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A New Concept of a Fluid Coupling for Belt Conveyor Drives

This paper gives a new concept of a starting fluid coupling which enables changing its starting characteristic, matching it to the motor characteristic and operation with small losses at rated loading.

1. Introduction

Lately, fluid couplings are more often applied in Poland for drives in many branches of the national economy. In power engineering, adjustable couplings are used — for example: drives of pumps supplying power unit boilers, drives of emergency starting pumps, dredging pumps, fan mills in 360 MW units. There are also produced starting fluid couplings for mining and power engineering purposes which allow cooperation of the electric drive with the working device. Besides, there is a demand for fluid couplings for car and construction machine drives. Especially the demand for high power couplings used in mining and power engineering (drives for belt conveyors and long coal feeding devices etc.) is growing. These products are at present imported. Therefore the need arose for developing own designs and technology of high-power starting couplings. Research was started by the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdańsk and it was financed by the Government Sponsored Research Program PR-8 — direction 6. The objective was to enable designing a high-power starting fluid coupling with an appropriate performance characteristic.

2. Assumptions for the New Concept of a Fluid Coupling

2.1. Characteristics of formerly used couplings

Electric squirrel-cage asynchronous motors, commonly used for driving heavy devices or machines with large moments of inertia, require that in the drive a starting fluid coupling with proper performance characteristics is used. The former starting couplings were of constant, predetermined filling which formed a tightly closed structure. They were designed to enable starting the electric motor and the

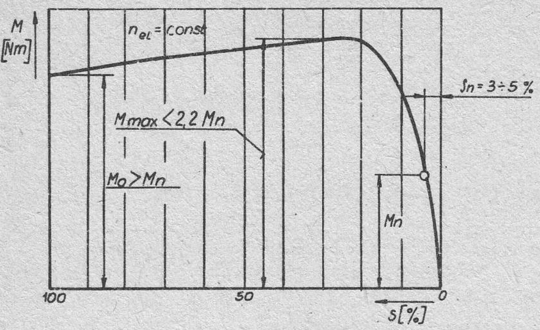

Fig. 1. Characteristic $M = f(s)$ of a typical starting coupling

M_n — rated moment, M_0 — moment at starting, M_{max} — maximum moment

machine. The performance characteristic of such a coupling is shown in Fig. 1. There is a quite large nominal slip $S_n \sim 3\text{-}5\%$ which determines the flow efficiency $\eta = 1 - S_n = 0.97 - 0.95$ and has constant, set once for all, characteristics and limited power for one coupling because of limited possibilities of receiving and discharging heat.

Because of their cooperation with an electric motor the basic requirements which these couplings must fulfill is matching the coupling characteristic to the motor characteristic. In practice the coupling characteristic is assumed to be correct one (Fig. 1) if $M_{max} \leqslant 2.2\, M_n$ and $M_0 > M_n$, where: M_{max} — maximum moment which can be carried by the coupling, M_n — performance moment of the coupling at rated loading, M_0 — starting moment of the coupling (at slip $S = 100\%$).

In order to ensure that these conditions are fulfilled, the designs contain certain modification: as introduction of the various types of additional chambers and so-called baffles (gates), nonsymmetric flow systems and obliquely situated blades (angle $\beta < 90°$). Additional chambers are used in the form of starting chambers, damming chambers, etc. and are located at the side of the outlet or inlet impeller and also below the internal diameter of these impellers. The object of using them is to cause "internal draining" of the coupling thanks to decreasing the amount of liquid circulating between the impellers, in the range of large and medium coupling slips caused under influence of a defined type of forces by liquid flux from the work chamber to the additional coupling chamber situated outside the flow system. Diagrams of such couplings are shown in Fig. 2.

