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FUNCTION OF THE COUPLINGS IN MODERN DRIVES OF MINING MACHINES

Summary. This article presents selection principles of the type of couplings for drives of mining machines for example: conveyors, ploughs or vibrating screens. It has been stated, that starting couplings in the drives of the belt and scraper conveyors can be in many cases replaced by cheaper permanent flexible couplings, that are producing in Poland. Overload couplings in the scraper conveyors and coal ploughs should be located on slow speed shaft of the drive but this condition requiers creating a new construction of high torque overload couplings.

INTRODUCTION

In the drives of the mining machines for example: conveyors or ploughs in the coal-mining most often used are cage electric engines and make start easier in the case of big power drives-starting couplings. In the drives, due to many appearing dynamics overloads coming from work machine, poupling should have the lead of mechanic "safety device". The character of starting belt and scraper conveyors depend largly on drive characteristic, change of the following work parameters in time: electric engine, coupling and moment of resistance. Unproportionate resistance moment coming from: work machine (for example: strikes of the lump of coal for idlers, unequal feeling up the chutes, etc.), electric engine (dynamic characteristic), should be "filtered" by the coupling. Complicated dynamics processed in the electromechanic systems (general in the system: engine-work machine) require calling special attantion to the lead of coupling in the drive [L.2]. In the case when unproportionate resistance moment from work machine achieves big values, in mechanic drives of coal machines, must be situated on suitable stage of the gear-overload coupling. In the drives of belt conveyors we don't use overload couplings, because the lead of "safety device" is played by friction coupling between the pulley drive and the belt. As for today's construotions overload

couplings have been used: fluid couplings or friction clutch. These couplings was been situated in the drive most often between electric engine and high speed shaft of the toothed gear. Location of the overload coupling on the high speed shaft of the drive protects from overload only the electric engine. The choice of suitable types of couplings and places of their location in the drives of scraper conveyors (or AFC) and ploughs, has a decisive importance in correct and realieble work of these machines.

STARTING COUPLINGS FOR BELT AND SCRAPER CONVEYORS

As the starting couplings in these machines many years we have been using fluid (hydrocinetic) or more often powder couplings (specially in power industry) [L.2]. It is using for drives of power over 40 kW. We haven't got any technical premises for rigid keep of this usage of the border for starting couplings. In many technical works has been ascertained [L.2], that choice of coupling type for the drive should be analysed indyvidually, depending of the kind of machine and conditions of its state and starting work. This is due to the usage of starting coupling deciding only mass of inertia. The drive should during the starting time accelerate this mass get over and overbalance the motor moment over the resistance moment of the work machine. Big power drives in slope conveyors but rather short may have permanent flexible couplings, because a large part of engine power is predestinate for lifting the mass on definite valtitude and only rest of that power is used for overcoming inertia of the conveyor. The confirmation of necessity of using the drive starting coupling, can be obtained by numbering symulation of the work conditions of the machine, that was done on the example of belt conveyors by means of computer program SYPTA-83. Symulation programs due to the enormous development of computers, specially microcomputers, become supporter tools for designers and users of these machines. Experiences based on application of high flexible couplings such as ZERKOPOL (fig.1, tab.1) in drives of scraper conveyors (AFC) in the "Knurow" Mine, allow to assume that in the machines of big dynamic, in the starting and constant period, we can use succesfully permanent flexible couplings instead of (fluid) (dydraulic) couplings.

But what kind of features should the flexible coupling has, that we can use in the drive instead of starting coupling? Technical parameters of this coupling should mark high elasticity of connectors (big angle of torsion) and large factor of dumping. Of course, for the programs of computer symulation it is necessary to have the knowlege of dynamic characteristics of the flexible coupling. Utility values of the flexible coupling are the following: high durability of the connectores and service simplicity, for example: replacement of the weared connector without the unecessity of putting away the engine.

