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MODELING ASSUMPTIONS INFLUENCE ON STRESS AND STRAIN STATE IN 450 T CRANES HOISTING WINCH CONSTRUCTION

Summary. This work investigates the FEM simulation of stress and strain state of the selected trolley's load-carrying structure with 450 tones hoisting capacity [1]. Computational loads were adopted as in standard PN-EN 13001-2. Model of trolley was built from several cooperating with each other (in contact) parts. The influence of model assumptions (simplification) in selected construction nodes to the value of maximum stress and strain with its area of occurrence was being analyzed. The aim of this study was to determine whether the simplification, which reduces the time required to prepare the model and perform calculations (e.g., rigid connection instead of contact) are substantially changing the characteristics of the model.

WPŁYW ZAŁOŻEŃ MODELOWYCH NA STAN NAPRĘŻEŃ I PRZEMIESZCZEŃ NA PRZYKŁADZIE WÓZKA SUWNICY 450 TON

Streszczenie. W pracy przeprowadzono badania symulacyjne MES stanu naprężenia i przemieszczenia wybranego ustroju nośnego wózka suwnicy o udźwigu 450 ton [1]. Obciążenia obliczeniowe przyjęto zgodnie z normą PN-EN 13001-2. Model wózka zbudowany był z kilku współpracujących ze sobą (kontaktujących się) części. Analizowano wpływ założeń (uproszczeń) modelowych w wybranych węzłach konstrukcyjnych na strefy występowania i wartości maksymalnych naprężeń oraz na przemieszczenia. Celem badań było ustalenie czy uproszczenia, które skracają czas przygotowania modelu i wykonania obliczeń (np. sztywne połączenie zamiast kontaktu) w istotny sposób zmieniają charakterystyki modelu.

1. INTRODUCTION

We can observe the development of international technical standardization, assuming that the development in the domain of calculations [2-4] and manufacture eliminate some dangers generated in the past (70s, 80s and 90s when most of cranes being used now were designed). In this study the FEM analysis of stress and strain state of the selected trolley's load-carrying structure with 450 tones hoisting capacity was made. This analysis could be an introduction for cranes load carrying structures and drives calculations already made [5-7] and for those which will be made in future.

Model of trolley was built from several cooperating with each other (in contact) parts. Main parts of hoisting winch load – carrying structure (fig.1) being under consideration are:

- 450 t pulley block girder (1) – free laying on buffer beams (5),
- 80 t pulley block girder (2) – free laying on buffer beams (5),

- 4 rockers,
- 2 buffer beams (5) together with connection beams.

Fig. 1 shows also the slide limiter (4)

FEM model of the winch was built from three parts:

- frame bearer (headstocks with connected beams, with rockers, but without the rail cars which are omitted in the model);
- 450 t pulley block girder;
- 80 t pulley block girder.

Preliminary analysis of the entire system of winch, allowed to highlight a few important structural nodes:

- connections between rockers and buffer beams;
- connections between rockers and rail cars (support in axes modelled);
- slide connections between girders and buffer beams.

