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ANTIFRICTION POROUS ALLOYS

By

Ye. F. Merkulov

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ANTIFRICTION POROUS ALLOYS

By: Ye. F. Merkulov

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ABSTRACT: This pamphlet discusses physical-mechanical properties and metallographic peculiarities of new antifriction porous alloys, alcusip instead of babbitts, alcusip instead of bronzes and antifriction porous cast iron. A description is given of technology of production of these alloys, their mechanical treatment, assembly, and usage of several machines working on inserts manufactured from these alloys. The pamphlet is intended for engineering-technical workers studying questions of investigation, production, and application of nonferrous metals and alloys in the machine-building industry and other branches of technology. English translation; 70 pages.

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Block	Italic	Transliteration	Block	Italic	Transliteration
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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
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Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

This pamphlet discusses physical-mechanical properties and metallographic peculiarities of new antifriction porous alloys, alcusip instead of babbitts, alcusip instead of bronzes and antifriction porous cast iron. A description is given of technology of production of these alloys, their mechanical treatment, assembly, and usage of several machines working on inserts manufactured from these alloys.

The pamphlet is intended for engineering-technical workers studying questions of investigation, production, and application of nonferrous metals and alloys in the machine-building industry and other branches of technology.

PREFACE

Practice of operation of motors and other machines, in which there are applied inserts from different antifriction materials (from high-tin babbits B83 and B90 to antifriction cast irons inclusively), showed that a decisive role in their reliable operation and periods of service is played by lubricant, which is closely connected with quality of material of bearings and especially with their porosity. In connection with this, for normal operation of bearings of various machines and mechanisms the application of porous antifriction materials and alloys is expedient.

In our country a large quantity of nonferrous metal is used; therefore, research of new alloys, replacing expensive nonferrous metals, is a great economic problem. Production of high-quality porous materials, satisfying need of different branches of contemporary technology, is a complicated and prolonged matter requiring great efforts of separate specialists and a number of collectives.

There are two methods of obtaining porous bearings: metallurgical, till now little practiced and little illuminated in literature, and mechanical, based on machining of bearings (network). This method is illuminated sufficiently in detail in literature, and therefore it is not allotted attention in this pamphlet.

In pamphlet there are examined antifriction alloys obtained by metallurgical method:

1) alcusip instead of babbitts (alcusip-1);
2) alcusip instead of bronzes (alcusip-2);
3) antifriction porous cast iron.

These alloys can be used as replacement of high-tin, expensive, highly critial, babbitts B83, B90, and high-tin bronzes. Br OTsS 6-6-3, Br OF10-1, Br OF10-0.5, since they possess high physical, technical, and antifriction properties.

At present in certain enterprises on extraction of oil in Azerbaidzhan Sovnarkhoz, alcusip found application as a substitute for high-tin babbitts and bronzes in the following machines and mechanisms: in oilpumping installations, in 75 ton swivels, in mud and depth pumps, compressors, and others, (Office of drilling of Ordzhonikidze oil, Azizbekov oil and others), on repair excavators (Gusi Gadzhiyev mechanical plant) drilling pumps of U8-3 type during manufacture of sealing rings of fire pumps PN-25 and PN-20 (Azerbaidzhan Soviet Socialist Republic. Control of fire protection); pistons of brakes of working cylinders (Bakinskiy taxi park No. 2), and others.

The present second publication of pamphlet is augmented by illumination of such questions as technical conditions on production, acceptance, tests, and on conditions of usage of bearings from alcusip; operation of various machines and mechanisms for which inserts are made from new alloys; preparation of charge of alcusip, depending upon technical conditions; centrifugal lining of bushings from alcusip.

Author is aware of the fact that properties of new antifriction alloys are insufficiently studied by him, and that their subsequent application in industry, on transport, and in other branches of technology requires carrying out a large quantity of experiments and tests. In this matter there is still a number of unclarified and debatable positions; nonetheless the author hopes that issue of this pamphlet will permit attracting attention of specialists, occupied with questions of development of alloys, and make it possible to direct their scientific activity to still greater and deeper study of nature of alloys, which will make it possible in the near future to ensure their wide practical application in technology.

At present the widest introduction of alcusip is carried out in enterprises of Petroleum Production Administration of Azerbaidzhan Sovnarkhoz.

There are also examples of application of alcusip in other enterprises of our country.

INTRODUCTION

For manufacture of parts working in conditions of sliding friction (bearings, inserts, guide bushings, and others), different antifriction materials are applied.

Contemporary antifriction metallic alloys contain tin, copper, lead, zinc, cadmium, iron, aluminum, antimony, and others as main components.

Besides, cermet materials and also alloys manufactured by special methods received propagation. Antifriction alloys should satisfy the following requirements:

1) possess sufficient hardness and plasticity;

2) be distinguished by high stability against abrasion;

3) have good lubricatability by oil and high adsorbability, permitting rapidly restoring break of oil film between working surface of neck of shaft and internal surface of bearing liner;

4) have fine-grained structure;

5) possess high thermal conduction and optimum machinability;

6) have as small a coefficient of friction as possible and sufficiently high mechanical properties in range of operating temperatures;

7) be easily fitted to metal, paired with which antifriction alloy operates;

8) resist score.

Besides, antifriction alloys should be prepared from non-scarce materials.

Ability of bearing material to rapidly restore break of oil film on rubbing surfaces is explained by separation of lubricant from pores of such material during its local heating. Cast antifriction alloys, for instance lead bronze, even without any special metallurgical action, possess microporosity.

Formation of micropores in these alloys is explained by nature of alloys themselves, by character of distribution of shrinkage porosity, by various coefficients of thermal expansion of structural components, and many other factors.

Porosity of binary lead bronze, including 30% lead, composes 2-7% of volume of casting.

Observations showed that thanks to porosity, lead bronze absorbs much oil, which will form as if an "emergency reserve" of bearing for lubricant of surface of friction at the moment of local overheating. This same reserve feeds rubbing surface in initial period of movement of machine.

With assigned porosity it is possible to manufacture sliding bearings from metallic powders by means of pressing and sintering. The greatest propagation was obtained by self-lubricating bronze bearings from sintered copper and tin powders. As a result of sintering process there is obtained compact extraordinarily porous material, able to hold lubricant in its pores. Such bearings, in spite of sharp deficiency of tin, in certain cases turned out to be profitable and their area of application during the last few years was very expanded.

While in standard bearings there is observed considerable leakage of oil and at high speeds an additional supply of lubricant is required, this does not occur in bronze porous bearings. This is explained by the fact that small increase of temperature of such bearings automatically causes additional separation of oil from pores on rubbing surface. During cooling, excess oil is absorbed by bearing.

Thanks to porosity of antifriction material, bearings made from it work more reliably, collapse less often, wear of insert and shaft is decreased, expenditure of oil is reduced, construction is simplified, and thereby operation of frictional units is facilitated. Along with production of porous bearings, in recent years porous chrome plating received wide application. It is applied during application of chrome coatings on surfaces of sleeves, piston rings of internal-combustion engines, sliding bearings, and many other articles.

With porous chromium-plating, in coating there are formed channels and pores, serving as reservoirs for oil expended while lubricating rubbing surfaces.

Wide propagation of porous cermet bearings is limited by low mechanical strength of material during its high hardness. However, regarding porous chrome plating of bearings, it did not obtain large propagation because of complexity of technological process.

Up to now porous bearings were applied basically at low and medium loads and speeds. Necessity of producing method porous bearings that are not inferior to high-tin babbitt B83 and B90, with respect to mechanical and antifriction properties, by standard metallurgical method caused appearance of new antifriction alloys based on aluminum and iron. These alloys, of great practical interest, include:

1) porous aluminum-copper-lead babbitt (alcusip);

2) porous antifriction aluminum-lead alloy (alcusip instead of bronze);

3) porous antifriction cast iron.

