STUDIEREA SI IMBUNATATIREA DISTRIBUTIEI INCARCATURILOR PE AXUL CILINDRULUI DE ACTIONARE AL UNEI BENZI TRANSPORTOARE, CU O IMBINARE CONSOLA LA GRUPUL REDUCTORULUI MOTORULUI

Conf. univ. dr. ing. Tsvetan Damyanov
Universitatea de Minerit si Geologie "St. Ivan Rilski", 1700 Sofia

STUDYING AND IMPROVING THE DISTRIBUTION OF LOADS ON THE SHAFT OF A DRIVING DRUM OF A BELT CONVEYER WITH A CANTILEVER JOINT TO THE MOTOR-REDUCER GROUP

Assoc. Prof. PhD. Eng. Tsvetan Damyanov
University of Mining and Geology "St. Ivan Rilski", 1700 Sofia

REZUMAT: *A fost studiata incarcarea unui ax al cilindrului de actionare al unei benzi transportoare cu doua actionari ale cilindrului si imbinare consola (pendul) la grupul reductorului motorului. Pe langa distributia deformarilor si tensiunii, reactiile fortei in pivotii axului si la imbinarile grupului reductorului motorului, cu cadrul statiei de actionare, au fost, de asemenea analizate. A fost sugerata o schema principala a egalizatorului mecanic, pentru reducerea reactiei fortei, care incarca pivotii sferici in pivotii axului.*

Cuvinte cheie: cilindru, banda transportoare, egalizator mecanic, pivoti sferici, pivotii axului.

ABSTRACT: *The loading of the shaft of a driving drum of a belt conveyer with a two-drum drive and cantilever (pendel) joining of the motor-reducer group has been studied. In addition to the distribution of deformations and tensions, the force reactions in the bearings of the shaft and the joints of the motor-reduction group with the frame of the driving station have also been analyzed. A principal scheme of a mechanical compensator for reducing the force reaction, which loads the spherical bearings in the bearings of the shaft, has been suggested.*

Key words: driving drum, belt conveyer, mechanical compensator, spherical bearings.

Introducere

Siguranta operationala si perioada de functionare a operatiunilor grele si benzile transportoare, foarte productive, reprezinta o caracteristica speciala, foarte importanta pentru sistemele de transport in mina, cu functionare continua. Pot fi mentionate multe motive pentru a intari declaratia de mai sus. Unul dintre acestea face referire la scara ridicata de pierderi directe si indirecte ale productiei, in cazul accidentelor in sistemul mecanic. Pe de alta parte, supraincarcarea mecanica a elementelor, le reduce timpul de functionare. Facand referire la cele mentionate mai sus, se poate conchide ca studierea valorii sistemelor de actionare pentru benzile transportoare, presiunile si reactiile de forta

Introduction

The operational safety and time of operation of the heavy-duty and highly productive belt conveyers is an especially important characteristic for the mine-transportation systems of continuous operation. Many reasons can be mentioned to substantiate the above statement. One of them is related to the large scale of direct and indirect production losses in case of accidents in the mechanical system. On the other side, mechanical overloading of the elements reduces their time of operation. With regard to the above, it may be summarized that studying the value and distribution of deformations, tensions and force reactions in

din elementele sistemului pentru actionarea benzilor transportoare, reprezinta o misiune importanta, de recent interes.

Starea discutiei si metodele de studiu

Distributia incarcaturii mecanice a cilindrilor de actionare si a arborilor acestora, pentru sistemele de actionare a multiplilor cilindrii de la benzile transportoare este mentionata ca un principiu in fig. 1. Pe langa fortele gravitationale interioare, volumetrice (G_P, P_G, P_{GR}), fortele exterioare, create de interactiunea curelei cu cilindrul (S_{in}, S_{out}) au fost, de asemenea, studiate si fortele reactiilor de la pivotii arborelui si imbinarile cardan din punctele A1 si A2. Sub actiunea fortelor de mai sus, apare o conditie complicata a fortei din cadrul obiectului studiat, care depinde, de asemenea, de tensiunea permanenta, creata de imbinarile arborelui cu capetele cilindrului si golul arborelui de actionare al reductorului [1, Damyanov]. Forta creata de reactiile din pivotii arborelui primului cilindru de actionare, este mare, deoarece actioneaza cu forte elastice mai ridicate, daca banda transportoare (S_{out} and S_{in}), care intra in contact si elimina contactul cu cilindru. Aceasta este baza care este folosita si pentru a calcula timpul de operare al rulmentilor sferici cu role, la pivotii arborelui, legati de cadru. Reducerea acestor reactii ale fortelor poate creste atat in timpul pentru functionare si siguranta operationala a unitatii de sprijin. Experienta practica a demonstrat ca toate daunele la acele unitati de suport produc accidente severe, ceea ce inseamna ca exista posibilitatea distrugerii arborelui cilindrului de actionare.

