**Annual of the University of Mining and Geology "St. Ivan Rilski"**
**vol.44-45, part III, Mechanization, electrification and automation in mines, Sofia, 2002, pp. 9-11**

# METHOD FOR DIMENSIONING OF HIGH POWER CENTRIFUGAL BALL CLUTCHES

**Venelin Tasev**

University of Mining and Geology
"St. Ivan Rilski"
Sofia 1700, Bulgaria
E-mail: lvtasev@mail.bg

ABSTRACT
The report suggests a method for determining the main parameters of centrifugal ball clutches for power higher than 500 kW. It employs other authors' developments aiming the minimization of mass and cost for equal initial parameters. The main geometric dimensions, contacts and masses of clutch and balls are determined. The methd is designed for dimensioning of high power clutches.

There are different methods (Mateev, 1984; Tasev, 1990) for dimensioning the centrifugal ball clutches (CBC). The initial moment of rotation ($M_c$) for nominal frequency of the motor ($\omega_н$) is most often considered the main parameter. Mass and cost prove to be very important for centrifugal ball clutches of high power (more than 500 кW) and comparatively lower frequency of rotation. The suggested method is established for constructing of centrifugal ball clutches of minimum mass and cost. The dependencies for lightening of centrifugal ball clutches are applied for the purpose (Tasev, 1990).

Quantity of ball filling is decisive for cost and mass of the centrifugal ball clutches. Ball filling quantity of the centrifugal ball clutch changes depending on filling of individuial chambers with balls. After rotation of the Centrigual Ball Clutch, the balls line up in a special order and form a later of radius $R_1$ concentric to the friction surface. Furthermore, the more filled chambers are, the lower $R_1$ is. In the CBC (Mateev, 1984) quantity of ball filling is shown by the coefficient $K_2 = \frac{R_1}{R_a}$, where $R_a$ is the radius of active friction surface. The author (Tasev, 1990) derived the following dependence or the coefficient $K_2$, which determines the filling of CBC:

$$K_2^3 + 3.K_2.\left(\frac{\psi_c}{\psi_n} + 1\right) - 4 = 0 \qquad (1)$$

where:

$K_2 = \frac{R_1}{R_a}$ is a coefficient;

$R_1$ – radius of free surface of the ball filling, m;

$R_a$ – active radius of friction, m;

$\Psi_c$ – density of CBC, which depend on its construction (Tasev, 1990);

$\Psi_n$ – density of ball filling $\Psi_n \approx 0,55$ (Тасев, 1990).

For different constructions of CBC the coefficient $\Psi_c$ changes from 0,6 to 1,2. Significant number of CBC, developed by the author, reveal that for high power cluctches the coefficient is $\Psi_c$=0,8÷1. For those values of $\Psi_c$ the coefficient $K_2$ gets values of 0,46÷0,52.

Mass of filling $m_n$ is determined by the dependence:

$$m_n = \pi.\rho.\psi_n.l_a.R_a^2.[\left(1 - K_2^2\right) - \\ - K_1.(1 - K_2)\ ], kg \qquad (2)$$

where:

ρ – is density of steel, kg/m³;

$l_a$ – active wide of the mantle, m;

$K_1 = \frac{a_л}{R_a}$ ;

$a_л$ – thickness of shovel, m.

After determination of coefficient $K_2$ and mass of filling, the basic geometric dimensions, active radius $R_a$ and active width $l_a$, in particular, are to be determined.

One exact determination of both values is impossible as the initial moment of rotation ($M_c$) depends on both. The following coefficient is employed for that reason:

$$K_5 = \frac{l_a}{R_a} \qquad (3)$$

Tasev (1990) performed a very detailed analysis on the effect of basic geometrical dimensions, in particular $R_a$ и $l_a$, on the mass of CBC for equal initial parametrs. It was proved that with the increase $R_a$, under equal other conditions, the mass

$m_c$ decreases significantly. Due to constructive and technical features this could not be unlimited.

For CBC of high power $K_5$=0,4 through 0,8, and the first values refer to CBC of lower frequency of rotation, and second value to higher frequencies.

The active radius $R_a$ of CBC for the minimum mass of the CBC ($G_c$) is determined by the expression:

$$R_a = \sqrt[5]{\frac{3.M_c}{2.\pi.\rho.\psi_n.f.\omega_n^2.K_5.\left(1-K_2^3\right)}}\text{, m} \qquad (4)$$

where:

f is the coefficient of friction $\approx 0,04$.

After determination of $R_a$ the approximate value of active width is determined l:

$$l \approx K_5.R_a\text{, m} \qquad (5)$$

Number of ball lines for balls of radius $r_c$ are determined:

$$n_p = \frac{1,1.l}{\sqrt{3}.r_c}, \qquad (6)$$

$r_c$ is the radius of balls, m,

and $n_p$ is approximated upward to an integer.