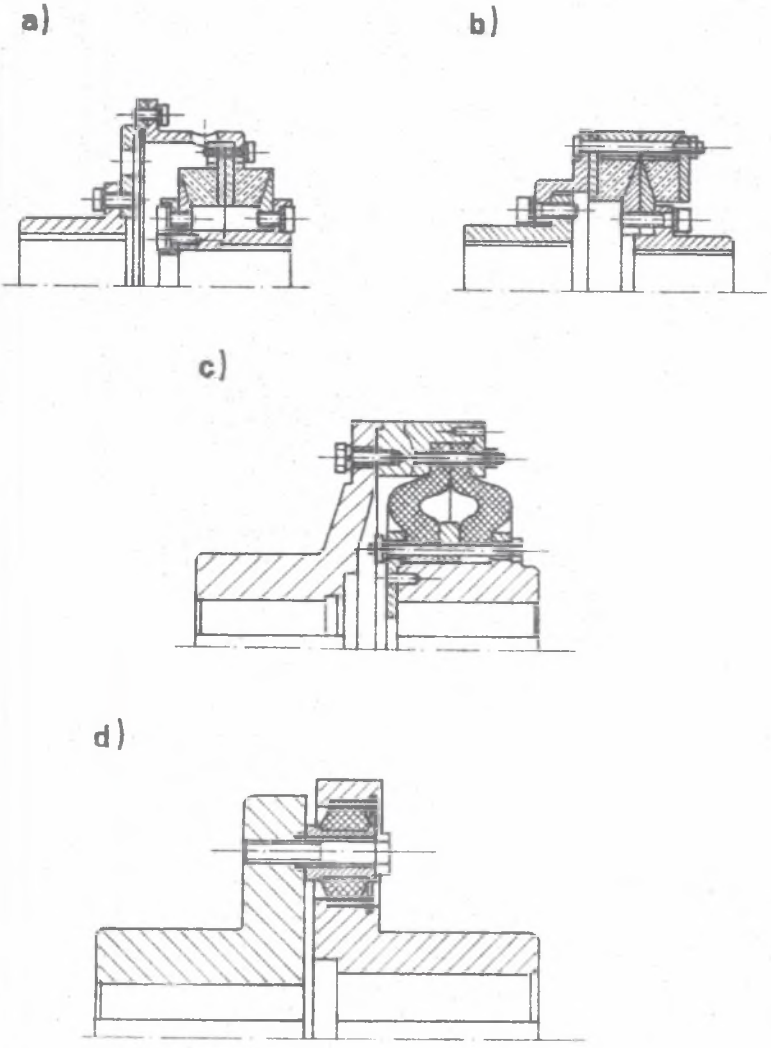

Fig. 1. Construction of the flexible couplings for shafts
a - with radial disassembly connectors (type TS 130 - ZERKOPOL), b - with axial disassembly connectors (type TS 240 - ZERKOPOL), c - membrane coupling, d - pins (busches) coupling

Table 1

Couplings in the drives of the mining maschines

Power in constant motion Nu	Motor speed n_s	Nominal torque Mn	Start coupling (sizes)		Flexible couplings (sizes)		Application
			powder couplings type	Fluid couplings type	highly flexible type ZERKOPOL	normal flexible type	
kW	min^{-1}	kNm	ASc	SH	TS	SP	
30 - 55	1500 - 750	0,3 - 0,72	-	SH 30 SH 40	005 - 010	-	belt conveyors (PTG) and scraper conveyors (SAMSON, ŚLĄSK, GROT)
55 - 110		0,5 - 1,25	020	SH 55 SH 100/75	010 - 020	SPP 55 SPP 100	scraper conveyors (RYBNIK, SUPERSAMSON), belt conveyors (GWAREK), coal ploughs (SWS), vibration screens
110 - 160		0,175-1,41	021	SH 132/110	020 - 030	-	
160 - 200		1,0 - 2,6	022	SHA 160	020 - 040	-	
200 - 400		1,3 - 3,9	023	-	030 - 050	-	belt conveyors on strip mines ventilators

It is also important, that the price of the flexible couplings are lower than the price of starting couplings, used now. Table 1 presents use areas of particular types and sizes of couplings for drives of machines used in coal and strip mining. Presented flexible couplings of ZERKOPOL (fig. 1 a and b) in the table 1, don't show all the types of permanent flexible couplings (for example: fig.1 c and d), produced in Poland now.

