Operating properties of composite antifriction materials on the base of aluminium alloys wastes for printing equipment

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The questions of using materials for friction units, first of all, the antifriction materials in particular on the aluminium alloy-based metal matrix take a central place in general problem of increasing the polygraph knife-machines quality. Endurance of such equipment determines a level of printing output quality.
This paper summarizes the recent developments of aluminium alloy AK12MMgN industrial grinding wastes-based usage for new antifriction materials and knowledge about their manufacturing technology; specific examples will be given. Research results of new composite material physical, mechanical and tribological properties in comparison with cast alloy have been presented.
The principle possibility to use the valuable industrial grinding wastes of ferrous and color metals for manufacturing of an effective parts of polygraph machines was shown.

Keywords: powder metal grinding wastes, aluminium alloy AK12MMgN, making technology, microstructure, tribological characteristics, physical mechanical properties, friction parts for polygraphic knife-machines.

Introduction

The growing demand for more energy-efficient and economical resources is a challenge for the printing-building industry. The continual increase in printing equipment quality (paper-cutters, knife-machines) is connected with perfection working rubbing elements in friction junctions because they support reliability and durability of high-speed machines in particular printing equipment.

Aluminium alloy-based metal matrix composites are established as a suitable wear resistant materials especially for sliding wear applications in printing machines. However, in actual practice engineering components usually encounter combination of wear types [1].

Material scientists and researchers in this area have been fulfilling the demand of the engineering sector since decades in synthesizing aluminium materials to attain the demanded properties to enhance efficiency and cost savings in the manufacturing sector [2].

Today existent parts of rubbing elements in printing machines (especially of cast aluminium alloys) are not capable to satisfy the modern strong requirements of polygraphic equipment [3].

It is connected with low antifriction properties of such parts, which are the consequence of imperfection of the existing manufacturing technologies and technology of finish mechanical grinding of such parts, which are not able to ensure high quality of contact surfaces [3, 4].

Al-alloy-based composites were always on the fore-front of research. Parallel areas of research had then emerged but after about two decades of research in various disciplines to further enhance the properties to satisfy the ever increasing demand of the engineering sector, composites took a lead compared to the other processes when the cost and ease of fabrication were compared [2].

Composite parts of rubbing elements are differentiated from cast ones first of all by their high cost. It is connected with high cost of starting powders.

On the other hand the great resource reserves exist in machine-building industry now. There are large in number of grinding powder wastes of ferrous and color metals.

Such metal powder wastes appear on the operations of abrasive grinding of different details in machine-building plants.

They consist of valuable alloy elements in large quantity (Ni, Cu, V, Mg, W, Si, Ti and others) and are not used in subsequent production cycle because they are polluted by grinding abrasives and cutting emulsion. Such wastes are usually removed to refuse tip. It is concerned aluminium alloys too.

At present time the information about use and processing of Al-powder wastes polluted by grinding abrasives is absent in technical literature.

The characteristic properties of composite aluminium, high thermal conduction, good formability and compressibility, good corrosion resistance, and recycling potential make it the ideal candidate to replace heavier materials (steel or copper) in the friction unit to respond to the wear-resistance demand within the printing-building industry [2].

Practical researches of the advantage of usage of the grinding metal wastes have shown the aluminium alloys could be successfully used for manufacturing effective antifriction materials after corresponding cleaning from abrasives [5-7]. There are valuable and inexpensive starting raw materials after cleaning from abrasives. It can be successfully used in recycling for manufacturing new antifriction parts.

Moreover, patent search analysis and literary data have shown there were no purposeful technological means which would allow to obtain the predictable structure of rubbing elements, and could ensure high functional properties, the high reliability and durability of friction junctions in printing machines [6,7].

Therefore a problem of development new technological processes of making effective antifriction details for rubbing elements in friction junctions of printing equipment remains an *actual* and requires the further researches.

The main tasks of the research were: the development of making technology of new composite antifriction materials on the base of aluminium alloy AK12MMgN wastes for friction junctions of printing knife-machines, studying features of their structure and operating properties.

