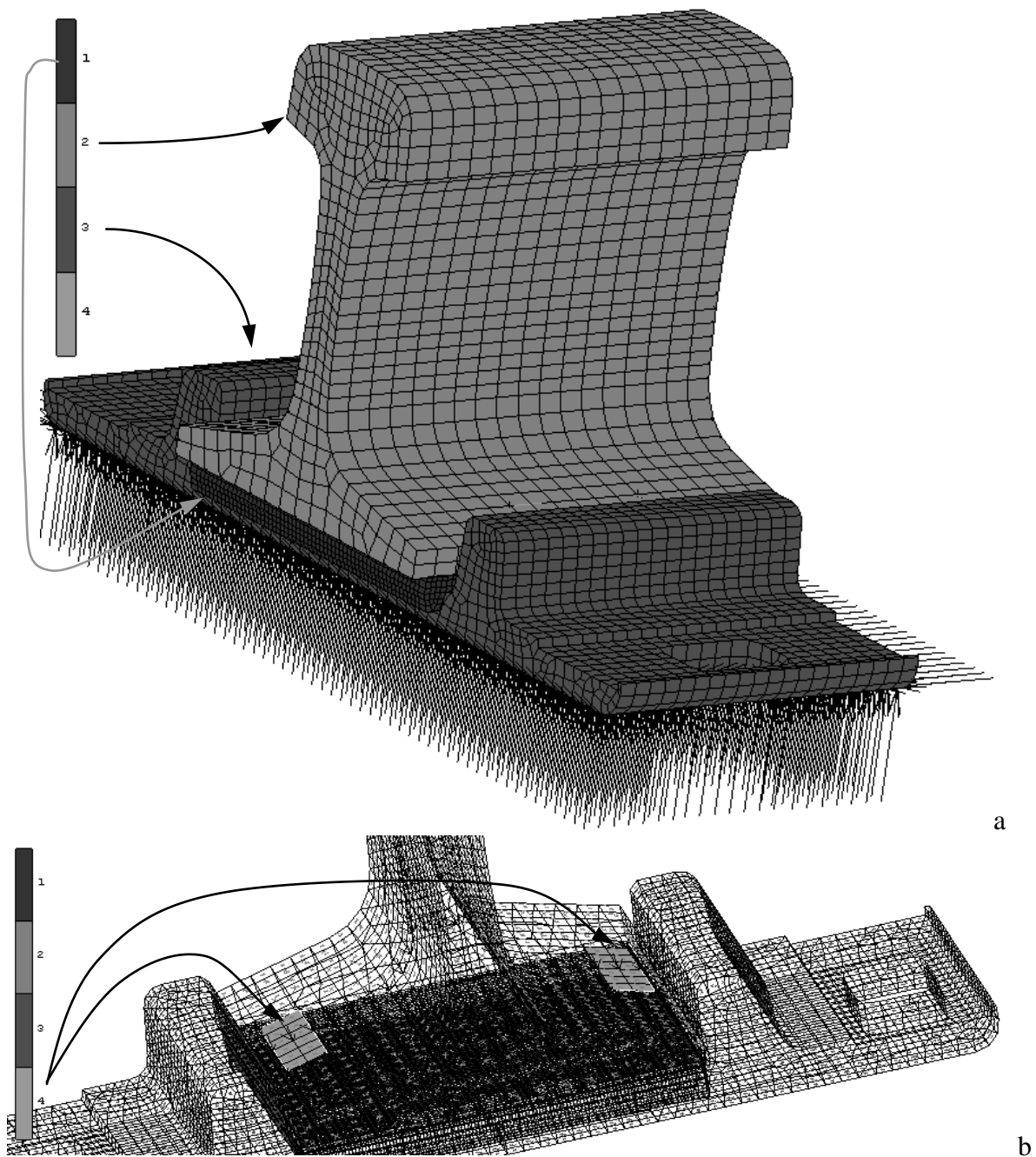


Fig. 5. Model of contact bodies in MSC.MARC program

Rys. 5. Modelowanie ciał kontaktowych w oprogramowaniu MSC.MARC

On fig. 6 distribution of normal contact stress in an elastic pad under a rail (fig. 6a) and also on the top surface of a tie plate (fig. 6b) is presented. Apparently from drawing, distribution of stresses completely corresponds to constructional features of considered bodies.

