

IMPROVEMENT OF THE ELECTRIC DRIVE OF TWIN-SHAFT MIXERS

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Abstract

Relevance. A priority for modern industrial power engineering is the systemic integration of resource-saving innovative technologies while improving productivity. In this context, the design of highly energy-efficient electromechanical systems and the digital automation of their control algorithms remains a key element of global technological transformation. Twin-shaft mixers play a key role in complex process cycles in the chemical, metallurgical, and construction industries, particularly in the homogenization of refractory and acid-resistant components. However, traditional electric drive systems with single-speed asynchronous motors in use in practice have a high inertia coefficient, leading to irreversible energy dissipation during transient conditions (startup and braking). This, in turn, reduces the overall system efficiency and causes an exponential increase in operating costs. Modernizing existing low-efficiency and inertial drives with intelligently controlled contactless modules is considered the optimal solution for minimizing energy consumption, extending the service life of devices, and ensuring process stability.

Target. Development and research of a two-speed asynchronous motor (DM) with a PPO for the electric drive of a two-shaft mixer providing a step start, precise stop and increased efficiency of the technological process.

The following methods were applied in the work: electromagnetic calculation with the selection of optimal winding parameters for the analysis of DD with PPO at a pole pair ratio of 2:4; computer modeling in the ANSYS Maxwell software environment for magnetic field analysis; development of a contactless starting circuit for two-speed asynchronous motors; experimental studies of a prototype AIR180M8/4 motor with the acquisition of operating, mechanical and starting characteristics under production conditions.

A new pole-switching winding circuit was developed, and the AIR180M8/4 two-speed motor was designed based on it. The motor produces 18.5 kW at 1500 rpm ($p=2$) with 90% efficiency and 13.9 kW at 750 rpm ($p=4$) with 85% efficiency. The implementation of a contactless commutation system ensures long-term, safe, quiet, and reliable operation of the electric drive. Industrial tests at the facilities of Almalyk Mining and Metallurgical Combine JSC showed that the motor's integration into the VL-400-VRU mixer drive reduced the rotation cycle by 420 seconds and increased the daily mix capacity by 580 kg.



Keywords: Electric drive, twin-shaft mixer, pole-switching winding (PSW), two-speed asynchronous motor (AM), energy saving, transient processes, contactless start.

Introduction

Twin-shaft mixers of the VL-400-VRU type are critical equipment in industrial processes involving the preparation of special mixtures (refractory, acid-resistant). The specifics of the process—frequency of operation, the need for precise shaft positioning for loading/unloading, and the large inertial mass of the mixture—place stringent demands on the electric drive.



Fig. 1. General view of a twin-shaft mixer.

Using traditional single-speed asynchronous motors requires multiple short-term switching cycles (7-10 times per revolution), which leads to excessive wear on windings and mechanical transmissions, as well as significant starting currents that negatively impact the grid. This necessitates modernizing the electric drive to reduce dynamic loads, facilitate starting, and improve overall energy efficiency.[1, 2].

The use of two-speed motors allows for step-starting (first at low speed, then at high speed), thereby reducing the process cycle time. However, existing PPO circuits often have design flaws: complex switching, numerous terminals, and imperfect electromagnetic characteristics, which limits their widespread adoption.

The basis of the development is the method of discretely specified spatial functionals (DZSF), which allows for the synthesis of a PPO with a given ratio of pole pairs and high electromagnetic performance.[6].The “Y- Δ /YY” configuration was used as the basic circuit (BC).

Based on the calculated data, an experimental model of a two-speed motor with a developed pole-switching winding for a pole pair ratio of 2/4 according to the BS “Y- Δ /YY” was manufactured at Energy Motors, based on the magnetic circuit of a serial machine of the AIR180M4U3 type with the number of stator slots $Z_1 = 48$ and rotor $Z_2 = 38$, the length of the stator package $l\delta = 185$ mm.

Electromagnetic calculation and selection of parameters: A comparative analysis of five winding options with different numbers of turns, conductor cross-sections and numbers of elementary conductors was carried out (Table 1).

