WAY OF IMPROVING THE STARTING PROPERTIES OF SYNCHRONOUS DRIVE
OF POWERFUL DRUM MILLS

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ABSTRACT

The paper contains a review of the results of studies related to the improvement of the starting properties of the synchronous drive of a powerful drum mill of the 90x30 MMS industrial series. Analysis of the conditions for starting mechanisms of this type led to the conclusion that the increase in the starting moment can be provided with the means of split excitation winding with active-inductive and intensifying parameters when it is configured into resonance during static launch mechanical characteristics. The results of mathematical modeling of direct start processes confirmed the possibility of a guaranteed start of the mill, even with a loaded drum and reduced by 10 % of the power supply voltage.

Topicality. It is known that the process of minerals dressing, in particular ore of ferrous metals, is accompanied by the opening of the material in order to further extract a useful mineral in one way (magnetic separation or flotation). Usually, the dressing factories use the scheme of stage processing, taking into account the size of the input material. This approach is dictated by the desire to increase productivity and reduce specific energy to the ton of manufactured products. As a rule, in the final stages of the technological scheme use mills of self- or mills with the presence of bodies of grinding. These mechanisms provide the desired grinding tonin, which is suitable for the dressing procedure.

In the case of wet grinding, situations of unauthorized stop of mills sometimes occur due to the termination of energy supply or violation of the technology of stopping the mechanism. The presence of a fraction of particles -0.75 mm in the intranmaline load leads to sealing the contents of the drum. As a consequence, such a circumstance, at the next direct start, turns the drum mill into a fairly powerful flywheel with the displacement of weight to its lower part.

Milling motors have restriction as for the attachment mass and in the case of violation of established mass standards, situations arise that do not allow the system to shift or, if you shift, reach the moment of entry of the motor into synchronism. The result is the need for re-launch, and if it becomes unsuccessful, the manufacturer proposes to run the next launch of the machine only after six hours. It is clear that with the productivity of processing input raw materials MMS 90x30 in 600 tons per hour the manufacturer carries significant financial losses [1].

Currently, synchronous motors can start in different ways. Considering that in case of direct starting, the SDMZ-2-24-59-80-UHL4 consumes current of nine denominations, special measures should be provided for eliminating such a situation. The restriction of dangerous currents can be carried out by a reactor or autotransformer way. But in this case, the state of limited current is simultaneously accompanied by a decrease in the starting moment, which in the case of the problem of launching mills makes the use of methods unsuitable. Among the launch methods is also a known method with a special starting acceleration motor. The presence of the latter complicates the system and is unacceptable under the requirements of today. A possible way to start is frequency converters at full motor power. This method is quite effective, though quite costly, in terms of initial capital costs. There are also known ways to use active-reactive elements in the excitation circuit. These methods are limited by the complexity of the switching schemes, the large voltage values on the capacitor and the need to install a capacity that reaches 1 Farad. An alternative to these

methods can be excitation systems that are built based on split excitation windings with concentrated-distributed capacitors throughout the winding length. These systems allow you to keep the capacitor at the permissible limits and increase the starting moment, which is sufficient to not allow the case of unsuccessful launch of the electromechanical system of MMS 90x30 Synchronous SDMZ-2-24-59-80-UHL4. Thus, the main attention of the authors is focused on viewing this way of controlling the excitation winding of a synchronous drive at direct start of the motor at the full voltage of the power supply.

Main part. The basic idea that became the development of split windings cultivated the issue of creation of a excitation system with active-inductive and intensity properties. Therefore, the excitation structure (Fig. 1), which is made in the form of two isolated tapes of conductor material, connected by variable resistors [2] is the one that has the properties of the delineated type.
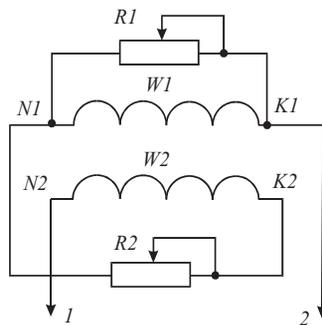

Fig.1. The excitation scheme with active-reactive properties:
$W1$ – the upper part of the winding;
$W2$ – the lower part of the winding;
$R1, R2$ – branch resistors;
1, 2 – power connection points

It was believed that combined properties would compensate for inductive current and increase the active current of the excitation winding, which would form an additional starting moment in the synchronous drive system. Unfortunately, at the time of research, the winding was built of capacitor covers did not allow sufficient compensation capacity at a given motor start frequency. The reason for this was a fairly large thickness of insulation, which did not allow the desired result.