On principle, pernament flexible coupling in big power drive of work machine should have high elasticity and dumping. High level of elasticity makes that critical speed rotation n_{kr} of drive is to be under idle running of machine. High dumping in the coupling makes it possible to get small amplitudes of vibration, that have evoked by irregularities of rotation. This feature is in particular important when rotation crossing through resonance area, but in the over critical area small dumping is profitable. Requirement of high torsion elasticity assumes that using soft elastomer for connectors of coupling which always gives weak dumping. These features of the coupling determined by its characteristic, that we describe by stiffnes C and dumping K. The characteristic may be static or dynamic, depending on torque, which is taken into consideration (fig. 2):

$$C = \frac{dM}{d\varphi}$$

With regard for their characteristic, couplings may be of constant stiffnes (fig. 2), with dumping or not and non-linear characteristic. Depending of the kind of work machine and drive engine (electric motor or combustion engine), the influence of coupling on non-constant carry on torque is great.

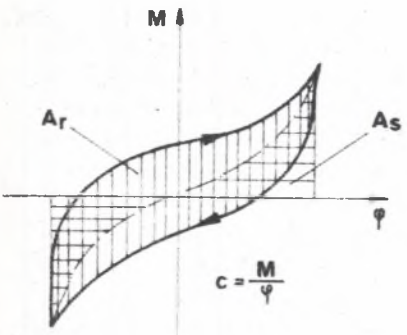

Fig. 2. Characteristic of the flexible coupling

For coupling with dumping by preliminary stress, the dynamic factor multiply amplitude of vibration is:

$$\nu = \sqrt{\frac{1 + \frac{\Psi^2}{4\pi^2}}{\left(1 - \frac{n_n^2}{n_{kr}^2}\right)^2 + \frac{\Psi^2}{4\pi^2}}}$$

where: n_n - nominal rotation of drive,
n_{kr} - rotation of resonance system.

Dumping factor of flexible coupling is [L.1] (fig. 1):

$$\Psi = \frac{A_r}{A_s}$$

where: A_r - the area of work dumping during 1 cycle of work,
A_s - the area of elastic deformation for 1 cycle of work.

For flexible couplings, such ZERKOPOL, the dumping factor has obtained $\Psi \cong 1{,}05$, couplings with rubber connectors $\Psi \cong 0{,}80$. The maximum increase of torque in the drive will be during resonance period, when $n_n = n_{kr}$ (fig. 3). In this case:

$$\nu_{max} = \sqrt{\frac{4\pi^2}{\Psi^2} + 1} \cong \frac{2\pi}{\Psi}$$

and is 6 for ZERKOPOL couplings and 7,85 for rubber connectors couplings (type SPP). From figure 3 we see, that high elasticity coupling has profitable influance on dynamic peculiarities of drive system only then $\nu < 1{,}1$, it is when: $n_n/n_{kr} > \sqrt{2}$.

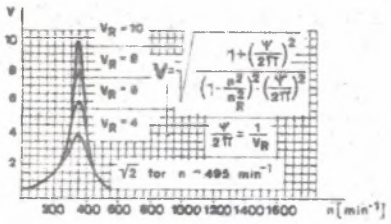

Fig. 3. Multi factor of vibration amplitude

The high elasticity coupling should still work on over critical rotation ($n > 350$ rpm), crossing resonance on the beginning of the period of starting, when dynamic moment isn't too high.

OVERLOD COUPLINGS FOR SCRAPER CONVEYORS AND COAL PLOUGHS

In the machines with hydraulic drives the problem of overload coupling doesn't appear. This function has been done by overflow valve located in front of work mechanism in the pressure network. In the mechanic drives, the problem of overloads coming from work machine (for example: exceptional cutting resistance, start of full loading scraper conveyor and so on) should be solved by location of overload coupling on the suitable shaft of the drive. As for today constructions of drives: scraper conveyors, coal ploughs, reclaimers and wheel excavators we use the following couplings: permanent flexible, fluid or multipledisc cultch. These couplings are "safety device" of the drive and they are located between electric engine and high speed shaft of the toothed gear. The problem of the best choice of place for overload coupling can be solved only by means of overloads size analyssis, that occur on the seperates stages of these mechanism. When we accept, that a drive of the machine is a system of double masses, then the maximum load moment in this system will be equal (fig. 4):

$$M_{max} = M_{op} + M_i \sin i\omega t \frac{J_2}{J_1 + J_2} \cdot \nu = M_{op} + M_d$$

where: M_{op} - static resistance moment of work machine during starting.

