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APPLYING ALUMINIUM ALLOYS GRINDING WASTE FOR MANUFACTURING EFFECTIVE COMPOSITE ANTIFRICTION PARTS OF PRINTING EQUIPMENT

The questions of using materials for friction units, first of all, the antifriction materials in particular on the aluminium alloy-based metal matrix take one of the central places in general problem of increasing the polygraph knife-machines quality. Endurance of such equipment determines a level of printing output quality. This article summarizes the latest developments on the use of industrial grinding waste of aluminum alloy AK12MMgN to create new effective antifriction materials and research of their manufacturing technology; specific examples have been given. Experimental results of new composite material's structure, physical mechanical and tribological properties have been presented compared with a cast alloy of a similar chemical composition. It was shown the principle possibility to use the valuable industrial grinding wastes of ferrous and color metals for manufacturing the effective wear-resistant parts of polygraph machines.

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

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ЗАСТОСУВАННЯ ШЛІФУВАЛЬНИХ ВІДХОДІВ АЛЮМІНІЄВИХ СПЛАВІВ ДЛЯ ВИГОТОВЛЕННЯ ЕФЕКТИВНИХ КОМПОЗИЦІЙНИХ АНТИФРИКЦІЙНИХ ДЕТАЛЕЙ ДРУКАРСЬКОГО ОБЛАДНАННЯ

Питання використання матеріалів для вузлів тертя, в першу чергу антифрикційних матеріалів, в тому числі з металевою матрицею на основі алюмінієвих сплавів, займають одне з центральних місць в загальній проблемі підвищення якості поліграфічних ножових машин. Витривалість такого обладнання визначає рівень якості друку. У цій статті резюмовані останні розробки по використанню промислових шліфувальних відходів алюмінієвого сплаву АК12ММгН для створення нових ефективних антифрикційних матеріалів, наведені результати дослідження їх технології виготовлення; продемонстровані конкретні приклади. Наведено експериментальні результати аналізу структури, фізико-механічних і трибологічних властивостей нового композиційного матеріалу в порівнянні з литим сплавом аналогічного хімічного складу. Показана принципова можливість використання цінних промислових шліфувальних відходів чорних і кольорових металів для виготовлення ефективних зносостійких деталей поліграфічних машин.

Ключові слова: *порошкові шліфувальні металеві відходи, алюмінієвий сплав АК12ММгН, технологія виготовлення, мікроструктура, трибологічні характеристики, фізико-механічні властивості, антифрикційні деталі для поліграфічних ножових машин.*

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ПРИМЕНЕНИЕ ШЛИФОВАЛЬНЫХ ОТХОДОВ АЛЮМИНИЕВЫХ СПЛАВОВ ДЛЯ ИЗГОТОВЛЕНИЯ ЭФФЕКТИВНЫХ КОМПОЗИЦИОННЫХ АНТИФРИКЦИОННЫХ ДЕТАЛЕЙ ПЕЧАТНОГО ОБОРУДОВАНИЯ

Вопросы использования материалов для узлов трения, в первую очередь антифрикционных материалов, в том числе с металлической матрицей на основе алюминиевых сплавов, занимают одно из центральных мест в общей проблеме повышения качества полиграфических ножевых машин. Выносливость такого оборудования определяет уровень качества печати. В настоящей статье резюмированы последние разработки по использованию промышленных шлифовальных отходов алюминиевого сплава АК12ММгН для создания новых эффективных антифрикционных материалов, приведены результаты исследования их технологии изготовления; продемонстрированы конкретные примеры. Приведены экспериментальные результаты анализа структуры, физико-механических и трибологических свойств нового композиционного материала по сравнению с литым сплавом аналогичного химического состава. Показана принципиальная возможность использования ценных промышленных шлифовальных отходов черных и цветных металлов для изготовления эффективных износостойких деталей полиграфических машин.

