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Effectiveness of Flexible Pin Type Couplings

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Abstract— The article shows that pin elastic couplings are not functionally elastic ones. Their endurance improvement is associated with their power intensity increase (stock of resilience). Another way is to replace elastic elements material (rubber) for more endurable and power-consuming polyurethane elastomers. Besides power capacity can be increased by elastic element mass expansion and the ration of the element mass to the coupling mass.

Index Terms—**Elastic, couplings, metallurgical machine, loading.**

I. INTRODUCTION

The peculiarity of metallurgical machine loading is parasitic loads because of dynamics and dysfunctions of geometrical arrangement. These loads are rather difficult to control and sometimes run up to the degree which causes damages of driving parts [1, 2, 7]. Shock-absorber system based on using more powerful spare parts which reduce dynamic loads influence is the main way in parasitic load-fighting. There are constructively and functionally flexible couplings [3, 4]. The first ones are couplings of all types with component called elastic part whereas the second ones are to perform its main function - to reduce dynamic loads with the help of power capacity comparable to the drive gear energy intensity (without elastic coupling). The bigger power capacity of a coupling, the better its elastic characteristics. Sleeve pin couplings are used in traversing mechanism (travel mechanism of bridge or monkey, lifting mechanism), in breast roll gear system, in roller conveyor and in screw down gear driving. It is considered that such couplings reduce dynamic loads. Flexible coupling parts here are ribbed rubber sleeves or rubber ring system with trapezoidal cross-section. Rubber has a set of properties such as high elasticity, power capacity and larger internal friction useful for load absorption.

II. MATERIALS AND METHODS

A. Theory and Practice

Power capacity is one of the main characteristics of shock-absorbers. The energy intensity of the elastic element (U) linearly depends on a number of conditions, the most important of which are: energy density of material (per unit weight), stressed elastic component quality coefficient, and elastic element weight. Energy density of elastomer is proportional to its stiffness [2, 8]. Thus, going from medium hard rubber (E= 6,0 MPa) to stiffer elastomers significantly increase energy density of elastic components material.

Reaching up more perfect structural system of flexible coupling (with an equal strain distribution in elastic element) the quality coefficient of stress state is also significantly increased (up to $\alpha = 0.5$). In sleeve pin coupling ($\beta = 0.006\text{-}0.010$). More advanced flexible couplings and shafts increases the figures up to forty times greater than in sleeve pin flexible couplings ($\beta = 0.3\text{-}0.4$). Thus these couplings power capacity leaves much to be desired; saving the same coupling weight this option can be enlarged tenfold.

Coupling construction quality is characterized by ratio of flexible part mass to gross mass of coupling (β). The higher this index, the more perfect construction of elastic coupling we deal with. As for sleeve pin flexible couplings this ratio is ($\beta = 0.006\text{-}0.010$). In case of more advanced coupling and shaft construction this ratio increased up to ($\beta = 0.3\text{-}0.4$), thus it is forty times greater than for sleeve pin flexible couplings. In that way these couplings are far from perfect; this index (saving coupling mass) can be increased tenfold.

These couplings features of elasticity are rather moderate; such couplings field experience in different loading degree shows that life time of rubber sleeve bearing is greatly limited. Thus the life time of elastic components under acceptable operating condition of travelling crane is 1-2 months, under the heavier duty operation this life-time decreased to 2-3 weeks (in drive cutting-out press and auxiliary rolling-mill equipment).

There are also cases when sleeve pin flexible couplings are replaced by standard tooth-type couplings (TTC and TTP1) or cardan shafts2. But these devices are compensating ones not flexible. It should have been expected dynamic load increase on the one hand and decreases drive spare parts endurance. But such changes don't arise in overwhelming majority cases. It is explained by the fact that these couplings are not flexible owing to the low power intensity (in functional sense). Its replacement by tooth-type couplings causes only some light load increase. There are several ways to improve sleeve pin flexible couplings avoiding the replacement by tooth-type ones which require careful care and are difficult to produce.

B. Procedure

Rubber flexible parts are replaced by polyurethane ones (more durable, harder and energy-consuming); the elastic elements resource is increased 8-10 times under a constant load level. Such couplings are especially useful during overloading here is shown their ability to dampen striking energy. Elastic sleeves of polyurethane elastomers were developed for these couplings: adipren L-100; adipren L-167; desmopan-192; desmopan-150 [5, 6, 7, 8]. These bushings have been tested for 5 years on metallurgical plants equipment in and showed perfect results concerning their endurance. Thus on the first stage of sleeve pin flexible couplings modernization can be recommended to replaceme rubber flexible components by polyurethane ones. Couplings power intensity can also be increased by changing ratio couplings dimensions in order to improve quality design characteristics (β). It can be reached by increasing the dimensions of elastic bushings and as a consequence the size of flexible bushing hollows even if it demands the reduction of number of hollows and bushings in one coupling. Dealing with unchanged bushings width (it can be enhanced in 1.2-1.5 times) it is also possible to increase resilient elements mass (reducing their quantity up to 3.0-4.0 units) in 2-3 times that can significantly help to increase power consumption of the system. Another way goes with the change of a stressed state quality factor (under the permanent coupling structure). If a coupling installed in irreversible drive elastic eccentric bushing results. Squeezing or compressing sleeves in the place of their maximum thickness increases the angle of twist almost twice and accordingly the power consumption as well.