A sufficient level of capacitance capacity was obtained when constructing a scheme from individual pole capacitors on sequentially with regulated resistors Fig. 2 [3]. The conducted complex of studies revealed a fairly high level of quality of the obtained R-L-C contours, which provided a positive effect but at a significantly narrow slide interval.
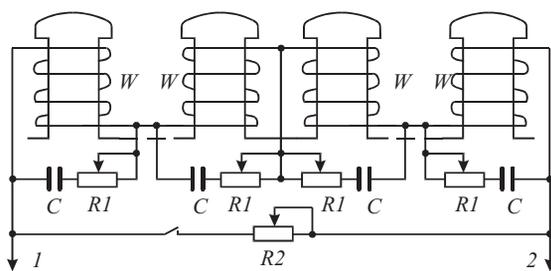

Fig.2. Scheme of excitation system with regular winding:
W – regular rotor coil;
$R1, R2$ – branch resistors;
C – capacitors;
1,2 – power connection points

More rational is the constructive solution proposed in [4], where the excitation winding is split in half and consists of the upper and lower row of half-coils (Fig. 3), in which the capacitors of the same capacity are turned on. The result of the approbation of the proposed structure Fig. 3 on the example of a quiet-legged motor SDMZ-2-24-59-80-UHL4 allowed to obtain a starting moment at a level of 2.5 nominal and with a range of sliding a few wider ones for the scheme Fig. 2. The illustration of proof of the result is static start characteristics of the high -speed electric motor of the motor SDMZ-2-24-59-80-UHL4, which is shown in Fig. 4 [5]. The attached dependence (Fig. 4) indicates that the use of the capacitor increased the starting moment by more than 7 times, and the power factor - 3 times with the growth of the starting current by 2 times.

The analysis of the trigger mechanical characteristics of Fig. 4, a) also indicates the insufficient duration of resonant effects during the launch of a mill electromechanical installation. Previous studies have found that MMS 90x30 mill requires the values of the starting moment 1.4… 1.5 of nominal during the sliding

change within 1... 0.5. Therefore, in the scheme of Fig. 3 it was proposed to install unequal capacitors, and several cascades
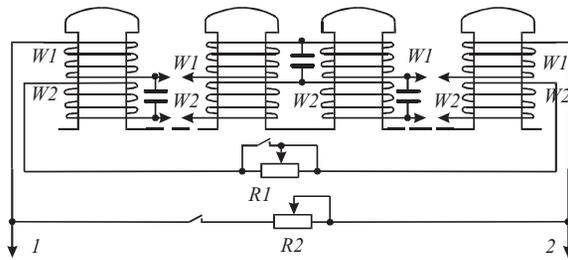

Fig.3. Scheme of excitation system with split winding:
 $W1, W2$ – top and lower half -coils;
 $R1, R2$ – branch resistors;
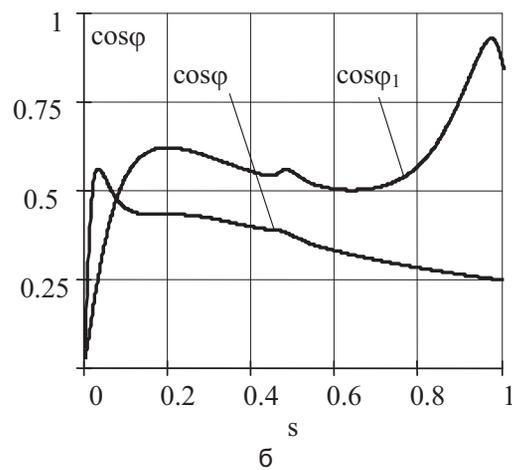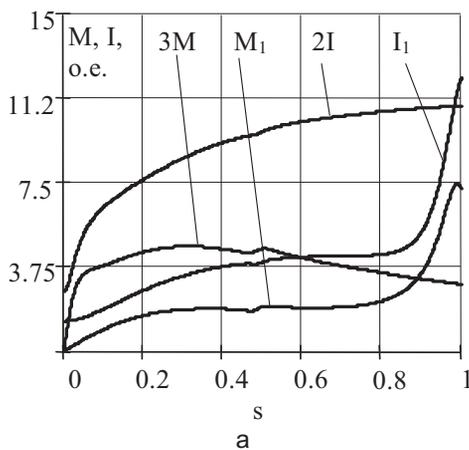 *C – capacitors;*
 1,2 – power connection points

