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DRIVE SYSTEMS WITH FILL CONTROLLED TURBO COUPLING FOR HIGH CAPACITY LONGWALL SCRAPER CHAIN CONVEYORS

Summary. Due to their advantages fill controlled water turbo couplings are commonly used in the drives of armoured face conveyors in longwalls of high production rates. At present 30 couplings of this type are at the disposal of the Polish hard coal mines. The technical specification of the coupling under discussion is given in the paper. The main advantages and disadvantages of this coupling are discussed in the paper.

SYSTEMY NAPĘDOWE ZE SPRZĘGŁEM HYDRODYNAMICZNYM O REGULOWANYM WYPEŁNIENIU DLA PRZENOŚNIKÓW ZGRZEBŁOWYCH W ŚCIANACH O DUŻEJ KONCENTRACJI WYDOBYCIA

Streszczenie. Dzięki licznym zaletom sprzęgła hydrodynamiczne o regulowanym wypełnieniu są szeroko stosowane w napędach przenośników zgrzebłowych w ścianach o dużej koncentracji wydobycia. Aktualnie około 30 tego typu sprzęgieł jest zainstalowanych w polskich kopalniach węgla kamiennego. Techniczne własności tego typu sprzęgieł zostały zamieszczone w pracy. Własności te były sprawdzane w badaniach prowadzonych in situ. Omówiono także zalety i wady tych sprzęgieł.

1. Operational requirements for the AFC drive systems

Armoured face conveyor systems transporting large quantities of coal and characterized by high installed total motors power placed several demands on the drive technology, which are listed below: performance equalization, gentle starting, creep drive, tension chain, shearer in zone close to drive and economical advantage. All these requirements are fulfilled by the new drive systems with fill controlled turbo couplings made by Voith-Turbo.

The smooth start-up of chain scraper conveyors can be achieved using hydrodynamic turbo couplings of constant or variable fill. Due to safety reasons water or water-oil emulsion is used as the working medium. The constant fill couplings type TVVF or TVVFS produced by Voith-Turbo and by the other factory are used in drives with motors of up to 400 kW. Water operated fill controlled turbo couplings type DTPPWL or TTT produced by the same company are used in drives of higher power. The advantages and relatively low purchase costs of these types of couplings cause that they make 87% of all armoured face conveyors couplings used in the USA, fig. 1. In Poland hydrodynamic couplings of constant fill are used in drives of stage loaders with engines of 200 to 250 kW.

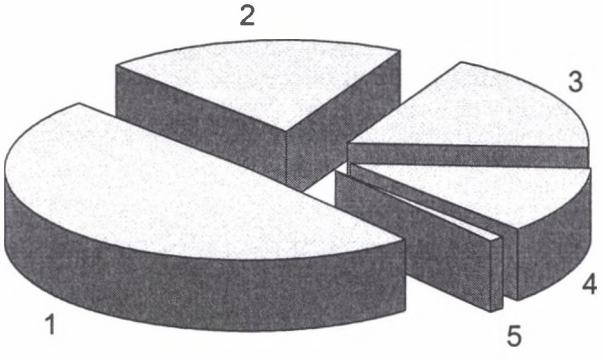

Fig.1. Armoured face conveyor drives in the USA (data from January 2001); 1 – 49% constant fill hydrodynamic couplings type TVVF, TVVFS produced by Voith-Turbo; 2 – 20% fill controlled turbo couplings type DTPPWL and TTT produced by Voith-Turbo; 3 – 18% hydrodynamic couplings produced by other companies; 4 – 12% mechanical transmissions with multidisc wet coupling produced by DBT; 5 – 1% drives with three-phase induction motors controlled by a frequency converter
Rys.1. Napędy zgrzebłowych przenośników ścianowych w USA w 2001 r.

Due to advantages of couplings type DTPPWL are commonly used in the drives of armoured face conveyors, in longwalls of high production rates. At present 30 couplings of this type are at the disposal of the Polish hard coal mines. Three couplings of this type operate with the motors of 500 kW each at the Bogdanka Colliery in the longwall No 10/1, of the day production rate from 16 to 20 thousand tons. All the other couplings are used by other collieries in the longwalls of the production rates from 8 to 12 thousand tons/day. The operational tests, carried out in the longwall face of high production rates at the Piast Colliery, have shown a full reliability of these couplings during the production process of 2.2 million tons of coal.

