ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #3, December 2016, http://www.imtuoradea.ro/auo.fmte/

ABOUT TECHNOLOGY FEATURES OF ASSEMBLING OF RUBBER-METAL CONNECTIONS

Nataliia VODOLAZSKAYA[1], Ramo BAKIĆ[2]
[1]Belgorod State Agricultural University, Russia, vnv26@bk.ru
[2]Inovation Center of Faculty of Mechanics, Belgrade, ramo.bakic@gmail.com

***Abstract* —** Assembly process is important technological operation when manufacturing products and equipment, and also it uses during operation and repairs different type of implements The modern automated manufacture cannot be presented without the existence of machines continuously action, in particular of belt conveyors. One of its basic units is the belt and ways of its connection. Usually, the quantity of cracks of belt joints is equal to (reaches) 62 within 1 km of a belt of conveyor during 10 years upon condition that equipment works in a difficult cycle of mines. One of the basic operation problems of these transports is the rupture of the joint of a belt as emergency idle times of conveyors makes approximately of 10 % of working hours, and planned stops on manufacturing or repair of joints - to of 20 %. Therefore, now research in the field of maintenance of qualitative manufacturing of a joint of conveyor belts are of interest at this time. The way of using of rubber-metal connections assembling with help self-cutting screws is offered. This allows increasing durability's characteristics of joints of the conveyor belt.

***Keywords* —** *belt conveyor, belt joint, life durability of joint, self-cutting screw, assembly connection*

I. INTRODUCTION

The technological level of the equipment made by the industrial enterprises should provide not only novelty and quality of let-out production, but also its reliability in working and maintainability, Vodolazska [1]. The specified aspect completely belongs the various vehicles, Vodolazska, Budiševskiy and Sulima [2], used in intensive by the power the enterprises. For example, in coal mines except for monorail transport, Gutarevych and Vodolaskaya [3] and Gutarevych, Vodolaskaya, Jakupović, Mirjanić [4], various conveyors has received a wide application, Baryšev, Budiševskiy, Sklyarov, Sulima and Tkačuk [5] and McGuire [6]. And if questions of dynamics and working of monorail transport found wide reflection in scientific publications, Chanda and Besa [7], True [8], and Museros, Molinerb and Martínez-Rodrigob [9] questions of reduction of free time of conveyors during repair are actual and demand the decision.

The modern automated manufacture cannot be presented without the existence of machines continuously action, in particular of belt conveyors. One of its basic units is the belt. It also concerns to most expensive elements. The deterioration of a belt in conditions of power-consuming industries is the basic problem arising while in service of the belt conveyor, Vodolazskaya [10]. And friction of a belt about metal ware of base and annotative rollers renders the significant influence of its deterioration.

Besides in collieries influence of aggressive action of mine waters also has a negative effect. The emergency downtimes of conveyors on coal mines make approximately 10 % of working hours, and scheduled on manufacturing or repair of joints – much of 20% Vodolazskaya [11] and Ihno, Belomestnov, Baštyrev, Fifindik and Grudačev [12]. Therefore research in the field of maintenance of qualitative manufacturing and repair of a joint of belts are urgent, Vodolazskaya [13], E. Vodolazskaya, N. Vodolazskaya [14], Vodolazskaya [15], and E. Vodolazskaya and N. Vodolazskaya [16].

From the analysis of the references, Vodolazskaya, Vodolazskaya, Vodolazskaya, Iskrickij [17] follows, that an interfacing of belts cold or hot vulcanization is most widespread now. But this way requires significant expenses of time for its realization. However, some mechanical ways of conveyor belts interfacing proceed much faster, but the reliability of joint decreases. Therefore, basic tendencies of increase of reliability of a joint of belts are directed on the perfection of engineering methods of account, increase of constructive durability, the perfection of the technology of manufacturing and assembly.

The way of split rubber-metal connection of details carried out by usual screws (bolts, studs) is most reliable, but it also has essential lacks, Zairov [18] and Vodolazskaya [19], namely: it is required preliminary thread cutting and existing allowances on manufacturing of screws on metal and thread-cutting tool don't allow to receive a close contact with a surface of a thread in a bore of a detail with a surface of a thread of the screw.