Principala misiune a studiului este reprezentata de determinarea unor variante diferite, de constructie a sistemelor de actionare, cu doi cilindrii (scheme cu motor in trei – si patru) asupra distributiei oportunitatilor pentru reducerea fortelor de reactie din cadrul pivotilor cadru si reducerea tensiunii din arborele de actionare, de

the elements of the system for driving the belt conveyers is and important engineering task of recent interest.

Status of the issue and method of the studies

The distribution of mechanical loading of the driving drums and their shafts for the systems of multi-drum drive of the belt conveyers is shown as a principle in fig. 1 In addition to the inner volumetric gravity forces (G_P, P_G, P_{GR}), the outer forces, created by the interaction of the belt with the drum (S_{in}, S_{out}) have also been studies and the force reactions in the shaft bearings and the cardan joints in points A1 and A2. Under the action of the above forces a complicated stress condition arises in the studied object, which depends also on the permanent tension, created by the joints of the shaft with the heads of the drum and the hollow driving shaft of the reducer [1, Damyanov]. The highest is the force, created by reactions in the bearings of the shaft from the first driving drum because it operates with higher tensile forces if the conveyer belt (S_{out} and S_{in}), which comes into contact and goes out of contact with the drum. That is the basis used also for calculation of the operational time of the spherical roller bearings at the bearings of the shaft, joined to the frame. The reduction of those force reactions may increase both the time for operation and the operational safety of the bearing units. Practical experience has shown that all the damages on those bearing units cause very severe accidents, which means cases of destruction of the shaft of the driving drum is also possible.

The main task of that study is determining the effect of different construction variants of the two-drum systems for driving (three- and four-motor schemes) on the distribution and opportunities for reduction of reaction forces in the frame bearings and reduction of tension in the driving shaft, as well. Another

asemenea. O alta lucrare a autorului [1] a prezentat studii similare pentru incarcatura extrema a fortei, la modulul pornire. Pentru ca perioada de functionare a unitatilor de suport este calculata pe baza incarcaturii mecanice, in regim continuu, aici, incarcatura mecanica a pivotilor cilindrului si arborele cilindrului, in mod de utilizare stationara, au fost definite, analizate si comparate.

Metoda de studiu este un studiu al modelului de simulare al obiectului real – banda transportoare cu doi cilindrii CAD-CAE, implementata in software-ul de la Cosmos Works si creat in cadrul conformitatii geometrice si fizico-mecanice cu obiectul real al unui astfel de sistem de actionare, cu doi cilindrii. Face referire la banda transportoare "ГТЛ № 3301" (Tabelul 1), care actioneaza la mina "Troyanovo 3" de la "Maritsa East Mines" EAD si este una dintre cele mai utilizate (cu cel mai ridicat flux de incarcatura). O aplicatie software a metodei elementelor finite a fost utilizata pentru a realiza analiza liniara, structurala (FEA) a obiectului de studiu si valorile urmatoarelor dimensiuni (tensiuni, deformari, forte de reactie, etc) au fost determinate in cadrul conditiilor si incarcaturilor, limita.

work of the author [1] has already presented similar studies for extreme force loading under the starting mode. As the time of operation of the bearing units is calculated on the basis of mechanical loading in a continuous regime, here, the mechanical loading of the bearings and the shaft of the drum in a stationary operating mode have been defined, analyzed and compared.