Fig.4. Starting mechanical, electromechanical and energy characteristics of a synchronous motor
 SDMZ –18–49–20– UHL4:
 M – moment without a capacitor; I – stator current without a capacitor;
 M1 – moment with a capacitor; I1 – stator current with a capacitor;
 $cos\varphi$ – capacity ratio without a capacitor; $cos\varphi 1$ – capacity ratio with the capacitor

of capacitors of different capacitance with a number of resonance-oriented inductor currents from 50 to 25 Hz. This idea is confirmed Fig. 5, where the action of the same capacitors of a single-off excitation system leads displacement of extrem of resonance towards smaller sliding.

The complexity of finding the desired capacity in each cascade was solved by developing an optimization problem, where the function of the purpose is the integral criterion of the unbiased standard deviation.
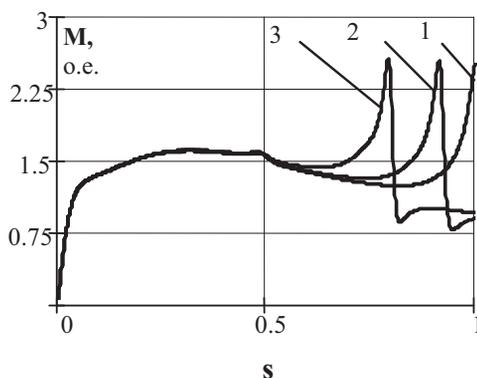

Fig.5. The impact of the capacity of external
 capacitors on the form starting
 mechanical characteristics:
 1 – capacity of 500 µF;
 2 – capacity of 600 µF;
 3 – capacity of 800 µF

$$\sigma = \sqrt{\frac{\sum_{i=0}^{n}(M_{\text{жел.}}(s) - M_{\text{ucm.}}(s))^2}{n-1}} \ ,$$

(1)

where $M_{\text{жел.}}(s)$ is desirable starting characteristics, r.un.; $M_{\text{ucm.}}(s)$ is true launch characteristics, r.un.; n is number of account steps.

The solution of the optimization problem on determining the capacities of cascading capacitors allowed to construct mechanical characteristics with a form that satisfies the mill mechanism Fig. 6 [6].
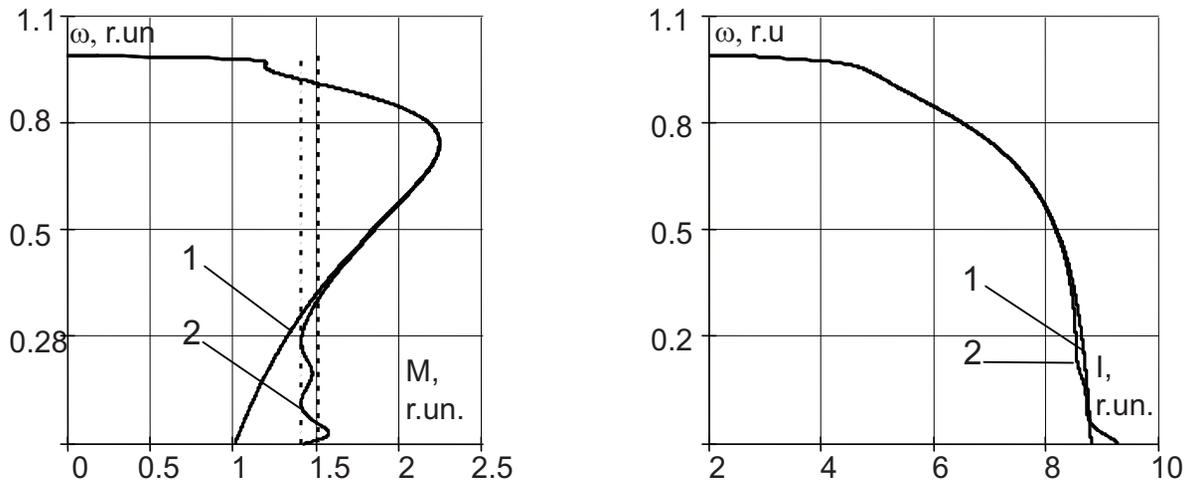
Rice. 6. Electromechanical characteristics of a serial motor (1)
SDMZ-2-24-59-80-UHL4 and with a cascade excitation winding (2)