Ключевые слова: *порошковые шлифовальные металлические отходы, алюминиевый сплав АК12ММгН, технология изготовления, микроструктура, трибологические характеристики, физико-механические свойства, антифрикционные детали для полиграфических ножевых машин.*

Introduction. The growing demand for more resource-efficient to reduce energy consumption and cash resources is a challenge for the printing-building industry. The continual increase of printing equipment quality (paper-cutters, knife- machines) is connected with perfection of the working rubbing elements in friction junctions because they support reliability and durability in particular printing equipment. Aluminium alloy-based metal matrix composites have been by now established themselves as a suitable wear resistant material 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) aren't capable to satisfy the modern strong requirements of polygraphic equipment [3].

It is connected with their low antifriction properties of such parts, which are a consequence of the imperfection existent making 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's 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 are appeared on the operations of different parts' abrasive grinding in machine-building plants.

They consist of valuable alloy elements large quantity (Ni, Cu, V, Mg, W, Si, Ti and others) and aren't used in subsequent production cycle because they are polluted by grinding abrasives and cutting emulsion. Such wastes are usually removed to garbage and scum. It's 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 specific properties of aluminium composites, such as high thermal conduction, good formability and compressibility, good corrosion resistance, and recycling potentially make it the ideal candidate to replace heavier materials (steel or copper) in the friction units to respond to the wear-resistance demand within the printing-building industry [2].

Practical research of the advantage use the grinding metal wastes have shown the aluminium alloys could be successfully use for manufacturing the effective antifriction materials after the correct 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 be allowed to obtain the predictable structure of rubbing elements, and could be ensure high functional properties, the high reliability and durability of friction junctions in printing machines [6, 7].

Therefore, a ***problem*** of development the technological means for use metal grinding waste to create the effective antifriction parts for rubbing elements in printing equipment antifriction junctions is an ***actual*** and requires the further research.

The main ***objectives*** were development of making technology for synthesis new composite antifriction materials based on grinding aluminium alloy AK12MMgN wastes for antifriction junctions in printing knife-machines, studying features of their structure and properties.

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

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

Table 1

Silumin AK12MMgN chemical composition

Element, mass. %											
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

Valuable alloy elements assortment (Table 1) in microparticles of alloy AK12MMgN powder wastes is able to ensure high level of parts' tribotechnical, physical and physical-mechanical properties.

At the researches it was developed the manufacturing 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: 1) Drying of moisture; 2) Annealing components of cutting emulsion; 3) 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.

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

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

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

During the experiments it was determined the technological properties, for example, packed density of regenerated silumin powder is 0.75 g/cm^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):

2. *Hot pressing*. A stage of preliminarily cold pressed samples hot pressing was carried at the temperature of external heating 400 $^{\circ}$C and loading 300 MPa. Hot pressing were carried out at hydraulic press for hot pressing with maximum nominal pressure 1.6 MN. This technological operation is necessary for obtaining maximum density of composite samples to avoid materials volume oxidation during their future exploitation on air in printing machines.

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

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

Liquid sliding friction wear tests were carried out on a pin-on-disc wear testing machine VMT-1 where the specimen was held against a rotating steel disc and this sliding motion resulted in wear of the pin. The specimen’s lineal dimensions 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 mass.% (HRC = 45–48); lubricant − machinery oil I-20; temperature of external heating - 100−150 °C 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 antifriction properties of the cast alloy [4] and new composite were determined under liquid sliding friction conditions for comparison of properties between cast aluminium alloy and composite aluminium alloy AK12MMgN grinding wastes-based. Physical mechanical properties were studied by standard methods [7–9].

Results and discussion. Complicated heterophase structure of the composite material AK12MMgN based on grinding wastes took place as a result of hot pressing process. First of all this structure consists of high-alloyed α-solid solution based on aluminium. In this solid solution there is an eutectic that formed at silicon content of 11.6 mass.% [5] and located as cellular structure of solid solution grains across the whole matrix volume (Fig. 2).

Moreover the alloying elements big quantity (Table 1) causes the formation of finest strengthen phases large number (intermetallics). There are $CuAl_2$ (θ-phase), Mg_2Si, $NiAl_3$ (ε-phase) (Fig. 3).

