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. 13-15

OPERATIVE THERMAL PROTECTION OF CENTRIFUGAL BALL CLUTCHES

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ABSTARCT
The report discusses different opportunities for performing an operative thermal protection for centrifugal ball clutches. Indirect schemes with analogous thermal and electric models are described in details. Dependencies for dimensioning of respective models are derived with the aim of applying them tas operative protection for centrifugal ball clutches.

Protection of cenrifugal ball clutches /CBC/ from unwanted overheating, resulting from irregular operation of or overloading of machine involves the application of protection, which will provide switching off the machine before reaching dangerously high temperatures.

TYPES OF OPERATING THERMA PROTECTIONS

Knowing the temperature in the clutch in each moment is needed for the operative protection. Depending on how this is realized protections may be of two types – of direct temperature registration and indirect temperature registration. In the first ones temperature control is realized by a thermal sensor, assembled steadily to the mantle, in a point where the highest heating is expected. Taking away of the obtained signal is realized by contact rings, brushes and brush-holders, assembled to the inlet shaft. Obtained signal is amplified appropriately, an reaching a certain temperature value it excludes engine supply. Applying this principle of action the protection provides a very reliable and effective control on clutch temperature, and possible error is reduced only to the error of temperature registration of the assembled sensor. The basic disadvantage is heavy constructive decision, involving the assembly of rings and brush-holders. To a certain extent, this makes maintenance and safety of protection more difficult. For that reason this type of protection has not been practically applied yet.

The same principle employs a protection, which observes temperature in the mantle from a ceratin distance. It is realized by a special thermal sensor (pyrometer), which allows determination of temperature by the radiation obtained while the clutch is heated. Advantage of this solution is that construction of the clutch does not change and taking away of the signal is realized by an easy and safe approach. Comparatively higher inaccuracy of measurement and effect of sensor contamination on its registrations may be mentioned as a disadvantage. This may bring to irregular and not in-time work of the protection.

Operative thermal protections with an indirect action are based on a dependence of temperature change with time, which is known in advance. The most simple protection of that type is realized by a time-relay, which is adjusted for a time of switching off, a little bit higher than the time needed for the realization of a normal start. A special sensor controls putting of the machine into motion. If this does not happen for the time provided, the relay starts and gives signal for switching the engine off. Protection of that kind is effective only for a single unsuccessful start, but it may not react to overheating caused as a result of too many switches for a certain period of time.

Another form for realization of a thermal protection of indirect action is modelling of the process of heating and cooling. This may be .realized by a thermal or electric model. Principle of both approaches is the same and consists in the following:

When the engine is switched on, models are supplied proportionally to the thermal flow released in the clutch. Special sensors provide information about speed of rotation, when engine and machine are rotated. Depending on differences in speed, intensity of heating changes in the same way as thermal flow in the clutch changes for the same period of time. When speed of working machine reaches speed of the engine, voltage in sensors equalizes and supply to models interrupts. From this moment on modeling of cooling process is performed. In case of good dimensioning, values of temperature, respectively voltage in respective models may precisely follow the temperature changes in the ball clutch.

INDIRECT OPERATIVE PROTECTION WITH A THERMAL MODEL

Dimensioning of the thermal model is performed as follows. Its mass is to refer to mass of clutch and moment of rotation in it as follows:

$$\frac{\sum_{1}^{i} m_i.c_i}{M_c.(\omega_1 - \omega_2)} = \frac{\sum_{1}^{n} m_n.c_n}{P_H} \qquad (1)$$

where:

m_i is the mass of respective eleemnt of CBC, kg;

c_i – specific heat consumption of respective element of CBC, J/kg.K˚;

M_C – moment, developed by CBC, Nm;

ω_1 – angular speed of engine, rad/s;

ω_2 – angular speed of machine, rad/s;

m_n – mass of respective element of the model, kg;

c_n – specific heat consumption of respective element of the model, J/kg.K˚;

P_H – power released in the heater, W.

