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BUILDING OF CALCULATION MODEL AND STRENGTH ANALYSIS BY USING FINITE ELEMENT METHOD ON EXAMPLE OF MOLD TO FOAMING OF COOLING FURNITURE

Summary

The article presents the way of creating calculation model of mold to foaming of cooling furniture for needs of conducting strength analysis by using Finite Element Method. The method of creating model is described in detail taking into account of modeling techniques available in NX system, the division of model into finite elements (discretization) by using three-dimensional, two-dimensional, one-dimensional elements was visualized. Finally, the results of numerical simulations in the form of stresses distribution in areas of considerable straining of structure was presented.
Key words: *Finite Elements Method, FEM modeling, FEA, CAE, strength, structural analysis, mold, cooling furniture, forming machine, foaming*

BUDOWA MODELU OBLICZENIOWEGO I ANALIZY WYTRZYMAŁOŚCIOWE PRZY UŻYCIU METODY ELEMENTÓW SKOŃCZONYCH NA PRZYKŁADZIE FORMY DO SPIENIANIA MEBLI CHŁODNICZYCH

Streszczenie

W artykule przedstawiono sposób tworzenia modelu obliczeniowego formy do spieniania mebli chłodniczych dla potrzeb przeprowadzenia analiz wytrzymałościowych przy wykorzystaniu Metody Elementów Skończonych. Szczegółowo opisano metodę kreowania modelu z uwzględnieniem technik modelowania dostępnych w systemie NX, zobrazowano podział modelu na elementy skończone (dyskretyzację) przy wykorzystaniu elementów trójwymiarowych, dwuwymiarowych oraz jednowymiarowych. Przedstawiono wyniki z przeprowadzonych symulacji numerycznych w postaci rozkładu naprężeń w obszarach o znacznym wytężeniu.
Słowa kluczowe: *Metoda Elementów Skończonych, modelowanie MES, FEA, CAE, wytrzymałość, analizy strukturalne, forma, meble chłodnicze, maszyna do formowania, spienianie*

1. Introduction

In computer mechanics (CAE) strength of structure is tested by using the Finite Element Method which allow recognize state of material straining. Finite Element Method is mathematical method of physical calculations depended on replacing of real object by way of elements about finite dimensions averaging its physical state [1].

FEM software allows to model of research object in great detail, but calculation time is significantly longer. A long calculation time is undesirable, especially in case of implementing frequent structural changes and multiple necessity of execution calculations. Therefore, should be entered simplifications in calculation models, which accelerate of solver acting. Enormously important is to adding of simplifications do not have meaningful impact to strength of tested construction. It is also important to simplifications accurately reflect reality (modeled objects and physical processes). To building of calculation models should be used appropriate finite elements ensuring convergence of gained results of simulation analysis with experimental research. Thus, this article presents the way of creating such calculation model on example of mold to foaming of cooling furniture together with results of simulation research.

2. Research purpose

The immediate purpose of research was state assess of construction straining of mold to foaming of cooling furniture type KL6-14 by using FEM. For the purposes of research execution simplification of calculation model was developed. Static simulation analyses for loads arising during normal exploitation in interim range was realized, stress distributions were determined and structural changes in nodes, which does not meet criterion of interim strength was proposed.

3. Research object

The research object was mold to foaming of cooling furniture type KL6-14 (fig. 1).

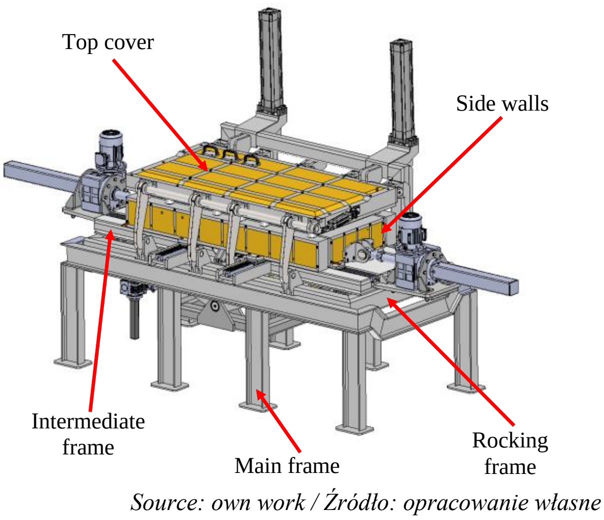

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Fig. 1. CAD 3D model of mold to foaming of cooling furniture type KL6-14
Rys. 1. Model CAD 3D formy do spieniania mebli chłodniczych serii KL6-14

