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Finite Element Analysis (FEA), flexible coupling,
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COMPUTER FINITE ELEMENT ANALYSIS OF STRESS DERIVED FROM PARTICULAR UNITS OF TORSIONALLY FLEXIBLE METAL COUPLING

Summary. In this article the results of Finite Element Analysis (FEA) results of stresses derived from chosen units of torsionally flexible metal coupling are presented. As model and simulation tool for particular component loads is used the Autodesk Inventor Professional 2009 program.

KOMPUTEROWA ANALIZA NAPRĘŻEŃ MES W WYBRANYCH ELEMENTACH METALOWEGO SPRZĘGŁA PODATNEGO SKRĘTNIE

Streszczenie. W artykule przedstawiono wyniki przeprowadzonej analizy naprężeń, wybranych elementów metalowego sprzęgła podatnego skrętnie z wykorzystaniem metody elementów skończonych (MES). Do zamodelowania oraz symulacji komputerowej obciążeń poszczególnych podzespołów zastosowano program Autodesk® Inventor® 2009.

1. INTRODUCTION

In numerous branches of industry the power transmission system components are exposed to high and time variable loads. One of dynamic duty reduction methods in the power transmission system is the application of metal couplings with torsional flexibility. Absolutely new construction dealing with above described questions is highly torsionally flexible metal coupling – a solution developed in the Institute of Mining Mechanization at the Silesian University of Technology in Gliwice[1, 2, 3, 4].

The torsionally flexible coupling is characterized by specific elastic and damping features, that are of crucial role in the power transmission system performance. It owes its properties to the change of run as well as the stabilization of the torsional vibration and load torque. In consequence, reduction of dynamic interaction in power transmission system components leads to their increasing durability and reliability.

One of the structure forms of a two-way- flexible torsional metal coupling is presented on Fig. 1.

2. TORSIONALLY FLEXIBLE METAL COUPLING - STRESS ANALYSIS OF SELECTED UNITS

The torsionally flexible metal coupling construction can be accounted to the novel machine constructions, in which computer programs allowing not only 3D object visualization but also complete coupling mechanism project evaluation (in kinematic, dynamic and durability aspect) are used. Application of appropriate CAD-type software enables performance test of a coupling, before its prototype will be elaborated.

In order to perform stress analysis of chosen coupling elements Autodesk® Inventor ® 2009 program was applied. This program provides a convenient way to create solid model of coupling, carries out dynamic analysis of working mechanism, supplies stress analyze derived from putting under load elements by means of FEA as well. Solver used in the discussed software is exactly the same as applied in the ANSYS® program.