Materials and methods

The grinding wastes of aluminium alloy AK12MMgN (silumin) were chosen like a basis for new composite antifriction materials.

Silumin AK12MMgN consists of different alloy elements (Table 1).

Assortment of valuable alloy elements (Table 1) in microparticles of alloy AK12MMgN powder wastes is able to ensure high level of tribotechnical, physic and physic-mechanical properties of details.

At the researches it was developed complex making technology that consists of two main stages:

– *First stage* – the technology of alloy AK12MMgN powder wastes regeneration (cleaning from abrasive);
– *Second stage* – the technology of new materials manufacturing, including preliminary cold pressing and next hot pressing of specimens.

The technology of wastes regeneration has been created at the experimental researches. This *regeneration technology* has 3 stages for obtaining clean alloy AK12MMgN powders:

- Drying of moisture;
- Annealing components of cutting emulsion;
- Electric static (separating) cleaning against abrasives.

After regeneration the remains of abrasives were come to 5% and it was confirmed by metallographic analysis.

Overview of alloy AK12MMgN powder wastes microparticles after regeneration have been presented on Fig. 1.

Well-known methods of hot pressing have taken the special significance for making antifriction materials of high density [1, 6].

Tab. 1. Chemical composition of Silumin AK12MMgN

Element, mas.%											
Si	Cu	Mg	Zn	Sn	Mn	Cr	Ni	Na	Fe	Ti	Al
11.0-13.0	1.2-1.6	0.9-1.2	0.3-0.5	0.01-0.02	0.3-0.6	0.05-0.2	0.8-1.3	0.05-0.1	0.5-0.8	0.05-0.2	rest

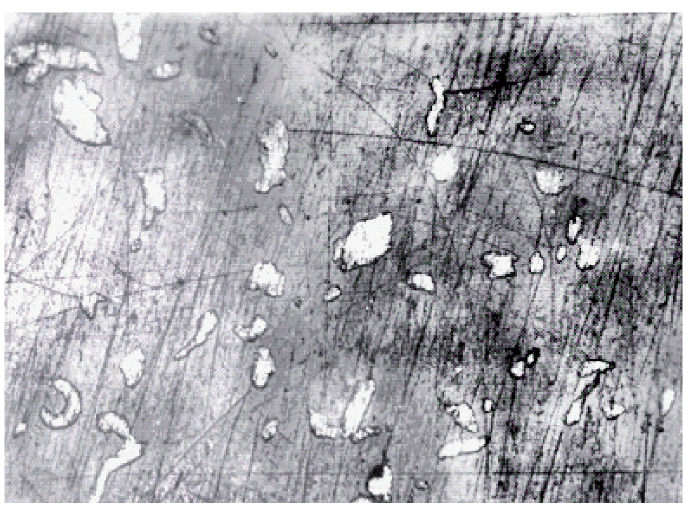


Fig. 1. Overview of alloy AK12MMgN powder wastes microparticles after regeneration (on plastic plate), ×32

These methods were used for development of the new composite materials on silumin AK12MMgN wastes-based *manufacturing technology*.

During the experiments technological properties were determined, for example, packed density of regenerated silumin powder is 0.75 g/ m^3. This parameter is technological characteristic for ensuring the constant shrinkage.

Manufacturing technology has 2 stages:

1. *Cold pressing*. Experimental samples have been manufactured at specific pressure 500 MPa and had a relative density 0.92. Pressing were carried out at hydraulic press PSU-125 for cold pressing. Experimental samples of regenerated alloy AK12MMgN were pressed at room temperature in press-forms of different dimensions (for different tests):
   1– in plug-and-socket press-form, dimensions 10×40 mm;
   2– in bushing press-form, ø32×12 mm;
   3– in cylindrical press-form, ø32 mm.
2. *Hot pressing*. A stage of hot pressing of cold pressed samples was carried at the temperature of external heating 400^{0} and loading 300 MPa. Hot pressing were carried out at hydraulic press for hot pressing with maximum nominal pressure 1.6 N. This technological operation is necessary for obtaining maximum density of composite samples to avoid volume oxidation of materials during their future exploitation on air in printing machines.