Lateral side walls have ability to move by using electric screw actuators, while position of longitudinal side walls and top cover is changed by using pneumatic actuators. After opening top cover and withdrawing all side walls, the cooling furniture together with inner (smaller) form is installed in internal area of mold. Closed side walls with top cover have a task to prevent of surface distortion of cooling furniture during execution of foaming process.

The mold construction also uses pneumatic cushions, which lift entire unit located on intermediate frame exerting pressure of side walls to top cover. Lifted unit by red color on (fig. 2) was marked. Every pneumatic cushions generates lifting force about 200 kN at pressure equals 0,8 MPa.

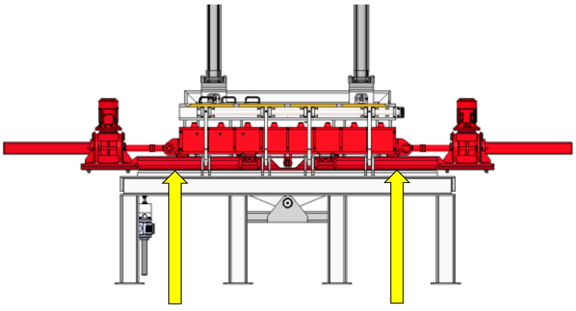

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Fig. 2. Unit lifted by using pneumatic cushions (marked red color)
Rys. 2. Zespół unoszony przy wykorzystaniu poduszek pneumatycznych (zaznaczono kolorem czerwonym)

4. Development of calculation model

Development process of calculation model of mold to foaming of cooling furniture along with multivariant structural analysis was executed in NX system. To creating model used following elements:

a) one-dimensional:
- rod elements (type ROD) allowing of pins modeling,
- beam elements (type CBEAM) and rod elements (type ROD) to modeling of pneumatic actuators,
- rigid elements type RBE2 to modeling screw actuators, spot welds and other connections allowing loads transfer between elements,
- interpolation elements type RBE3 to modeling of screw connections. These elements enable modeling of relative movements between nodes,

b) two-dimensional: plate-shell modeling of sheet metal surfaces and structural profiles,

c) three-dimensional: tetrahedral [2] finite elements to modeling walls and linear guides.

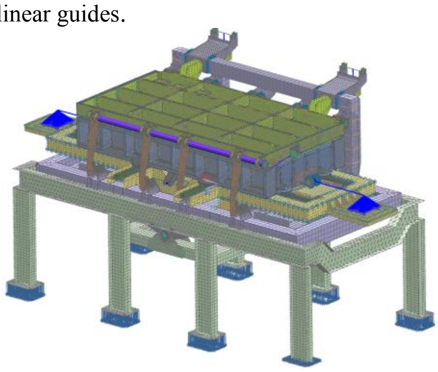

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Fig. 3. Calculation model of mold to foaming of cooling furniture
Rys. 3. Model obliczeniowy formy do spieniania mebli chłodniczych

In fig. 3 is showed complete calculate model of mold to foaming of cooling furniture.

On fig. 4 was presented the way building of calculation model of machine frames and side walls. Profiles of intermediate frame and rocking frame modeled by using 2D elements. Upper and lower sheet metal parts of intermediate frame was joined with profiles by means of 1D elements symbolizing spot welds. Application spot welds in model enable to gaining information about stress values in welding connections. To creating side walls 3D elements was used. Plate-shell elements were not used due to model necessity of screw connections by using 1D elements (RBE3).