It is possible to exclude these lacks at the use of belt interfacing by self-tapping screws. This way will allow to save time at its realization and to ensure higher reliability in comparison with other ways mechanical interfacing of belts, and also on account of its design features (absence of nibbled metal parts) to reduce the abrasion of a belt about a transpose cargo and basic devices.

II. RESEARCH AND RESULTS

The feature of the technology of conveyor belts interfacing with the help of self-tapping screws is the given process can proceed with complete plastic deformation: elastic - plastic or elastic. The study of forming process of a deforming detail allows defining a ratio of the initial sizes of a bore and received threads in yet-to-be-assembled details.

It is necessary to study the mechanics of the process and to develop the mathematical theory of intense and deformed condition, definition of deformation and straining size, their distribution, and also conditions of transition of a body in a plastic condition for designing the most rational technological operations of the assembly of conveyor belts. In theoretical accounts of components, stress and torsion moment of thread formation it is necessary to proceed from the true size of materials yield point of a belt and washer. The essence of a forming method of a thread in a conveyor belt consists information of threads in joining part of a belt, overlays and in a smooth bore of a nut by rotation and forward movement of tapping screws made on special technology.

The self-tapping screws partially cut and squeeze out a thread during assembly of details. The absence of design-analytical methods of the formation process of a joint of conveyor belts by straining complicates designing operations of forming. With this purpose, the strengthening physical essence of complex surfaces as forming of threads is theoretically investigated during a joint of the ends of a conveyor belt. In a Fig. 1 the screw connection which contacts to connected surfaces of a conveyor belt on the basis of plastic deformation is shown.

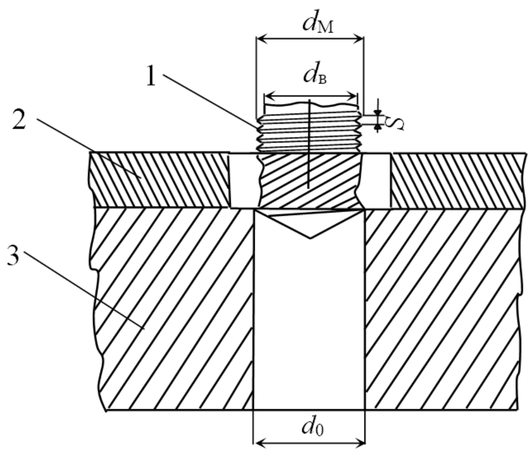

Fig. 1. The scheme of threaded connection assembly by plastic straining

1- The self-tapping screw, 2 and 3-connected details

At a performance of the interfacing operation of a belt, the self-tapping screws carry out some technological transitions, most important of which are: thread cutting in a belt without the previously prepared bore and thread cutting in a metal nut sealed - in a rubber overlay with the previously prepared bore.

At thread cutting in metal, the greater effort of tightening is spent. Therefore, it is necessary to consider pressing-out of a thread in a smooth bore of a connected detail, which is reached by transfer by the assembly tool of the torsion moment and axial feeding to the self-squeezing screw. At contact of a starting taper of the self-squeezing screw with the bore, it is important to put the certain axial force, which provides an introduction to the metal of first two turns of thread structure of the screw, Kačanov [20].

The further process occurs without forced feeding. The rotary movement and feeding of the self-squeezing screw in a smooth bore are created by conditions of the plastic current of metal in a zone pressing-out. The structure of a thread in the previously drilled bore is formed pressing-out of a material of a sample by the screw.

The reception of a complete structure of a thread depends on physical-mechanical properties of a material of connected details, geometry, and inaccuracies of their forms, arrangements of screw surfaces and mode of assembly, Dalskiy [21].

The triangular structure of a thread, taking root in a material of a sample, forces out metal on sides of turns, it fills in the trapezoidal form between turns. Thus there is the intensity of stress working on walls of turns in a zone of plastic deformation.

It is possible to explain such process of the plastic current of metal arising at thread forming, having solved a task of the mechanics of continuous environment — of the flat and axial-symmetric balance of plastic weight between rigid walls. The task is solved by the assumption that adhesion of metal particles along surfaces of walls results in integration of the ordinary nonlinear differential equations.