III. RESULTS AND DISCUSSION

Table 1 shows parameters necessary for selecting a flexible coupling. It also contains power, elastic and energy coupling characteristics that are comparable to the same ones for other types of couplings. It can be noted that elastic parts of such couplings are rather small in size and weight, the most advanced have a mass of 0.01 by coupling weight. Comparing these couplings with other flexible ones we can reveal a significant drawback - their low energy consumption. In such couplings in many drives of metallurgical and hoisting machines were also tested elastic sleeves of polyurethane elastomers. For these purposes were used polyurethanes with the normal compressive modulus of elasticity where E_c =20 MPa, 30MPa, 60MPa. All materials showed good results in tests despite the stiffness differences, determined by the normal compressive modulus of elasticity (E_c). These results have been constantly confirmed during 10 years of exploitation. The minimum life-time of elastic parts under the most unfavorable conditions was 6-10 months.

It is evident that bushings stiffness has little effect upon total drive stiffness and dynamic load degree in actuator. Speaking about high life-time of polyurethane elastic components we can say that it is not explained by dynamic load reduction, but by higher endurance and wear resistance of polyurethanes in comparison with simple rubbers. It should be noted that this way of couplings modernization by replacing elastic element material is the simplest one and rather accessible. But before choosing the suitable material for elastic part of couplings it is necessary first and foremost to take into consideration different experience in stiffness, endurance and power capacity identification of new elastic components. The authors performed different static tests of elastic elements of various materials for the standard type sleeves made from a) rubber B-14, b) a rubber-treated conveyor belt, c) polyurethane adipren L167, and d) polyurethane desmopan-150.

The rubber had compressive modulus of elasticity (Ec= 11-12 MPa), polyurethane (Ec40-45 MPa). As for the desmopan material produced by "Bayer" AG; it is a single-component thermoplastic (recyclable) polyurethane where Ec=110-120 MPa [2]. The tests were carried out on the machine MI-20UM (MI-20-UM -testing machine

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[1] Pool couplings

[2] produced by the Voith GmbH

where $P_{max.}$=20kN, with mechanical drive group), which was previously equipped with the patterned dynamometer.

Table 1. The basic energy and power characteristics of flexible pin type couplings (FPTC)

Coupling identity and type	Torque rating. H·m	Coupling mass. kg	Elastic member quantity. pcs	Elastic member mass. $\times 10^{-3}$ kg	Elastic member volume (net). $\times 10^{-6}$ m^3	Power capacity where $\varphi_{max} = 1°$. J	Quality coefficient of stress condition α	Quality characteristic of the system $\beta \times 10^{-3}$
FPTC 6.3-11-1	6.3	0.625	3	3.72	3.45	0.0439	0.0235	5.95
FPTC 16-14-1	16	0.729	4	4.96	4.60	0.111	0.0446	6.80
FPTC 31.5-18-1	31.5	1.01	4	10.1	9.36	0.219	0.0433	5.28
FPTC 63-22-1	63	2.55	6	15.1	14.0	0.439	0.0579	5.92
FPTC 125-28-1	125	5.31	4	35.3	32.7	0.872	0.0493	6.64
FPTC 250-36-1	250	7.45	6	52.9	49.0	1.74	0.0656	7.10
FPTC 500-45-1	500	12.8	8	70.6	65.4	3.48	0.0985	5.51
FPTC 1000-56-1	1000	22.7	10	209	193	6.97	0.0668	9.20
FPTC 2000-71-1	2000	43.2	10	426	394	13.9	0.0653	9.86
FPTC 4000-90-1	4000	83.0	10	828	767	27.9	0.0673	9.97
FPTC 8000-110-1	8000	175	10	1680	1550	55.8	0.0666	9.60
FPTC 16000-140-1	16000	335	10	2970	2750	111	0.0747	8.86

Fig.1 shows this testing device. It contains two supports 1, a pin 2, an elastic sleeve 3 and cylindrical case 4. This device was installed into the tested machine and was compressed in the direction of the force P (elastic sleeve 3 compressed in the radical direction). The results of this experience are shown on Fig.2.