2. Fill controlled water turbo couplings

Fill controlled water turbo couplings designated with the DTP symbol (i.e. two pumps and two turbines), transmits the torque from an asynchronous, one-speed motor with special mechanical characteristics (ratio of starting torque to break-down torque is 3.2), through a rotating water ring, to a receiver, which is an armoured face conveyor. A symmetric location of two pairs of pump and turbine wheels has eliminated the axial forces of the opposite sign and has enabled to reduce the diameter of the coupling paddle wheel. The quantity of the transmitted torque is controlled in an infinitely variable way by the level of water in the coupling working space. In these couplings the flow of water stream depends on the coupling operational rate, which is of the essential importance when the drive overcomes big and differentiated resistances of an armoured face conveyor. These couplings are being improved continuously as far as their design is concerned.

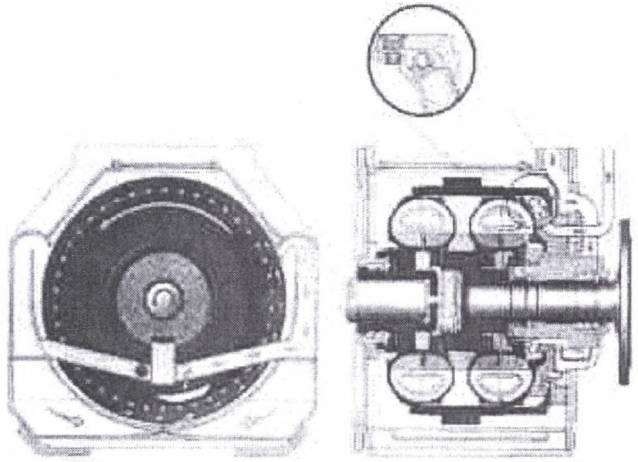

Fig.2. Fill controlled water turbo coupling of the type 487 or 562 DTPPWL.2, made by the Voith Turbo Company
Rys.2. Sprzęgło hydrodynamiczne z regulowanym wypełnieniem typu 487 lub 562 DTPPWL.2 w wykonaniu firmy Voith Turbo

The individual letters in the coupling 487 or 562 DTPPWL.2 type stand for: emptying the coupling with the sucking pump (P), water as medium (W), a coupling situated in the bearing unit on one side, from the gear-box side (L.2) – Fig. 2. The coupling is installed in the bearing unit only from the pump side, on the half-shaft with a flange connected with a high-speed shaft of the gear-box. Due to this arrangement the length of the coupling has been reduced to 800 mm.

For a proper usage of the motor torques in the case of the coupling of the 487 or 562 DTPPWL.2 types, the Damel Factory from Dąbrowa Górnicza has designed and manufactured a special asynchronous, one-speed motor of the SG3-450 S-4 type of the power 400 or 500 kW for the voltage 1000 or 3300 Volts. The motor of the 400-kW power has the starting torque slightly higher than the rated torque which is 2574 N·m, and the break-down torque is more than three times higher than the rated one. This torque has the quantity of 8237 N·m.

A new fill controlled water turbo coupling of a new generation, being a result of cooperation with the Deutsche Steinkohle AG (DSK), fulfilling the additional requirements, specified by the customer, has been produced by the Voith Turbo Company. It is the coupling of the 562 DTPKWL2E-S1-C type (Table 1) for the driving units from 800 to 1050 kW and maximal torques 15000 or 18000 N·m respectively. A novelty consists in equipping the couplings with their own control system, enabling, among others, an inspection running with the determined speed e.g. 50 percent. The amount of water supplied to the coupling is also controlled. A constant control of the coupling fill increases the conveyor availability, because in the case of worse coupling fill, in the auxiliary drive, the whole conveyor needs not to be switched off. A sensor of revolutions, which is to control the output revolutions during the inspection running has been installed on the coupling output shaft. Besides, on the water outlet the temperature sensor, which is to measure the temperature constantly, has been installed. A checked level sensor, together with the pressure switch, are used for determining the state of the maximal fill of the rotors. A valve unit is installed directly on the coupling between the coupling and the supply pipeline. Its task consists in a control of the water supply to the coupling at the pressure changes from 6 to 16 bars. The unit is equipped with two piston electrovalves and a membrane cut-off valve, used for more efficient drainage of water from the coupling.