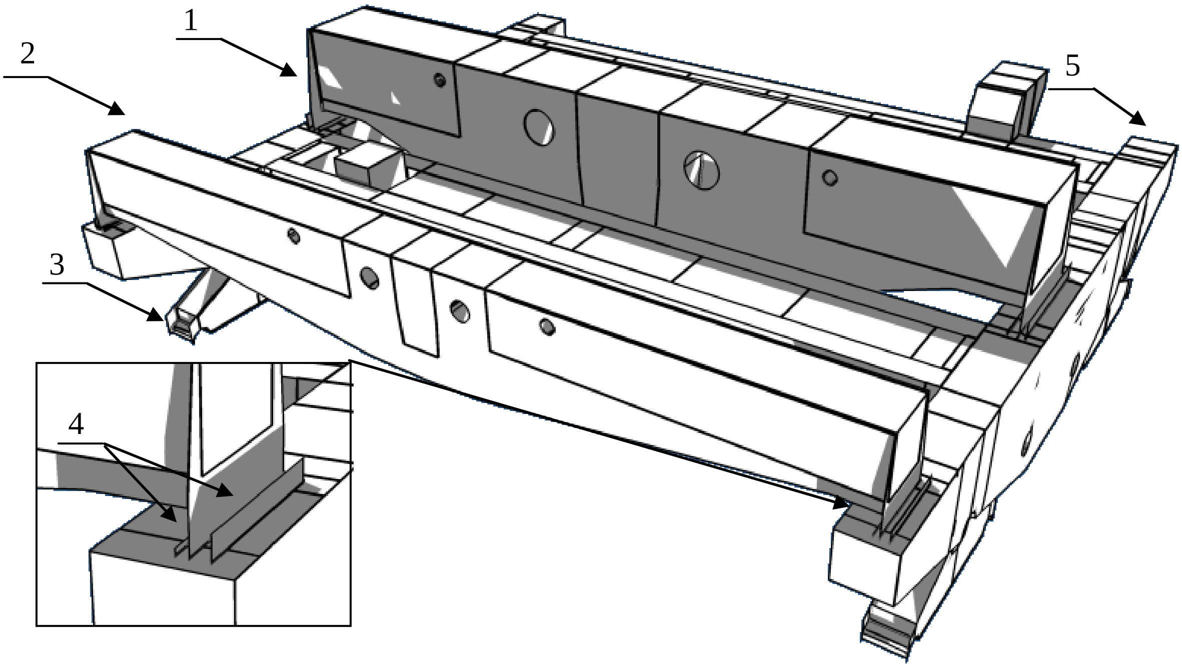


Fig. 1. Load carrying hoisting winch structure
Rys. 1. Ustrój nośny wciągarki

Three kind of models with different level of simplification – time needed for preparation and computation were considered.

Basic model (A) was made as maximal simplified and with minimal time for preparation needed. Connections between buffer beams and rockers and also girders with buffer beams were assumed as rigid (without joint rotation). The axes between rail cars and rockers wasn't being modelled. Therefore only adjoining nodes (picked directly) of rockers FEM mesh were supported. It simplified and made faster the mesh generation which was build up only from shell elements.

In extended model (B) kinematic coupling and distributing coupling elements for axes between rockers and rail cars and also joints (connections between buffer beams and rockers) were applied.

In full model (C) also contact elements "node to surface" and "surface to surface" were applied for modeling the slide between girders and buffer beams.

The frame bearer (C and B models) was supported in axes connecting rockers and rail cars. For one axe 6 degree of freedom were taken away, and the all other only the Y and Z directions (fig. 2).

For all models loads were calculated according to standard PN-EN 13001−2:2006 [8]. Loads are shown in table 1 (fig. 2 shows the way how loads were applied).

Hoisting and gravity effects acting on the mass of the load – carrying winch structure, 450 t engine, 80 t engine, 450 t gear, 80 t gear, 450 t rope drum and 80 t rope drum were applied. All loads were multiplied by dynamic factors according to [8].