Table 1 shows that the energy performance of a two-speed electric motor in nominal operation was calculated by varying the number of turns in the winding slots, the conductor diameter,



and the number of elementary conductors n . The results obtained suggest a significant impact of these parameters on motor efficiency.

The performance characteristics of the AIR180M8/4 electric motor were obtained under direct load conditions (Table 2). A separately excited DC generator was used as the load machine. The shaft power of the tested motor was calculated by adding the generator output power to the generator losses.

Table 2. Performance data

No.	P2	U1	I1	η	cos ϕ	M	n	s
	kW	IN	A	%		N·m	min-1	%
from the side p=2								
1	2.4	380	14	71	0.24	15	1498	0.13
2	5.3	380	16.3	84	0.57	34	1495	0.33
3	8.2	380	19.5	87	0.70	52	1490	0.67
4	10.8	380	23.1	89	0.78	70	1486	0.93
5	13.5	380	27.1	90	0.82	86	1483	1.13
6	16	380	31.2	90	0.85	102	1480	1.33
7	18.5	380	35.2	90	0.86	117	1476	1.60
8	20.7	380	39.3	90	0.87	132	1473	1.80
9	22.8	380	43.2	89	0.88	147	1470	2.00
from the side p=4								
1	2.6	380	15.9	70	0.34	33	747	0.4
2	4.6	380	17.6	79	0.50	60	745	0.66
3	6.5	380	19.7	82	0.60	84	742	1.06
4	7.5	380	20.9	83	0.63	96	740	1.33
5	9.2	380	23.4	84	0.70	120	738	1.6
6	10.9	380	26.0	85	0.73	140	736	1.86
7	12.5	380	28.7	86	0.76	160	734	2.13
8	13.9	380	31.5	86	0.78	180	732	2.4
9	15	380	34.1	85	0.79	200	730	2.66

As a result of experimental studies, the new AIR180M8/4 motor with $p_1=2$ (four poles) achieved a useful power of $P_2=18.5$ kW at an efficiency of $\eta=90\%$, $\cos \phi=0.86$, $I_1=35.2$ A and slip $s=1.6\%$; with $p_2=4$ (eight poles), the motor develops a power of $P_2=13.9$ kW at an efficiency of $\eta=85.5\%$, $\cos \phi=0.78$, $I_1=31.5$ A and slip $s=2.4\%$.

Using a LeCroy WaveRunner 64Xi digital oscilloscope, the starting and gear shifting processes were studied.

Start at $p=4$: Starting current amplitude is 140–150 A ($4.5 I_{\sim nom}$). The mode is established in ~ 1.3 s.



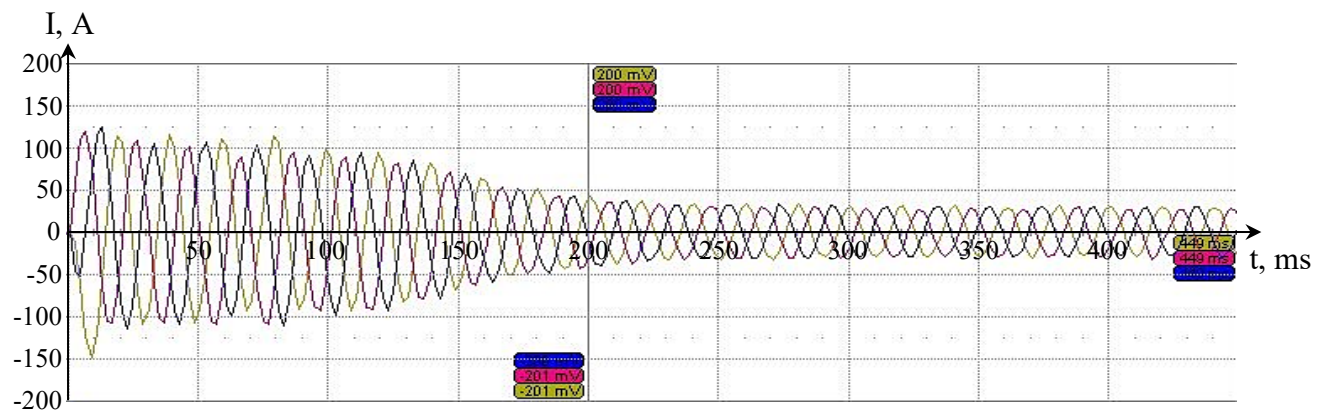


Fig. 2. Curves of change in stator current depending on time during starting from a standstill of an AIR180M8/4 type electric motor at $p_2=4$

Start at $p=2$: Starting current amplitude is 280–300 A ($4.5 I_{\sim nom}$). The mode is established in ~ 3.5 s.