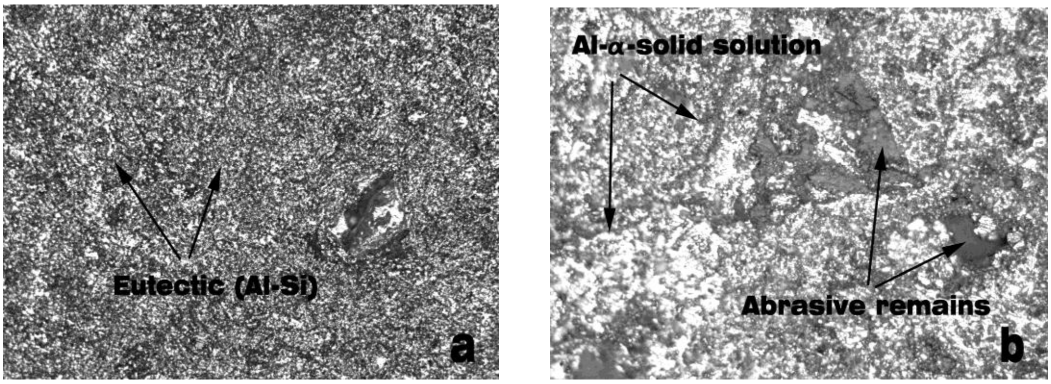

Fig. 2. - **Microstructure of composite material based on alloy AK12MMgN grinding wastes: etched slice, ×100 (a) , ×500 (b) (etching in 5% NaOH)**

Structural research (Fig.3) are evidence of presence the initial and second intermetallics as strengthen phases - T($AlCu_2Mn$), S(Al_2CuMg), $MnAl_6$, $TiAl_3$, AlFeSi (α-phase), N(Al_7Cu_2Fe) in metal matrix. These phases have a high density and uniform distribution across all volume of the samples. It favours decrease of grains size and increase physical mechanical and antifriction properties.

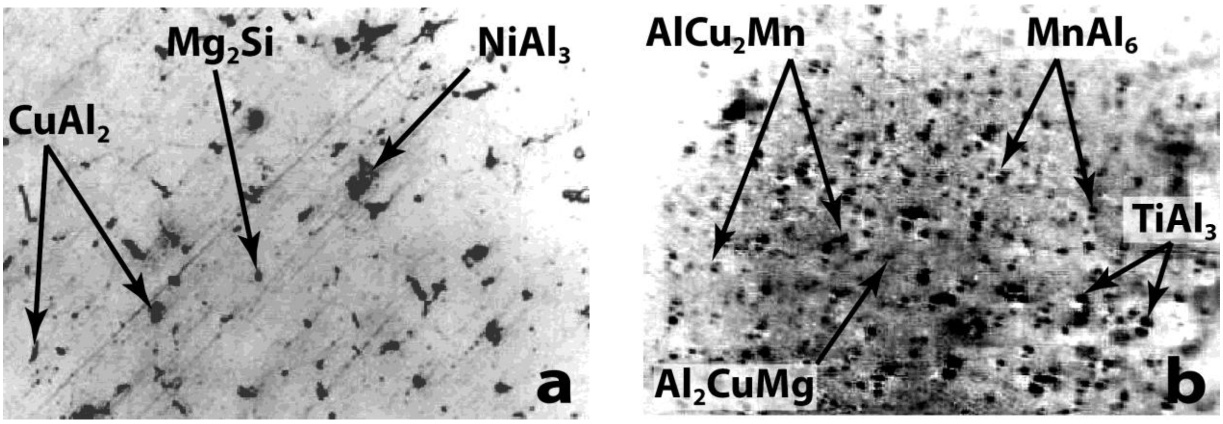

Fig. 3. - **Initial (a), ×200, and second (b), ×100000, intermetallics in composite material based on alloy AK12MMgN grinding wastes**

Physical mechanical and antifriction properties of new composite material based on grinding waste alloy AK12MMgN have been presented in Table 2 compared to the cast alloy same mark.