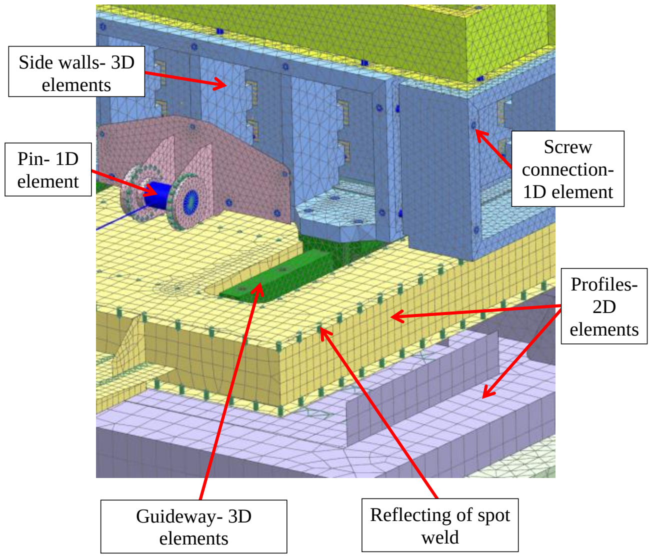

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Fig. 4. The way building of calculation model of rocking frame, intermediate frame, side walls etc.
Rys. 4. Sposób budowy modelu obliczeniowego ramy kołyskowej, ramy pośredniej, ścianek bocznych itd.

On fig. 5 was presented the modeling way of screw actuator. The task of screw actuator is moving of mold lateral wall and keeping it in fixed position during acting of forces in foaming process. Thereupon, actuator transmit loads from side walls to intermediate frame. Screw actuator by means of RBE2 rigid elements was modeled.

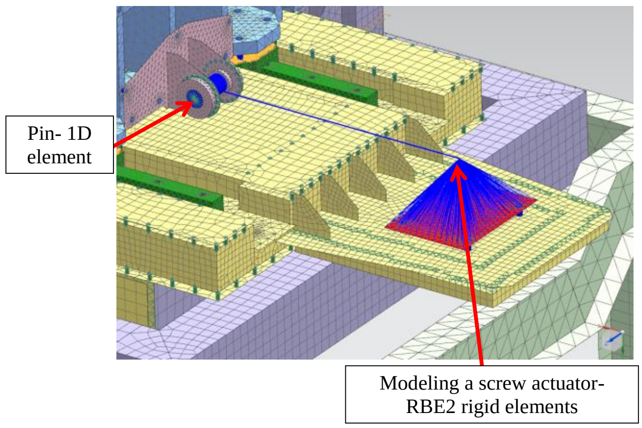

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Fig. 5. The modeling way of screw actuator
Rys. 5. Sposób zamodelowania siłownika śrubowego

Handles connection with frame construction of top cover was modeled in way presented on fig. 6. Interpolation elements type RBE3 forming screw connections and contact sets type „Surface to surface contact" were used for this. Handles in a discrete model of mold were created by means of three-dimensional tetrahedral elements whereas connection of hook with handle by using rod element (type ROD) reflecting pin connection.

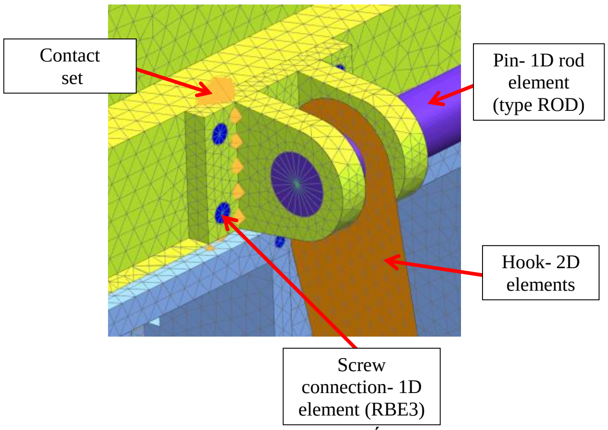

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Fig. 6. The modeling way of handle connection with frame construction of top cover
Rys. 6. Sposób zamodelowania połączenia uchwytu z konstrukcją ramową pokrywy górnej

To building of model of screw included in screw actuator between rocking frame and main frame RBE2 rigid element was used (fig. 7). RBE2 element was connected in one side with pin of rocking frame modeled by means of 1D rod element (type ROD), whereas on the other side groups of rigid element, which join screw with handle of actuator body. The actuator body has not been modeled, because it haven't significant impact to straining of construction elements of machine frame.