Porosity, giving improved antifriction properties to these alloys, permits competing them with known expensive antifriction materials.

In sliding bearings there occur liquid, semiliquid, and boundary or medium-dry friction. Till now it was affirmed that for operation of bearings in conditions of liquid friction, viscosity of oil, precision of manufacture of rubbing surfaces, and relationship of magnitude of sliding rate to magnitude of load had basic value, and heat withdrawal was placed last.

However, where there is observed a sharp increase of specific pressures and speeds in different machines, circulation of lubricant, its heating, and heat exchange affect correct and normal operation of mechanisms to a considerable degree.

In motors, wear of necks of shafts is in direct dependence not so much on conditions of dynamic loads of shaft, as on heat exchange of bearing inserts.

Heat exchange of inserts, working in kinematic couple with shaft, primarily depends on their thermal conduction.

Hear flow q through bearing liner is determined by formula

$$q = \lambda s \frac{dT}{dx} \tau,$$

where λ – specific thermal conduction, cal/cm·deg·sec; dt/dx – temperature gradient along length of wall of insert; τ – time, sec; s – section of metallic body, cm^2.

For average temperature $T_{cp} = T_1 + T_2/2$, magnitude of specific thermal conduction λ is determined from expression

$$\lambda = \frac{wl}{s(T_1 - T_2)} \cdot$$

where w – quantity of heat separated in a unit of time; T_1-T_2 – established difference of temperatures between two points, being at distance l.

On the other hand, heat exchange, processes of which are studied mainly experimentally, is based on theory of similarity, and λ increases for building and heat-insulation materials with an increase of time t and, besides, depends on porosity.

Four types of pores are distinguished: 1) closed-type of bubbles not connected together, 2) channel-elongated, united together, 3) pocket-like large pores of closed type, and 4) micropores, dispersed along entire thickness.

It is natural that the more the total area of cross section of pores, evenly scattered along entire thickness, the more intense will be heat exchange of bearings thanks to lubricant circulating through pores of antifriction material of bearings.

Porosity of antifriction materials creates a somewhat emergency reserve of oil not only in case of medium-dry friction, but also for work without lubricant during a prolonged period. In this case the area of total cross section of pores F cm^2 of antifriction material, impregnated by oil, will be greater, the longer normal units of rubbing parts of mechanism or instrument will operate without supply of lubricant, and the less, as is shown by experiments, will be coefficient of friction of kinematic couples. However, sharp increase of total macro- or microporosity in antifriction materials is impermissible, since excessive porosity, lowers their mechanical properties. From practice of usage of cermet materials and articles, it is known that their mechanical properties are increased 3-10% with a decrease of porosity by 1%, since basic factor generally affecting all properties of cermet articles is their porosity. Besides, peculiarity of porous cermet materials is absence of proportional dependence between hardness, compression resistance, and breaking strength, characteristic for cast materials. It is true that compression resistance of porous cermet materials is often not inferior and sometimes even exceeds compression resistance of cast material of the same composition, whereas breaking strength is considerably lower. Together with the fact that another peculiarity of porous cermet materials is combination in them of high brittleness during extension and high plasticity during compression, which is explained by incomplete contact between particles, of which these materials consist. Mechanical properties of materials manufactured from coarse powders are worse than for materials manufactured from fine powders; these properties drop with increase of number of components entering composition of materials.

Thus, porosity of pseudo alloys, which are cermet materials, along with positive factors create a series of negative, limiting their application and operation.

The situation is completely different with considered porous antifriction alloys. Their mechanical, physical, and technical properties, thanks to porosity, not only are not inferior to properties of standard antifriction alloys of babbitt and bronzes, but as a rule exceed them. Porosity is regulated by dosages of potash from 1 to 5% of weight of charge material in process of melting.

Thus, for instance, experience has shown that in shown limits of application of potash there is obtained porous material, for which all physical and mechanical properties are not only identical, but by some parameters are better as compared to solid alloys based on aluminum and iron.

With introduction of alcusip with minimum volume of micropores (solid alcusip) instead of B83, especially during production of bearings of high-powered motors, it is necessary to consider that before putting such machines with bearings from solid alcusip into operation, oil gaps between neck of shaft and bearing should be made 1.5-2 times larger than in cases of application of B83. Therefore, in such machines it is necessary to make bearings from porous alcusip, then the necessity to occupy gaps falls off.

During application of porous alcusip, consumption of lubricant turned out to be less than during use in bearings of other material.

By virtue of porosity of alcusip, coefficient of friction is lowered, which was confirmed in testing pseudo alloys, metal-ceramic materials, for which coefficient of friction with abundant lubricant was less than for bearings of tin bronze.

During experience of operation of experimental automobiles and trucks in Baku-Surakhany, and also experimental data of Novocherkasskiy electric locomotive building plant, it was proven practically that liquid friction in bearings with inserts from above-shown antifriction porous alloys is characterized by coefficient of friction within limits from 0.0025-0.003 to 0.055 (latter for alcusip instead of bronze) with the most insignificant wear of linked kinematic couples of friction. By applying, for instance, bearings from alcusip in 11 ZIL-120 automobiles, as far back as 1950 it was revealed that such deficiencies of sliding bearings as great starting moment of friction and wear during frequent starts and stops under load are almost absent in the engine.

Porosity of antifriction materials in conditions of high speeds and pressures in machines ensures great efficiency of such material as compared to babbitt and bronzes. This was checked by three-year practice of operation of machines and mechanisms in Petroleum Production Administration (NPU) "Ordzhonikidze oil."

Work of friction, characterizing intensity of work of bearings, determined by formula $L = pv$, for solid alcusip inserts varies from 180 to 800 kg-m/cm^2·sec. Here p — specific pressure in kg/cm^2 and v — speed in m/sec; they are selected depending upon character and kind of loads, but in such a manner that their product would not exceed 300 kg-m/cm^2·sec for case of sharply variable and impact loads.

For low-speed motors with not more than 1200 rpm, at specific pressures 80-120 kg/cm^2, work of friction of microporous alcusip (with introduction of potash not over 3% of weight of charge) can vary within limits of 800-1000 kg-m/cm^2·sec.

Finally, in separate cases of special application of articles, microporous alcusip with upper content of copper 5.5% and limiting content of lead 8.5% during conditions of liquid friction can operate at frictional works on the order of 2000 kg-m/cm^2·sec.

Thus, porosity of antifriction materials and primarily their microporosity are obligatory and necessary conditions of profitableness and reliability of operation of any frictional units of machines and mechanisms.

Regulation of porosity in antifriction materials considered by us — alcusip instead of babbitt, alcusip instead of bronze and antifriction porous cast iron, is produced by potash K_2CO_3, which is introduced during meltings in a quantity of from 1 to 5% of combines weight of charge.

While applying potash during preparation of alcusip, it is necessary to consider that with potash there occurs thermal dissociation at a temperature of +891°C on metal oxide and carbon dioxide. During this carbon dioxide, separating during reaction, also creates basic porosity — new variety of gas porosity. Degree of porosity is established according to the following five standards:

1) small porosity;
2) reduced porosity;
3) average porosity;
4) raised porosity;

5) large porosity.

Permissible quantity of pores on 1 cm^2 of surface of macrographs and diameter of pores are given depending upon number of standard of porosity.

Unregulated macroporosity up to 3rd standard of scale can be obtained, for instance, in alcusip instead of bronzes and without application of potash, by teeming in green sand molds.