The method of studies is a model simulation study of a real object – two-drum belt conveyer. The simulation model is parametrical CAD-CAE, implemented in a software medium of Cosmos Works and created under the geometrical and physical-mechanical compliance with the real object of such two-drum system for driving. It refers to the belt conveyer "ГТЛ № 3301" (Table 1), which operates at "Troyanovo 3" mine of the "Maritsa East Mines" EAD and is one of the most heavily operated (with the highest load-flow). A software application of the finite elements method has been used for performing structural linear analysis (FEA) of the studies object and the values of the following magnitudes (tensions, deformations, force reactions etc.) have been determined under the described boundary conditions and loadings.

Tabel 1

№	Transportor-T7	Cantitate formula	Unitate	Valoare
Parametrii tehnici majori ai benzii transportoare -T7			
1	L	Lungime transportor	m	1162
2	Δ	Diferente totale la nivel	m	33.00
3	v_b	Viteza benzii	m/s	5.24
4	Q_o	Volum de transport	m^3/h	8000
5	ρ	Densitate masa	t/m^3	1.28
6	q_L	Greutate banda	N/m	1070
7	α_1	Arc invelire contract-I drv.cilindru.	[deg]	177^0
8	a_2	Arc invelire contract -II drv. cilindru	[deg]	190^0
9	F_o	Forta tensiune	N	180000
10	D_b	Diametru cilindru	m	1.63

Table 1

№	Conve-yor-T7	Formula quantity	Unit	Value
Major technical parameters of belt conveyer -T7				
1	L	Conveyor length	m	1162
2	Δ	Total difference in levels	m	33.00
3	v_b	Belt speed	m/s	5.24
4	Q_o	Conveying volume	m^3/h	8000
5	ρ	Bulk density	t/m^3	1.28
6	q_L	Belt weight	N/m	1070
7	α_1	Arc of contact wrap-I drv.drum.	[deg]	177^0
8	a_2	Arc of contact wrap-II drv.drum	[deg]	190^0
9	F_o	Tension force	N	180000
10	D_b	Drum diameter	m	1.63
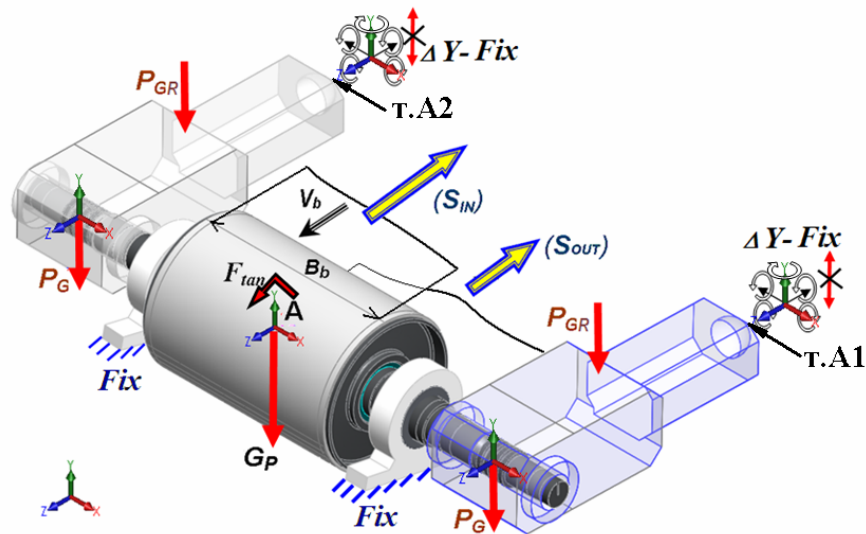
Figure 1 Cilindru de actionare, cu doua laterale, avand ansamblu consola (pendul) al unitatilor motor- reducator, unde: S_{in} reprezinta forta presiunii asupra curelei, care intra in contact cu cilindrul; S_{out} – forta presiunii partii exterioare a curelei; G_P – forta gravitationala a cilindrului de actionare; P_G– componenta fortei gravitationale a grupului motor - reducator; P_{GR}- forta gravitationala a grupului motor - reducator; F_{tan} – forta tangentiala, de actionare, intre curea si cilindru.