Solving a flat task on the basis of the differential equation and under the condition of plasticity, we can pass on the decision to a volumetric task. The scheme of strengthening, submitted in a fig. 2, allows considering the balance of plastic weight filling area of the form of a wedge, limited by two flat rigid walls of the next turns of a thread. The corner between planes is equal 2γ

We use a cylindrical system of coordinate's zθz. The axis z is directed along a straight line of the crossing of walls, r, θ - polar coordinates of a projection of the point *A* on a plane. Let's consider that the intense condition of plastic weight does not depend on coordinate *r*. Thus the components of stress are equal: $\tau_{\theta z} = \tau_{z\rho} = 0$

And other components of stress $\sigma_\rho, \sigma_\theta, \sigma_z, \tau_{z\rho}$ are functions from ρ and θ (fig. 2, a).

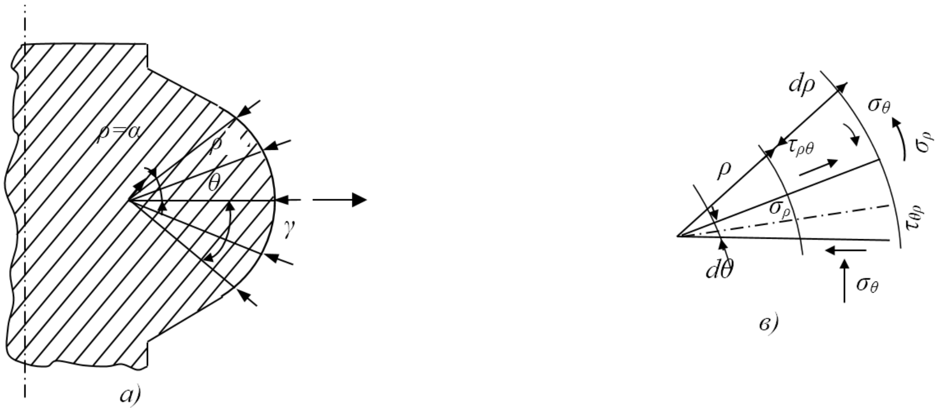

Fig. 2. The scheme of the intense condition a thread formation

The differential equations of equilibrium in cylindrical coordinates with reference to a considered flat task describe the well-formed connection of stress in the plastic environment and look like:

$$\begin{cases} \dfrac{\partial \sigma_\rho}{\partial \rho} + \dfrac{1}{\rho}\left(\sigma_\rho + \sigma_\theta\right) + \dfrac{\partial \tau_{\rho\theta}}{\rho \partial \theta} = 0, \\ \dfrac{\partial \tau_{\rho\theta}}{\partial \rho} + \dfrac{1}{\rho}\dfrac{\partial \sigma_\theta}{\partial \theta} + \dfrac{2\tau_\theta}{\rho} = 0. \end{cases} \quad (1)$$

The well-formed connection between components of a stress and yield point of a material according to a condition of plasticity of a constancy octahedral shear stress is determined by the equation

$$\sigma_T = \frac{2}{\sqrt{2}}\sqrt{(\sigma_\rho - \sigma_\theta)^2 + (\sigma_\theta - \sigma_z)^2 + (\sigma_z - \sigma_\rho)^2 + 6\tau_{\rho\theta}^2},, \quad (2)$$

where σ_T - yield point of material,
σ_ρ, σ_θ, σ_z - main normal stress,
σ - average normal stress,
$\tau_{\rho\theta}$, $\tau_{\theta z}$, $\tau_{z\rho}$, $\tau_{\theta\rho}$ - components of shearing stress, MPa.
The components of stress can be expressed through an average normal stress σ $\frac{\sigma_T}{\sqrt{3}}$ and parameter Ψ like that:

$$\begin{aligned} &\sigma_\rho = \sigma + \frac{1}{\sqrt{3}}\sigma_T \cos\psi, \\ &\sigma_\theta = \sigma - \frac{1}{\sqrt{3}}\sigma_T \cos\psi, \\ &\tau_{\rho\theta} = \frac{\sigma_T}{\sqrt{3}}\sin\psi, \\ &\sigma = \sigma_z = \frac{\sigma_\rho + \sigma_\theta}{2} \end{aligned} \quad , \quad (3)$$