Power, P_H, heating the model is determined depending on the heat, released in CBC:

$$P_H = M_c.(\omega_1 - \omega_2).\frac{\sum_{1}^{i} m_i.c_i}{\sum_{1}^{n} m_n.c_n}, \text{W} \qquad (2)$$

In case of certain ratio of masses and heat power, the power released in the heater is to be of a respective value. Observing the following equation is needed for realizing one and the same conditions of cooling (Chichinidze, 1970):

$$\frac{W_c.e^{-K_C.t_{OX}}}{\sum_{1}^{i} m_i.c_i} = \frac{W_M.e^{-K_M.t_{OX}}}{\sum_{1}^{n} m_n.c_n}, \qquad (3)$$

where:

W_C is the whole quantity of heat, released in CBC, J;

W_M – whole quantity of heat, released in the model, J;

K_C and K_M – coefficient of cooling, for CBC and model, respectively, 1/s;

t_{OX} – time of cooling, s.

As above mentioned ratio of masses towards ratio of powers is a constant value. In this case, the observatiopn of the above equation for one and the same period of cooling needs: $K_C = K_M$.

$$K_C = \frac{\alpha_C.S_C}{\sum_{1}^{i} m_i.c_i} = \frac{\alpha_M.S_M}{\sum_{1}^{n} m_n.c_n} = K_M, \text{ 1/s} \qquad (4)$$

where:

α_C is the coefficient of heat release of the CBC, W/m^{2}K°;

S_C – surface of CBC, m^2;

α_M – coefficient of heat release of the model, W/m^{2}K°;

S_M – surface of the model, m^2.

The coolong surface of the model for realizing the same conditions of coolong, as in the clutch, is to be:

$$S_M = \frac{\alpha_C.S_C}{\alpha_M}.\frac{\sum_{1}^{i} m_i.c_i}{\sum_{1}^{n} m_n.c_n}, \text{ m}^2 \qquad (5)$$

If the above conditions are observed, it may be considered that heating and cooling of clutch and model are performed in one and the same way and the average volumetric temperature in each moment will be equal.

Temperature in the mantle differs from the average volumetric temperature with 5÷25 °C. Sensor assembled on the model is adjusted to switch off when temperature of 110°C is reached with the aim of providing its safe work.

Accurate and precise adjustement is performed at the place of work of the ball clutcher for a give quantity of filling and lubrication in it. Creating different modes of operation for the clutch, temperatures in it and in the model are measured simultaneously, and supplying voltage is selected in such a way that obtained temperatures differ with a minimum. The principal scheme employed by the protection is shown in fig.1.

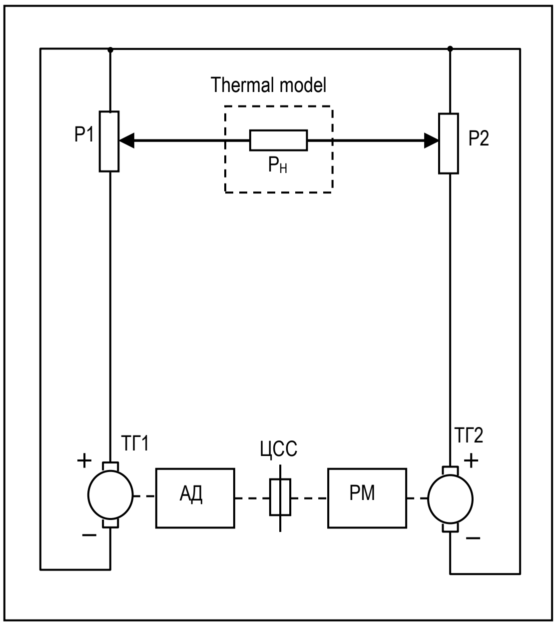

Figure 1.

OPERATIVE THERMAL PROTECTION WITH AN ELECTRIC MODEL

Constructing a protection based on electric model is reasoned by the electrothermal analogy – equal occurring and description of thermal and electric processes. Basic dependencies and correspondence in mathematical description of phenomena are cited in specialized references (Kuzmin, 1974).

The principal scheme is shown in fig. 2. Supply of current, proportional to thermal flow in the clutch is realized by the transistor T1, and by means of tachiogenerators, connected to engine and machine, the value of current changes analogically to thermal flow in the CBC.