Un cilindru de actionare, cu doua unitati de actionare, care sunt pozitionate bilateral, in ceea ce priveste axului cilindrului, este prezentat in fig. 1. Legatura cinematica intre axul extern al reductorului

Figure 1 Two-sided driving drum with a cantilever (pendel) assembling of the motor-reducer units, where: S_{in} is the force of stress in the belt, which comes into contact with the drum; S_{out} – force of stress of the outgoing side of the belt; G_P – gravity force of the driving drum; P_G– component of the gravity force of the motor-reducer group; P_{GR}-gravity force of the motor-reducer group; F_{tan} – tangential driving force between the belt and the drum.

A driving drum with two driving units, which are bilaterally positioned with regard the shaft of the drum, is shown in fig. 1. The kinematics joint between the outer shaft of the reducer and the shaft of the motor is an immovable joint, performed by tightening

si axul motorului este o legatura imobila, realizata de inelele de etansare ale RF 7012-XXX-XXX, in conformitate cu normele DIN 7012. Suportul extern al grupului motor-reducator este legatura cinematica pe care o care cu cadrul, cu 5 grade mobilitate (DOF=5) si care previne miscarea liniara de-a lungul axei verticale Y-(ΔY=0). Cilindrul de actionare este conectat de cadrul statiei de miscare, cu doi pivoti sferici, cu DOF=3.

Caracteristicile modelului parametric CAE s-au bazat pe alte studii ale autorului [1, Damyanov] si pot fi descrise dupa cum urmeaza:

1. Presiunile mecanice, cauzate de inelele de etansare (RF7012) in zonele de contact cu axul, capetele cilindrului si orificiul cilindrului la reductor au fost suprimate, deoarece valorile dominante ale acestor presiuni fac dificila analiza distributiei tensiunii, cauzata de forta interactiunii intre curea si cilindru si alte incarcaturi;

2. Modelul CEA va fi simplificat, referitor la numarul valorilor discrete ale distributiei fortei tangentiale, de actionare si presiunea normala, care sunt transmise de cureaua cilindrului, in contact cu zona de frecare. S-a stabilit ca zonele celor mai ridicate deformari si tensiuni sunt pe ax iar acele valori, sunt mai scaute decat pentru cilindru;

3. Subiectul studiului este primul cilindru de actionare, deoarece suporta o incarcatura mai mare datorita fortelor elastice ale curelei pentru schemele consecutive (statii de actionare cu 4 motoare si 2 cilindri);

4. Incarcatura consola pe axul cilindrului, datorita fortei gravitationale a grupului motor-reducator, nu este exprimata in parametrii, datorita faptului ca programul CAE il defineste in mod automat.

Rezultate

Pe langa o simulare a 8 variante de

rings of the RF 7012-XXX-XXX, according to the DIN 7012 norms. The other support of the motor-reducer group is the kinematics joint with the frame with 5 degrees of freedom (DOF=5) and preventing the linear displacement along the vertical axis Y-(ΔY=0). The driving drum is joint to the frame of the driving station by two spherical bearings with DOF=3.

The characteristics of the parametrical CAE model have been based on other studies of the author [1, Damyanov] and may be described as follows:

1. The mechanical stresses, caused by the tightening rings (RF7012) in the areas of contact with the shaft, the heads of the drum and the hollow shaft of the reducer have been suppresses, because the dominating values of those stresses make difficult the analysis of the distribution of tension, caused by the force interaction between the belt and the drum and the other loads;

2. The CEA-model will be simplified with regard the number of discrete values of the distribution of the tangential driving force and the normal pressure, which are transmitted from the belt to the drum in the contacting frictional area. It has been established that the areas of the highest deformations and tensions are on the shaft and those values are negligibly lower for the drum;

3. Subject of the study is the first driving drum, because it experiences higher loading due to tensile forces of the belt for the constructive schemes (4-motor two-drum drive stations);

4. The cantilever load on the shaft of the drum due to the gravity force of the motor-reducer group is not expressed parametrically, because the CAE program defines it automatically.

Results

Further to a simulation of 8 variants of

combinatii a doua scheme constructive (statii de actionare cu 3 si 4 motoare), 2 moduri de stationare (miscare inutila $Q_o=0$ m^3/h si incarcatura nominala $Q_o=8000$ m^3/h) si 2 moduri de compensare (cu si fara egalizator) rezultatele reactiilor fortei in unitatile de sprijin si tensiunile (^{von}) in toate punctele obiectului studiat au fost obtinute si sistematizate in Tabelul 2 si Tabelul 3.

combination of two constructive schemes (3 and 4 motor driving stations), 2 stationary modes (idle move $Q_o=0$ m^3/h and nominal load $Q_o=8000$ m^3/h) and 2 modes of compensation (with and without a compensator) the results of the force reactions in the bearing units and the tensions (^{von}) in all the points of the studied object have been obtained and systematized in Table 2 and Table 3.