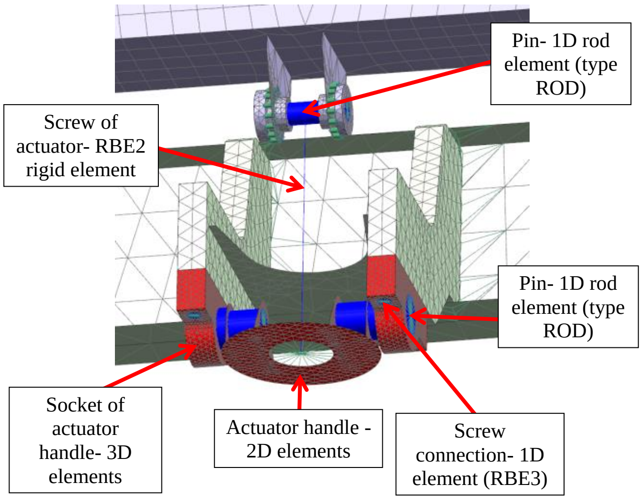

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Fig. 7. The modeling way of screw actuator connection with rocking frame
Rys. 7. Sposób zamodelowania połączenia siłownika śrubowego z ramą kołyskową

On fig. 8 was shown modeling method of pneumatic actuator with its connection to construction of top cover. Actuator body was modeled by using beam element (CBEAM) whereas piston rod by means of rod element (type ROD). On fig. 8, the beam and rod element in line form with assigned dimensional and material parameters was illustrated. In rod element added preload (type PRE-LOAD) in order to conducting analysis taking into account force generated by actuator. It allowed stresses recognition in handle of longitudinal pin in case of blocking of hook.

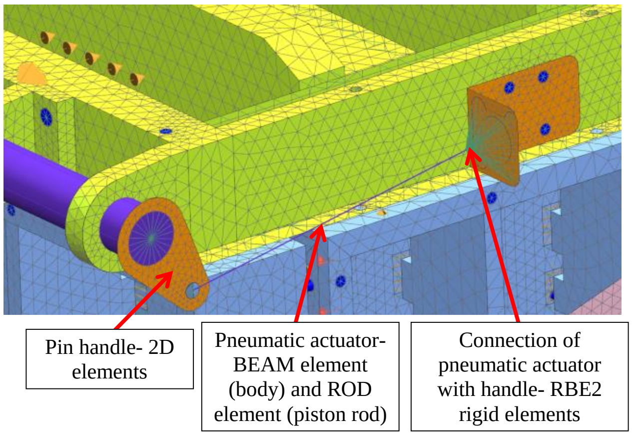

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Fig. 8. The modeling way of pneumatic actuator
Rys. 8. Sposób zamodelowania siłownika pneumatycznego

The size of finite elements was diversified in areas where elevated stress distribution was expected. Exemplary mesh density was presented on fig. 9. Decreasing of finite element sizes in chosen areas allowed to gaining more accurate stresses distribution (more accurate analysis results).