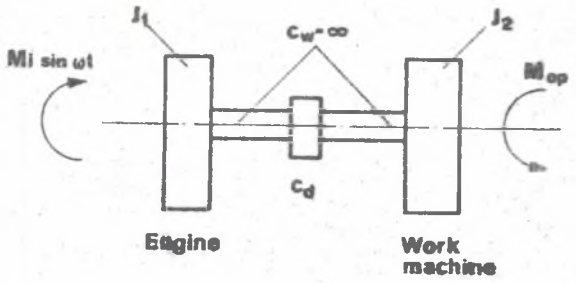

Fig. 4. Drive model of conveyor or coal plough

In such a drive we define nominal factor of overload γ_1, that characterize possibilities of overloading work machine and loading interval, where overload coupling should work [L.2].

$$\gamma_1 = \frac{M_{max}}{M_{op}}$$

Overload factor of drive has the shape:

- in the starting period on a first shaft of drive:

$$\gamma_1 = \frac{I_2 \frac{M_s}{M_{op}} + I_1}{I_1 + I_2} = \frac{I_2}{I_1}\frac{M_s}{M_{op}} + \frac{I_1}{I_{zr}}$$

- in the brake period on a first shaft of drive:

$$\gamma_{1h} = \frac{I_2 \frac{M_H}{M_{op}} + I_1 \frac{M_{oph}}{M_{op}}}{I_1 + I_2} = \frac{I_2}{I_{zr}}\frac{M_H}{M_{op}} + \frac{I_1}{I_{zr}}\frac{M_{oph}}{M_{op}}$$

where:

M_s - moment of electric engine,
M_H - brake moment,
$I_{zr}=I_1+I_2$ - reduced moment of inertia (fig. 4),
M_{oph} - resistance moment of machine during braking.

During starting most overloads in the drive will occur on the engine shaft, when it gets maximum moment. In the brake period, in the mechanism will take place the active resistance moment M_{oph}, it comes from large moment of inertia of work machine. Stream of power flows in this case, from the work machine to the brake. Overload factor of drive on "i" stage of drive, during breking period will be equal:

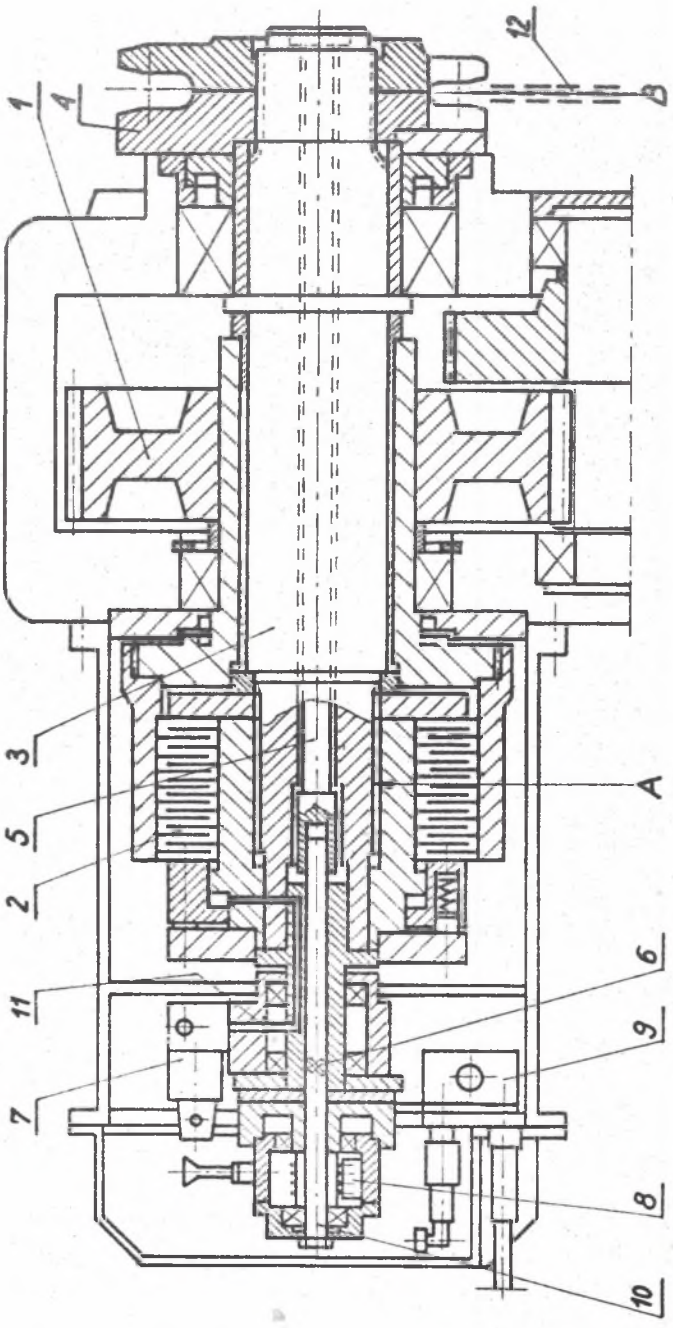

Fig. 5. Overload coupling of the Westfalia Lünen Company (West Germany)

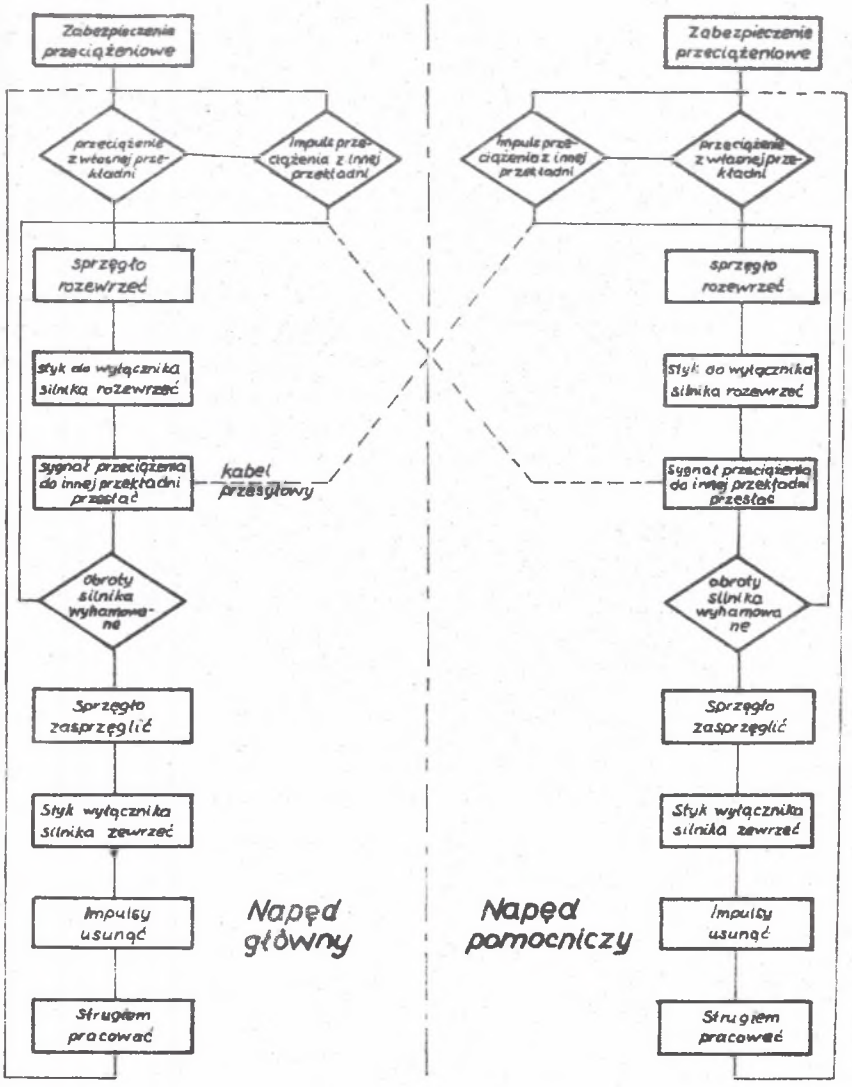

Fig. 6. Principle algorithm of the overload coupling in drive of coal ploughs

$$\gamma_{ih} = \frac{M_{in\ max}}{M_{ioph}} = \frac{\gamma_{ih}}{\eta_m \cdot \eta_{mn}}$$

where:

η_m, η_h - total efficiency factor of drive during starting time or braking time.