Tabel 2	SCHEMA ACTIONARII – 4 motoare (2x1000 kW + 2x1000 kW)							
Q_o, m^3/h	F_{in}, kN	F_{out},kN	F_{sum},kN	F_{tan}, kN	M_t, N.m	$^{max}\sigma_{von}$, MPa	F_{res}, kN ($F_{comp}=0$)	F_{res}, kN ($F_{comp}=300kN$)
0	311	242	553	62	49957	27 56	325	173
8000	672	422	1094	242	196016	65 80	558	264

Tabel 3	SCHEMA ACTIONARII – 3 motoare (2x1000 kW + 1x1000 kW)							
Q_o,m^3/h	F_{in},k N	F_{out}, kN	F_{sum},kN	F_{tan}, kN	M_t, N.m	$^{max}\sigma_{von}$, MPa	F_{res}, kN ($F_{comp}=0$)	F_{res}, kN ($F_{comp}=300kN$)
0	311	221	533	82	66609	29 48	318	166
8000	672	341	1013	323	261355	81 98	514	216

8000	672	341	1013	323	261355	81 98	514	216

Vectorii reactiilor fortei care rezulta in pivotii fiecarui grup motor- reductor, sunt prezentati in figura 2 si in figura 3 iar distributia si valorile tensiunii maxime, echivalente, $^{max}_{von}$ sunt prezentate in figura 4 si figura 5.

The vectors of the resulting force reactions in the bearings of each of the motor-reducer group are shown in figure 2 and figure 3 and the distribution and values of maximum equivalent tension $^{max}_{von}$ are shown in figure 4 and figure 5.
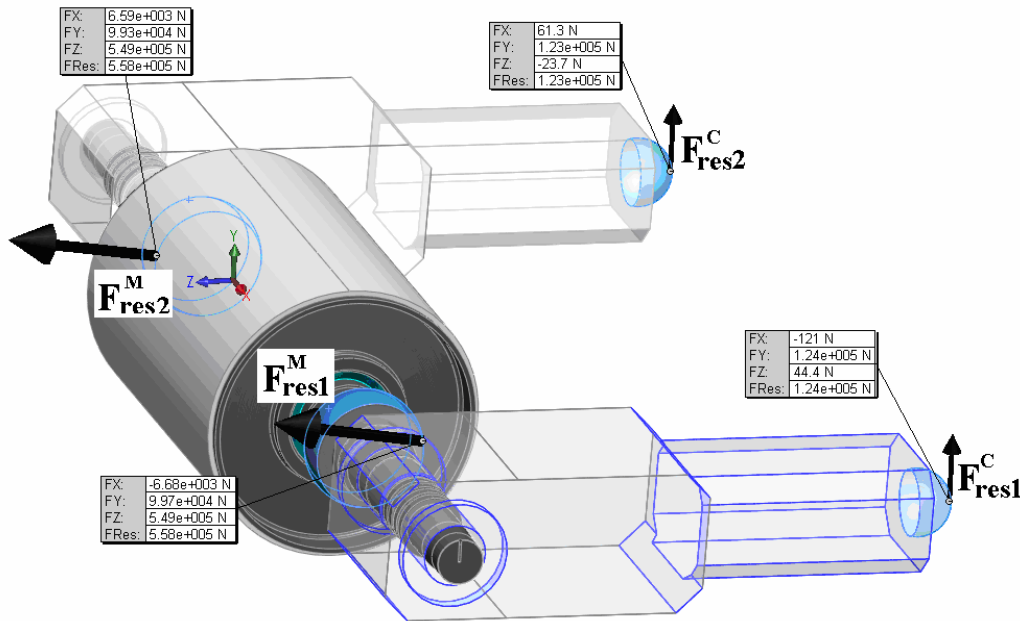
Figura 2. Reactia pivotilor la primul cilindru pentru actionarea cu doua laterale ale celor doi cilindrii (2x1000 kW + 2x1000 kW)