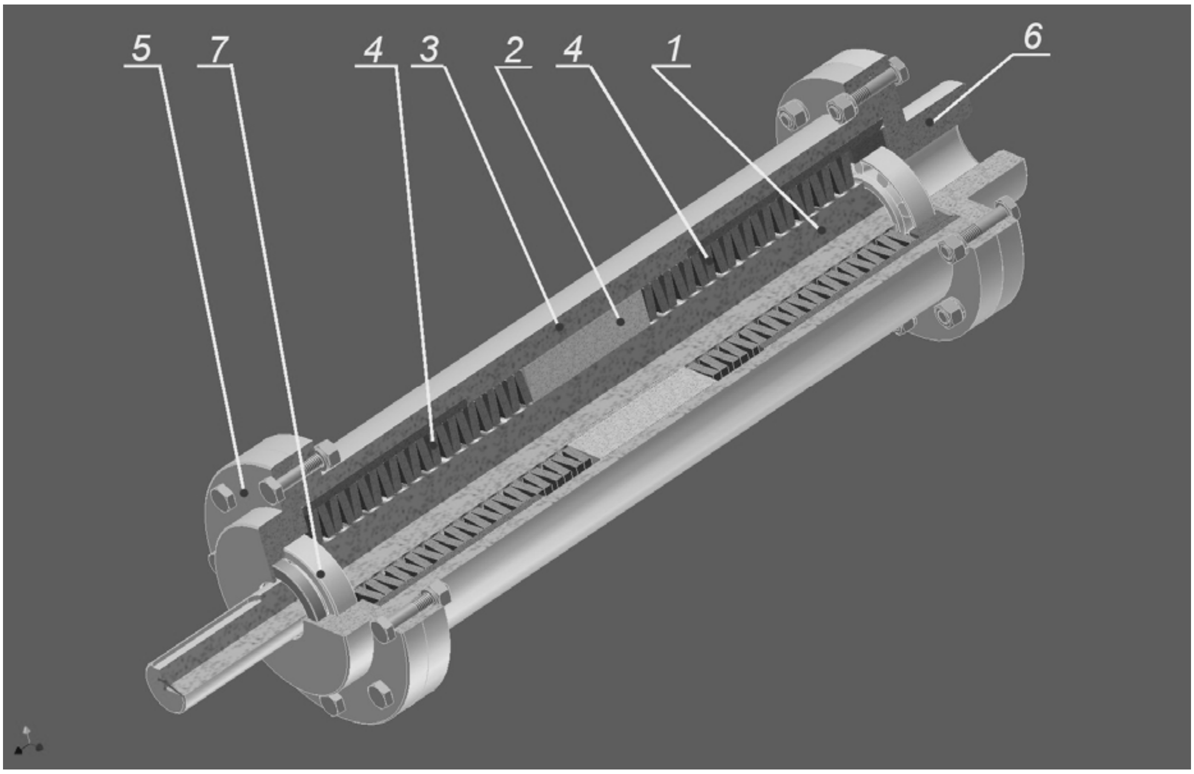

Fig. 1. Two-way- flexible torsional metal coupling prototype construction. 1 – screw-threaded coupling shaft, 2 – splinded sliding sleeve with internal screw thread, 3 – housing with cut splines, 4 – disk spring set, 5 – cover plate, 6 – coupling hub, 7 – cone bearings

Rys. 1. Budowa prototypu metalowego sprzęgła podatnego skrętnie dwukierunkowego działania, gdzie: 1 – wał sprzęgła z wykonanym gwintem, 2 – tuleja przesuwna z wykonanym gwintem wewnętrznym i wielowypustami, 3 – obudowa z naciętymi wielowypustami, 4 – zestawy sprężyn talerzowych, 5 – pokrywa zamykająca, 6 – piasta sprzęgła, 7 – łożyska stożkowe

It was established prior to the FEA was made, that the interest of the study should concern the single chosen coupling parts transmitting working load and playing a crucial role in principle of operation and coupling construction. This premise was adopted due to the needs of maximal simplification of the simulated model. In consequence, the obtained results presented higher correctness than it would be in a case of more complicated modelling of contact between particular construction elements and whole coupling mechanism consideration. Furthermore, implementation of more complicated analyze possibilities was also narrowed by a low computing power of available FEA software version.

2.1. Stress analysis of the coupling shaft

FEA simulation was performed for coupling with definite geometrical features that result from previous made standard strength calculations. In the calculations taken into consideration were all dependences necessary to carrying out a properly running mechanism in aspect of dynamic and durability.

During coupling shaft stress analysis we decided to consider two cases. In the first of them a coupling shaft was put under load by maximal torque moment that for investigated coupling prototype amounted to 410 Nm; considered were only stresses derived from this type of load, i.e. from torsional shaft load.

Preliminary calculations which shows, that in axial force acting in sliding sleeve screw joint trigger the torque moment of 39000 N. The force causes sleeve translation along coupling axis, i.e. simultaneous compression and relaxation of disk spring sets.

Considered was the most unfavorable case, where the analyzed shaft segment length is equal to the distance between maximal torque moment point (key joint origin) and the maximal shaft translation point produced by maximal axial load (maximal torque moment).

Fig. 2 shows graphic illustration of analyzed case.