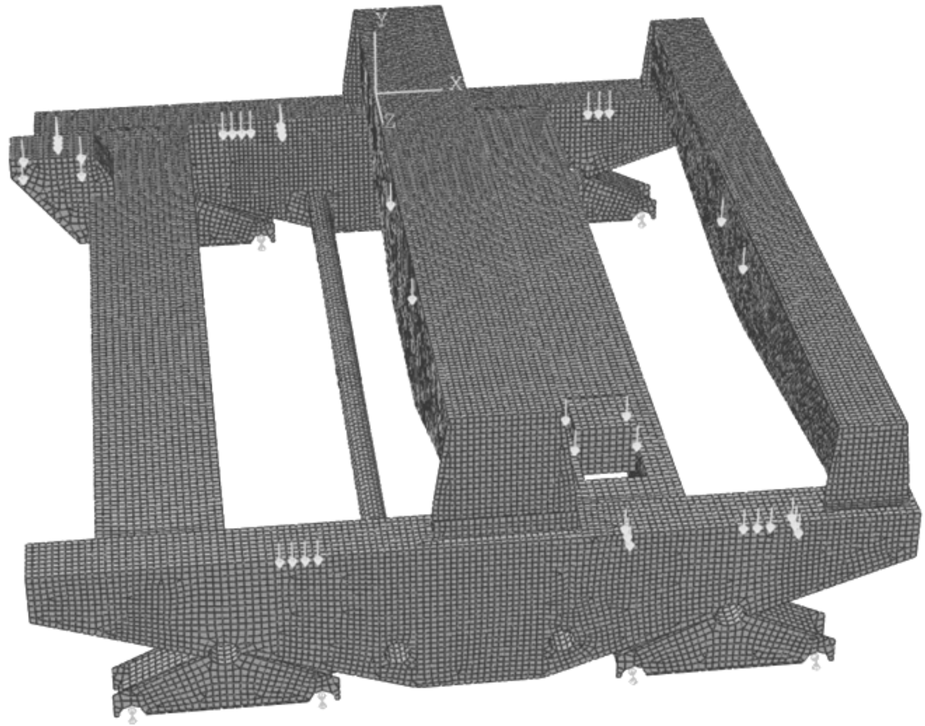


Fig. 2. Schematic model of loads
Rys. 2. Schemat obciążeń modelu

Table 1

The values of the forces applied to the load – carrying winch structure

Name	Value	Unit
Gravity effects acting on the mass of the load – carrying winch structure	1,48E+01	m/s^2
Gravity effects acting on the mass of 450 t engine	1,10E+04	N
Gravity effects acting on the mass of 80 t engine	1,10E+04	N
Gravity effects acting on the mass of 450 t gear	1,04E+05	N
Gravity effects acting on the mass of 80 t gear	1,93E+04	N
Hoisting and gravity effects acting on the mass of 450 t rope drum	6,57E+05	N
Hoisting and gravity effects acting on the mass of 450 t girder	5,07E+06	N
Hoisting and gravity effects acting on the mass of 80 t rope drum	1,78E+05	N
Hoisting and gravity effects acting on the mass of 80 t girder	1,06E+06	N

N, mm, MPa system of units was applied, therefore results of stresses are in MPa and displacements I mm shown. The load – carrying winch structure was made from S355 where the limit design stress for sheets thickness < 63 mm is 305 MPa [9]. The basic model (A) was made up of 69829 elements and 68200 nodes.

Calculations were made using the cluster IBM BladeCenter HS21 with Linux RedHat, 56 nodes (112 processors Intel Xeon Dual Core 2.66 GHz) and computation power 1192 Gflops. The solver was Abaqus 6.9 EF1 according to MNiSW/IBM_BC_HS21/PŚląska/021/2010 grant.

2. SIMULATIONS AND ANALYSIS RESULTS

Calculations for A and B models was made in two stages (steps). In the first one gravity effects acting on the mass was applied and the hoisting effects in the second one.

For C model calculations were made similarly but in the first stage no contact was being analysed and girders (in reality free lying on the buffer beams) were hold thanks to additional boundary conditions. In second stage all other loads were applied and both girders were set free. Thanks to contact elements girders were hold on buffer beams.

2.1. Model A

As it could be supposed, simplifications (overrigids) caused local stress concentrations. Maximal computed stress in rockers with buffer beams connections exceeded significantly the limit design stress (fig. 3). No slide possibility between girders and buffer beams caused sheets bending (fig. 4). At the other parts of the structure stresses and displacements values are similar to those from A and B models.