The quantitative parameters of the winding are obtained at a unbiased standard deviation at 0.281, with the desired shape of the curve of the moment is within the selected borders, and the launch current of the stator of the modernized motors differs from the serial slightly (Fig. 6, b). The number of poles in groups 1, 2, 3, 4 and 5 is 16, 7, 1, 7, 7 and 49, and their capacitors capacity are 29 µF, 0 µF, 6.8 µF, 12.4 µF and 36.3 µF, respectively.

The assessment of the thermal load of the synchronous motor system is made on the basis of construction of transient mechanical processes Fig. 7.
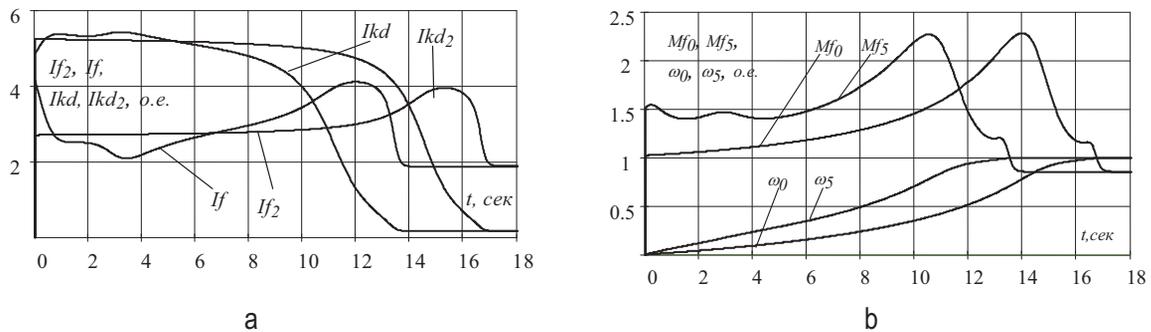
$$M_{\partial} - M_s = j\frac{d\omega}{dt}, \text{ N·m,}$$

(2)

where M_{∂} is moment of motor, N·m
  M_s is static moment, N·m
  j is moment of inertia of the motor, kg m²;
  $\frac{d\omega}{dt}$ is derived speed.

Ikd, If are dempfer and split winding currents, r.un.;
Ikd_2, If_2 are dempfer and classical excitation winding currents, r.un.;
Mf_0, Mf_5 are moments of the motor of ordinary and split excitation windings, r.un.;
ω_0, ω_5 are angular speed of ordinary and five-click motor, r.un.

Fig. 7. Electromechanical transitional processes of the SDMZ-2-24-59-80-UHL4 motor

The results show a reduction in the start of the modernized motor by 3.2 seconds, which allowed the reduction of the heating of the rotary windings according to Table 1.