Figure 2. Reaction of the bearings of the first drum for two-sided drive of the two drums - 4 motors (2x1000 kW + 2x1000 kW)
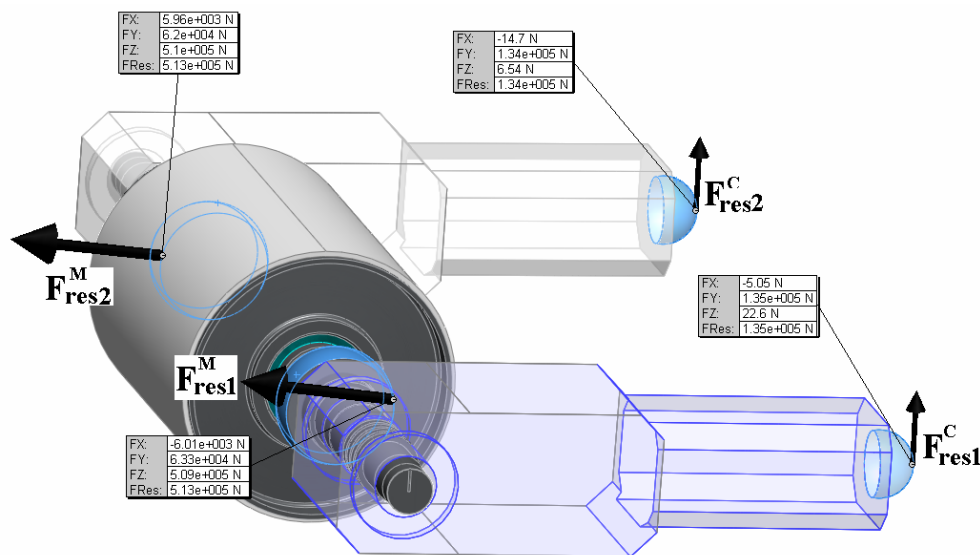
Figura 3. Reactiile pivotilor la primul cilindru pentru actionare cu doua laterale la primul cilindru si o laterala – a celui de-al doilea cilindru – 4 motoare $(2x1000\,kW + 1x1000\,kW)$

Figure 3. Reactions of the bearings of the first drum for two-sided drive of the first drum and one-sided – of the second drum – 4 motors $(2x1000\,kW + 1x1000\,kW)$

Figurile prezinta vectorii fortelor care rezulta si componentele acestora pe aza X, Y si Z sunt prezentate numeric in tabele, in fiecare dintre figuri. Continuitatea a fost stabilita pentru a forma reactii ale fortei in pivotii axului, care indica faptul ca valoarea dominanta este valoarea componentei pe axa $Z - (F_z)$. Pe baza conceptului pentru compensarea partiala a componentei, a fost desemnata F_z cu o forta externa a valorii permanente. Figura 6 prezinta schema principala a structurii arcului egalizator, care poate realiza conceptul descris mai sus de catre autor. Legatura surubului la rezistenta arcului poate fi utilizata pentru a regla valoarea fortei de compensare. Aceasta simulare pe computer a oferit rezultate dupa aplicarea conditionala a unei $F_{comp} = 300$ кN compensate, pentru variante diferite ale modului de functionare, cu sau fara incarcatura, si pentru sisteme de doua tipuri (sistem motor 3 si 4). Reducerea vectorului la reactia care rezulta la apasare, poate fi definita de Tabelul 2 si 3.