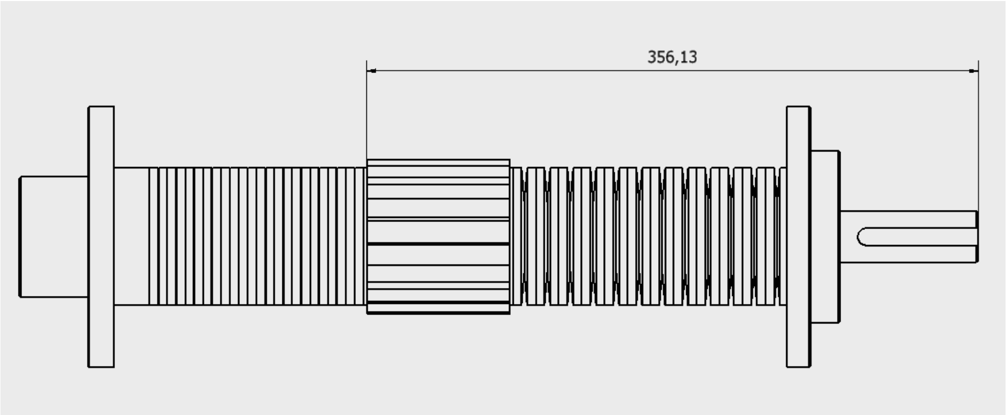

Fig. 2. Analyzed coupling shaft length resulting from maximal axial load originating in coupling screw thread mechanism

Rys. 2. Analizowana długość wału sprzęgła, wynikająca z działania maksymalnej siły osiowej, powstałej w mechanizmie gwintowym sprzęgła

This above mentioned finding implicates input shaft length of 356,13 mm.

In a previously defined by an established sliding sleeve position cutting plane we estimated so-called ‘stability bound’. From splineway side the shaft was put under load by maximal running torque amounted to 410 Nm. The graphic presentation of the analysis results is highlighted in Fig. 3.

The input shaft of coupling is produced from improved and hardened steel 41Cr4. In the whole screwed shaft partly the main stress values do not overcome 71,2 MPa. The maximum stresses occur in a splineway as a result of notch effect. In that point about 164 MPa.

The second analyzed concern is a consideration and of the thrust originating from a collaboration with the coupling sliding sleeve that occurs in rectangular profiled screw joint. In order to reach that above mentioned aim, an input shaft segment of 83mm length corresponding to the sliding sleeve length was separated. The stability bound was established on the cross-section surfaces of the shaft. After the screw thread surface was put under load and maximum load was estimated at 14 MPa the compute procedures were conducted for kinetic screw joint and steel made material [3]; the results are presented in Fig. 4.