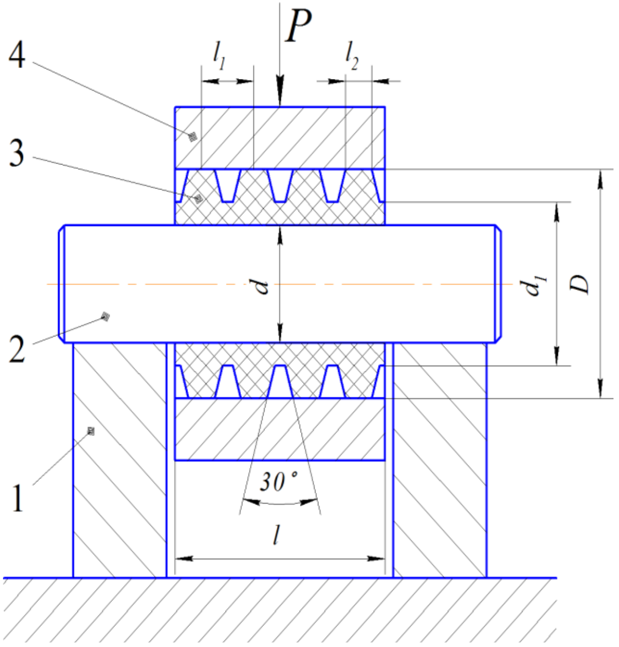

Fig.1. Device for elastic components testing

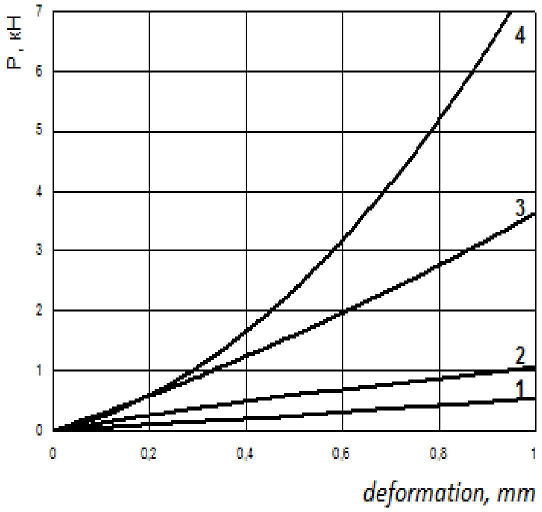

Fig. 2. Operating characteristics of couplings elastic elements: 1 -rubber B-14; 2- fanged (reinforce) rubber; 3 -adipren L167; 4 -desmopan-150.

The characteristics are close to the linear but deformed (concaved) in some degree (hardening or stiff characteristics). The energy intensity of elastic element is determined by :

$$U = \psi \cdot P^{*} \Delta^{*}, \qquad (1)$$

Where ψ - block coefficient of operating characteristic; P^* and Δ^* - the limit values of the operating characteristic. For bushes with ribs $\psi \approx 0.45$, for rubberized tape ribs-free bushes the characteristic is stiffer where $\psi \approx 0.4$. This test results are shown in Table.2. Under the nominal load the relative deformation of rubber elastic components is $\varepsilon \approx 0.3$-0.45, that is unacceptably high value. As for the compressible elastomer elements the recommended values of working (allowable) stress degree are proportional to the admitted deformations which are in the limit of $0.2 \leq [\varepsilon] \leq 0.3$.

The smaller the value, the more durable elastic element is. It is necessary for existing couplings to reduce compressive deformation of elastic element up to $[\varepsilon] = 0.2$.

Besides it is advisable that we should apply to these components more durable elastomers. Table 3 shows values of loads and energy consumption (for one-sized elastic elements) under the constant deformation degree $\varepsilon=0.2$, $\Delta=1.0$. One can see the degree of couplings power consumption increasing when using rigid polyurethanes such as desmopan-150.

Allowable deformation $\varepsilon^{*}=0.2$ (two times less than on standard rubber elements) is the reason for increasing durability ten times, that is we observe when using polyurethane elastic elements. The most promising for observed couplings is the usage of polyurethane elastic elements, which allow the same deformation degree as rubber. At the same time due to higher stiffness degree allowable stress become much larger.

Polyurethane elastic sleeves usage allows us to increase elastic components resistance up to 6-12 months even under the most severe operating conditions. The most common upcoming trend in couplings modernization is their energy consumption enlargement.