This formula shows the necessity of locating the overload coupling on slow speed shaft (the closest to work mechanism), specially in machines of big moment of inertia and small efficiency of these mechanisms. Small efficiencies of mechanisms are result multistage toothed gears using in drives (for example differential gears). It is due to the of necessity assuring minimal rotation speed of the work mechanism. Using overload coupling on a slow speed shaft of the drive require building new generat'on of overload couplings with immense torque (M_{max} = 25 - 200 kNm). Some companies specialising in overload couplings already have first new construction of these couplings. For example, Westfalia Lunen Company (West Germany) in the new construction of coal plough use overload coupling (fig. 5) located on last shaft in the gear of drive. It's multipledisc coupling with control torque. Functioning algorithm of this coupling in the drive of plough can be see on fig. 6.

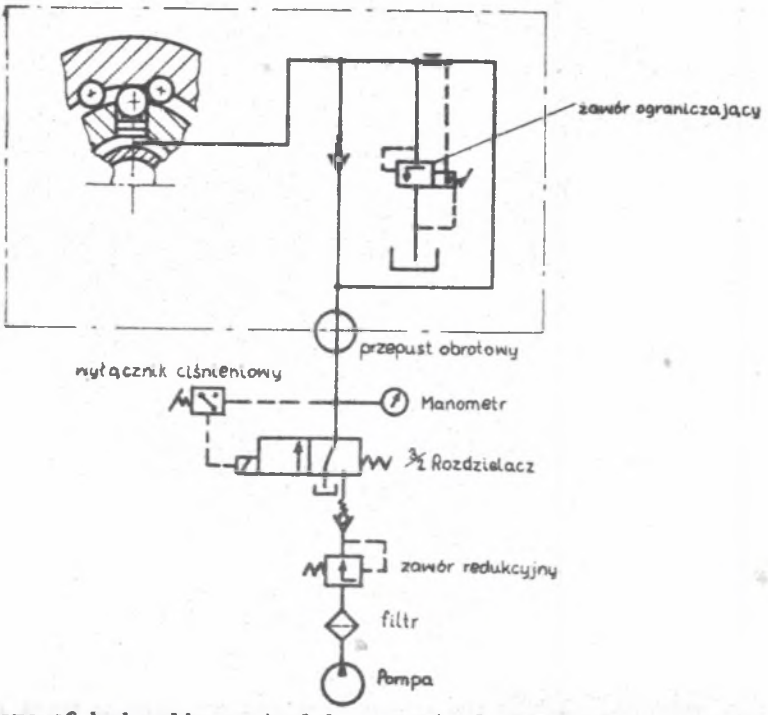

Fig. 7. Shems of hydraulic control by moment of the overload coupling

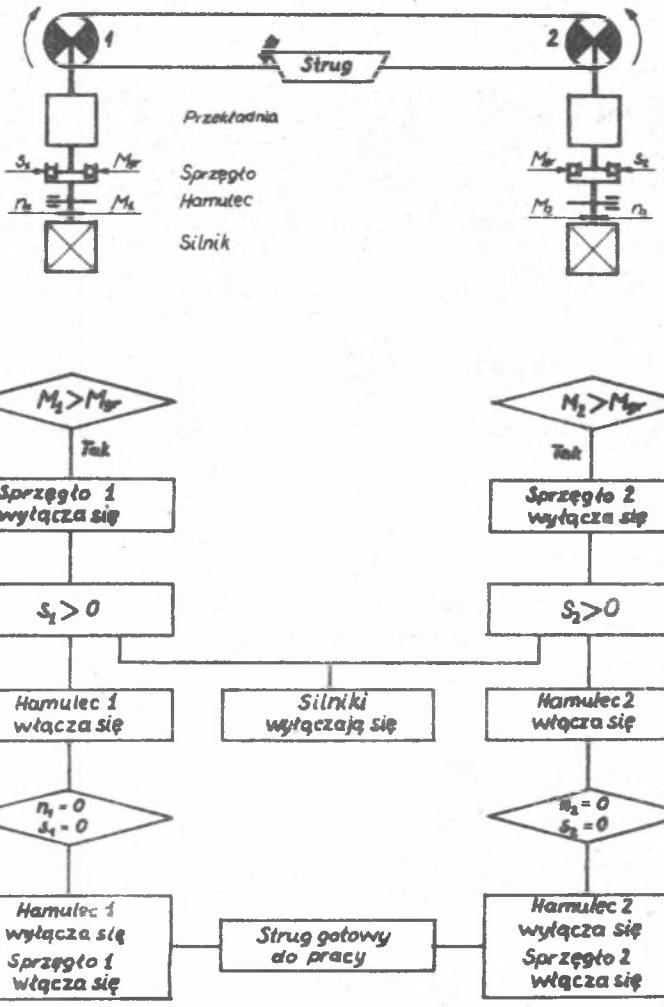

Fig. 8. Principle working of the overload coupling in drive of the coal ploughs

Studies on new construction of high moment overload couplings are carried in some designing centers in Poland. We can also find overload couplings, where connectors have the shape of small globules, the quantity of pressure to the discs of couplin and quantity of tourque in the coupling maybe controlled, for example hydraulically (fig. 7). Working principle of such coupling in the drive of coal plough can be see on fig. 8.

CONCLUSIONS

- Using starting couplings in drives of conveyors and coal ploughs should follow starting analysesis of maximum loaded machines. We should creat mathematical models of these machines and with the help of computer starting symulation caloulate starting time. It permits that designer of the machine to decide about the necessity of starting coupling application.