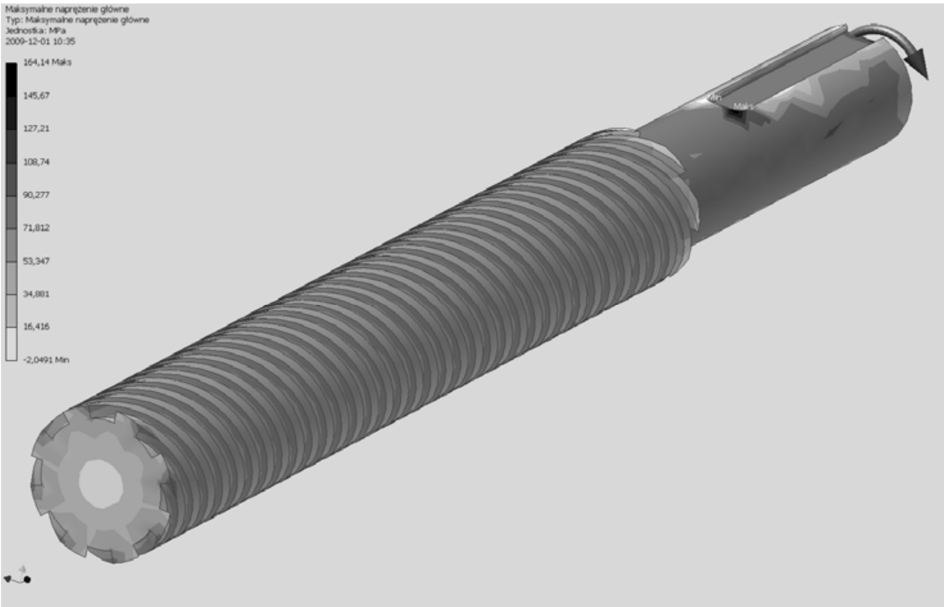

Fig. 3. The maximum main stress values in the coupling shaft as a function of the maximum torque moment
Rys. 3. Wartości maksymalnych naprężeń głównych w wale sprzęgła w wyniku działania maksymalnego momentu obrotowego

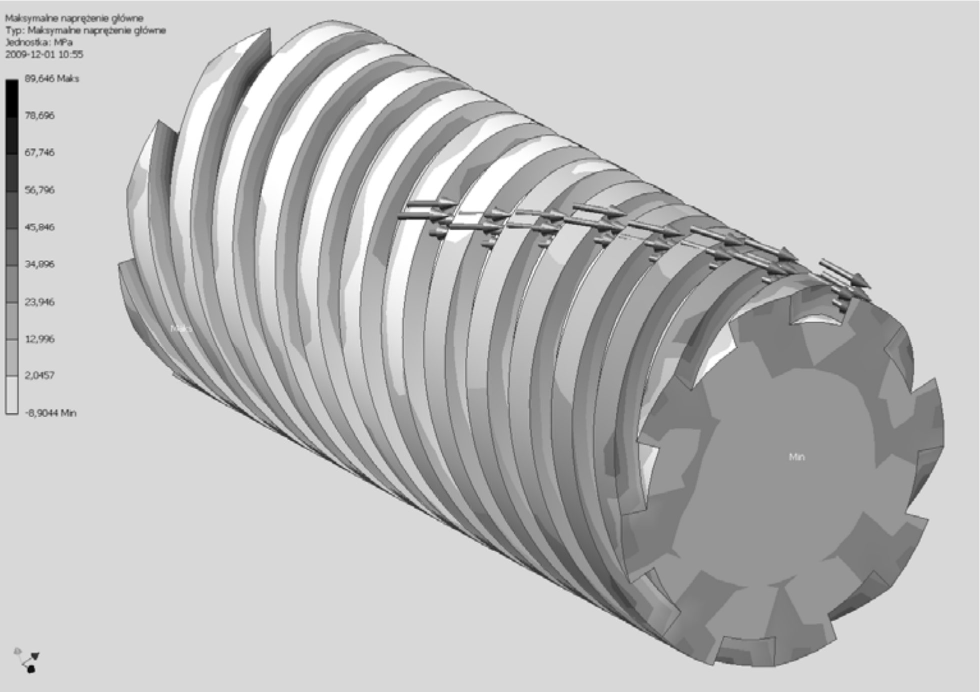

Fig. 4. The maximum main stress values in the coupling shaft as a result of thrusts exerted on screw joint surface
Rys. 4. Wartości maksymalnych naprężeń głównych w wale sprzęgła w wyniku działania nacisków na powierzchniach połączenia gwintowego

The main stress values determined in analyzed element as well as in considered shaft segment are uniformly distributed. Hereby, the values do not exceed 25 MPa. Minimum and maximum main stress values are located in element rims, which not fully reflect the real state of stresses, because this kind of distribution is strictly connected with method of stability bound determination and load type.

2.2. Stress analysis of the internal threaded and splined sliding sleeve

The load put on the bronze made (alloy B101) sliding sleeve mainly results from force values and force distribution in screw joint between coupling sleeve and coupling shaft as well as from force interaction between sleeve and coupling housing (splined connection).