Table 1 Thermal modes of windings of the SDMZ-2-24-59-80-UHL4 motor

Type of excitation winding	Starting time, sec.	Reducing the heating of the excitation winding,%	Reducing the heating of the dempfer winding,%
split	12.3	24	20
regular	15.5	-	-

Estimation of dynamic loads of shift, synchronization and resynchronization was performed on the experimental synchronous motor SDMZ-2-24-59-80-UCHL4. As for it, an algorithm for calculating electromagnetic transitional processes of starting the motor with a conventional excitation winding and split with five groups of capacitors of different capacity is developed. The modeling mode was carried out at the nominal voltage of the supply network and full static load. The total resistance of the bit resistors was chosen 1.6 Ohm, which meets the manufacturer's recommendations, and the capacity and number of capacitors in groups were made from the solution of the optimization problem. The results of the study are shown in Fig. 8 and Fig. 9.
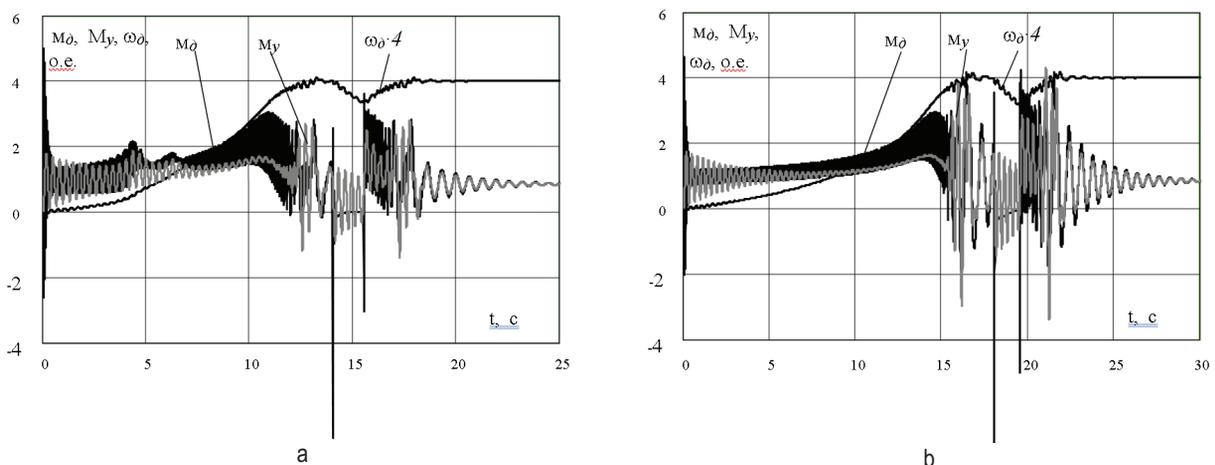

Fig. 8. The starting moment of the motor SDMZ-2-24-59-80-UHL4 according to U1 = 1: a) with split and b) with a regular winding
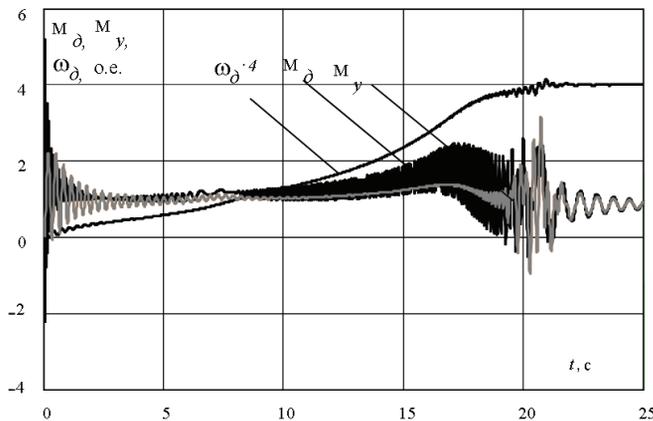
Fig. 9. The launch characteristics of the upgraded SDMZ-2-24-59-80-UHL4 motor at U1 = 0.9
M_∂ - of momenr,
M_y – of elastic moment,
*ω_∂ – of speed*

It should be noted that the motor with a regularexcitation winding and, if the supply voltage and the loaded drum, the mill is reduced, is not started at all.