The expression of stress (3) satisfies a condition of plasticity (2). In the differential equation (1), using the meaning of components of stress (3), we shall receive:

$$\begin{cases} \dfrac{\partial \sigma_\rho}{\partial \rho} + \dfrac{1}{\rho}\left(\sigma + \dfrac{1}{\sqrt{3}}\sigma_T \cos\psi - \sigma + \dfrac{1}{\sqrt{3}}\sigma_T \cos\psi\right) \\ + \dfrac{1}{\rho}\dfrac{\sigma_T}{\sqrt{3}}\cos\psi \dfrac{d\psi}{d\theta} = 0, \\ 0 + \dfrac{1}{\rho}\left[\dfrac{\partial \sigma}{\partial \theta} + \dfrac{1}{\sqrt{3}}\sigma_T \sin\psi \dfrac{d\psi}{d\theta}\right] + \dfrac{2}{\rho}\dfrac{\sigma_T}{\sqrt{3}}\sin\psi = 0. \end{cases} \quad , \quad (4)$$

The partial derivatives of components of stress are equal:

$$\begin{aligned} &\frac{\partial \sigma_\theta}{\partial \theta} = \frac{\partial \sigma}{\partial \theta} + \frac{1}{\sqrt{3}}\sigma_T \sin\psi \frac{d\psi}{d\theta}; \\ &\frac{\partial \tau_{\rho\theta}}{\partial \theta} = \frac{\sigma_T}{\sqrt{3}}\cos\psi \frac{d\psi}{d\theta}; \\ &\frac{\partial \tau_{\rho\theta}}{\partial \rho} = 0, \qquad \frac{\partial \sigma_\theta}{\partial \rho} = \frac{\partial \rho}{\partial \rho}; \qquad \frac{\partial \sigma_\theta}{\partial \rho} = \frac{\partial \sigma}{\partial \rho}. \end{aligned} \quad , \quad (5)$$

Into the equation of balance (1) we shall enter expressions of the partial derivative of components of stress;

$$\begin{cases} \dfrac{\partial \sigma_\rho}{\partial \rho} + \dfrac{1}{\rho}\dfrac{2\sigma_T}{\sqrt{3}}\cos\psi + \dfrac{1}{\rho}\dfrac{\sigma_T}{\sqrt{3}}\cos\psi \dfrac{d\psi}{d\theta} = 0, \\ \dfrac{\partial \sigma}{\partial \theta} + \dfrac{\sigma_T}{\sqrt{3}}\left(2 + \dfrac{d\psi}{d\theta}\right)\sin\psi = 0. \end{cases} \quad (6)$$

$$\begin{cases} \dfrac{\partial \sigma_\rho}{\partial \rho} + \dfrac{1}{\rho}\dfrac{\sigma_T}{\sqrt{3}}\left(2 + \dfrac{d\psi}{d\theta}\right)\sin\psi = 0, \\ \dfrac{\partial \sigma}{\partial \theta} + \dfrac{\sigma_T}{\sqrt{3}}\left(2 + \dfrac{d\psi}{d\theta}\right)\sin\psi = 0. \end{cases} \quad (7)$$

from a comparison of these equations follows that

$$C = \left(2 + \frac{d\psi}{d\theta}\right)\cos\psi = \text{const} \quad (8)$$

and the average normal stress σ is equal:

$$\sigma = \sigma_z = \frac{\sigma_\rho + \sigma_\theta}{2}, \quad (9)$$

where

$$\frac{\partial \sigma_\rho}{\partial \rho} = f_1^1(\rho) = -\frac{1}{\rho}C, \qquad (10)$$
$$\frac{\partial \sigma}{\partial \theta} = f_2^1(\theta) = -\frac{\sigma_T}{\sqrt{3}}\left(2+\frac{d\psi}{d\theta}\right)\sin\psi.$$