Table 2. Deformation of elastic elements

Coupling identity and type	Dimensions of flexible bushes						Ribs quantity on flexible bushes. pcs.
	d. mm	d_1. Mm	*D*. mm	*l*. mm	l_1. mm	l_2. mm	
FPTC 6.3-11-1	8	12	16	10	5	2.5	2
FPTC 16-14-1							
FPTC 31.5-18-1	10	14	19	15			3
FPTC 63-22-1							
FPTC 125-28-1	14	20	26	28	7	3.5	4
FPTC 250-36-1							
FPTC 500-45-1							
FPTC 1000-56-1	18	25	35	36	9	4.5	4
FPTC 2000-71-1	24	32	45	44	11	6	
FPTC 4000-90-1	30	40	56	56	14	7.5	
FPTC 8000-110-1	38	50	71	71	18	9.5	
FPTC16000-140-1	45	60	85	88	22	11.5	

Coupling identity and type	Torque rating power *P*. H	Deformation of elastic element (mm)			
		Rubber B-14	Fanged rubber	Adipren L 167	Desmopan-150
FPTC 6.3-11-1	93.3	1.01	0.666	0.246	0.162
FPTC 16-14-1	160	1.29	0.934	0. 354	0.205
FPTC 31.5-18-1	250	1.28	0.690	0.390	0.239
FPTC 63-22-1	295	1.35	0.789	0.439	0.298
FPTC 125-28-1	694	1.45	0.884	0.459	0.304
FPTC 250-36-1	793	1.67	0.950	0.501	0.344
FPTC 500-45-1	961	1.78	1.04	0.558	0.375
FPTC 1000-56-1	1250	2.02	1.37	0.412	0.312
FPTC 2000-71-1	2000	2.45	0.783	1.02	0.701
FPTC 4000-90-1	3333	3.67	1.58	1.06	0.720
FPTC 8000-110-1	5000	5.04	2.13	1.71	1.07
FPTC16000-140-1	8000	4.13	1.93	1.24	0.988

Table 3. Power and energy characteristics of elastic elements (D = 35 mm; d =18 mm; n = 10 pcs)

Material of elastic element	Deformation of elastic element $\varepsilon = 0.2$ Δ, mm	Coupling twist angle, γ, deg.	Power in elastic element P, H	Torque moment of coupling M_t,N ·m	Coupling power capacity, U, J
Rubber B-14	1.0	0.716	452	362	2.03
Fanged rubber			798	639	2.56
Adipren L 167			3670	2960	13.3
Desmopan 150			7460	5970	26.9

IV. CONCLUSION

Flexible pin type couplings have a low life time resource and poorly perform their main function dynamic loads reduction under the shock loading. Couplings endurance improving is connected with their energy intensity increase (that is the stock of potential energy of elastic strain). The common way of energy consumption development is the replacement elastic components material (rubber) to more durable and energy-consuming polyurethane elastomers. Increasing elastic element mass and the ratio of this element mass to the mass of the coupling are valid options for energy consumption.

NOMENCLATURE

U - Power capacity (J)
α –Q-factor (quality coefficient) of a stressed state of elastic component;
m – Mass of an elastic element, kg
E – Modulus of elasticity, MPa
Ec – modulus of elasticity in compression, MPa;
β – Coupling quality characteristics
P – Power at rating moment, H
P* – Full power loading of elastic element
ψ – Fullness coefficient of operating characteristic
ε – Relative deformation
[ε] – Admitted relative deformation
Δ – Elastic element deformation, mm
Δ* – Ultimate strain of elastic element, mm
γ – Twist angle of coupling, °;
Mt – Torque (rotational moment), N-m

REFERENCES

[1] V. G. Artyukh, “Loads shock absorption in metallurgical machines: Breakdowns protection system of metallurgical machines,” Mariupol, vol. 4, pp. 160-165, 1999.

[2] V. G. Artyukh, “Energy intensity of polyurethane shock absorbers: Breakdowns protection system of metallurgical machines”, Mariupol, vol. 4, pp. 166-172, 1999.

[3] J. D. Xuebao. B. J. Gongxue, “Elastic plate couplings wear-life under a high speeds and dynamic load”, Deng Baoqing [e.a.]: Jilin Univ., Eng. and Technol., vol. 33(3c), pp. 1–4.

[4] Stahl und Eisen, “Elastische Kupplungen optimieren den Antriebsstrang in der Stahlindustrie”, Stahl und Eisen, vol. 126(3c), pp. 30. 2006.

[5] V. G. Artyukh, “Peculiarities of elastomers usage for dynamic loads lowering in metallurgical machines // Breakdowns protection system of metallurgical machines:, Mariupol, vol. 2, pp. 155-158, 1997.

[6] W. Huber, and K. G. Carl Freudenberg, “Torsion-elastic coupling, its production method and equipment to test the method”, Drehelastische Kupplung sowie Werkzeug und Verfahren zu ihrer Herstellung, 2003. Appl. 10211640 Germany.

[7] J. X. Daxue, “Elastic-plate coupling endurance test under the conditions of high speed rate and dynamic load”, Eng. Technol. Ed., 33(3): 1-4, 2003.

[8] A. Jakop, “Elastomer Clutch for the Smallest Space”, Maschinenmarkt, 49: 47, 2006.

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