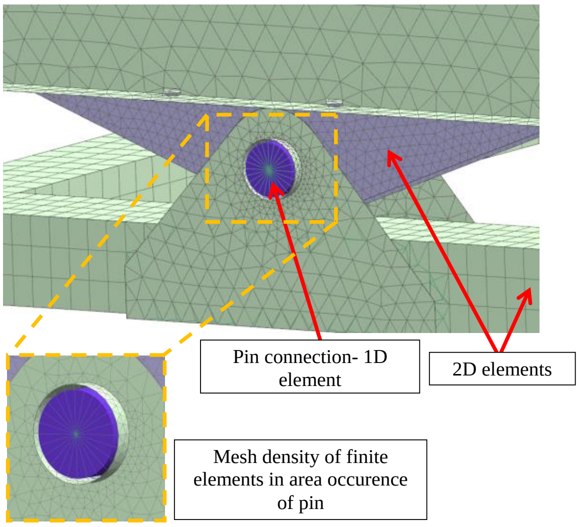

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Fig. 9. The way of mesh density of finite elements in connection of rocking frame with main frame
Rys. 9. Sposób zagęszczenia siatki elementów skończonych w połączeniu ramy kołyskowej z ramą nośną

On fig. 10 was presented modeling method of pneumatic cushion located in chamber of rocking frame. Pneumatic cushion in inflate state is connected between rocking frame and intermediate frame. Model of pneumatic cushion is very simplified model, which task is joining of intermediate frame with rest of machine construction and transmit loads to rocking frame. Finite elements of pneumatics cushions was preloaded (type PRE-LOAD).

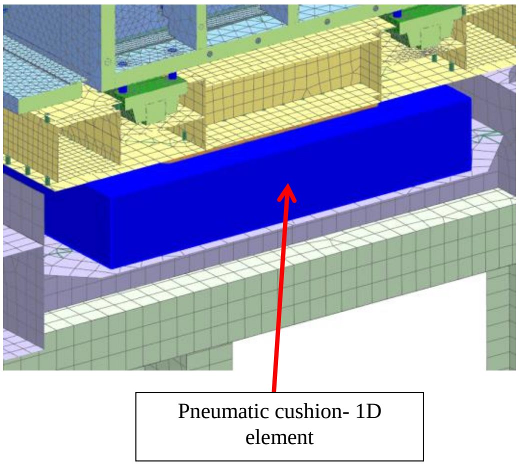

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Fig. 10. The modeling way of pneumatic cushion in calculation model
Rys. 10. Sposób zamodelowania poduszki pneumatycznej w modelu obliczeniowym

5. Results of simulation analysis

Calculations by means of finite element method was conducted for forces generated by pneumatic cushions (force: 200 kN every cushion) and foaming pressure, which act to side walls of mold and top cover. Forces from foaming process transmitted to intermediate frame via internal mold was included.

Calculation model presented in 4 chapter is a model with structural changes realized before. Results in form of H-M-H stress plots were presented on fig. 12. In hooks closing top cover acceptable of stress levels for S355 steel were exceeded. It was recommended to use steel with better strength properties in closing system - Hardox 500 steel.

In turn, on fig. 11 and 13 was presented results of earlier strength analysis before implementing of structural changes. Changes was implemented due to numerous exceedance acceptable stress values and displacements in mold construction to foaming of cooling furniture.

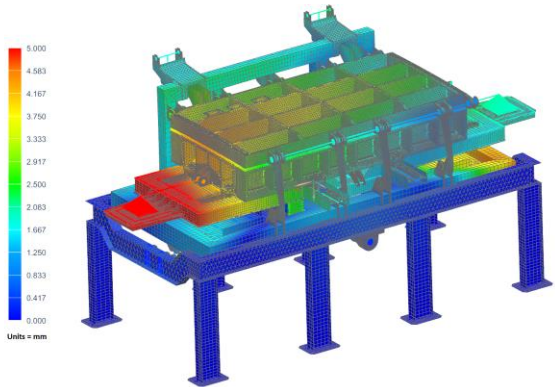

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Fig. 11. Displacements plot (before structural changes)
Rys. 11. Mapa przemieszczeń (przed zmianami konstrukcyjnymi)

6. Summary

The calculation model prepared in accordance with chapter 4 is base to conducting strength analyzes. For needs realize of purpose research multivariant structural analysis by using FEM was performed and state of construction straining of mold to foaming of cooling furniture type KL6-14 was assessed. In this article was presented final results of analyzes after implementing structural changes (fig. 12) and before any changes (fig. 13).