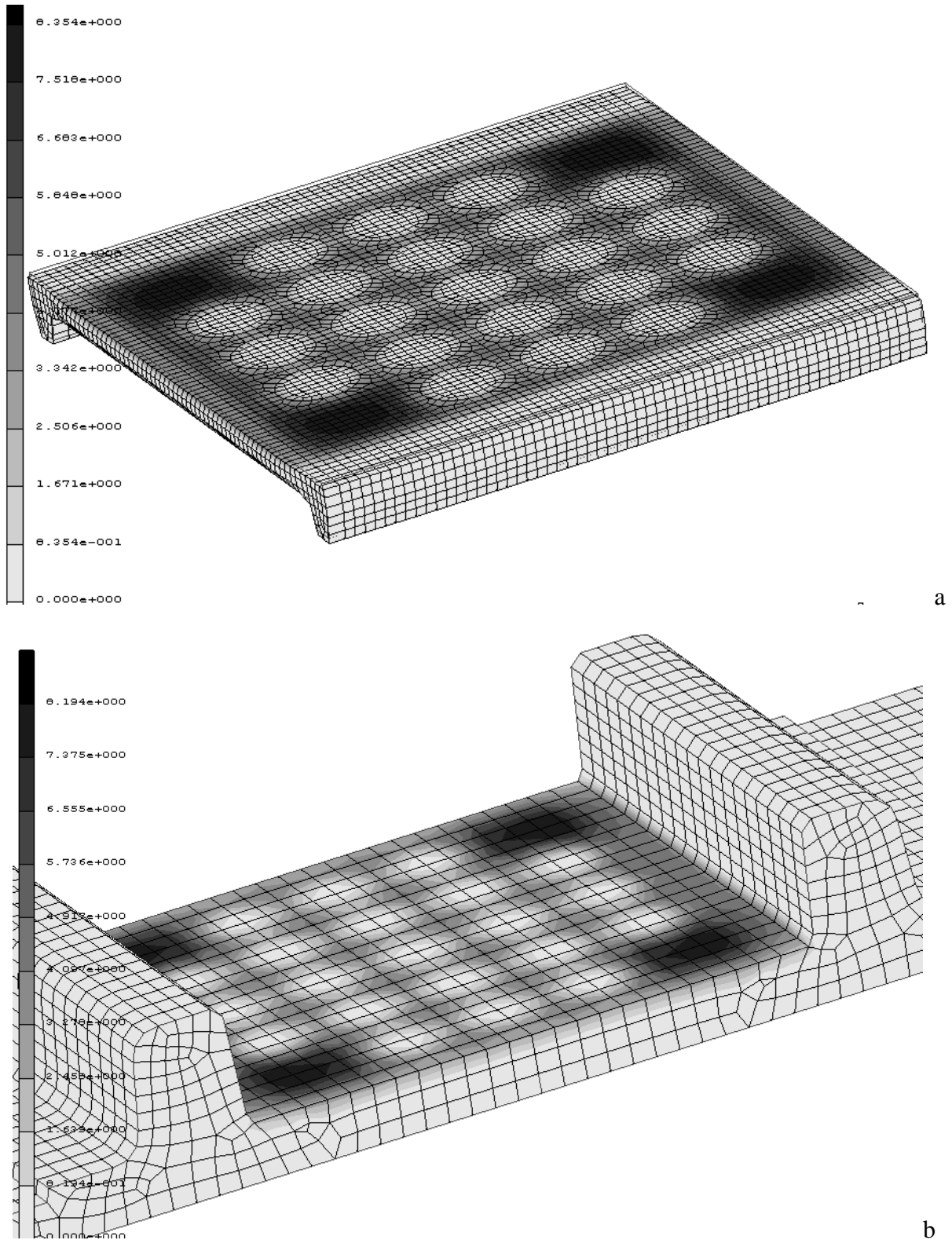


Fig. 6. Distribution of normal contact stress in the pad under a rail (a) and on the tie plate surface (b)  
Rys. 6. Rozkład normalnych naprężeń kontaktowych w przekładce pod szynę (a) i na powierzchni podkładki (b)

## 5. CONCLUSION

The finite element method can be used with success for definition of elastic characteristics of pads under a rail and under a tie plate. The developed design procedure has allowed to estimate the amount of rigidity of the specified parts of a rail fastening of KB-type.

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