The couplings operate in the closed-loop supply system, which enables a significant reduction of the water supply. A relatively big amount of water in the system, i.e. about 200 l/min, enables simultaneously to adjust the coupling to the states of partial fill.

Each coupling is equipped with its own IKM (intelligent coupling module) controller, which is to control, check and perform the required operational state. The intelligent coupling module IKM is a powerful, inherently safe control module, with a modular design, and can be programmed with a standard language. It has numerous interfaces for communicating with the outside world, LCD displays, signal inputs and outputs, A/D and D/A transducers, analogue inputs and outputs, power outputs as well as frequency inputs and outputs. Due to its fast

processor and the associated peripheral equipment, it is also able to take on time critical control tasks. The connected face control simply provides the IKM with the required basic functions and is thus ready for other process control tasks. The multifarious nature of the IKM permits the networking together of up to 127 drive units.

The superordinated unit for the individual IKM controllers is the IKM-Master, which can supervise in total up to four individual IKM controllers. The IKM-Master gets an order of performing the required operational state from the whole longwall control system, it forms one network with the individual controllers, controls the individual drives and transmits to them the orders from the superordinated control system.

The following coupling operational states are realized by the supply and control systems described above: starting the motor is performed through progressive switching-on the individual drives, the filling valve opens and the emptying valve is closed; operational steady-state conditions, the filling valve is closed and the coupling operates in the closed-loop system, water gets out from the working chamber to the pump pan from which it is pumped back to the working chamber by the scoop pipe; the exchange of water after exceeding the permissible temperature (about 55^0C), the emptying valve opens and the membrane cut-off valve gets closed, so the water from the scoop pipe is drained out, simultaneously, opening of the filling valve enables a supply of cold water from the pipeline, when water reaches the temperature of 40^0C, the water exchange is finished and the coupling returns to the operational steady-state condition; the inspection running (50 percent of rated speed) is performed through a reduction of the coupling fill; the chain tensioning, the required output torque is achieved by timing of the filling and emptying valves; the emergency running is performed through an individual direct control of each coupling; cooling (after exceeding the temperature of 65^0C and before starting the chain tensioning) consists in filling the coupling with water at the stopped motor, the cooling time is initially given.

In the American market the hydrodynamic coupling with the water flow, controlled by the operational state condition, determined by the symbol 562 DTPKW (TTT) – Fig. 3. – produced by the Voith Company in cooperation with the Joy Company, which manufactures the planetary gears belonging to this type of drives, is available.

3. Control element "open circuit"

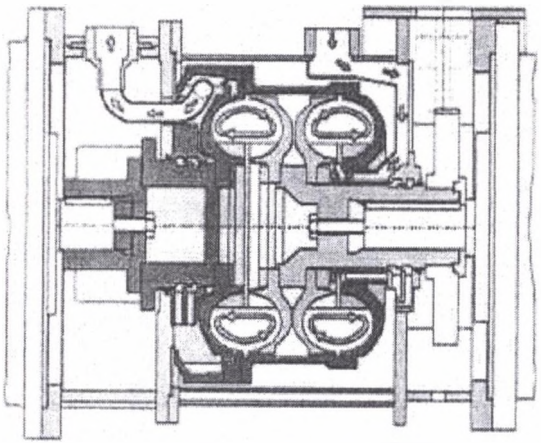

Fig. 3. Hydrodynamic water coupling with a controlled new generation emptying system, of the 562 TTT type, made by the Voith Turbo and Joy Companies
Rys. 3. Sprzęgło hydrodynamiczne z regulowanym wypełnieniem typu 562 TTT w wykonaniu firmy Voith Turbo i Joy

Fill controlled water turbo couplings, used in Poland, are supplied with water in an open hydraulic system as in Fig. 4.