The scheme solution of Fig. 3 provides a cut in half of the pole coil, which disrupts the technology of their manufacture, namely the main thing complicates the scheme of the magnetic system in determining the parameters of the motor. Therefore, the next step in the study is to create a excitation system with a split winding that leaves the pole coil whole, and splitting is carried out by connecting them through the pole Fig. 10 [7]. Reactivity compensation is achieved by transversely attached capacitors of the same capacity.
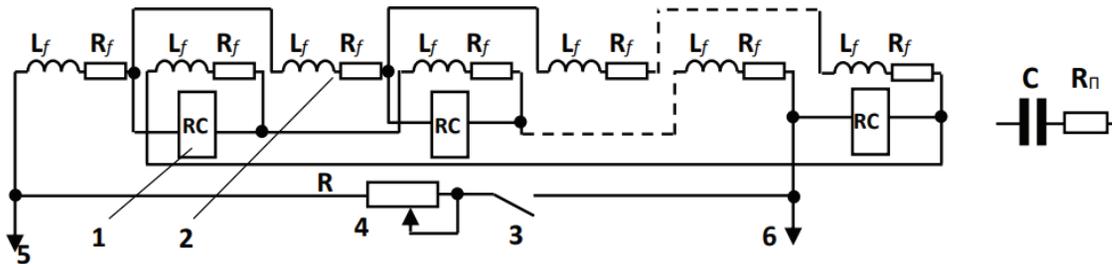
1 – RC circuit; 2 – pole coil; 3 – switch; 4 – branch resistor; 5, 6 – power supply terminals
Fig. 10. The split winding with an improved scheme solution - a and the RC module - b.

Theoretical processing of calculation of the parameters of the magnetic system made it possible to carry out mathematical modeling of the starting mechanical characteristics of the motor SDMZ-2-24-59-80-UCHL4 Fig. 11
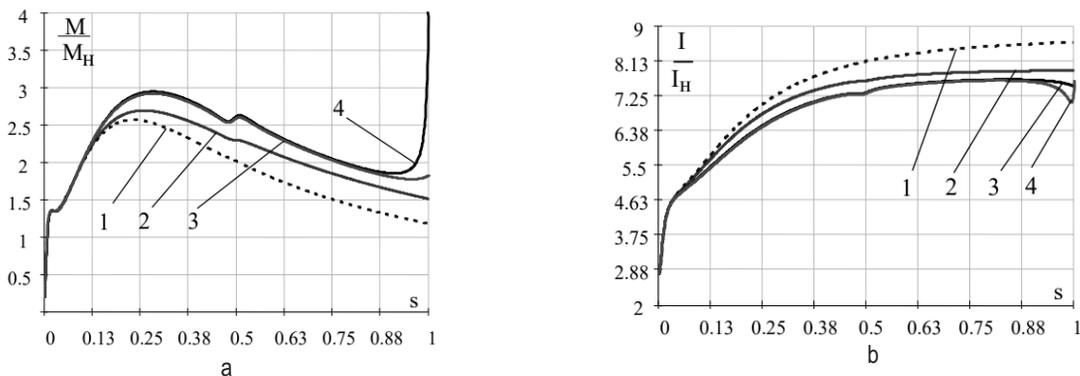
moments a) i armature current b), where 1 – traditional and 2 - 4 µF, 3 - 7 µF, 4 - 12 µF split excitation
Fig. 11. Starting characteristics of the motor SDMZ-2-24-59-80-UHL4

The analysis of the characteristics of Fig. 11 demonstrates a significantly less quality of the contours of the magnetic excitation system, which allowed to limit the capacity of pole capacitors at 4 µF, which is sufficient to provide the desired launch properties of the mill, and the presence of a solid pole coil and one type of capacitors simplifies the calculation of the split excitation winding.

Conclusions.

Experimental-analytically demonstrated the possibility of improving the starting properties of the synchronous drive MMS 90x30 due to the additional moment, which is provided by means of split winding of excitation with capacitors of uneven capacity and their adjustment to several extremities, which are dispersed, which is disconnected, and at nominal loading of the drum and reduced by 10 % of the network supply voltage.

The latest version of the split excitation winding has advantages over the cascade form by simplifying the magnetic system, the presence of one type of condenser and a more monotonous form of starting characteristics, which gives a greater prospect of its introduction into industrial production.

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