The figures show the vectors of the resulting forces and their components on the axis X, Y and Z are shown numerically in tables in each of the figures. Regularity has been established for the formation of force reactions in the bearings of the shaft, which indicates that the dominating value is the value of the component on the axis $Z - (F_z)$. On that basis the concept for partial compensation of the component F_z with an outer force of permanent value has been designed. Figure 6 shows the principal scheme of the structure of a spring compensator, which may perform the above described concept of the author. The screw joint of the spring resistance may be used for adjusting the value of the compensating force. This computer simulation has given the results after conditional application of a compensating $F_{comp} = 300$ кN for different variants of the operating mode with and without loading, and for the two type systems (3 and 4 – motor system). The reduction of the vector of the resulting reaction in the bearing may be defined by Table 2 and 3.
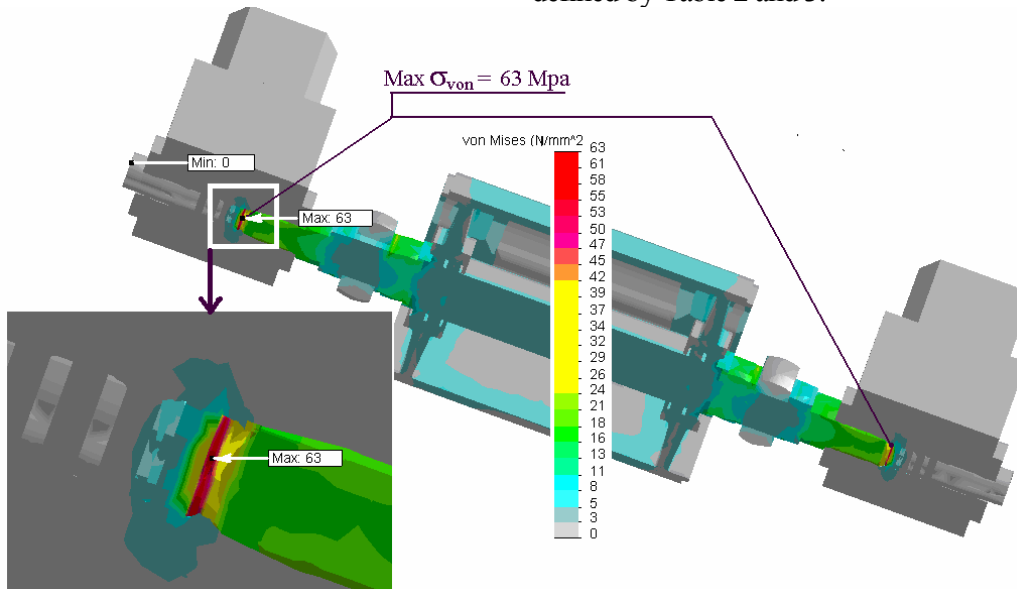

Figura 4. Distributia tensiunilor echivalente la primul cilindru, in cazul actionarii cu doua laterale ale primului si celui de-al doilea cilindru

Figure 4. Distribution of equivalent tensions in the first drum in the case of two-sided drive of the first and the second drums
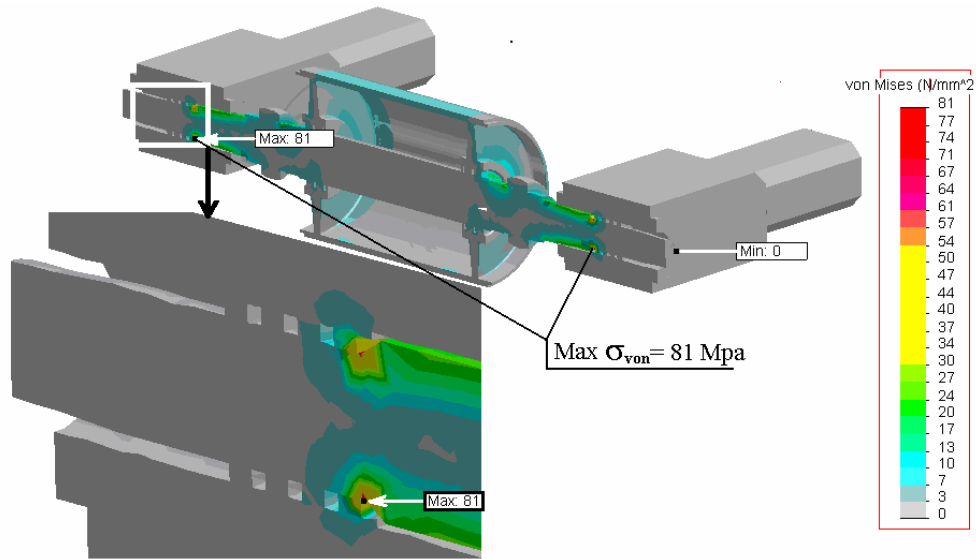
Figura 5 Distributia tensiunilor echivalente la primul cilindru, in cazul actionarii cu doua laterale ale primului cilindru si actionare pe o parte a celui de-al doilea cilindru