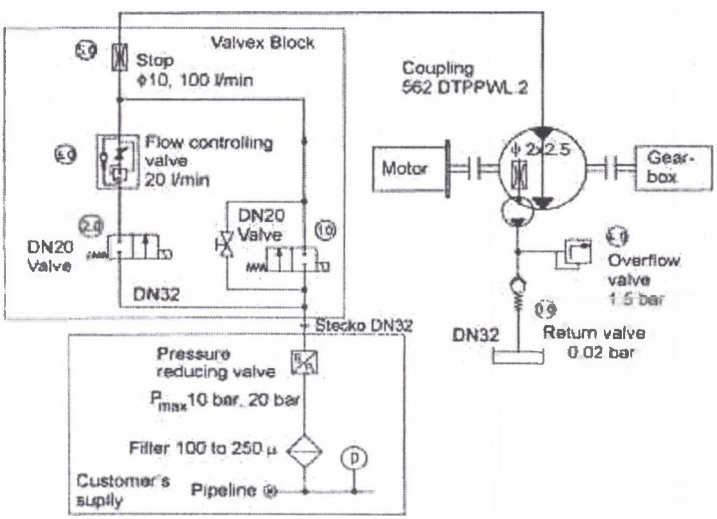

Fig. 4. A diagram of an open hydraulic system of the 562 DTPPWL.2 coupling
Rys. 4. Schemat otwartego układu zasilania sprzęgła hydrodynamicznego typu 562 DTPPWL.2

Water is supplied to hydrodynamic couplings from the fire-control pipeline at the pressure of about 1.2 MPa after its prior filtration. A valve assembly, equip-ped with the Valvex EV 2120 electrovalves for the voltage of 12 Volts D.C., controls the flow of water through the coupling. A pressure limiter, as a protection of the electrovalves, is shown in Fig. 4. During the start-up of an armoured face conveyor both electrovalves 1.0 and 2.0 are open, due to this fact the water supply to working chambers of the coupling is about 100 l/min, which is controlled by the stop 5.0. After having completed the start-up, i.e. after having filled in the coupling, the electrovalve 1.0 closes and the amount of water, supplied to the coupling is kept on the constant level of 20 l/min by the flow controller 6.0. The outflow of water occurs through the return valve 3.0, at a blocked run-off (pressure increase to about 0.4 MPa) through a relief valve 4.0. The couplings of this type, in the version installed in Poland, are not equipped with the peripheral devices such as sensors etc.

4. The technical specification of the fill controlled water turbo couplings

Table 1

Technical parameters of fill controlled water turbo couplings

Specification	Type of coupling		
	487 DTPPWL.2	562 DTPPWL.2	562 TTT and 562 DTPKWL.2E-S1-C
Material of paddle wheels	aluminium alloy or bronze		
Material of coupling housing	alloy steel of highest quality or steel galvanized igneously		
Working medium	water		
Motor rated power, kW	up to 400	up to 750	1000 at n=1500 min^{-1} 1200 at n=1800 min^{-1}
Maximal torque, N·m	-	12000	18000 for bronze wheels
Heat capacity, determining the number of possible starts	excellent		
Load equalization	self-acting		self-acting or controlled
Soft start	splendid		
Control system + sensors	-	-	yes
Hydraulic supply system	open		open or closed
Conveyor with side discharge or cross-drive	only side discharge		yes

5. Operational features of fill controlled water turbo couplings

The main advantages, resulting from an application of the couplings of this type in drives of armoured face conveyors are as follows:

- for the control element "open circuit":

  a possibility of using cheap, one-speed induction motors of the power from 400 to 800 kW, of a special, advantageous, mechanical characteristics; a simplification of the electric installation in the longwall; an application of water as a working medium; tandem and load-less start-up of the motors; progressive switching of individuals drives due to differentiating the time of filling the couplings with the liquid; average start-up acceleration for an empty conveyor is about 0.24 m/s^2 and for a loaded one it is about 0.15 m/s^2, start-up of a loaded conveyor is a lot smoother than a start-up of an empty one; simple control because important functions such a torque limitations and load sharing occur automatically as a result of natural characteristic of the coupling; an automatic limitation of the torque during the start-up and lack of the possibility of the motor transition over the break-down torque to the saddle point of the motor torque; a soft and quick increase of the torque transmitted to the chain; an increase of the chain, sprockets and gear-box life;
- for the control element "closed circuit":

  all advantages listed above in the control system "open circuit" and additional minimum water consumption with shortest start-up repeat times; saving water by utilising maximum possible temperature range between water inlet and outlet; frequent start-ups against blocked conveyor are possible; break-away torque can be maintained in less than 20 seconds; designed for powers up to 1100 kW (in future up to 1500 kW); a possibility of correcting the starting characteristics of the conveyor, changing the way of filling the coupling; an unlimited number of start-up actions after an exchange of water without any heat problems; a controlled equalization of drive loads; dumping of torsional vibrations in the drive; a possibility of an inspection running of the chain with a creep speed; an additional possibility of a precise tensioning of the chain with a required force is available; a simple control and a compact construction.