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CHAPTER I

POROUS ALUMINUM-LEAD BABBITT (ALCUSIP)

1. Chemical Composition of Alcusip

Antifriction alloys based on aluminum possess low specific gravity, are able to sustain high specific pressures, are distinguished by good antifriction properties, by cheapness of base metal, and by other useful properties. Problem of introduction of these alloys into industry by virtue of their merits is very urgent.

Basic components determining composition of antifriction alloys based on aluminum are copper, iron, tin, and antimony, forming heterogeneous structures with aluminum in solid state. These structures consist of a soft base of eutectic – and solid inclusions – chemical compounds AlSb, Al_3Fe, Al_2Cu.

In alloys with silicon, solid inclusion is pure silicon. Binary alloys of aluminum with tin do not contain solid inclusions, if one were not to take into account the more solid phase of practically pure aluminum in comparison with eutectic Al-Sn. Basic and auxiliary additions, such as copper, zinc, and magnesium, having comparatively large solubility in aluminum, give aluminum bearing alloys raised strength at an increased load. These additions (copper, zinc, and magnesium) are especially important during operation of inserts, since they ensure increase of yield point of alloy and thereby promote expansion of its field of application with an increase of operating temperatures.

However, aluminum antifriction alloys with above-mentioned additions possess smaller plasticity than babbitt because of high hardness, which led to lowering of antifriction properties of alloys and primarily fitability. Attempts of application of aluminum bearing alloys even for tractor engines with speed 1000-1200 rpm were not met with success, mainly due to great wear, ellipsness, and scores on certain parts of engine, making the motors unfit. Still greater difficulties appeared during attempts of application of bearing alloys based on aluminum for truck engines with 2300-2700 rpm and for other high speed machines.

Necessity of introduction of lead for improvement of antifriction properties of aluminum alloys was fully evident, but difficulty consisted in the fact that lead, as the most fusible and heavy component, usually liguates; both direct and inverse liquation occur.

In virtue of this, it was absolutely impossible to obtain eutectic alloy aluminum — lead.

However, in German patent No. 265924 there is led characteristic of alloy Al-Pb with 11% Pb content.

In earlier known multicomponent alloys, lead is encountered more frequently. Thus, for instance, one of the types of magnalium along with Mg, Cu, and Zn contains still 0.7% Pb. In another German patent No. 45051 an aluminum alloy is recommended in which besides Mn, Zn, Sn, and P, there is also 1.4% Pb. Alloy was qualified as "stable with respect to sand and humidity."

However, indicated alloys did not obtain wide propagation because of their insufficient stability.

As a result of prolonged experimental work, the author obtained eutectic alloy of aluminum with lead, which was attained by means of selection of necessary chemical composition, by technology of melting and pouring, and also by application of potash.

This alloy received the name alcusip,[1] in accordance with abbreviated names of four components entering it: Al, Cu, Si, Pb.

Aluminum-lead-copper babbitt — alcusip should not be mixed with alcusin-D, which was offered in 1938, but did not receive wide practical application because of raised hardness (100 HB).

Chemical composition of alcusip is given in Table 1.

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[1]Invention is registered with administration for inventions and discoveries of state committee for new technological methods of USSR for 1950, No. 410570.

Table 1. Chemical Composition of Alcusips

Designation of alcusip	Content, %					Brinell hardness
	Aluminum	Copper	Lead	Iron	Silicon	
Alcusip from aluminum-lead-copper babbitt . . .	85.5-95.5	5.5-1.5	8.5-2.5	≤0.4	≤0.4	28-40
Alcusip instead of B83.	91	3	5.5	≤0.4	≤0.4	30-35
Alcusip instead of tinless babbitt	95.2-94.4	2.5-2.6	2.0-2.5	0.1-0.2	0.2-0.3	32-38
Alcusip instead of tin bronzes	93.4-92.0	5.0-5.5	1.0-1.5	0.2-0.4	0.4-0.6	50-60

Alcusip instead of tinless babbitt, according to technology corrected by author, is applied chiefly on bearing inserts during repairs of plant equipment.

Chemical composition of alcusip instead of tin bronzes Br 010, Br OTs10-2, Br OTs8-4, Br OTsS6-6-3, Br OF10-1, Br OF10-0.5 is simpler with respect to technology of manufacture, since lowered content of lead in alloy and higher content of iron and silicon facilitate conditions of obtaining assigned chemical composition.

Practically, alcusip of two brands will be more acceptable: alcusip-1 (alcusip instead of babbitt) and alcusip-2 (alcusip instead of bronze) in view of the following reasons.

Both these brands of alcusip contain little lead, which facilitates obtaining of its homogeneity, make it possible to conduct melting without treatment by potash at lower temperatures, facilitate and accelerate melting and filling of casting molds in chill mold or green sand, and thereby prime cost of alcusip is lowered in production. After mastering alcusip of shown brands, it is possible to start to apply alcusip instead of B83. In instrument manufacture, where more rigid technical conditions occur, can find the application of alcusip and other brands can be found; however, not comming out of chemical composition shown in Table 1.

For creation of conditions of formation of eutectic alloy Pb-Al, for its purification, and also for lowering of hardness of alcusip, potash is applied in a quantity 1-5% of weight of charge.

Application of potash, in distinction from other salts, tested during experimental meltings of alcusip as fluxes (Na_2CO_3, NaOH, NaCl, and others), gives good results exclusively: alcusip is not only cleaned from slag and impurity in period of melting, but obtains porosity and lowers its hardness by (8-12) HB.

Aluminum plastic antifriction alloys for a long time could not be used for the same purpose as tin babbitt, i.e., to apply it in the form of film on basis of structural, more durable material, and to thus obtain a bimetalic insert. Such position was observed because problem of bonding of aluminum with ferrous metals was not solved. With introduction of alcusip the application of special solder of binary composition became possible: 30% aluminum plus 70% zinc (in weight ratio). Such solder ensures completely reliable, durable, and tight bonding of alcusip with cast-iron or a steel base with necessary preliminary copper plating.

2. Charge Preparation, Melting, and Pouring of Bushings and Bearing Inserts From Alcusip

For melting alcusip, there can be used universally widespread melting units such as forging hearth, Kaliman furnace, "Mechta" furnace, and other units. Melting is conducted in fire clay or graphite crucibles.

In production of alcusip in a furnace of Kaliman type, average waste of charge composes 12%. Average waste of lead composes 25%.

Table 2. Composition of Charge of First Melting with Sharply Raised Waste of Lead

No. of melting	Composition of charge											
	Aluminum		Red copper ore		75% ferrosilicon		Lead		All		Potash	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
1	23,0	74,2	0,8	2,6	0,45	1,45	6,75	21,75	31	100	1,0	3,2
2	23,0	76,7	0,8	2,7	0,5	1,6	5,7	19,0	30	100	1,0	3,3
3	23,0	76,7	0,8	2,7	0,45	1,43	5,75	19,17	30	100	1,2	4,0
4	23,0	76,7	0,7	2,3	0,45	1,5	5,85	19,5	30	100	1,5	5,0
5	24,0	75,0	0,5	1,56	0,3	0,94	7,2	22,5	32	100	1,5	4,7

Table 2 contains composition of charge of the first five standard melting of alcusip with sharply raised waste of lead in Kaliman furnace, and in Table 3 – chemical composition of finished alloy of the same melting.