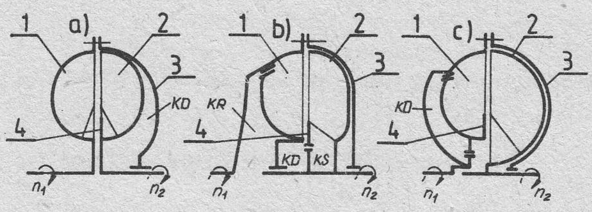

Fig. 2. Diagrams of starting/overload fluid couplings: a) with static selfdraining, b) with dynamic self-draining, c) fluid coupling of SH series of types made by the K. Świerczewski Mining Tools and Machinery Works in Katowice

1 — pump impeller, 2 — turbine runner, 3 — rotating envelope, 4 — gate, KD — additional chamber, KS — damming chamber, KR — starting chamber, n_1 — speed of input shaft, n_2 — speed of output shaft

In the type SH starting fluid couplings, worked out in the design office of the mining machinery industry and manufactured, by the Gen. K. Świerczewski Mining Tool and Machinery Works in Katowice, is used a coupling with a nonsymmetrical flow system in the form of nonsymmetrical caps with the additional chamber at the pump impeller side and with a shield (see Fig. 2c).

It should be stressed that the most commonly used in turbomachines adjustable type fluid couplings — which form a separate group of fluid couplings — cannot be used for cooperating with electric motors for driving large mass machines or machines with large mass moments of inertia. The basic difficulty which precludes the use of couplings of adjustable type in these drives most often is due to the instability of coupling work which occurs at partial filling and during work in the large slip range. Besides, another disadvantage precluding the use of adjustable fluid couplings instead of starting couplings is their filling control system which should be adjustable. This is impossible in case of typical starting couplings, because of the required simplicity of the driving system.

2.2. Requirements which should be fulfilled by the coupling according to the new concept

In the light of the remarks contained in Section 2.1, when working out the concept of a new coupling, the objective was to obtain such a starting fluid coupling which:

1) would be characterized by torques in accordance with the ones shown in Fig. 1, and with the possibility of matching the torque to a given type of electric motor;

2) could transmit rated power in a relatively wide range;

3) could ensure work with nominal slip S_n = 1-2%, i.e. at correspondingly high efficiency = 0.98-0.99;

4) would enable increasing the coupling boundary power limited by thermal reasons.

3. The Method of Realizing the New Concept of the Starting Coupling

Fig. 3 presents a diagram of the new concept of a starting fluid coupling, which would fulfil the requirements presented in Section 2.2. The design consists in:

1. Determining during standstill before starting, the liquid level in the coupling (filling of the coupling) by selecting an appropriate external overall height (e.g. h_1, h_2, ... etc.), flange 8 or situation of the scoop 4.

2. Running-in the coupling at determined and fixed in the above way amount of liquid which influences the torque curve during starting of the coupling (Fig. 3).

3. Further filling during and after starting of the coupling, until complete filling σ = 100% is attained, as shown in Figs 3 and 4.