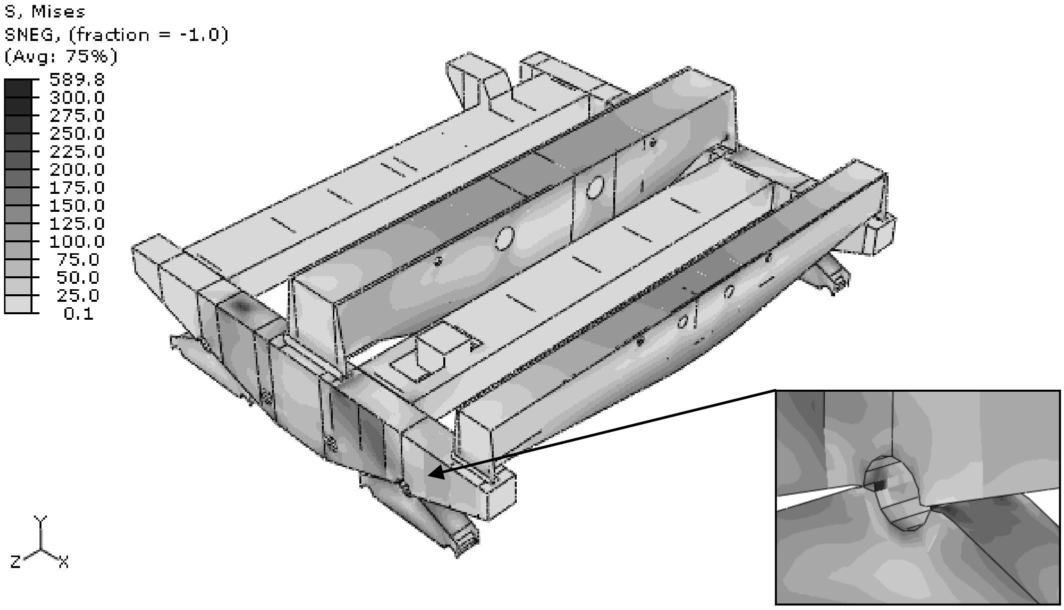


Fig. 3. Stress in the hoisting winch construction (model A) according to Huber-Mises-Hencky theory
Rys. 3. Mapa naprężeń konstrukcji (model A) wg teorii Hubera-Misesa-Hencky'ego

2.2. Model B

In this model axes connecting rockers and rail cars were modelled. Also kinematic coupling for rotating the rockers in relation to buffer beams were applied. It was noticed that kinematic coupling was the stress concentrator in rockers axes (780 MPa - fig. 5b). Application of distributing coupling [10] generated a much better effect in this places (70 MPa – fig. 5a).

Maximal computed stress in B model decreased in relation to model A and reached 300 MPa (fig.6). Stress concentration (distinguished place in fig. 6) on girder sheets connection results from no slide possibility between girder and buffer beam. Time of computation in case of model B was 3 minutes (using computer with Intel Core 2 Duo 2.5 GHz about 35 minutes).

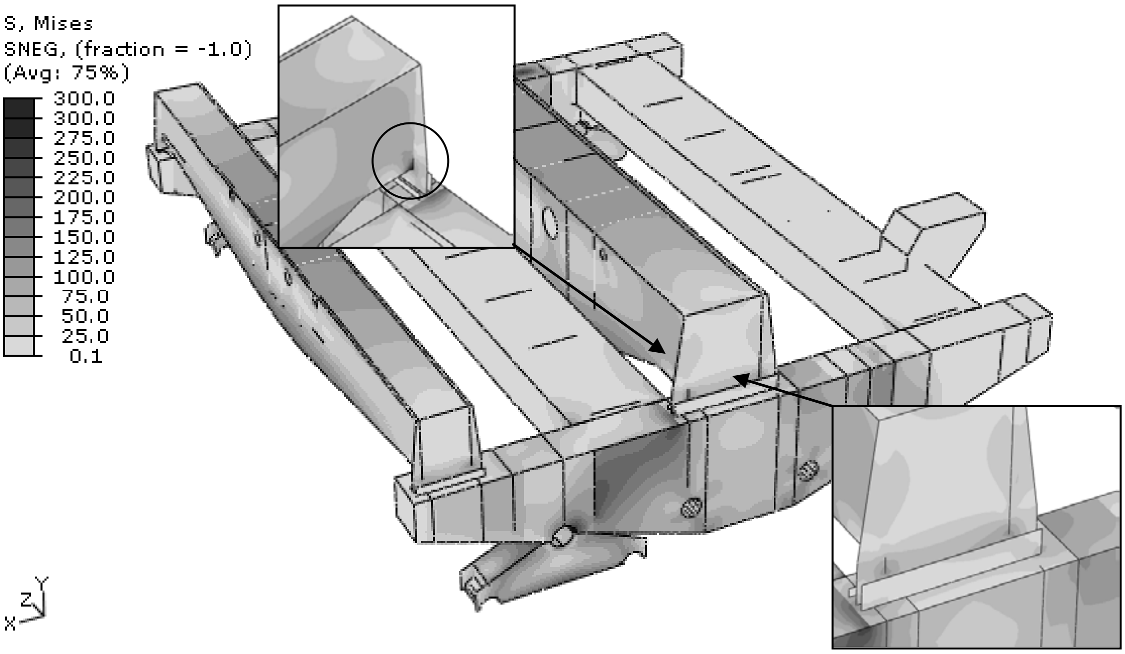
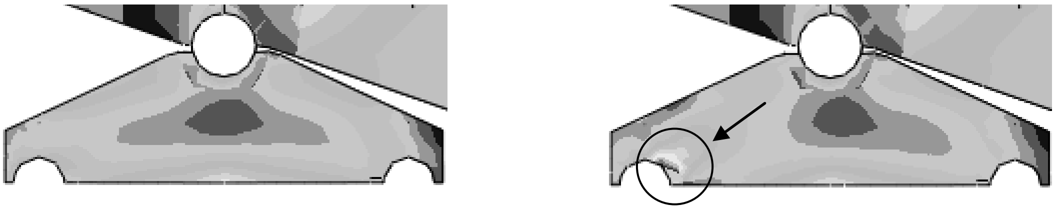