Table 3. Chemical Composition of Alcusip of First Melting, %

No. of melting	Al	Cu	Pb	Fe	Si
1 and 2	91,69	3,83	4,21	0,2	0,07
3	90,33	3,50	5,9	0,20	0,06
4	91,76	3,01	4,92	0,22	0,09
5	92,51	1,76	5,39	0,26	0,08

As initial charge materials in production of alcusip, there are applied aluminum, lead, copper, and ferrosilicon with content 75% Si or 45% Si.

All initial charge materials should be prepared accordingly for their filling in crucible.

Primary pig aluminum should be in pieces weighing 1-5 kg; red copper ore is prepared by small pieces or strips; ferrosilicon is preliminarily crushed; lead is chopped into pieces weighing 0.1-1 kg each.

Potash should be preliminarily dried, fired, and then crushed into small pieces. It is necessary to produce crushing shortly before melting, since potash is hygroscopic, rapidly becomes moist, and then it is necessary to redry it or even to fire it. It is necessary to consider that to introduce moist potash into crucible is dangerous and impermissible from the point of view of technology of safety.

Melting of charge and lining of bushings for inserts are conducted in such a sequence.

In a preliminarily heated up graphite or fire clay crucible, the base of charge is initially melted – aluminum. Then copper is loaded, which is dissolved well in liquid aluminum.

For the purpose of protection of charge from oxidation after melting of aluminum and copper, on the surface of liquid metal is applied charcoal.

After complete melting of aluminum and copper, charcoal is cleaned from surface of alloy and powdered ferrosilicon, lead, and heated potash are loaded in crucible consecutively. Contents of crucible are thoroughly mixed and melting (during which some overheating of alloy actually occurs) continues for still 15-20 minutes.

For the purpose of best mixing and production of more uniform alloy, it is recommended to introduce lead and potash in two processes with equal doses; second time – before the actual pouring of metal.

Casting of various bushings and inserts from alcusip is produced in special built-up metallic molds with thorough preliminary purification of alloy from slag. Before pouring of first bushings, holding and settling of alloy is accomplished. Optimum pouring temperature is 760-790°C. In the case when only one or two parts are poured and the necessity to keep alcusip hot for a long time is absent, best pouring temperature is 720-740°C with fast knockout of castings from chill molds and their rapid cooling.

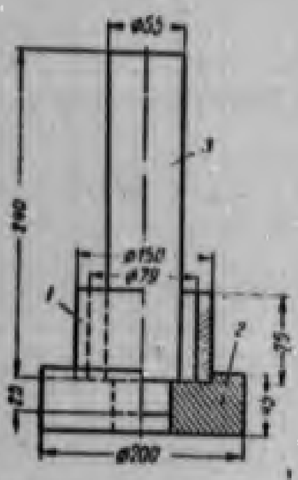


Fig. 1. Metallic mold (chill mold) for lining bushings of bearing inserts.

For the purpose of protection of poured bushings from cracking under the influence of temperature changes, it is necessary to accomplish disassembly of flooded molds and knockout of center core immediately after solidification of alloy. Temperature and time factors are decisive during pouring of bushings.

For prevention of work hardening, poured bushings should be placed in a temperature range on the order of 60-80°C, and they should not be left in cold air.

Built-up chill mold (Fig. 1) for lining of bushings, from which are machined inserts of connecting rod and main bearings of ZIL-120 engine, consists of bushing 1, plate 2, and core 3, having a casting incline $\alpha = 3\text{-}5^{\circ}$.

Cores are made elongated for convenience of holding them with tongs during knockout.

By the above-cited technology it is possible to conduct casting of alcusip bushings for bearings of any motors, even in haphazard foundry conditions.

Alcusip inserts do not need any metallic base, as occurs during use of B83 and B90. Alcusip is so cheap an alloy that any inserts can be made one-piece from it. Thus, we do not have to complicate production by technology of a bimetalic insert.

3. Technology of Lining Body of Bearings with Alcusip

In the case when it is necessary to line body of bearings with alcusip central question is its durable bonding with metallic base. The tightest coupling of alcusip with steel or cast-iron base is ensured by application of ~~special~~ solders of following compositions: 30% Al + 70% Zn or 20% Al + 80% Zn. Even in haphazard conditions of repair-mechanical workshop motor pools, it is completely possible to produce this work. Lining body of bearing with alcusip is produced by following technology.

1. Thorough cleaning of working surfaces of bearings by a file, scraper, or steel brush is preliminarily conducted.

2. Tin coating is carried out with above-indicated solder, for which bearings are completely dipped into melted solder, located in a separate crucible.

3. Lining with alcusip is produced in metallic molds, where temperature of

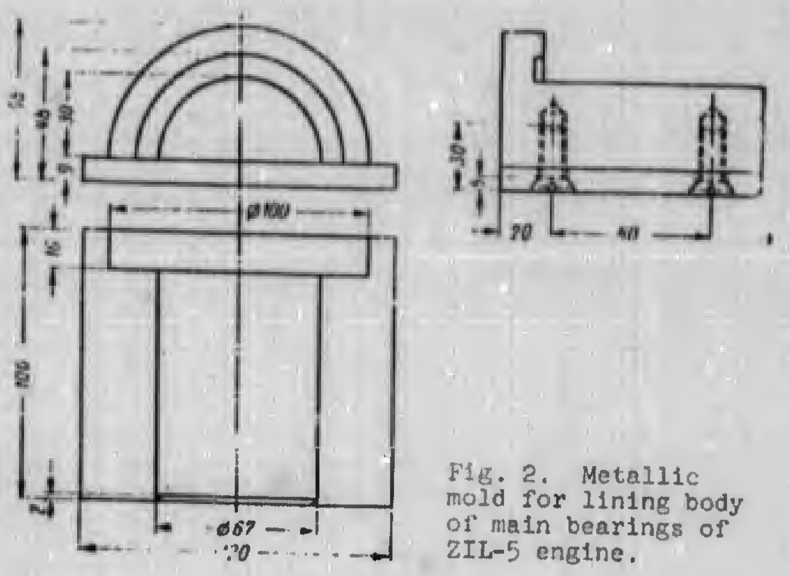


Fig. 2. Metallic mold for lining body of main bearings of ZIL-5 engine.

alcusip should be within limits of 760-790°C. Figure 2 shows basic dimensions of metallic molds for lining body of main and connecting rod bearings of ZIL-5 engines, similar to which it is possible to make mold of other dimensions.

4. Lined bearings are placed in a cabinet with temperature 60-80°C, where they are gradually cooled for 2-3 hours, then they are removed and cooled to ambient temperature.

5. Before sending to machining, bearings should be checked for hardness and also for quality of bonding of alcusip with metallic base. Quality of bonding is checked by means of infliction of blows on suspended bearing; trembling sound testifies to defects of filling.

In connection with the fact that in a number of cases because of complexity of lining body of bearings with alcusip and also because of tendency of plants to obtain the tightest cohesion of alcusip with steel and cast-iron base, lining was hampered; the three following solders were tested with positive results:

20% Al + 15% Cu + 65% Zn;
12% Al + 8% Cu + 80% Zn;
7% Al + 3% Cu + 90% Zn.

Basic condition of good cohesion is cleanness of connected surfaces. In this respect, alcusip, as an alloy based on aluminum, can be covered in certain cases by a thin transparent film Al_2O_3. Therefore, special attention should be turned to selection of suitable flux for removal of this film. Best flux should have following salts in its composition: calcium chloride, lithium chloride, sodium fluoride, and zinc chloride. It is possible to take also a mixture of zinc chloride with sodium chloride as flux.

During the last few years for strength of cohesion we started to apply rare-earth metal indium with melting temperature +156°C. However, for increasing strength of bonding it is better and simpler to produce copper plating of steel or cast-iron base before its tin coating.