4. Selecting proper flow intensity of the liquid supplying the coupling, in order

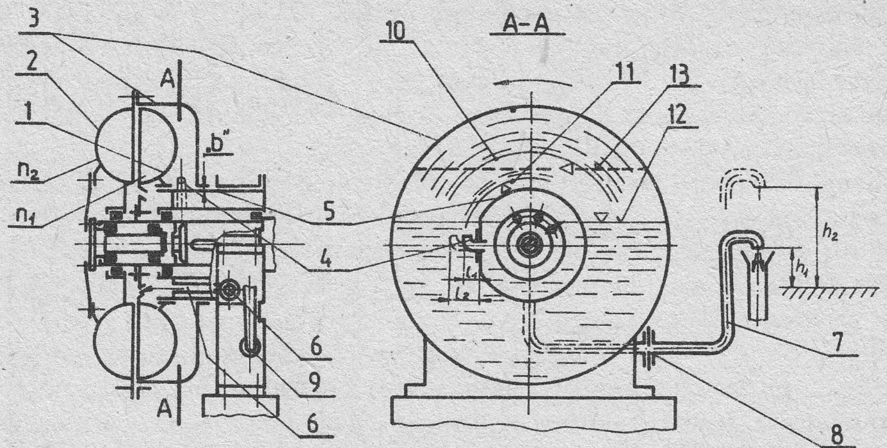

Fig. 3. Diagram and principle of operation of the new concept coupling

1 — pump impeller, *2* — turbine runner, *3* — rotating envelope, *4* — scoop, *5* — coupling casing, *6* — coupling supply pipe, *7* — outlet tube with overall, *8* — throttling flange, *9* — pipeline for draining liquid from coupling, *10* — liquid surface directly after starting the motor, *11* — liquid surface at $\varphi = 100\%$ (some time after starting), *12* — liquid surface before starting at position h_1 of component 7, *13* — liquid surface before starting at position h_2 of part 7, *b* — gap between rotating envelope and casing, l_1, l_2 — consecutive scoop positions, adjusting maximum filling of the coupling

to obtain the required speed at which the torque transmitted by the coupling increases, so that it is fitted to the motor performance characteristic.

5. Selecting an appropriate coupling flow system ensuring stable work and optimum performance curves of the coupling at various fillings.

Therefore the new concept coupling has an open circuit for supplying the work medium like water, oil or some other liquid. Because of that, there can be a constant flow of liquid in the coupling also during standstill. Flow of liquid into the coupling is opened before it is started.

The liquid with flow intensity Q_z fills the flow system and rotating envelope *3* throught the pipeline *6* (Fig. 3). Some of the liquid flows out through the gap *b* between the rotating envelope and casing *5*. The rest, after attaining a certain constant level, flows out of the coupling through the scoop *4* and the outlet tube. The overall height h_1, h_2, ..., throttle opening diameter or length of the scoop determine the coupling filling, and are fixed at such a value that an optimum coupling starting characteristic is obtained. After starting the coupling, i.e. after the envelope *3*, and impellers *1* and *2* begin rotating, the automatic outflow of the water through the circumferential gap *b* and scoop *4* stops, and the supplied with flow intensity Q_z liquid increases the coupling filling, topping up to the amount determined by scoop protrusion. Therefore, after several minutes the coupling starts operating at complete filling (100%), determined by scoop protrusion and the nominal slip S_n = 1-2% is attained. From this moment, liquid flowing into the coupling flows out exclusively through scoop *4*. The complete coupling filling time from starting, i.e. the rate of torque increase (curve *I* in Fig. 4) depends on Q_z and may be changed in order to match the coupling characteristic to the motor characteristic. The supply of liquid must be closed after stopping the coupling, because within 1-2 minutes from motor stopping, the level of liquid stabilizes by itself.

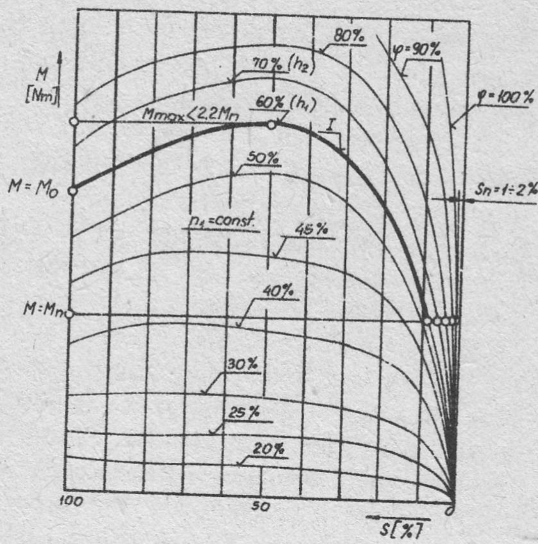

Fig. 4. Characteristic curves of the flow system of the new concept fluid coupling $M = f(S, \varphi)$ for different coupling fillings. I — starting torque curve of the new concept coupling for electric motor rated torque $M = M_n$

It should be mentioned that when the machine is driven simultaneously by two or more electric motors (this happens sometimes in drives of long coal conveyors), by changing scoop protrusion $I_1 \dots I_2$ (Fig. 3) the maximum coupling filling may be adjusted and thereby the nominal torque transmitted at constant nominal slip S_n. This allows accurate adjusting of uniform loading of motors cooperating in the drive.