- In the case of short starting time of conveyor drive or plough we shoud use much cheaper permanent flexible couplings.
- Taking into consideration a large ununiform loading in scraper conveyors, coal ploughs and vibrating screen, we recommend using flexible couplings with high elasticity (torsion angle $\varphi \cong 38^{\circ}$) and large dumping factor of ZERKOPOL type. In drives of belt conveyors because of belt elasticity we can use simple and cheaper flexible couplings with connectors or joint flexible type SPP.
- We should creat Polish construction of overload coupling for scraper conveyors and coal ploughs that would have a big torque, which could be located on slow speed shaft of the drive.

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DOBÓR SPRZĘGIEŁ DO WSPÓŁCZESNYCH NAPĘDÓW MASZYN GÓRNICZYCH

S t r e s z c z e n i e

W artykule przedstawiono zasady doboru typu sprzęgła do napędów maszyn górniczych takich jak: przenośniki, strugi lub przesiewacze. Stwierdzono, że sprzęgła rozruchowe w napędach przenośników taśmowych i zgrzebłowych można w wielu przypadkach zastąpić dużo tańszymi sprzęgłami nierozłączonymi podatnymi produkowanymi w Polsce. Sprzęgła przeciążeniowe w napędach przenośników zgrzebłowych oraz w strugach powinny być usytuowane na stopniu wolnoobrotowym napędu, co wymaga jednak stworzenia nowej konstrukcji sprzęgieł przeciążeniowych wysokomomentowych.

ПОДБОР МУФТ ДЛЯ СОВРЕМЕННЫХ ПРИВОДОВ ГОРНЫХ МАШИН

Р е з ю м е

В статье представлены принципы подбора типа муфты для привода горных машин таких как: конвейеры, струговые установки, грохоты и другие. Доказывается, что разгонные муфты в приводах ленточных конвейеров во многих случаях можно заменить более дешевыми, неразъёмными, податливыми муфтами. Предохранительные муфты в приводах скребковых конвейеров, а также в струговых установках должны быть расположены на степени медленно вращающегося привода, что однако требует создания новой конструкции предохранительных высокомоментных муфт.