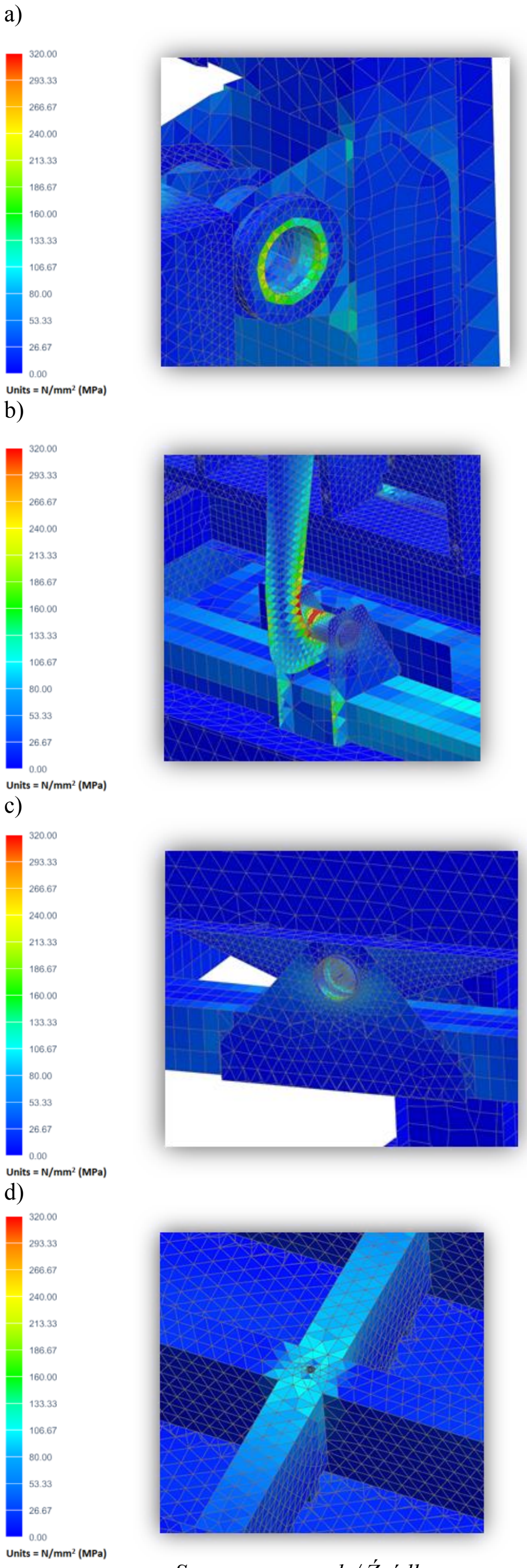

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Fig. 12. H-M-H stress plots (after structural changes): a) in pin connection of top cover and rocking frame, b) in hook, c) in connection of rocking frame with main frame, d) in ribs of top cover (PA4 aluminum)
Rys. 12. Mapy naprężeń H-M-H (po zmianach konstrukcyjnych): a) w połączeniu sworzniowym pokrywy górnej i ramy kołyskowej, b) w haku, c) w połączeniu ramy kołyskowej z ramą nośną, d) w użebrowaniu pokrywy górnej (aluminium PA4)