The presented method of coupling starting can be explained basing on performance characteristics of the coupling $M = f(S, \varphi)$ shown in Fig. 4, where: S — coupling slip; φ — filling; M — torque transmitted by the coupling. This method allows work of the coupling at nominal load and very small slip of 1-2%. Characteristics presented in Fig. 4 can be obtained by selecting an appropriate flow system, ensuring — among others — the small coupling slip at nominal torque and stable work within the whole range of slip variation.

4. Final Remarks and Summing-Up Comments

A starting fluid coupling made in accordance with the new concept is characterized by the following features:

1. It ensures the possibility of matching the starting characteristic to the motor characteristic.
2. It enables coupling work at nominal load with very small slip of 1-2%, i.e. smaller than the slip in typical starting couplings of traditional design.
3. It ensures that the external coupling supply system has a larger heat capacity and better possibilities of heat dispersion than in case of constant fill couplings. This allows to increase the nominal coupling power.
4. It allows for the possibility and facility of changing the starting torque which together with simultaneous large amount of transferred heat allows to increase the

range of transmitted power by a small change of the coupling flow efficiency at nominal loading. E.g., decreasing efficiency η from 0.99 to 0.98 enables to double the transmitted nominal power.

5. It ensures that if several motors work for one power receiver the loading of cooperating motors may be corrected by adjusting the maximum coupling filling through changing scoop protrusion.

6. The new concept starting couplings have a more complicated flow and installation system than constant fill starting couplings, which increases its cost and is a disadvantage.

Basing on the presented concept and the results of model tests which confirmed the performance and energy advantages, the starting coupling SHP-630 of power $N = 630$ kW was designed at the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdańsk. Production has been undertaken by the Zakłady Mechaniczne Górnictwa i Energetyki „Wiromet" in Mikołowo. Two prototype couplings will be ready in the first quarter of 1986 and mounted in drives of long coal conveyors in the dry ash disposal system of Bełchatów Power Plant.

References

[1] Z. Szydelski, *Sprzęgła, hamulce i przekładnie hydrokinetyczne* (Fluid couplings, hydrokinetic brakes and hydrokinetic torque converters). Wyd. Komun. i Łączn., Warszawa 1981.

[2] O. V. Yaremenko, *Ogranichivayushchie gidrodinamicheskie mufty*. Mashinostroenie, Moscow 1970.

[3] S. Dąbrowski, *Problemy cieplne i sprawnościowe związane z regulacją maszyn wirowych przy użyciu sprzęgieł hydrokinetycznych* (Heat and efficiency problems connected with adjusting fluid-flow machines using fluid couplings). Prace IMP no. 67-68, 1975.

[4] J. Czerwonka, R. Jaśniewski, J. Krasuski, T. Przychodzień, *Rozruchowo-przeciążeniowe sprzęgła hydrokinetyczne. Właściwości i zasady doboru do napędów elektrycznych* (Starting and overload fluid couplings. Properties and principles of selecting with regard to electric drives). Materiały Konferencji Naukowo-Technicznej „Przekładnie i sprzęgła hydrokinetyczne", NOT, Łódź, 1984.

[5] E. Szczygieł, *Sprzęgła hydrokinetyczne rozruchowo-przeciążeniowe w napędach maszyn górniczych* (Starting and overload fluid couplings in mining machines drives). ibid.

[6] Z. Stankiewicz, J. Choromański, *Określenie zasad projektowania sprzęgieł do podajników węgla, odżużlaczy i taśmociągów na podstawie badań modelowych* (Principles of designing cuplings for coal feeders, dirt traps and belt conveyors, basing on model tests). Oprac. wewn. IMP PAN Gdańsk, nr arch. 146/84.