Table 2

Physical mechanical and antifriction properties of materials

Material	Ultimate strength, MPa	Hardness, HB, MPa	Impact elasticity kJ/m^2	Friction coefficient at loading, MPa		Linear wear, μm/km at loading, MPa		Linear wear of counterface, μm/km at loading, MPa		Limited temperature, ^{0}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 standard cast alloy AK12MMgN [6] material has been also tested for comparison with new composite material based on alloy AK12MMgN grinding wastes.

Analysis of Table 2 data shows the composite material based on alloy AK12MMgN grinding wastes is not inferior to cast alloy by physical mechanical properties (Ultimate strength, Hardness, Impact elasticity) and has a much lower friction coefficient and wear rate than cast alloy AK12MMgN [6] used in similar operating conditions, especially under loads up to 7 MPa.

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

Cast alloy AK12MMgN manufactured by melting method has liquations of alloy elements that becomes apparent as chemical composition heterogeneity in volume of material.

As against cast alloy, new composite material based on wastes was manufactured by 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. The full-scale tests of new composite material showed increase of wear resistance by a factor of 2.47 compared to cast alloy AK12MMgN.

This fact is explained the liquid lubricant for cast alloy 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 antifriction materials have a dry friction contact with the shaft because the surfaces remain unprotected, juvenile.

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

Contact surfaces research (Fig. 4) after tribological tests show the friction surfaces of new composite material based on alloy AK12MMgN grinding wastes and counterface are not damaged, have high quality, and are usable.

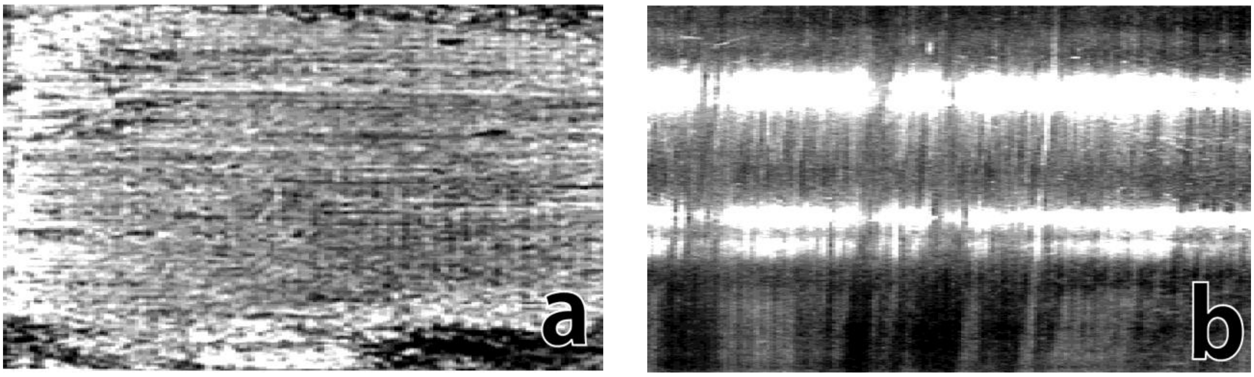

Fig.4 − **Friction surfaces of composite material based on alloy AK12MMgN grinding wastes (a) and counterface of 45 steel (b), ×5**

Thus, the obtained research results had confirmed adequacy and practicability of new composite antifriction materials manufacturing technological principles. Such data illustrate availability to use the high-alloyed valuable and inexpensive grinding wastes of aluminium alloy AK12MMgN as initial resource for manufacturing quality antifriction parts for printing machines.

Conclusions. It was developed new effective composite antifriction material based on aluminium alloy AK12MMgN industrial powder grinding wastes. This material has the high antifriction properties and demonstrates good friction behavior in heavy friction exploitation conditions compared to a cast aluminium alloy AK12MMgN.

Full-scale industrial tests of new composite antifriction material AK12MMgN had been carried out in the friction units of 3-knife polygraph machine Wohlenberg-1A438 (Germany). Fifteen control evaluations of friction units have been carried out. Visual inspection and surface roughness measurements have shown the friction parts' contact surfaces are not damaged, have high quality, and are usable.

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

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