Fig. 4. Stress in the hoisting winch construction (model A) according to Huber-Mises-Hencky theory
Rys. 4. Mapa naprężeń konstrukcji (model A) wg teorii Hubera-Misesa-Hencky'ego


a) Coupling distributing

b) Kinematic coupling

Fig. 5. Coupling type
Rys. 5. Typ połączenia

2.3. Model C

In model C not only the kinematic coupling but also contact elements, allowing for girders sheets slide over the buffer beams, were applied. The friction factor was assumed as 0,3. Additional contact elements "surface to surface" limit the slide size where the friction factor was assumed as 0,1. Fig. 7 shows the pressure in contact surfaces according to Huber-Mises-Hencky theory. Maximal stress in C model occurs at the edge of buffer beams bottom and are in amount of 294 MPa (fig. 8).

Fig. 9 is a diagram showing the displacement on the girders edge, sliding on the winch's buffer beam. Maximal displacement is in the range of 0,6 – 1,2 mm, by 5 mm clearance. Displacement of the hole structure shows fig. 10. There won't be any contact between supporting and limiting sheet. Therefore it is no sense of making contact in this place. Without contact in this place the computation time is three times faster. Time of computation with simplified C model was 20 minutes (using computer with Intel Core 2 Duo 2.5 GHz about 100 minutes).

The results of C model were compared with fourth alternative for contact analysis model, in which girders were modelled as two independently beams on two pivot bearing (one movable). Stress, displacement and support reactions were computed. This support reactions were treated as loads acting on buffer beams in connection with girders area. Results were almost the same as in model C and the time of computation much shorter. Friction influence between girder and buffer beam is therefore not big.