Final width of mantle $l_a$ is:

$$l_a = \sqrt{3}.r_c.\left(n_p - 1\right) + 2.r_c\text{, m} \qquad (7)$$

Initial moment of rotation $M_c$, that is able to rotate the CBC is calculated for the determined active width of the mantle:

$$M_c = 6.\omega_n^2.f.\rho.\psi_n.l_a.R_a^4.\left\{\frac{\pi}{9}.\left(1-K_2^3\right) - \frac{K_1}{2}.\left(1-K_2^2\right) + \frac{R_a}{l\sqrt{6}}.\right.$$
$$\left.\left[\frac{\pi}{45}.\left(2-5.K_2^3+3.K_2^5\right) - \frac{K_1}{2}.\left(1-2.K_2^2+K_2^4\right)\right]\right\}\text{, Nm} \qquad (8)$$

is calculated for the determined active width of the mantle:
where:

$$K_1 = \frac{a_л}{R_a} \approx 0,05.$$

In case the calculated $M_c$ differs more than 10% of the given one, $K_2$ has to be changed and calculation has to start again.

Contact tensions $p_o$ in the zone of friction between balls and inner cylindrical surfacesв are calculated.

$$p_o = \frac{1,5}{\pi.n_a.n_b}.\sqrt[3]{\left(\frac{E'.R_a.\omega}{3}\right)^2.\rho.\psi_n.\left(1-K_2^3\right)}\text{, Pa} \qquad (9)$$

where:

$n_a$ and $n_b$ are parameters of the contact, determined by Hord;

E' – reduced modulus of elasticity, Pa.

Contact pressure may not be higher than 0,5 GPa. When higher values are obtained extension of width of mantle is needed, and reduction of active radius, respcetively.

Another more reasonable option for reducing contact tension is the change of parameters of contact, i.e. changing the sizes of grooves (its radius $r_ж$ and depth $h_ж$), hich was discussed in detail by Tasev (1989).

Change of groove radius $r_ж$, as it has to be similar to radius of ball $r_c$, brings to change of $n_a$ and $n_b$. Latter being identified from specialized tables for calculating the contact tension according to the formulas of Hertz. For the needs of CBC the author (Tasev, 1989) suggests the following formula, which determines precisely the tension in the contact zone:

$$p_o = 175.10^8.(\beta-1)^{0,185}.(\omega_n.R_a)^{0,67}.\left(1-K_2^3\right)\text{, Pa} \qquad 10)$$

where:

$\beta = \frac{r_ж}{r_c} = 1,05 \div 1,005$ is the coefficient, depending on precision of groove performance. Lower values correspond to more precise performance.

Distance between separate grooves $a_ж$ and depth of groove $h_ж$ are calculated by the following formulas:

$$a_ж = \sqrt{3}.r_c\text{, m,} \qquad (11)$$

$$h_ж = 1,2.r_c.\left[1 - \omega_n.\frac{0,005.\left(\omega_n.R_a\right)^{2/3}}{(\beta-1)^{0,38}}\right]\text{, m}$$

After obtaining acceptable contact tensions $p_o \leq$ 0,5GPa quantity of ball filling in one chamber ma be determined $Q_{кам}$:

$$Q_{кам} = \frac{\pi}{6}.\rho.\psi_c.l_a.R_a.\left[\left(1-K_2^2\right) - K_1.\left(1-K_2\right)\right]\text{, kg,} \qquad (12)$$

For the entire clutch quantity of balls is:

$$Q_{пълнеж} = 6.Q_{кам}$$

Expected mass of the clutch without balls is:

$$G_c = \pi.\rho.\psi_c.R_a^2 l_a\text{, kg} \qquad (13)$$

Total mass of the clutch is:

$$G_{ЦСС} = G_c + G_п\text{, kg.}$$

Thus the dimensioning of centrifugal ball clutch is performed.

## REFERENCES

Mateev, M.N. 1984. Improving the driving of mine transport machines by centrifugal start-protection clutches of free filling, *Thesis for awarding the title of professor, Higher Institute of Mining and Geology*.

Tasev, V.P. 1990. Opportunities for application of centrifugal ball clutches with a guiding six-shovel rotor to the driving of machines in mining sector, *PhD thesis, Higher Institute of Mining and Geology.*

Tasev, V.P. 1990. Reducing the weight of centrifugal ball clutches, *Annual of Higher Institute of Mining and geology.*

Tasev, V.P., Some topics on dimensioning of centrifugal ball clutches, *Annual Higher Institute of Mining and Geology, p. 165*.

*Recommended for publication by Department of Mine Mechanization, Faculty of Mining Electromechanics*