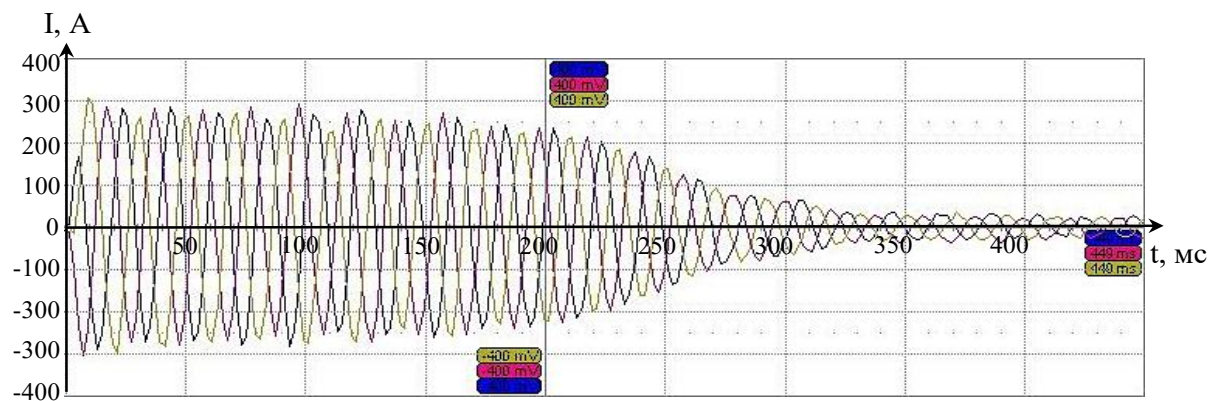


Fig. 3. Curves of change in stator current depending on time when starting from a standstill of an AIR180M8/4 type electric motor at $p_2=2$

Switching $p=4 \rightarrow p=2$: The switching process lasts ~ 1.2 s, the currents do not exceed the starting values for the corresponding speed.

The dynamics of starting currents and transient processes are typical for asynchronous motors of this class and are within acceptable limits.

A prototype of the AIR180M8/4 engine was implemented in the drive of the VL-400-VRU two-shaft mixer in workshop No. 35 of NPO Almalyk GMK JSC.

Technological result: The use of a two-speed drive made it possible to implement the following optimal cycle:

Smooth start of the process and mixing at low speed ($p=4$, 750 rpm).

Switch to high speed ($p=2$, 1500 rpm) for the main mixing cycle.

Shift to low speed and stop precisely in a convenient position for unloading and braking.



As a result, the cycle time was reduced to 420 seconds (7 minutes). This allowed for an increase in the number of cycles per shift and an increase in daily production of finished mix by 580 kg. Economic calculation: The net additional profit from implementing one motor amounted to approximately 37.4 million soums per year. Taking into account the operation of four VL-400-VRU mixers at the plant, the total annual economic benefit from implementing the developed drive is estimated at 149.4 million soums. This calculation includes energy savings due to reduced operating time and the elimination of multiple starts, as well as profit from increased output.

Conclusion

The motor's efficient operation in transient conditions (starting, gear shifting) has been experimentally confirmed. Starting currents and dynamic loads comply with standards.

Industrial implementation of the drive on a twin-shaft mixer has proven its technological and economic advantages: a reduction in cycle time by 7 minutes, an increase in daily production volume of the mixture by 580 kg, and an annual economic effect of ~149.4 million soums for four units of equipment.

Thus, the electric drive developed on the basis of a two-speed motor with a pole-switching winding is an effective solution for the modernization of two-shaft mixers, ensuring significant resource and energy savings, and is recommended for widespread implementation at enterprises of a similar profile.

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