The microstructure and abrasive remains of obtained new material AK12MMgN grinding wastes-based were researched using by quantitative metallographic methods (Fig. 1) at images analyzer Leco IA3001 IMAGE SYSTEM (USA).

Initial intermetalides were studied on unetched microsections. Second intermetalides were identified using scanning electron microscopy (SEM) by electron microscope SELMI-200 (Ukraine) (Fig. 2).

Liquid sliding wear tests were carried out on a pin-on-disc wear testing machine VMT-1 in which the specimen was held against a rotating steel disc and this sliding motion results in wear of the pin. The line dimensions of the specimen were taken after every 1.0 km sliding distance. The dimensions losses were calculated from the difference in dimensions between the initial dimension and dimension after a specified number of rotations.

Experiments were carried out at two loads of 5 and 7 MPa, the counterface is made of 45 steel – unalloyed carbon steel, C=0.45 mas.% (HRC = 45–48); lubricant - machinery oil I-20; temperature of external heating – 100-150^{0} and at speed of rotation V =1.0 m/s up to sliding distance of 2.5 km.

Conditions of tribological tests correspond to real operating conditions of printing machines' friction units. Dimensions loss measurements were taken after every 500 m sliding distance approximately.

The sliding wear properties of the cast alloy [4] and new composite were determined under liquid sliding conditions for comparison of properties between the cast aluminium alloy and composite of aluminium alloy AK12MMgN grinding wastes-based.

Physical mechanical properties were studied by standard methods [8-10].

Results and Discussion

Complicated heterophase metallographic structure of composite material AK12MMgN grinding wastes-based formation took place as a result of hot pressing process.

This structure consists of high-alloyed a-solid solution on the base of aluminium. In this solid solution there is an

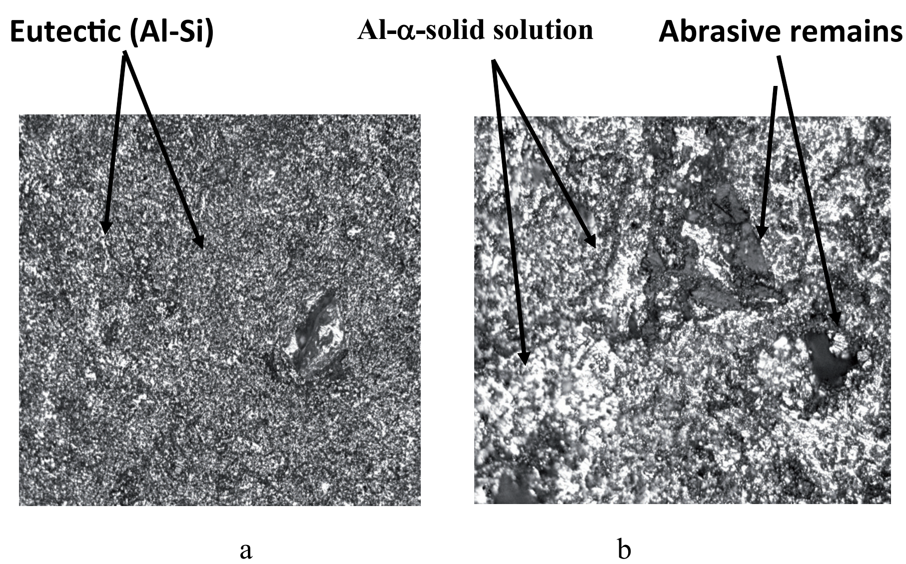


Fig. 2. Microstructure of composite AK12MMgN grinding wastes: etched slice, x100 (a) , x500 (b) (etching in 5% NaOH)

eutectic that forms at silicon content of 11.6 mas.% [5] and seats as cellular structure of solid solution grains along the whole matrix volume (Fig. 2).

Moreover a big quality of alloy elements (Table 1) causes the formation of fine reinforcing phase's large number – intermetalides. There are $CuAl_2$ (q-phase), Mg_2Si, $NiAl_3$ (e-phase) (Fig. 3).