Internal multiturn thread of sliding sleeve cooperates with external threaded shaft. While the shaft is put under load by torque, the performed screw joint enables sliding sleeve movement along shaft axis. Hence, this is kinetic connection with permissible surface thrust according to equalling [3] 14 MPa.

The load was put on the side surface contour of the square thread located in the sleeve, and next the bound was estimated on the surface of splines that limit the rotation movement of sliding sleeve, subsequently the bound was estimated on the sleeve's front surface (sleeve's surface bound is at the same time the spring set interaction); above mentioned operations were followed by computer simulation, the results are presented in Fig. 5.

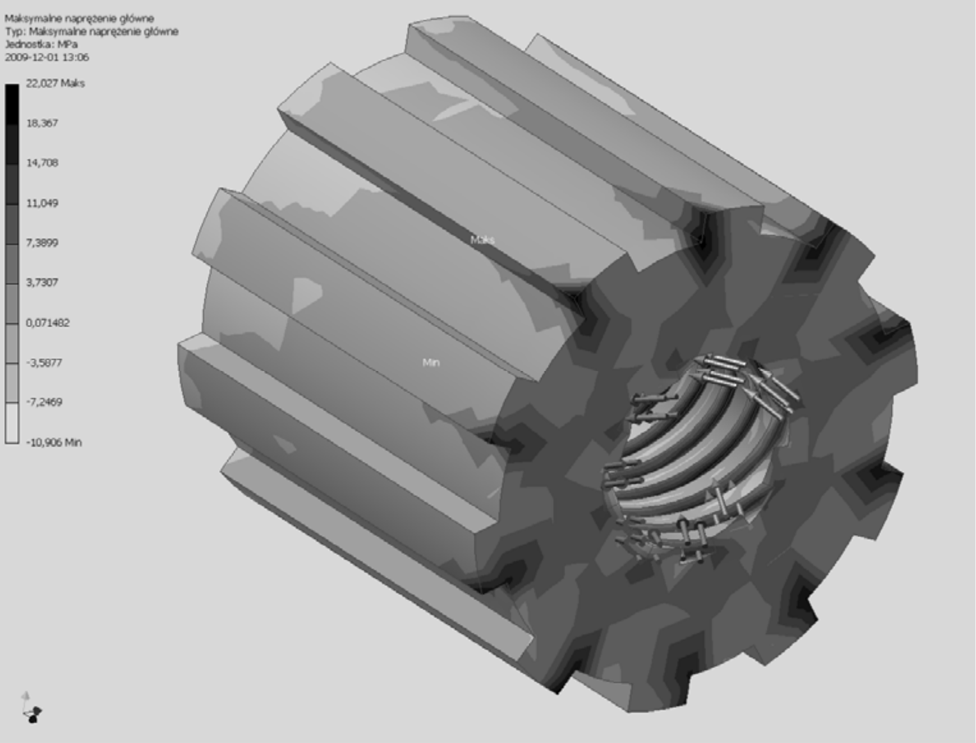

Fig. 5. The maximum main stress values in the sliding sleeve as a result of forces originating in the screw thread mechanism

Rys. 5. Wartości maksymalnych naprężeń głównych w tulei przesuwnej w wyniku działania sił pochodzących od mechanizmu gwintowego

It can be observed that the highest main stress values appear in the notch areas of the structure, i. e. at the groove bottom of multiturn square thread and splines. These values averaged about 22 MPa. Although, the mean stress values mostly do not exceed 4 MPa.

In further analysis considered was a case of surface thrust imposed on the sides of splines (Fig. 6). On the basis of the results obtained from this study we can draw conclusion that for defined sliding sleeve length the main stress values are about 4 MPa.

The same as previous, the highest stress accumulation (Fig. 6) occurs in the places with abrupt change of surface contour, i. e. at the bottom of cut internal thread or at the bottom of each groove between the splines; the stress reaches about 7 MPa. Simultaneous compression occurs on the splines surfaces with the mean pressure value lower than 0,72 MPa.