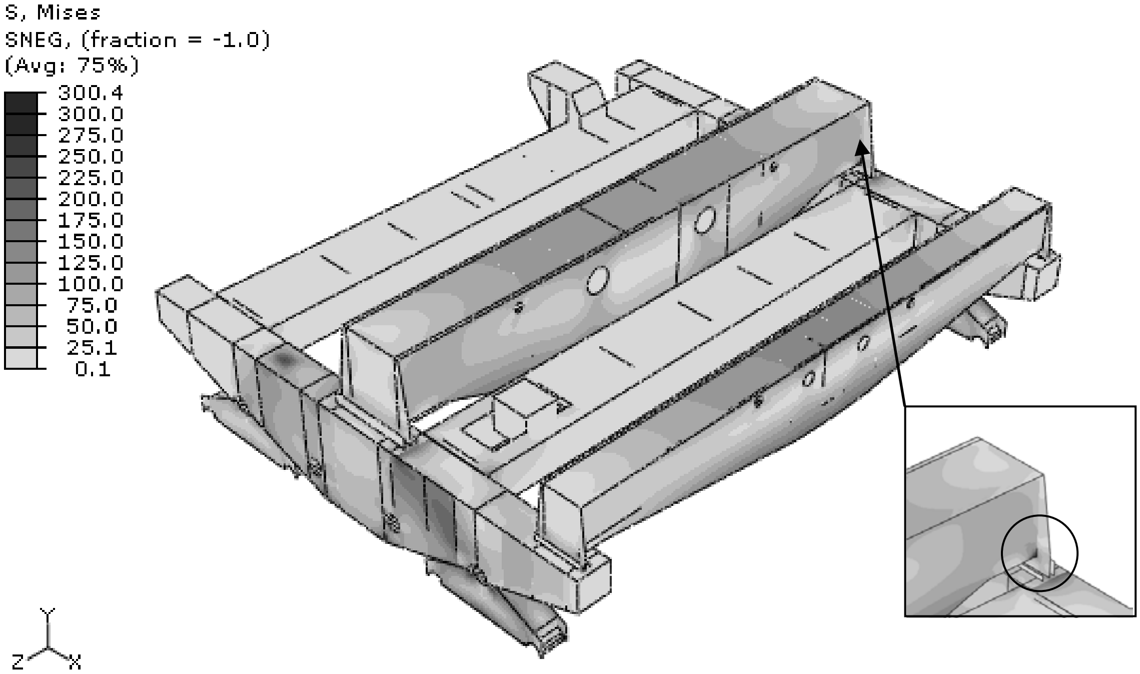


Fig. 6. Stress in the hoisting winch construction (model B) according to Huber-Mises-Hencky theory
Rys. 6. Mapa naprężeń konstrukcji (model B) wg teorii Hubera-Misesa-Hencky'ego

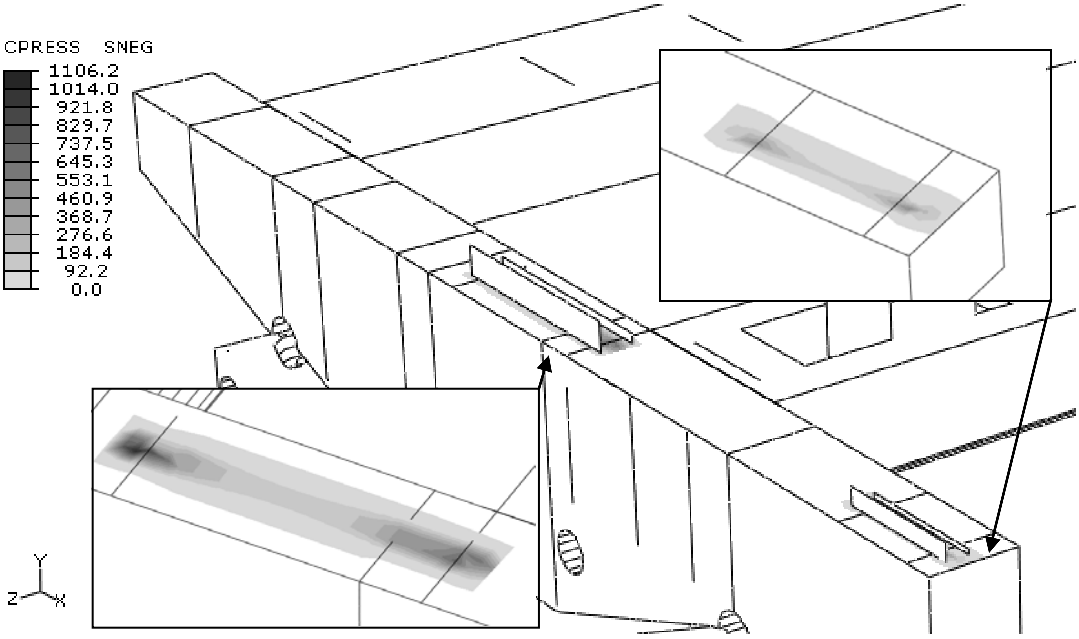


Fig. 7. Pressure in contact surfaces according to Huber-Mises-Hencky theory (model C)
Rys. 7. Mapa rozkładu ciśnienia na powierzchniach kontaktowych konstrukcji (model C)