4. Technology of Casting

Expounded technology of production of alcusip is simplified if silumin, containing silicon, and master alloy aluminum – copper are taken as initial materials. Their usage not only simplifies foundry technology, but also sharply lowers waste of valuable components and melting point of alloy. It is known that eutectic Al-Si contains 11.6% Si and is melted at 557°; eutectic Al-Cu contains 33% Cu and is melted at 548°C.

Charge preparation is conducted in accordance with assigned chemical composition of alcusip and calculation of waste in induction furnaces not over 8-10%.

As an example we calculated a charge for smelting alcusip of following chemical composition: Cu – 3%, Si – 0.4%, Fe – 0.2%, Pb – 5.0-5.5%, remaining – aluminum. Example is per 100 kilograms.

Primary aluminum	86 kg
50% copper master alloy Al-Cu . . .	5 kg
Silumin (Si = 11-13%)	1 kg
Lead	8 kg
Potash (3% of weight of charge) . .	3 kg

Charge is prepared the same as was indicated above.

Potash should be preliminarily fired at a temperature of 150-200°C, and then crushed into powder or into small pieces. Shortly before introduction of potash into crucible or furnace, it should be collected in a "Bell," and in the absence of the latter, should be turned into dry paper and held at all times in temperature range 100-120°C. It is categorically prohibited to introduce dampened potash into crucible.

Smelting of alcusip in induction furnaces after preparation of charge is conducted by following technology. Into graphite or fire clay crucible there is loaded in consecutive order all master alloy (Al + Cu), entire primary aluminum, and after them allumin. After their complete melting and subsequent thorough mixing in crucible, melting point is increased to 910-920°C, after which potash, which is melted at 891°C, is introduced into crucible. Increase of melting point of potash by 20-30°C is necessary, especially as together with potash there is simultaneously introduced the first half of charged lead, which naturally somewhat "cools" the liquid alloy. After achievement of 910-920°C in the furnace, current is turned off. With the help of "bell" heated potash is introduced on bottom of crucible and together with it or immediately after it the first half of charged lead. This is one of the most important moments of melting of alcusip and observance of the above-described technology is obligatory. Lead and potash are mixed for 2-3 minutes, naturally with the current turned off. From this moment current is not turned on again unless heating of sharply cooling alcusip is required during filling of molds or chill molds.

Then slag is cleaned and new measurement temperature follows. If it is considered necessary to recast liquid alcusip in a ladle for convenience of pouring, measurment of temperature before standing of alloy is made in the ladle. Before the actual pouring, there is introduced into crucible, and still better directly into ladle, the second half of lead and the alloy is again thoroughly mixed. Optimum pouring temperature of big parts is 740-760°C, and small parts 730-740°C. If, however, it is necessary to use the same chill mold for several castings of billets from melting, one should start pouring at a temperature of alloy 780-790°C in order to pour the outlined quantity of parts from melting of the same kind to such a degree, as liquid alcusip starts to thicken at a temperature lower than 700°C.

For prevention of appearance of cracks in bushings poured from alcusip, operation of their knockout should be conducted rapidly and neatly, with application beforehand of tool and attachments manufactured for their knocking out.

For the purpose of protection from sharp cooling in air, castings from alcusip are placed on an oven or in furnace with temperature at 60-80°C and are left for gradual cooling to room temperature.

It is necessary to immediately check Brinell hardness of smelted parts from alcusip after their cooling.

If hardness during correct burdening is obtained somewhat raised, its lowering is attained by additions of lead into melted alcusip with thorough and multiple mixing of lead in ladle, prepared for filling of molds or chill molds.

In separate cases, workers of plants on first time of introduction of new antifriction alloys require tests of both porous and solid alcusip, i.e., alcusip without its treatment by potash. Such requirements are supported usually by the considerations that it is simpler and more convenient to conduct melting of alcusip without potash. In these cases, temperature rate is also lower, waste is less, and meltings go faster.

Smelting of bushings, made from solid alcusip without potash, for connecting rod inserts of engines of S-80 tractor was conducted on order of Gatchinskiy mechanical plant of Leningrad-Sovnarkhoz in a metallurgical laboratory. For this purpose we used a chill mold with earthen sand center cores which were filled with tin bronze OTsS 3.5-6-5.

After detailed familiarization of author with technical conditions of plant for bushings, a charge was composed from account of production of finished alcusip of following chemical composition: Cu – 3.0%; Si – 0.3%, Fe – 0.15%, Pb – 4-4.5%, and remaining – aluminum. During this, HB hardness should be within limits of 35-38.

Preparation of charge of alcusip on 10 kg for its melting in laboratory electric furnace was the following:

Primary aluminum	8.4 kg
30% copper master alloy Cu-Al . .	0.9 kg
Silumin (Si = 11%)	0.1 kg
Lead	0.6 kg

It is natural that temperature of alloy only reached 800°C and all charged lead was introduced directly into ladle before pouring and was mixed thoroughly in it.

First bushings in the beginning emerged with cracks, then speed and method of hand pouring were depleted, after which bushings began to emerge without rejects. Poured alcusip bushings were placed, as always, in a warm place for cooling.

However, one should note the fact that inserts poured from solid alcusip without treatment by potash, i.e., without proper porosity, wear out in operation, even in tractors, one and a half times faster in comparison with inserts from porous alcusip.

5. Centrifugal Pouring of Bushings from Alcusip

Above we indicated that alcusip instead of bronze is a simpler antifriction alloy with respect to technology of manufacture, since it contains less lead than alcusip-1.

Besides, small lead content simplifies and expands methods of pouring of alcusip instead of bronze, starting from pouring into green sand and loam molds and finishing by pouring into chill mold with application of centrifugal pouring.

First centrifugal pouring of alcusip instead of bronze was applied in one of the Leningrad plants, during which liquation of lead was not observed.

One melting of alcusip was conducted in an induction furnace with application of Silumin and master alloy aluminum — copper from calculation:

Aluminum	40.0 kg
Master alloy Al + Cu (36% Cu) . .	4.5 kg
Silumin (Si = 12%).	2.0 kg
Lead	3.5 kg
Potash	1 kg

With this alloy 5, 65 × 130 × 300 mm bushings were poured on a centrifugal machine. Speed of rotation of chill mold was 1200 rpm. Chemical analysis of melting showed the following results: Cu — 3.48%, Pb — 1.46%, Fe — 0.13%, Si — 0.44, Al — remaining.

On the end of every bushing in two places — near external and internal diameters, Brinell hardness was measured; hardness varied from 45.0 to 44.0.

Irrevocable losses composed 14%.

Second melting was conducted by the same technology, in the same induction furnace, with preparation of charge of copper master alloy and Silumin from calculation:

Aluminum	42 kg
Master alloy (Al + Cu 36%) . .	3.5 kg
Silumin (Si = 10.6%)	1.0 kg
Lead	3.5 kg
Potash (2.8% of weight of charge	1.4 kg

With this alloy 2, 100 × 200 × 300 mm bushings were poured on centrifugal machine. Speed of rotation of chill mold was 1200 rpm.

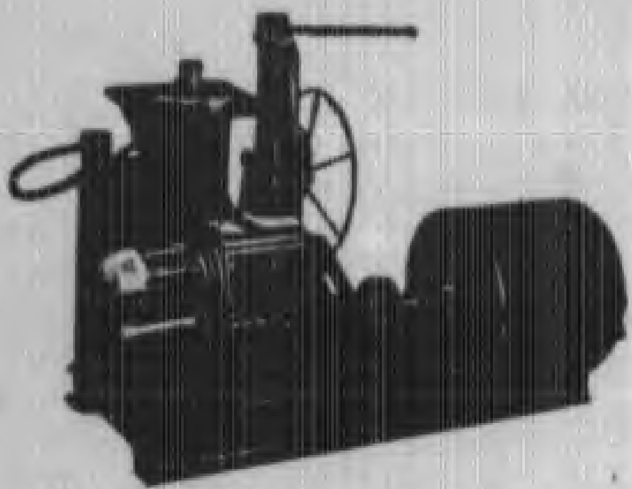


Fig. 3. Induction furnace in complex with centrifugal machine.