Structural researches (Fig.3) are evidence of the presence of the initial and second intermetalides as reinforcing phases – ($AlCu_2Mn$), S(Al_2CuMg), $MnAl_6$, $TiAl_3$, AlFeSi (a-phase), N(Al_7Cu_2Fe) in metal matrix. These phases have a high density and uniform distribution round the volume of samples. It favoures decrease of grains size and increase in physical mechanical and antifriction properties.

Physical, mechanical and antifriction properties of new composite material AK12MMgN grinding wastes-based in comparison with the same mark cast alloy have been presented in Table 2.

A standard cast alloy AK12MMgN [6] material has been also tested for comparison with new composite material of alloy AK12MMgN grinding wastes-based.

Analysis data of Table 2 shows the composite material of AK12MMgN grinding wastes-based does not yield to cast one by physical, mechanical properties (Ultimate strength, Hardness, Impact elasticity) and has a much lower friction coefficient and wear rate than those of cast alloy AK12MMgN used in similar operating conditions, especially under loads up to 7 MPa.

These facts can be explained by the essential distinctions of cast and composite materials structural formation. Such distinctions appear in consequence of different principles of their synthesis.

Cast alloy AK12MMgN manufactured by moulding method has liquations of alloy elements that becomes apparent as chemical composition heterogeneity in volume of material. As against cast alloy new composite material of wastes-based was sintered (hot-pressing method) of AK12MMgN powder microparticles that are microingots without any liquation. As a result the structure of such composite material is homogeneous that ensures higher properties.

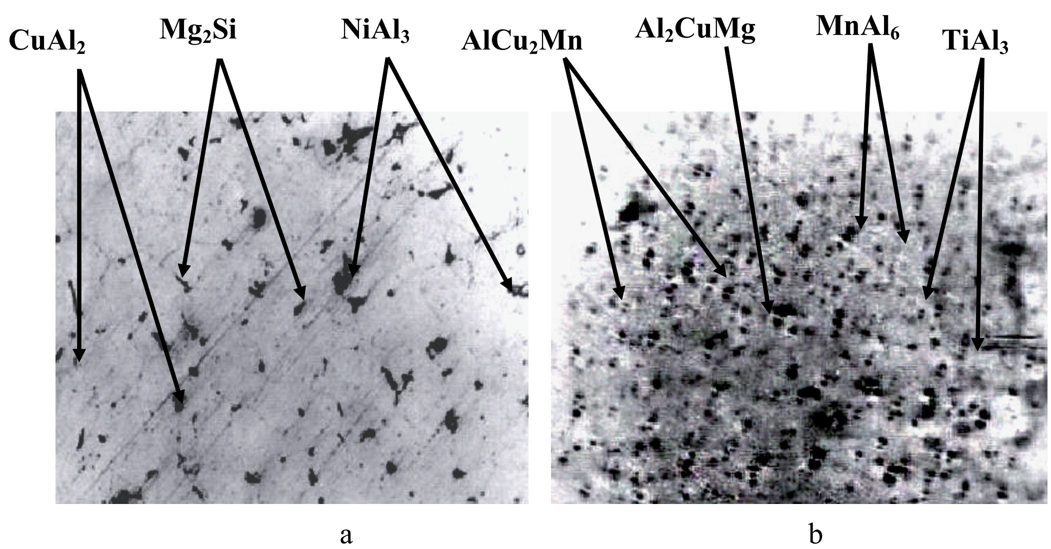
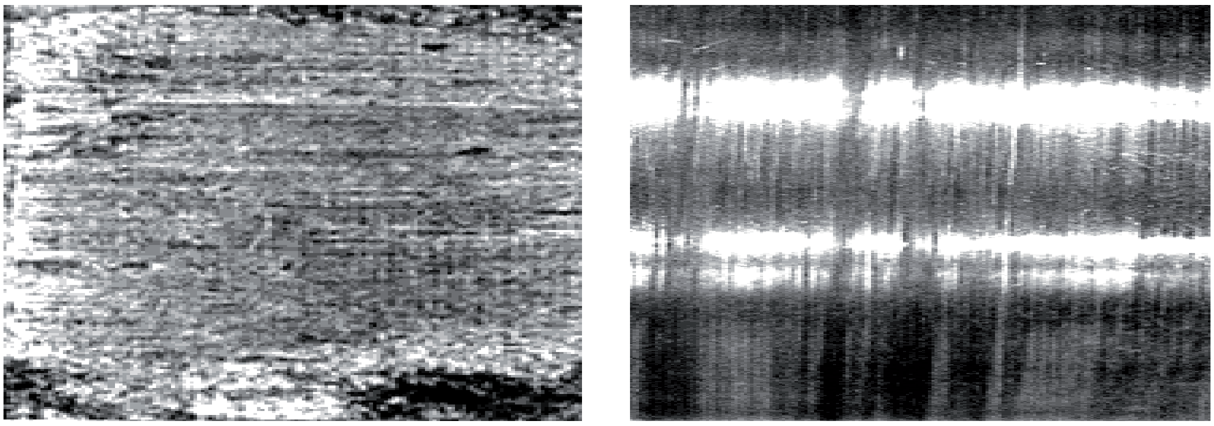