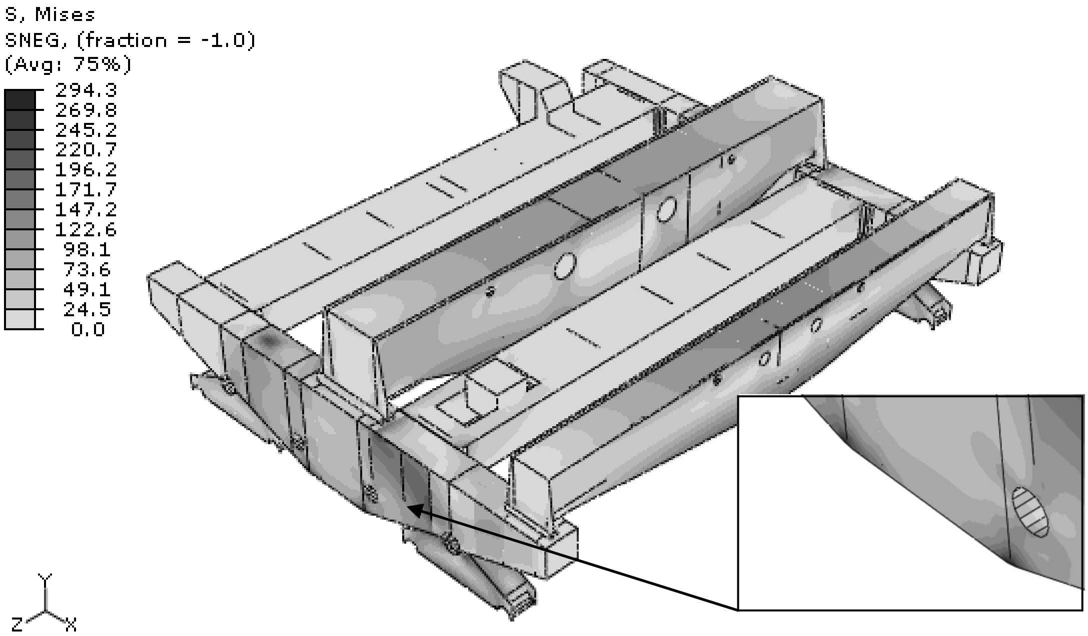


Fig. 8. Stress in the hoisting winch structure according to Huber-Mises-Hencky theory (model C)
Rys. 8. Mapa naprężeń konstrukcji (model C) wg teorii Hubera-Misesa-Hencky'ego