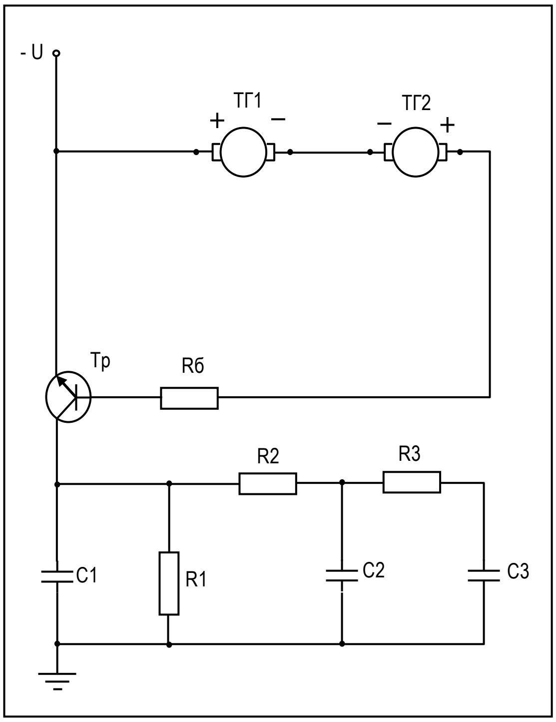

Figure 2.

Modeling of the heating of clutch is reduced to several RC – groups, having the following designation:

- the condenser C1 corresponds to the thermal capacity of the mantle;
- resistance R1 corresponds to disseminated heat by the clutch in the surrounding room;
- condensers C2, C3 and C4 correspond to thermal capacities of ball filling and the other elements of the clutch;
- resistences R2 and R3 are proportional to respective conductivities.

Dimensioning of separate elements is carried out in the following consecution:

- current I through transistor to be proportional to thermal flow through the mantle and ball filling (Kuzmin, 1974).

$$I = K_I.\frac{Q_C}{S_C} = \frac{M_C.(\omega_1 - \omega_2)}{S_C}, \text{ A} \qquad (6)$$

- voltage U on condenser C1 is to correspond to the temperature T in the mantle:

$$U = K_U.T \ ; \quad K_U = \frac{U}{T} \qquad (7)$$

- values of condensers, C_i corresponding to thermal capacities of respective details are calculated according to selected scales of current and voltage:

$$C_i = \frac{K_I}{K_U}.\frac{1}{\sum_1^i m_i.c_i}, \text{ F} \qquad (8)$$

- resistance R1, corresponding to disseminated heat is determined:

$$R_1 = K_U.\frac{U}{S_i.\alpha_i}, \ \Omega \qquad (9)$$

where:

S_i is the respective surface, m^2;

α_i – respective heat conductivity, $W/m^2{}^\circ K$.

- resitances, coreesponding to respective heat conductivities are determiend:

$$R_i = K_U.\frac{U}{S_i.\alpha_i}, \ \Omega \qquad (10)$$

where:

S_i is the respective surface, m^2;

α_i – respective heat conductivity, $W/m^2{}^\circ K$.

Detailed development of an operative protection of that type was performed (Tasev, 1974) for a ball clutch ЦПСС 9, and the same is implemented and tested in practice

Protections, based on electrical modeling and thermal processes are very fleible, and practically one and the same protection may be applied to all types of clutches.

CONCLUSION

Indirect schemes always represent a certain element of insecurity. This may be caused by inaccurate adjustment, incorrect indications of the tachiogenerator and most often to possible change of clutch characteristics, due to change of filling and/or frictional parameters. For that reason their use in explosive atmosphere has to be combined with an accidental heat protection, which has to work n case of possible lack of in-time action of the operative protection.

REFERENCES

Chichinidze, A.V. 1970. Thermal dynamics of friction, *Nauka, Moscow, (in Russian).*

Kuzmin, M.P. 1974. Electrical modeling of non-stationary heat–exchange processes, *Energy, Moscow,* (*in Russian).*

Tasev, V.L. 1974. Operative heat protection for ball clutch, ЦПСС-2., *Diploma thesis, (in Bulgarian)*.

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