Integrating, we shall find an average normal stress

$$\sigma = -\frac{\sigma_T}{\sqrt{3}}C\ln\rho + f_2(\theta) + C_1, \qquad (11)$$

$$\begin{cases} C = \left(2+\frac{d\psi}{d\theta}\right)\cos\psi, \\ f_2^1(\theta) = -\frac{\sigma_T}{\sqrt{3}}\left(2+\frac{d\psi}{d\theta}\right)\sin\psi. \end{cases} \qquad (12)$$

Parameter ψ depends on a corner θ ; $\psi=f(\theta)$.
We solve the equation (12) concerning parameter θ approximately. Believing, that $C\geq 1$,

$$\frac{d\psi}{d\theta} = \frac{C}{\cos\psi} - 2 \approx \frac{C}{\cos\psi}; \qquad d\theta = \frac{\cos\psi d\psi}{C} \qquad (13)$$
$$\theta = -\frac{1}{C}\int\cos\psi d\psi = -\frac{1}{C}\sin\psi + C_1$$

Under boundary conditions $\theta=0$; $\psi=0$; $C_1=0$; $\theta=\gamma$,

$$\psi = \frac{\pi}{2}; \qquad C = -\frac{1}{\gamma}. \qquad (14)$$

Solving (13) at constant equal $-\frac{1}{\gamma}$

$$\theta = -\frac{1}{-\frac{1}{\gamma}}\sin\psi; \qquad \sin\psi = \frac{\theta}{\gamma} \quad . \qquad (15)$$

After differentiation relative to $f_2(\theta)$ the equation (12) simplifies to this form:

$$f_2(\theta) = \int -\frac{\sigma_T}{\sqrt{3}}\left(2+\frac{d\psi}{d\theta}\right)\sin\psi d\theta + C_2.$$

The result of the solution (12) is entered in expression (11):

$$\sigma = -\frac{\sigma_T}{\sqrt{3}}\left(-\frac{1}{\gamma}\right)\ln\rho + \left(-\frac{\sigma_T}{\sqrt{3}}\cos\psi\right) + C_3, \qquad (16)$$
$$\sigma = \frac{\sigma_T}{\gamma\sqrt{3}}\ln\rho - \frac{\sigma_T}{\sqrt{3}}\cos\psi + C_3, \qquad C_3 = C_1 + C_2.$$

After the appropriate transformations finally we shall receive:

$$\sigma = \sigma_z = \frac{\sigma_T}{\sqrt{3}}\left[\frac{1}{\gamma}\ln\frac{\rho}{\alpha} - \frac{3}{2}\left(\sqrt{1-\frac{\theta^2}{\gamma^2}}\right) - 1\right]. \qquad (17)$$

The total maximal stress σ exceeds yield point σ_T of a material of a sample that results in the occurrence of deformities effects. Discontinuity of the intense condition in sites of a surface, as is specified, results in irregular plastic deformation, but it is not constant and changes with depth and on a surface of a sample. The size of stress components depends on the sizes of a structure of the screw, of the yield point of a material and size underfilling of a structure (*a* is equal 0,01... 0,15 mm). Using the given formulas, it is possible to find the meaning of stress for screws applied for a joint of belts. A roughness of the processed surface of the screw influence size of tension components and receiving a full profile of a thread, Dalskiy [21]. In the created thread the profile is not filled that speaks properties of a material and the wrong choice of diameter of a bore of the screw. On Fig. 3 it is presented distribution diagram and radial forces.

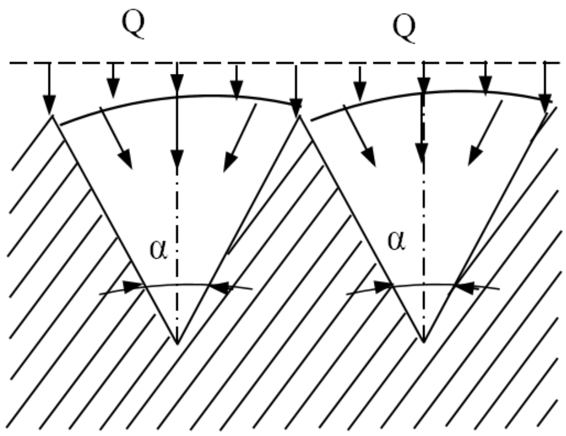

Fig. 3. Distribution diagram and radial forces

It is possible to define the necessary size of the radial effort creating possibilities for plastic deformation of metal on the following formula:

$$Q = 2\int_0^\gamma \left[\frac{\sigma_T}{\gamma\sqrt{3}}\ln\frac{\rho}{\alpha} - \frac{\sigma_T}{\sqrt{3}}\sqrt{1-\frac{\theta^2}{\gamma^2}}\right]\rho B d\theta, \qquad (18)$$

where B — width of an elementary platform;
r — intermediate value of radius.