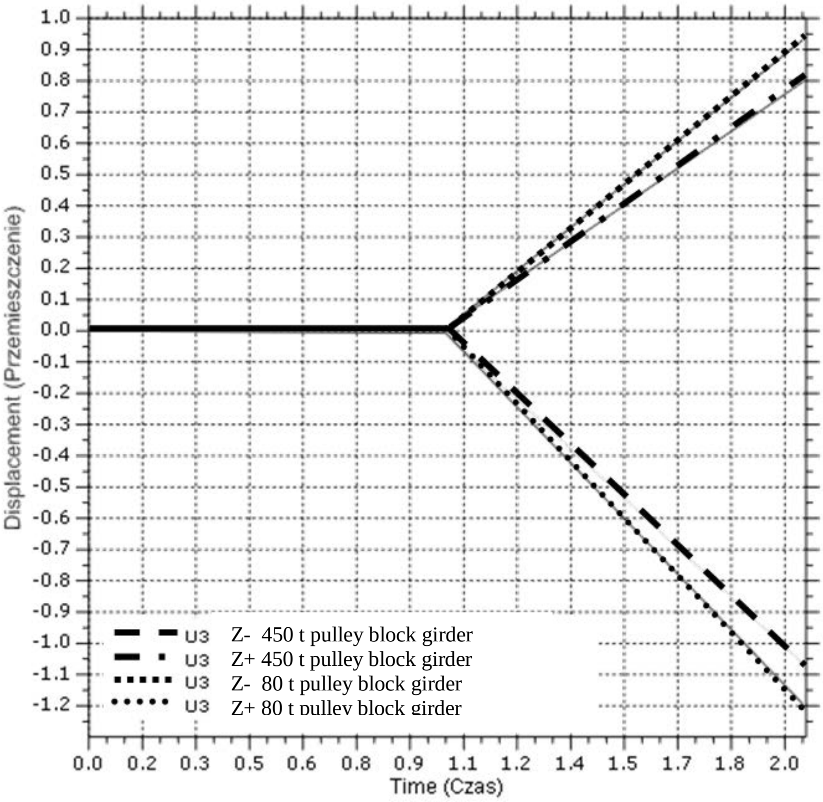


Fig. 9. Diagram showing the displacement on the girders edge, sliding on the winch's buffer beam (model C)
Rys. 9. Wykres przedstawiający przemieszczenia węzłów krawędzi dźwigara ślizgających się po czołownicy (model C)

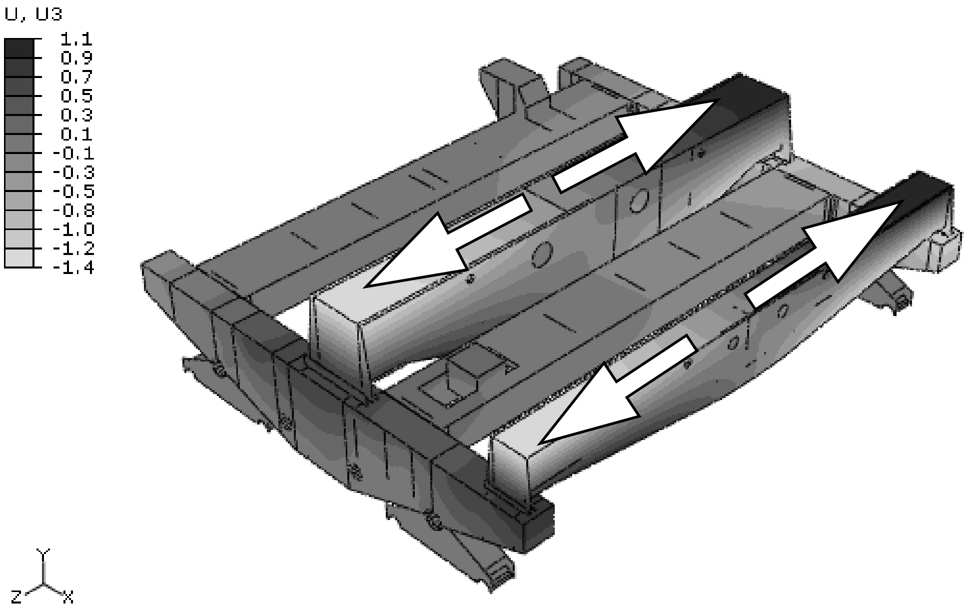


Fig. 10. Displacement in the construction of the girder on z axis (model C)
Rys. 10. Mapa przemieszczeń w konstrukcji w osi dźwigara (Z) (model C)

3. SUMMARY

The simulations allow to make some conclusions:

1. Maximal simplified and therefore over rigid model (A) could be used only in the stage of preliminary computations of structure prototype. It us useful for determining the maximal displacement quite precisely. Local stress concentrations makes impossible the proper strength analysis of construction nodes.
2. Satisfactory and precisely results through only little more preparation time needed characterize model (B). Time of computation is almost the same as in (A), higher than in reality stress values appears only between girders support and side sheet. This problem can be solved by independently computations of girders supported in pivot bearings.
3. In the case of model (C), the stress pattern in the hoisting winch structure is the most similar to real ones. At the same time expenditures incurred during the modelling work and the time needed to carry out the calculations are many times higher than in variants (A) and (B). Therefore, this model can be regarded as the ultimate model for the verification "ready" form of construction. It is not needed to use such complicated model in the design phase.

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