Fig. 4. Microstructure of alcusip bushings of centrifugal pouring.

Chemical analysis of melting showed the following results: Cu – 4.6%, Pb – 2.66%, Fe – 0.28%, Si – 0.86%, Al – remaining.

On ends of bushings in three places – near external diameter, middle, and near internal diameter, there were performed measurements of Brinell hardness (Table 4).

In some other plants there is also applied centrifugal pouring of bushings from alcusip instead of bronze.

Figure 3 shows special installation of induction furnace and centrifugal machine for manufacture of alcusip bushings in Aleksandriyskiy mechanical plant of Kirovograd region.

Table 4. Results of Measurements of Hardness

No. of bushing	External diameter	Middle	Internal diameter
	Brinell hardness		
1	48,6	45,5	45,5
2	47,5	47,5	47,5

Microstructure of alcusip bushings poured by centrifugal method, as can be seen in Fig. 4, has porosity of third class and has uniform structure without any liquation of lead. With lead content in alcusip over 3%, there occurs heterogeneity of its distribution in alloy, without liquation however.

6. Machining of Inserts and Their Assembly

Inserts for main and connecting rod bearings are manufactured by means of lathe treatment from bushings poured in metallic molds.

Treatment of bushings from alcusip should be produced at high rpm (not less than 900 rpm) and at small feeds — on the order of 0.1 mm and cutting depth 0.5 mm. The higher the rpm, the higher is cleanness of treatment. Alcusip is machined well with cutters from high-speed cutting steels, and there is no necessity for application of cutters with tips from hard alloys.

At the same time one should note that treatment of alcusip can be produced at any speeds. From the point of view of increase of productivity, it is rational to conduct treatment of alcusip on machines at 1200-2000 rpm.

After lathe treatment the bushings are cut with thin milling cutters (thickness not more than 0.5 mm) into two halves, with subsequent pressing of fixing flanges.

During assembly of such inserts, it is necessary to turn special attention to cleanness of treatment, for which inserts are subjected to finishing operations for achievement of surface cleanness of sixth class.

Operational treatment and assembly of inserts (after their lathe treatment) are produced in such a sequence:

1) cutting of bushings into two halves with milling cutter of 0.5 mm thickness;
2) drilling of holes with 8 mm diameter in inserts;
3) survey of faces inside drilled holes;
4) pressing of fixing flanges (locks) in a special attachment;
5) removal of projecting edges from fixing flanges;
6) installation of inserts with linings into block;
7) reaming of inserts under necessary repair dimension of crankshaft;
8) preparation of oil refrigerators;
9) packing of crankshaft in bed with adjustment of each journal.

For the purpose of prevention of pulling of inserts, it is necessary to conduct their assembly in such a manner that there would be no gap between insert and bed of block. At the same time it is necessary to practice application of one thick (0.1 mm) unyielding lining along with several thin (0.05 mm each) linings.

In the case when with respect to consideration of great reliability it is necessary to conduct pouring of inserts on a steel base with obligatory application of solder 30% Al + 70% Zn, order of machining of inserts and their assembly remain without any changes.

In view of the fact that in automobile engines turning of inserts is completely eliminated by their assembly without play (without gap), technological process of production of inserts should not be complicated, since pouring of inserts from alcusip on steel base involves additional technological operations additional expenditure of solder, and billets of steel rings.

During installation of alcusip inserts in an engine, it is necessary to pay attention to gaps and lubrication of engine. It is known that liquid friction is ensured if carrier ability of oil layer will be equal to normal force at assigned speed of relative motion and with thickness of oil layer exceeding the sum of heights of unevenness on surfaces of friction.

In case of small roughness (the greatest height of unevenness – up to 0.1 thickness of oil layer), there is obtained reliable liquid friction with character of movement of liquid in the gap close to laminar.

With rougher surfaces of friction and high speed of relative motion of surfaces, movement of liquid in gap becomes turbulent and losses on friction strongly increase. Heating of oil in gap, obtained due to this, and lowering of its viscosity create danger of break of oil layer and disturbance of liquid friction.

In connection with this, question about gaps during assembly of engines, in which inserts from alcusip are applied, is exceptionally important.

It was established that before putting automobile engines into operation, gaps between neck of shaft and bearings from alcusip should be made 1.5-2 times larger than in cases of application for bearings B83 and B90.

Thus, during assembly of ZIL-120 engines, gap in necks of main bearings of crankshaft should be within limits of 0.10-0.11 mm and in connecting rod necks – within limits of 0.07-0.08 mm.

Observance of such gaps is necessary since their change toward decrease not only immediately reflects on engine operation, but also can cause its breakdown.

Increased gaps are necessary also because during heating alcusip is expanded twice more than cast iron or steel.

In the same cases when, with respect to structural considerations, it is impossible to increase gaps, it is necessary to apply in engines inserts from porous alcusip, melted with 5% dosages of potash.

7. Breaking in Conditions of Engines

After thorough assembly of engine, in which inserts from alcusip are applied, as in all other cases, it should pass a breaking in period. In period of utilization and introduction of alcusip, bench running of engines should be conducted in special conditions. As a rule, engines, in which inserts from alcusip are applied, require large expenditure of time on cold and hot running in without load in view of more prolonged fitting of alcusip to necks of crankshaft.

Table 5 contains conditions of experimental running in of ZIL-120 engines. From the table one may see that overall time consumed on test composed 10 hours 25 minutes. Gasoline and oil consumption during this was also very great — 210.7 and 14.7 kilograms respectively. After experimental running in, the very large indicated figures of gasoline and oil consumption, obtained during test, were almost brought to usual norm.

Table 5. Running in Conditions of ZIL-120 Engines with Use of Inserts from Alcusip

Conditions	Designation of operations	Assignment of operations	Number of rpm of crankshaft	Time, minutes	Total time, minutes	Note
1	Cold running in	Fitting of fundamental parts	418	60	100	Turn on 4th gear
2	The same	The same	795	30		3rd gear
3	The same	The same	1388	10		2nd gear
4	Hot running in without load	Fitting of parts and connections	600-1000	120		After hot running in without load, change oil in crankcase of engine and check it
5	The same	Adjustment of gap between end of valve and bolt of tappet	1000-1400	40		
6	The same		1400-1600	20	190	
7	The same	Check of oil pressure and adjustment	600-2400	10		At 2400 rpm operation is allowed for not more than 3-5 minutes
8	Hot running in with load P = 35 kg	Final adjustment of engine	1200-1400	120		Disassembling and measurement of main and connecting rod journals of crankshaft and internal diameters of inserts
9	P = 50 kg		1400-1600	60	300	
10	P = 65 kg		1400-1800	60		Strictly observe thermal condition and revolutions
11	P = 80 kg		1800-2200	60		Disassembling and measurement of main and connecting rod journals of crankshaft and internal diameters of inserts
12	Hot running in without load	Check OTK. Check of operation at various rpm	500-2600	30		Operation at 2600 rpm is allowed for not more than 5 minutes

Table 5 (Continued)

	Designation of operations	Assignment of operations	Number of rpm of crankshaft	Time, minutes	Total time, minutes	Note
13	Hot running with load P = 95 kg	Check OTK. Measurement of power Adjustment of number of revolutions at 2400 rpm	2000-2600	5	35	According to technical conditions on breaking in and testing of engine

Note: P – reading of scale of hydraulic brake.