Under condition of $\theta=\gamma$ the radial effort has the maximum $d\theta=d\gamma$ value:

$$Q = \frac{2\sigma_T}{\sqrt{3}}BP\int_0^\gamma \frac{1}{\gamma}\ln\frac{\rho}{\alpha}d\gamma,$$
$$Q = \frac{2\sigma_T}{\sqrt{3}}\ln\frac{\rho}{\alpha}BP\int_0^\gamma \frac{d\gamma}{\gamma}. \qquad (19)$$

Radial forces affect (Figure 3) the screw on a circle $2\pi r_н$, where $2r_н$ - external diameter. The value of radial effort gives the chance to define further a torque of formation of a thread at the calculation of modes of the assembly of the connections received by plastic deformation.

Available literature on metal-rubber bonding covers a wide variety of applications like: failure analysis, Ballhorn [22], methods for bonding, Bobrov, Kandyrin, Shmurak and Potapov [23], Costin and Nagel [24], Kochishek [25], and Lake [26], fracture energy of bonds, Lefebvre and Dillard [27], techniques and testing of metal-rubber bonding, Lewis [28], Lindsay [29], mechanisms for assembly, Vodolazskaya, Iskrickij and Vodolazskaya [30], Iskrickij, N. Vodolazskaya and E. Vodolazskaya [31], quality and trends, Meier and Findley [32], Raison and Lallet [33], techniques and technologies of assembly Vodolazskaya [34], N. Vodolazskaya, E. Vodolazskaya, Iskrickij [35] various applications in different fields, Saveleva, Stanovska, Lebedeva and Toropenko [36], Petropoulos, Marinkovic, Vodolazskaya, Korlos and Ntziantzias [37], strength and properties of rubber to metal bonding, Schurmann and Ozelli [38], Setiawan, Schoenherr and Weihe [39], Streit and Reggentin [40], Van Ooij [41], Wake [42], Wanders [43], White [44].

III. CONCLUSION

The research of split rubber-metal connection of details realized by usual screws (bolts, studs) is carried out, and a number of essential lacks are determined. It is reasonable to use self-tapping screws, which are a convenient means of repair work, including for interfacing of conveyor belts, because of the absence of necessity to make preliminary thread cutting in a bore. On the basis of the strengthening scheme of split rubber-metal connection of details, the balance of plastic weight filling an area of the form of a wedge, limited by two flat rigid walls of the next turns of a thread is considered. The mathematical model of the calculus of stress components working on a detail of rubber-metal connection is developed on the basis of the theory of plastic working of complex configurations by a method of plastic deformation.

The given analytical dependencies allow if necessary:

1) *To find value of tension for the screws used for a joint of belts;*
2) *To define necessary size of the radial effort creating possibilities for plastic deformation of metal at an inhaling of metal-rubber connection;*
3) *To calculate a torque arising in a zone of a thread formation for different types of detail materials.*