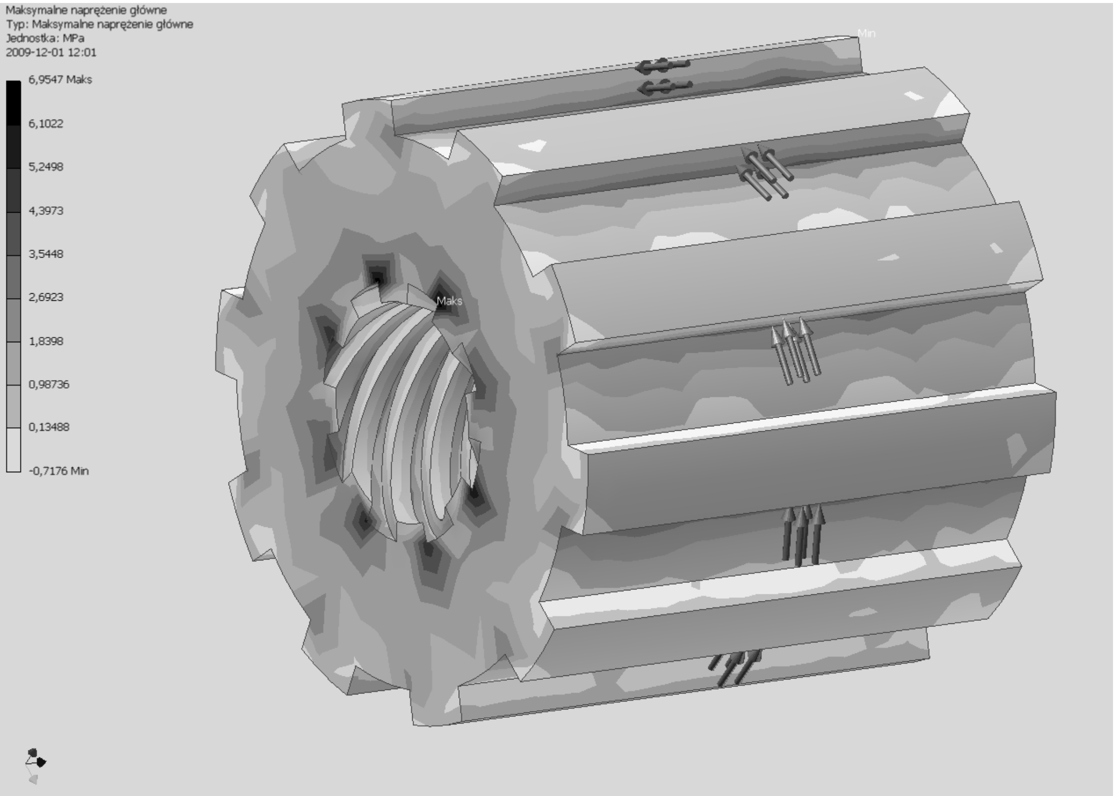

Fig. 6. The maximum main stress values in the sliding sleeve as a result of force originating in splined connection
Rys. 6. Wartości maksymalnych naprężeń głównych w tulei przesuwnej w wyniku działania sił pochodzących od połączenia wielowypustowego

2.3. Stress analysis of the coupling housing

Analogous to the deliberations regarding the coupling shaft, FEA was conducted only in the section of coupling housing with direct contact to the sliding sleeve and serving as a load transmitter; the analyzed segment length equaling the sleeve length counts 83mm. The load in the form of surface threads was put on the side surfaces of splines; the discussed case is presented in Fig. 7. The stability bound was established on the periphery of the housing section.

The graphic analysis shown in Fig. 7 indicates that the maximum main stress values averaging 2 MPa are located in the so called ‘notch effect’ region. Hence, a general conclusion can be drawn, that the housing is not a high loaded element of the coupling.