Following bench running in after check and acceptance, engine was installed on motor vehicle for necessary running in trip conditions. After running in the engine was inspected and all defects revealed in trial run were removed. However, one should consider that complete fitting of alcusip inserts sets in after running motor vehicle not less than 1000 km.

Consequence of incorrect fitting of bearing inserts can be: scores of cylinders, jamming of piston pins, appearance of cracks in blocks. Load of automobiles on first 1000 km of running is taken lowered, for instance for ZIL-150 – not more than 2000 kg, and speed – not exceeding 25 km/hr.

Type of engine lubricant is applied the same as during usual operation of automobiles.

It is necessary to change all oil after a run of first 1000 km, and in crankcase of engine, in addition to that – after every 200-250 km; in crankcases of remaining units – after 500 km. It is necessary to thoroughly flush crankcase during replacement of oil.

During run of first 1000 km, it is necessary to thoroughly watch for appearance of knocks in engine. After 1000 km of run, it is necessary to produce the third replacement of oil in crankcase, and to hear operation of engine. In the absence of any defects, the automobile is allowed further normal operation.

8. Wear of Journals of Crankshaft, Gathered on Inserts from Alcusip

Basic factors affecting wear of rubbing surfaces are the following: material of surfaces, quality and accuracy of treatment of surfaces of friction, degree of contamination of places of friction, character and kind of lubricant, microstructure and porosity of antifriction alloy, magnitude of specific pressure, magnitude of specific work of friction, speed, character and kind of load, temperature rate, and conditions of operation (character and state of roads).

Usually wear of metals is obtained less, the higher is their hardness. In every frictional kinematic couple, more wear of simple and easily replaceable parts and less wear of expensive and parts complex in manufacture are preferable.

At the same time, distribution of wear along surface of friction depends on type, conditions of operation, and work of kinematic couple.

It is established that bearings of an automotive engine wear out more during periods of coasting and racing than during entire period of operation at established motion.

In view of what was presented, alcusip is the best material as compared to high-tin babbitt B83 and B90, which is confirmed by less wear of journals of crankshaft during operation of engines in which alcusip bearings are used (Tables 6 and 7).

Table 6. Chart of Measurements of Main and Connecting Rod Journals of Crankshaft, Working on Alcusip Inserts on ZIL-120 Engine No. 04, After Running Automobile 27,340 km.

No. of journals of crankshaft	Nominal dimension of diameters of journals, mm		Dimensions of diameters of journals, mm		Conicity of journals, mm		Ellipseness of journals, mm		Wear of journals, mm	
	main	connecting rod	main	connecting rod	main	connecting rod	main	connecting rod	main	connecting rod
1	65,95	61,91	65,81 - 83 / 65,80 - 80	61,76 - 76 / 61,77 - 78	0,01	0,01	0,03	0,02	0,12	0,15
2	65,95	61,92	65,85 - 875 / 65,87 - 89	61,78 - 785 / 61,81 - 805	0,025	0,005	0,02	0,03	0,10	0,14
3	65,96	61,93	65,86 - 85 / 65,87 - 87	61,71 - 705 / 61,755 - 74	0,01	0,015	0,02	0,045	0,11	0,225
4	65,96	61,93	65,91 - 91 / 65,91 - 92	61,79 - 79 / 61,81 - 81	0,02		0,03	0,02	0,05	0,14
5	65,96	61,93	65,89 - 87 / 65,90 - 89	61,84 - 835 / 61,87 - 86	0,02	0,01	0,02	0,03	0,09	0,095
6	65,94	61,92	65,87 - 88 / 65,89 - 90	61,825 - 79 / 61,84 - 81	0,01	0,03	0,02	0,02	0,07	0,13
7	65,95		65,89 - 88 / 65,91 - 90		0,01	—	0,02		0,07	

Table 7. Chart of Measurements of Main and Connecting Rod Journals of Crankshaft, Working on Alcusip Inserts on ZIL-120 Engine No. 01, After Running Automobile 26,962 km.

No. of journals of crankshaft	Nominal dimension of diameters of journals, mm		Dimension of diameters of journals mm		Conicity of journals, mm		Ellipseness of journals, mm		Wear of journals, mm	
	main	connecting rod	main	connecting rod	main	connecting rod	main	connecting rod	main	connecting rod
1	65,99 / 65,985	61,93	65.84—83 / 65,90—89	61,73 72 / 61,75 74	0,01	0,01	0,06	0,02	0,16	0,21
2	65,985 / 65,98	61,935	65,86—85 / 65,88—87	61,72 75 / 61,74—77	0,01	0,03	0,02	0,02	0,135	0,215
3	65,99 / 65,98	61,93	65,88 - 86 / 65,89 88	61,78—73 / 61,82—77	0,02	0,05	0,02	0,04	0,13	0,20
4	65,975 / 65,985	61,94	65,89 87 / 65,91—89	61,79—78 / 61,81—80	0,02	0,01	0,02	0,02	0,105	0,16
5	65,99 / 65,98	61,94	65,86—87 / 65,87 - 89	61,83—83 / 61,85 - 86	0,02	0,01	0,02	0,03	0,13	0,11
6	65,98 / 65,985	61,93	65,87—875 / 65,885—89	61,83 - 83 / 61,78—79	0,005	0,01	0,015	0,04	0,11	0,19
7	65,985 / 65,98	—	65,88—88 / 65,90—89	—	0,01	—	0,02	—	0,105	—

From analysis of charts one may see that wear of journals of crankshafts of ZIL-120 engines No. 01 and 04, after running about 27,000 km, for connecting rod journals composed 0.16 mm on the average and for main journals 0.10 mm.

Raised wear of journals is explained by the fact that engines No. 01 and 04 at the automobile repair plant were the first on which the plant learned to produce assembly similar to that of auto engines on bearings from B83.

After running in of these auto engines on a stand of machinery-assembling workshop of automobile repair plant in Baku with allowed stiff tightening, scratches were revealed on journals of crankshafts. These crankshafts were assembled on alcusip inserts of raised hardness — 38 HB. Nonetheless, under these conditions wear of main journals of crankshafts turned out to be lower than norm by on the average of 25-30% as compared to engines in which bearings from B83 were applied.

It is impossible not to note that if in very heavy road conditions inserts from B83 collapse when running an automobile on the average of 22,000 km, inserts from alcusip worked without replacement after running 34,000 km.

Considering that thermal conduction and heat capacity for aluminum are higher than for tin, during operation of engines on alcusip inserts more abundant lubricant is necessary, which obliges, in particular, drivers of automobiles to attentively watch the oil pressure, not allowing it to drop.

With alcusip inserts the necessity of covering bearing inserts of auto engines with indium, which increases wear resistance, is eliminated.

9. Physical-Mechanical Properties and Metallographic Peculiarities of Alcusip

Table 8 shows comparison of physical-mechanical properties of alcusip and high-tin babbitt of brands B83 and B90.

Table 8. Physical-Mechanical Properties of Alcusip and High-Tin Babbitt

Designation of properties	Alcusip instead of babbitt	B90	B83
Specific gravity.	2.75-2.80	7.30	7.38
Beginning of hardening, °C.	625-623	342	370
End of hardening, °C.	600-610	241	240
Ultimate tensile strength, kg/mm^2 . . .	13.0-15.0	9.2	9.0
Elongation per unit length, %	12-16	9.0	6.0
Brinell hardness.	28.0-35.0	27	30
Coefficient of friction with lubricant.	0.003	–	0.005

From the table one may see that alcusip possesses great elongation per unit length at large ultimate tensile strength, i.e., best primary mechanical properties with hardness close to that of tin babbitt.