Fig. 3. Initial (a), x200, and second (b), x100000, intermetalides in composite material AK12MMgN grinding wastes

Tab. 2. Physical mechanical and antifriction properties of materials

Material	Ultimate strength, MPa	Hardness, HB, MPa	Impact elasticity kJ/m²	Friction coefficient at loading, MPa		Linear wear, µm/km at loading, MPa		Linear wear of counterface, µm/km at loading, MPa		Limited temperature, °C	Limited load, MPa
				5	7	5	7	5	7		
AK12MMgN of grinding wastes-based	180-185	550-570	0,18-0,30	0,0075-0,0080	0,03-0,032	3,9	14,8	signs	6,4	130	7
Cast AK12MMgN [6]	186	620	0,30-0,40	0,0250	0,08-0,087	6,0	33,2	2,5	18,6	120	3,5



a b

Fig. 4. AK12MMgN grinding wastes-based (a) and counterface of 45 steel (b), x5

The full-scale tests of new composite material of AK12MMgN grinding wastes-based showed increase in wear resistance by a factor of 2.47 as compared with cast alloy AK12MMgN.

The liquid lubricant on cast AK12MMgN is inoperative as it is squeezed out from the friction zone by pressure at high operating loadings of printing machines. In such case the cast aluminium bearing materials have dry friction contact with the shaft because the surfaces remain unprotected, juvenile.

Composite material of AK12MMgN grinding wastes has porosity 2-3% where liquid lubricant is stopped and can run out to contact friction surfaces under operating loads. Surface topographies of friction zones of new material and counterface have been presented in the Fig. 4.

Investigations of contact surfaces (Fig. 4) after tribological tests show the friction surfaces of new composite material AK12MMgN wastes-based and counterface are not damaged, have high quality, and are usable.

Thus obtained research results confirmed adequacy and practicability of new composite antifriction materials manufacturing principles. Such data illustrate availability of use high-alloyed valuable and inexpensive grinding wastes of aluminium alloy AK12MMgN like initial resource for manufacturing quality friction details for printing machines.

Conclusions

A new effective composite antifriction material on the base of aluminium alloy AK12MMgN industrial grinding wastes was obtained. This material has high antifriction properties and demonstrates good operation in heavy friction exploitation conditions in comparison with cast aluminium alloy AK12MMgN.

Full-scale industrial tests of the new composite antifriction material AK12MMgN in friction units of 3-knife-machines WOHLENBERG-1A438 (Germany) have been conducted. Fifteen control evaluations of friction units have been carried out. Visual inspection and measurement of surface roughness have shown the friction details contact surfaces are not damaged, have high quality, and are usable.

The principle possibility to use the valuable and inexpensive industrial grinding wastes of color metals for manufacturing effective friction parts of printing machines was presented.

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