REFERENCES

[1] N.V. Vodolazska, *Technical systems: today and tomorrow*, Donetsk DVNZ, DonNTU, 2008.
[2] N.V. Vodolazska, V.O. Budiševskiy, A.O. Sulima, *Theory, and practice of energy-intensive operations of TV producer*, Donetsk: DVNZ, DonNTU, 2009.
[3] V. Gutarevych, N.V. Vodolaskaya, "Influence of the moving load on suspended monorail oscillations," *In Proceedings of the 14th International Conference Research and Development in Mechanical Industry*, Topola, 2014, pp. 228-234.
[4] V. Gutarevych, N.V. Vodolaskaya, E. Jakupović, D. Mirjanić, "Research on the Influence of Dynamic Load on Suspended Monorail," *Applied Mechanics and Materials*, Vol. 830, 2016, pp. 23-29.
[5] A.I. Baryšev, V.A. Budiševskiy, N.A. Sklyarov, A.A. Sulima, A.M. Tkačuk, *Designing of continuous vehicles: a Scientific manual for schools*, Doneck, 2005.
[6] P. McGuire, *Conveyors: Application, Selection, and Integration*, CRC Press, 2009.
[7] E.K. Chanda, B. Besa, "A computer simulation model of a monorail based mining system for decline development," *International Journal of Mining, Reclamation and Environment* Vol. 1, No. 25, 2011, pp. 52 - 68.
[8] H. True, "Dynamics of Railway and Rail/Wheel Contact, Dynamical Analysis of Vehicle Systems," *CISM International Centre for Mechanical Sciences*, Vol. 497, 2009, pp. 75 - 128.
[9] P. Museros, E. Molinerb, M.D. Martínez-Rodrigob, "Free vibrations of simply supported beam bridges under moving loads: Maximum resonance, cancellation and resonant vertical acceleration," *Journal of Sound and Vibration*, Vol. 332, No. 2, 2013, pp. 326-345.
[10] N.V. Vodolazskaya "Models of network planning and management of power- consuming industries," *Proceedings of the conference. Application of new technologies in management*. Zivota Radosavljevič, 08 – 11 February 2009. Belgrade. Vol.2, 2009, pp. 811 – 818.
[11] N.V. Vodolazskaya, "Features of threaded products for assembly cramps of nonmetallic compounds," *Proceedings of the 5th International Conference Problems and prospects in Mechanical Engineering*. Kramatorsk, 4-7 June 2007, DDMA 2007, pp. 14.
[12] S.A. Ihno, Ю.A. Belomestnov, V.V. Baštyrev, V.A. Fifindik, A.Я. Grudačev, "Basic ways of quality improvement of conveyors," *Ugol Ukraine*, No 6, (2004), 32–34.
[13] N.V. Vodolazskaya, *Models, and algorithms for technical systems and properties*, Monography, Doneck, DVNZ DonNTU, 2013.
[14] E.G. Vodolazskaya, N.V. Vodolazskaya, "About increased the quality of assembly threaded connections," *International Conference on Machining* (23-30 April 1998). Vol 9. Dnipropetrovsk, 1998, pp. 38.
[15] N.V. Vodolazskaya, "Analysis of automated assembly screw connection technology," *Advanced technologies and mechanical systems*, Doneck, 2002, pp. 31-36.
[16] E.G. Vodolazskaya, N.V. Vodolazskaya, "Management Process of regulation quality of operations," *Pridneprovsky Scientific Journal*, 1998, Vol.110, No. 177, pp. 19-21
[17] N.W. Vodolazskaya, E.G. Vodolazskaya, W.M. Iskrickij, *The dynamics of the process of the modular assembly of bolted joints, Technology and automation installation,* Warsaw, OBR TEKOMA, 2002, No. 1. pp. 30-32.
[18] I.U. Zairov, *Technological process of automating assembly joints of plastic deformation.* FAN Publishing, Taškent, (1984). p. 136.
[19] N.V. Vodolazskaya, "Analysis of strength characteristics of joints of conveyer belts," *Proceedings of sectorial mechanical building and construction*, Tehničniy Poltava National University named after Yuri Kondratyuk. Vol. 3, No. 25, Poltava, PoltNTU, 2009, pp. 46 – 50.
[20] A.M. Kačanov, "Basic theory of plasticity", *Mechanical engineering*, 1969.
[21] L.M. Dalskiy, *Elastic deformations during in the assembly, Assembling, and a montage of mechanical products*, Vol. 1, M., Nedra, 1983.
[22] M. Ballhorn, "Failure analysis of rubber-to-metal bonded products [Schadensanalyse an Gummi/Metall-Bauteilen]," *KGK Kautschuk Gummi Kunststoffe*, vol. 60, no. 5, 2007, pp. 249–256.
[23] Y. A. Bobrov, K. L. Kandyrin, I. L. Shmurak, and E. E. Potapov, "Rubber to metal cord bonding with the use of compounds of a metal of variable valence," *Kauchuk i Rezina*, No. 2, 2005, pp. 37–45.