2.4. Stress analysis of the disk sprig set

In the coupling mechanism the function of a spring and damping element exercise the disk springs of suitable characteristics; the springs aligned in an appropriate sets and packets ensure at the same time the required elastic characteristics of coupling. Due to the considerable deformations of springs and significant problem modelling their with mutual interaction the available software precludes comprehensive spring set analysis. Therefore, analyzed is only individual disk spring.

From the forces estimated for the screw thread mechanism follows that the sliding sleeve can act on the disk spring set with maximum axial force of 39000 N. In the coupling set the individual disk springs form packets, furthermore in every particular spring occurs the same compressing elastic force equaling maximum axial force derived by screw thread mechanism. The load is put on the internal edge of the spring (Fig. 8). The stability bound is estimated on the external circumference of the spring, on the other side of the spring (opposite to the compression side).

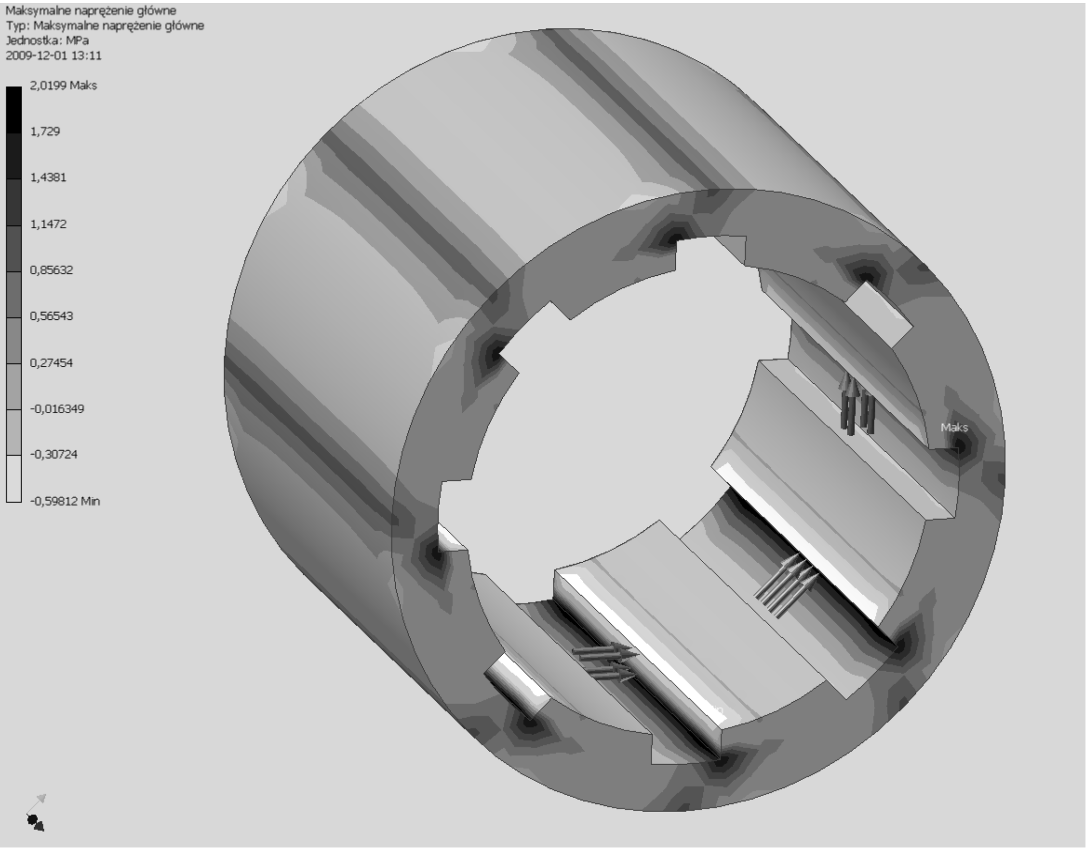

Fig. 7. The maximum main stress values in the analyzed section of the coupling housing
Rys. 7. Wartości maksymalnych naprężeń głównych w analizowanym odcinku obudowy sprzęgła

The distribution of the main stress values in the spring is clearly uniformly gradated, ranges from the internal to the external diameter of the spring (Fig. 8). The maximum main stress values amounting to about 83 MPa occur on the external circumference of the spring, whereas the minimum stresses occur on the internal circumference; on the internal circumference the negative stresses (compressing stresses) with the pressure values below 12,2 MPa are found as well.