The disadvantages of the fill controlled turbo couplings include as follows: a significant quantity of the moment of inertia of the coupling filled with water (for the 562 DTPPWL coupling it is about 15 $kg \cdot m^2$ at the coupling capacity 55.2 cm^3); lack of the conveyor protection against the results of the chain lockup (it requires an application of an additional safety coupling – hydrodynamic or mechanical); a danger of a precipitation of calcium and magnesium salts from the row water, which settle in a form of fur on the coupling elements. Due to the operating principle, the coupling operates with permanent slip 2.5 ÷ 4%.

6. Final remarks

All mechanical and control-related variations of flow-controlled couplings are based upon the hydrodynamic core element. This derives from a 1905 patent by Hermann Föttinger which refers to the wear-free power transmission between adjacent fluid machinery – a pump and a turbine. Therefore, the hydrodynamic core element still consists of a pump and a turbine. In their most simple form, both basic components create a closed hydrodynamic circuit, as utilized in all constant-fill couplings. However, system-inherent heat created by coupling slip can only be dissipated up to a physically determined limit via the surface of the coupling. The solution to this problem is the flow-controlled turbo coupling, which is open outside and hence allows a replacement of the operating medium in order to dissipate heat. These hydrodynamic couplings are in position to fulfill the demands made on drive systems for armoured face conveyors: simple electrical supply system in comparison to one applied in a two-gear drive; virtually load-free start-up of the asynchronous motors; sequential start of individual drives by variable filling of the couplings; automatic torque limitation during start-up, no stalling of the motor over break-down torque; smooth and rapid build-up of torque at the chain; torque build-up against blocked conveyor and holding of the motor break-down torque; start-up with small acceleration; repeated start-ups without thermal problems; automatic load sharing; possibility of running at creep speed; chain tensioning in connection with brake; simple control; protection of the chain against "rapid blockage" with additional "Safeset" coupling between gearbox and chain sprocket; utilization of water as operating medium and limitation of water consumption in the supplying "closed circuit".

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Omówienie

Sprzęgła hydrodynamiczne o regulowanym wypełnieniu komór roboczych wodą pracują na podstawie zasady Föttingera. Sprzęgła te znalazły szerokie zastosowanie w napędach wysoko wydajnych ścianowych przenośników zgrzebłowych o mocach do 800 i do 1100 kW, a w przyszłości do 1500 kW. Omawiane sprzęgła w połączeniu z pozostałymi elementami napędu wypełniają wszystkie najważniejsze zadania stawiane napędom ścianowych przenośników zgrzebłowych. Zadania te zostały opisane w pracy. Omówiono także sterowanie tych sprzęgieł w otwartym i zamkniętym układzie hydraulicznym zasilania. Więcej funkcji spełnia napęd wyposażony w sprzęgło hydrodynamiczne o regulowanym wypełnieniu pracujący w zamkniętym układzie zasilania, które posiada szereg czujników przeznaczonych do kontroli i sterowania pracą sprzęgła. W tym też przypadku istnieje możliwość pełnego sterowania wszystkimi napędami danego przenośnika zgrzebłowego. Do tego celu wykorzystywany jest inteligentny moduł sprzęgła IKM. Oczywiście, rozszerzenie funkcji realizowanych przez sprzęgło podraża jego wykonanie. W pracy podano parametry techniczne tego typu sprzęgieł oraz ich zalety i wady, które zostały potwierdzone odpowiednimi badaniami przeprowadzonymi na obiektach przemysłowych w KWK Piast i w innych kopalniach. Wyniki tych badań nie zostały omówione w tej pracy, lecz znajdują się w artykułach wymienionych w załączonym spisie literatury.