[24] R. Costin and W. Nagel, "Techniques for bonding rubber to metal using metallic coagents," *Rubber World,* Vol. 219, No. 2, 1998.
[25] M. Kochishek, "Preparation methods for bonding rubber-to-metal or other substances by ChemosilR bonding agents," *Kauchuk i Rezina,* No. 2, 2003, pp. 42–44.
[26] G. J. Lake, *Rubber to metal bonding applications*, 2005.
[27] D. R. Lefebvre and D. A. Dillard, "Development of a modified double cantilever beam specimen for measuring the fracture energy of rubber to metal bonds," 1986, pp. 513–521.
[28] P. M. Lewis, *Rubber to metal bonding-basic techniques,* 2005.
[29] J. A. Lindsay, *Rubber to metal bonding: Testing,* 2005.
[30] E.G. Vodolazskaya, V.M. Iskrickij, N.V. Vodolazskaya, "Choice of power parameters of blocks of technological influence for assembly of threaded connections," *Reliability and optimization of technological systems* Is. 15, 2004, pp. 174-180.
[31] V.M. Iskrickij, N.V. Vodolazskaya, E.G. Vodolazskaya "Dynamics of the process of impact in mechanisms for the assemblage of carving connections," *International scientific conference UNITECH'04*. Vol. 1. Gabrovo, Bulgaria, 18–19 November 2004, pp. 244 –249.
[32] J. L. Meier and H. J. Findley, "Current trends in rubber to metal bonding," *Rubber Chem. Technol.*, vol. 47, no. 2, 1974.
[33] J. Raison and P. Lallet, "Quality assurance for rubber-metal components of SNCF rolling stock," *J. Railway. Transp.*, Vol. 125, No. 9–10, 2001, pp. 338–342+344.
[34] N.V. Vodolazskaya "Technological features of different types of the assembly of products of mechanical engineering," *Journal of Advanced Research in Technical Science*. Is.2, North Charleston, USA, 2016. pp. 12 – 16.
[35] N.V. Vodolazskaya, E.G. Vodolazskaya, V.M. Iskrickij *Assembly of threaded connections. Problems and prospects of the perfection of assembly technology processes*: Monography. - Kramatorsk: DSMA, 2014. - 192
[36] O. Saveleva, I. Stanovska, E. Lebedeva, and A. Toropenko, "Information technologies of optimizing designs and manufacturing techniques of rubber-metal products," *Eastern European J. Enterp. Technol.,* Vol. 2, No. 2, 2015, pp. 28–35.
[37] G. Petropoulos, A. Marinkovic, N. Vodolazskaya, A. Korlos, I. Ntziantzias "Another approach of surface texture in turning using motif and ''Rk'' parameters," *Journal of the Balkan Tribological Association.* Vol. 12, № 1, 2006, pp. 7 – 15.
[38] K. Schurmann and R. N. Ozelli, "Rubber-to-Metal Bonding (Conclusion)," *Polimery/Polymers,* Vol. 19, No. 8, 1974, pp. 394–397.
[39] L. Setiawan, D. Schoenherr, and J. Weihe, "Influence factors on bonding strength of rubber to metal parts," *Gummi, Fasern, Kunststoffe,* Vol. 46, No. 7, 1993, pp. 357–363.
[40] G. Streit and S. Reggentin, "Zur kinetik der peroxid-vulkanisation," *Gummi, Fasern, Kunststoffe,* Vol. 49, No. 2, 1996, pp. 134–145.
[41] W. J. Van Ooij, "Rubber to metal bonding", *Rubber World*, vol. 215, no. 2, 1996, pp. 26–33.
[42] W. C. Wake, "Rubber-metal bonding.," *Prog. Rubber Technol.*, Vol. 45, 1983, pp. 61–88,.
[43] G. Wanders, "Minicomputer controls servo-hydraulic testing machine.," Wire Ind, Vol. 46, No. 546, 1979, pp. 417–418.
[44] L. White, "Aqueous systems grow stronger," Eur. Rubber J., Vol. 178, No. 2, 1996, pp. 19–21.