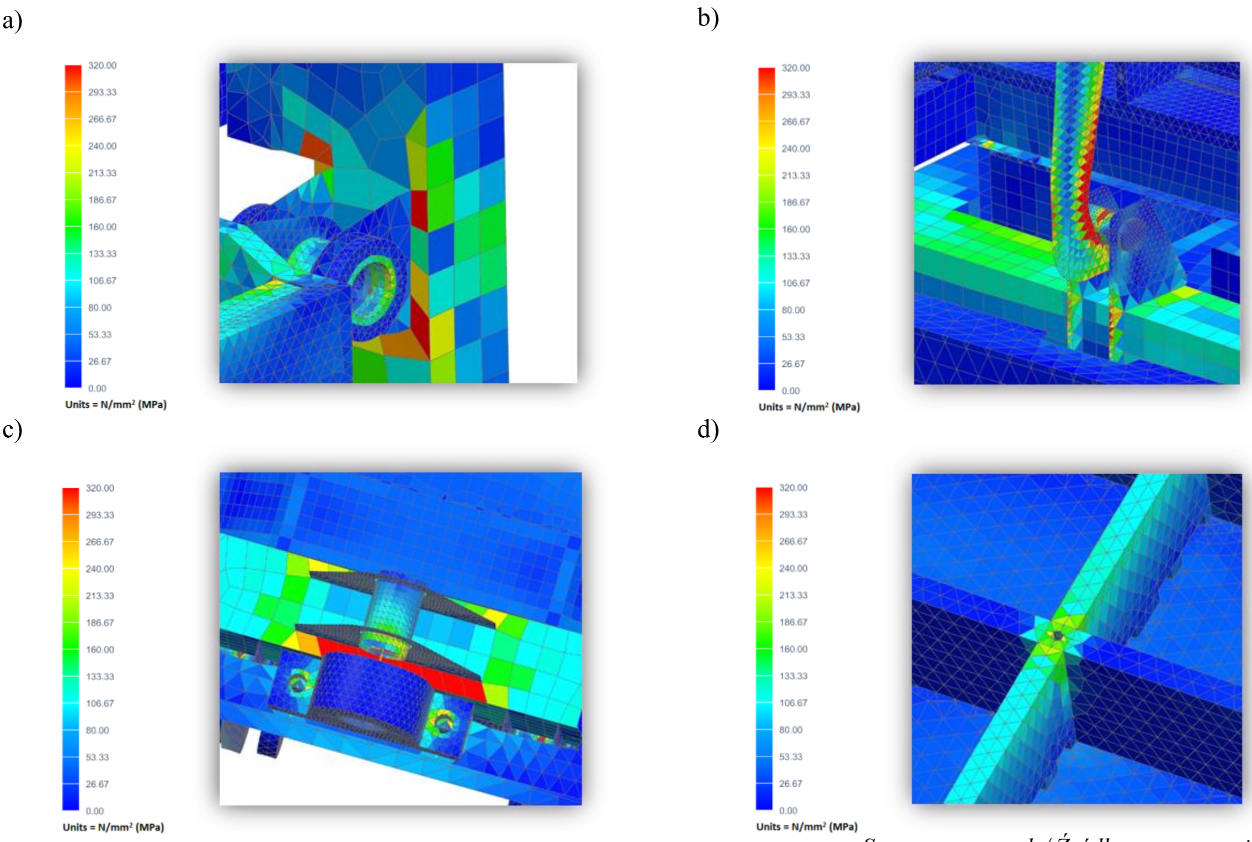

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Fig. 13. H-M-H stress plots (before structural changes): a) in pin connection of top cover and rocking frame, b) in hook, c) in connection of rocking frame with main frame, d) in ribs of top cover (PA4 aluminum)
Rys. 13. Mapy naprężeń H-M-H (przed zmianami konstrukcyjnymi): a) w połączeniu sworzniowym pokrywy górnej i ramy kołyskowej, b) w haku, c) w połączeniu ramy kołyskowej z ramą nośną, d) w użebrowaniu pokrywy górnej (aluminium PA4)

Based on results was affirmed, that is necessary:

- adding ribs and increase thickness of profiles walls in rocking frame,
- strengthen ribs in top cover,
- moving of pneumatic cushions close to center of mold in order to minimize displacements of top cover and intermediate frame,
- connection rebuild of rocking frame with main frame,
- rebuild of pins connection in top cover,
- use steel with better strength properties in closing system - Hardox 500 steel.

7. References

[1] Bąkowski H., Stanik Z., Kubik A., Wieszała R.: Prognozowanie zużycia w skojarzeniu ślizgowym na podstawie rozkładów i wartości naprężeń za pomocą MES. TTS Technika Transportu Szynowego, 2016, 12, 49-51.
[2] Zienkiewicz O.C.: Metoda Elementów Skończonych. Arkady, Warszawa 1972.

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