Nowa koncepcja sprzęgła hydrokinetycznego do napędu przenośników taśmowych

Streszczenie

Artykuł poświęcony jest opisowi nowej koncepcji sprzęgła hydrokinetycznego rozruchowego, przeznaczonego do współpracy z silnikami elektrycznymi przede wszystkim w napędach przenośników taśmowych. Idea nowego sprzęgła polega na ustaleniu odpowiedniego poziomu cieczy w sprzęgle przed startem, wypełnieniu sprzęgła cieczą bezpośrednio po starcie i ciągłej pracy sprzęgła przy pełnym wypełnieniu, a więc przy wysokiej sprawności energetycznej. Uzyskano to dzięki zastosowaniu zewnętrznego obiegu cieczy roboczej, wyposażonego w zbiornik, pompę zasilającą, a także przewody rurowe. Optymalny

poziom cieczy roboczej w sprzęgle przed startem z uwagi na współpracę sprzęgła z silnikiem elektrycznym napędowym zgodnie z rysunkiem 3 uzyskiwany byłby przez dobór wysokości przelewu h, lub też kryzy dławiącej *8*. Dobrany poziom cieczy w sprzęgle przed startem równoznaczny byłby z uzyskiwaniem przez sprzęgło wymaganej, z uwagi na pracę silnika elektrycznego, charakterystyki ruchowej podanej na rysunku 1.

Typowe sprzęgła hydrokinetyczne rozruchowe, których układy przepływowe podano na rysunku 2, pracują przy niepełnym wypełnieniu cieczą układu przepływowego. Sprawność energetyczna tego typu sprzęgieł jest przez to obniżona i wynosi $\eta = 0{,}95 \div 0{,}97$. Sprzęgło wg proponowanej koncepcji pracowałoby przy całkowicie wypełnionym układzie przepływowym, a uzyskiwana sprawność energetyczna, potwierdzona badaniami modelowymi, wynosiłaby $\eta = 0{,}98 \div 0{,}99$. Sprzęgło hydrokinetyczne wg nowej koncepcji charakteryzowałoby się ponadto możliwością lepszego dopasowania charakterystyki rozruchowej sprzęgła do charakterystyki silnika, większą pojemnością cieplną niż sprzęgła rozruchowe o stałych napełnieniu, co pozwala na zwiększenie mocy nominalnej sprzęgła, a także możliwością rozszerzenia zakresu przenoszonej mocy. Wadą proponowanego sprzęgła jest jego większy koszt i nieco bardziej skomplikowana instalacja w napędzie.

Новая концепция гидрокинетической муфты для привода конвееров

Резюме

Статья посвящена описанию новой концепции гидрокинетической пусковой муфты, предназначенной для содействия с электродвигателями прежде всего в приводах конвееров. Идея новой муфты заключается в установлении соответственного уровня жидкости в муфте перед пуском, наполнении муфты жидкостью непосредственно после пуска и непрерывной работе муфты при полном наполнени, т.е. при работе с высоким значением энергетического к.п.д. Это достигнуто благодаря применению внешнего цикла рабочей жидкости, оснащённого резервуаром, питающим насосом и трубопроводами. Оптимальный уровень жидкости в муфте перед пуском, с учёта на содействие муфты с приводным электродвигателем, согласно с рис. 3, был бы достигнут путём отбора высоты перелива h или же дроссельного сопла *8*. Отобранный уровень жидкости в муфте перед пуском был бы однозначен с работой муфты по характеристике необходимой с учёта на работу электродвигателя, представленной на рис. 1.

Типичные пусковые гидрокинетические муфты, которых проточные системы показаны на рис. 2, работают при неполном наполнении жидкостью проточной системы. Из-за того энергетический к.п.д. такого типа муфт достигает низшие значения $\eta = 0{,}95 \div 0{,}97$. Муфта по предлагаемой концепции должна работать при полном наполнени проточной системы, а значения энергетического к.п.д., подтверждённые модельными исследованиями должны достигать $\eta = 0{,}98 \div 0{,}99$. Гидрокинетическая муфта по новой концепции должна кроме того характеризоваться возможностью лучшего приспособления пусковой характеристики муфты к характеристике двигателя, большей теплоёмкостью чем теплоёмкость муфт с постоянным наполнением, что позволяет увеличить номинальную мощность муфты, а также возможностью расширения предела переносимой мощности. Изьяной предполагаемой муфты является её большая стоимость и немного более комплицированный монтаж в системе привода.