3. SUMMARY

Implementation of innovative machine forms and devices is supported by appropriate software enabling performance tests, before the prototype will be elaborated.

In order to verify the durability of planned torsionally flexible metal coupling construction a virtual prototype in Autodesk Inventor 2009 program was modeled. Computational simulation was preceded by consideration of expected loads, implicating from constructional features of coupling stability bounds as well as the coupling mechanisms concerning particular solid models. The simulation result consists of the graphic presentation of the main stress distribution in analyzed element. Analysis of obtained results ascertained, that in every investigated element the yield point of material was not exceeded. A conclusion can be drawn that the analyzed construction of the torsionally flexible metal coupling prototype affirms its correctness in the durability aspect.

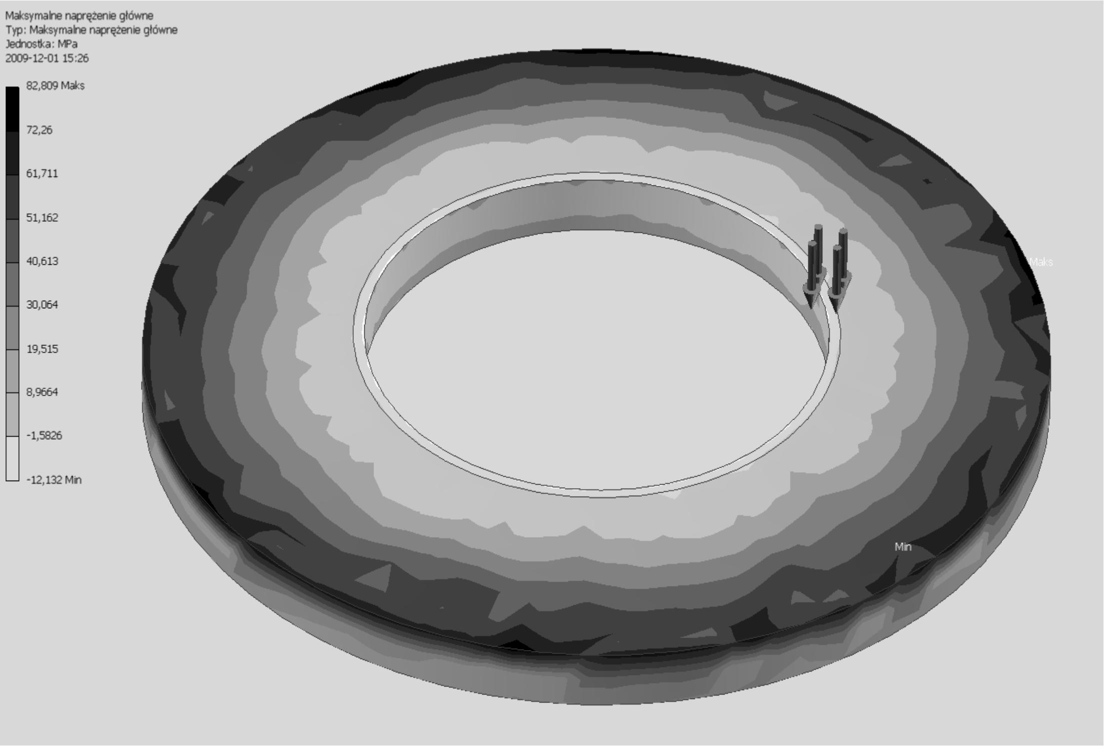

Fig. 8. The maximum main stress values in the individual disk spring
Rys. 8. Wartości maksymalnych naprężeń głównych w pojedynczej sprężynie talerzowej

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