Figure 5 Distribution of equivalent tensions in the first drum in the case of two-sided drive of the first drum and one-sided drive of the second drum
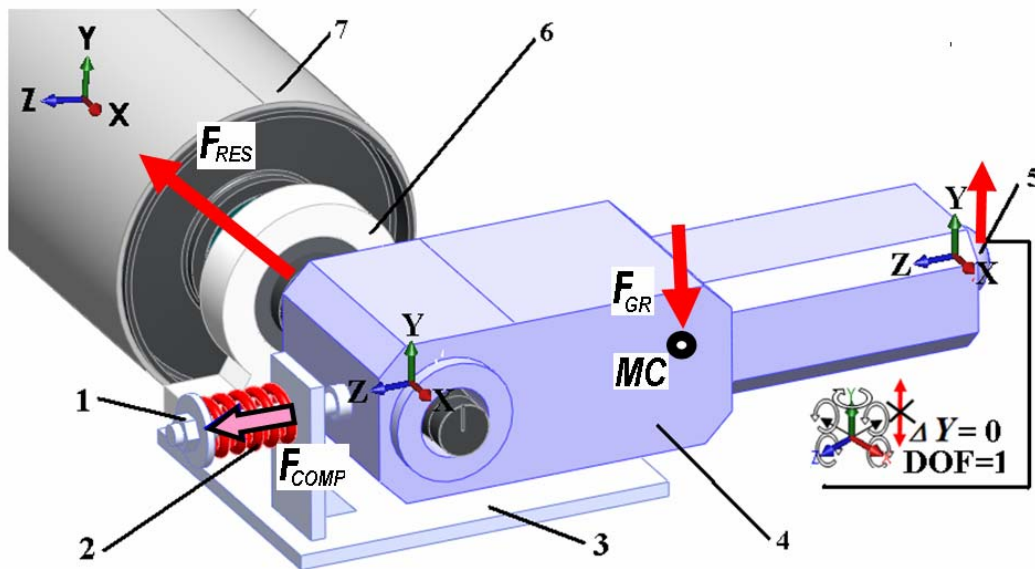

Figura 6. Schema fortei Схема на силов компенсатор на лагерното натоварване
1- Bara elastica, reglabila; 2-element arc; 3-cadru; 4-grup motor- reducator; 5-suport cardan; 6-pivot; 7- cilindru de actionare

Figure 6. Scheme of force Схема на силов компенсатор на лагерното натоварване
1-adjustable tensile bar; 2-spring element; 3-frame; 4-motor-reducer group; 5-cardan support; 6-bearing; 7-driving drum

Reducerea vectorului in cadrul reactiei care rezulta poate fi determinata de Tabelul 2 si Tabelul 3. Pentru acest caz specific, pentru toate

The reduction of the vector of resulting reaction may be determined by Table 2 and Table 3. For this specific case for all variants of the

variantele de simulare a reactiei care rezulta in pivotii axului, reducerea poate fi realizata de doua ori.

Rezumat al comentariilor si al concluziilor

A fost realizat un studiu de modelare CAD-CAE pe computer, desenat specific pentru necesitati practice. Analiza rezultatelor permit realizarea unui rezumat al urmatoarelor concluzii:

➢ Rulmentii cu role sferice, care au fost selectati, nu permit mobilitatea deplasarii pe axa X si aceasta este o conditie pentru reactiile fortei, de-a lungul directiei axei X si un punct de aplicare in pivoti;

➢ Rezultatul actiunii compensatorului reactiv, care a fost propus, trebuie sa fie confirmat si mentionat atat prin studii detaliate, de modelare si prin experimente practice, cu prototip fizic al structurii in cadrul conditiilor operationale, reale.

simulation the resulting reaction in the bearings of the shaft may be reduced twice.

Summarizing comments and conclusion

A computer modeling CAD-CAE study, specifically designed for practical needs, has been performed. The analysis of results allows the summarizing of the following conclusions:

➢ The selected spherical roller bearings do not allow freedom of linear displacement along the X axis and this is a precondition for force reactions along the direction of X axis and an application point in the bearings;

➢ The results of the action of proposed reactive compensator have to be confirmed and précised both by detailed modeling studies and by practical experiments with the physical prototype of the structure under real operational conditions.

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