Operational experience of trucks showed that inserts from alcusip with raised hardness, as compared to B83 and B90, are not only considerably stabler in operation, but also journals of crankshaft wear out less.

Coefficient of friction with the presence of lubricant for alcusip inserts is favorably distinguished from coefficient of friction of tin babbitt, other antifriction aluminum alloys, and low-tin babbitt, which can be seen from Table 9.

Low coefficient of friction of alcusip is explained by its good antifriction properties and microporosity.

Work of friction, characterizing intensity of work of bearings, depending upon technical and operational conditions for alcusip instead of babbitt varies within limits of 180-300 $kg\text{-}m/cm^2 \cdot sec$.

Alcusip possesses high anticorrosive stability, evaluation of which was performed by means of determination of loss of weight of samples after their 60 hour stay in artificially oxidizable motor oil. It is established that alcusip is not subject to corrosion in oxidizable oil.

Alcusip does not give adhesion or coating on steel journal of shaft during friction. Phenomena of adhesion are encountered during friction of metals in conditions of imperfect lubricant or without lubricant, when as a result of friction or large local loads there occurs plastic deformation of one or both conjugated metals, or during formation of products of wear getting into gap between rubbing surfaces.

Table 9. Comparison of Physical-Mechanical Properties of Alcusip with Antifriction Aluminum and Low-Tin Babbitt

Physical constants	Alloys											
	№ 216	№ 234	№ 235	АСС-6-5	№ 280	БН	Б16	БТ	Б6	[illegible]	БК	Alcusip instead of babbitt
Specific gravity . . .			—			9,5	9,29		9,6	10	10,5	2,75 2,80
Ultimate tensile strength, kg/mm^2. . . .	9,6	6,3	8,3	8,1	10,7	7	7,8	8	6,8	1,2	10	13,0 15,0
Elongation per unit length, %	9,1	2,0	16,7	13,9	21,9	1	0,2	2	0,3	0,6	2,5	12 16
Brinell hardness . . .	31,3	31,9	28,3	31,4	31,3	29	30	25	32	20	32	28,0–35,0
Coefficient of friction with lubricant			—	—	—	0,006	0,005	0,009	0,005	0,007	0,001	0,011

Alcusip is so viscous and soft antifriction alloy, that even during heating, while not adhering to journals of shaft, it at the same time is easily fitted to them.

Alcusip, as experience has shown, does not give wear, ellipseness, and scoring of shaft of engine. At the same time, physical-mechanical properties of alcusip guarantee high-quality of operation of low-speed machines-engines.

Mastering 5-component alcusip with different melting points and specific gravity of its components at first presented great difficulties.

Microstructure of alcusip without its treatment by potash in liquation zones of lead is presented in Fig. 5. Black spots and black bands show liquating lead. Alcusip, obtained according to given technology with treatment by potash and with observance of all above-mentioned conditions of its production, possesses proper evenly uniform microstructure (Fig. 6).

Analysis of microstructure (Fig. 6) with different percentage of lead content shows that for alcusip, aluminum composes base in which lead is evenly distributed

a) b)

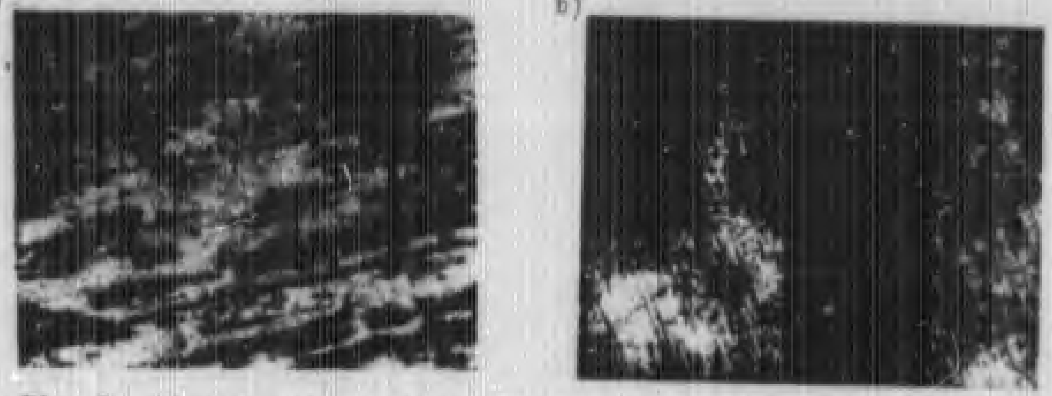


Fig. 5. Microstructure of alcusip in zones of liquation of lead: a) Pb – 4.9%; b) Pb – 5.49%.

in the form of black grains, forming a network. Separate black spots represent lead that is nonuniformly distributed in alloy due to imperfection of conducting of melting and primarily because of poor mixing of potash and lead during their introduction into crucible or ladle.

a) b) c)

Fig. 6. Microstructure of alcusip with various content of lead: a) Pb – 4.92%; b) Pb – 8.0%; c) Pb – 3.75%.

Regarding other components of alloy, for instance copper, iron, and silicon, insignificant change of their dosage, both toward decrease and toward increase, has no affect on character of structure of network.

Thus, with strict observance of foundry technology during treatment of alloy by potash, lead with aluminum will form an alloy similar to eutectic.

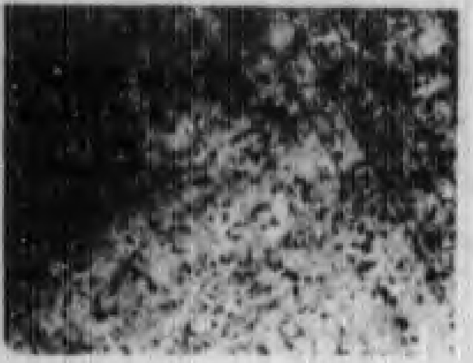
Porosity of alcusip, as a result of influence of potash on it, is revealed even by naked eye and during use of simple magnifier or microscope it is possible to easily measure diameter of pores, which varies from 0.1 to 0.2 mm.

With increase of quantity of introduced potash, porosity in alcusip is increased, which has a favorable influence (as shown by experience) on operating conditions of automobiles, increasing both life of crankshafts and duration of operation of inserts.

Thus, alcusip not only has small capillary paths, but also pores, through which lubricating oil penetrates, decreasing friction in bearings, which gives properties of reticular bearings to inserts from this alloy.

Figure 7 shows microstructures of alcusip connecting rod main inserts of first experimental engines with which ZIL-150 trucks were made with respect to 34,000 km range. More reliable operation of engines on up grades and absence of knocks were attained in them.

a)



b)

c)

Fig. 7. Microstructure of experimental alcusip connecting rod and main inserts of ZIL-150 motor vehicle: a) Pb-3.14%; b) Pb – 3.84%; c) Pb – 4.21%; Hb = 37.2 – 38.8.

It is possible to produce etching of slides by sodium hydroxide, nitric acid, hydrochloric acid, and sulfuric acid. Usually etching is produced with a 10% solution of sodium hydroxide, and for production of the most perfect and clear photography of microstructures, it is recommended to produce etching with sodium fluoride.

Control of macro- and microstructure is necessary for all compositions of alcusip with magnification of 150 or 200 times.

Figure 8 shows microstructure of alcusip instead of bronze, revealed after two-minute etching in 5% solution of NaOH, heated to 70°C and microstructure with small lead content.

a) b)

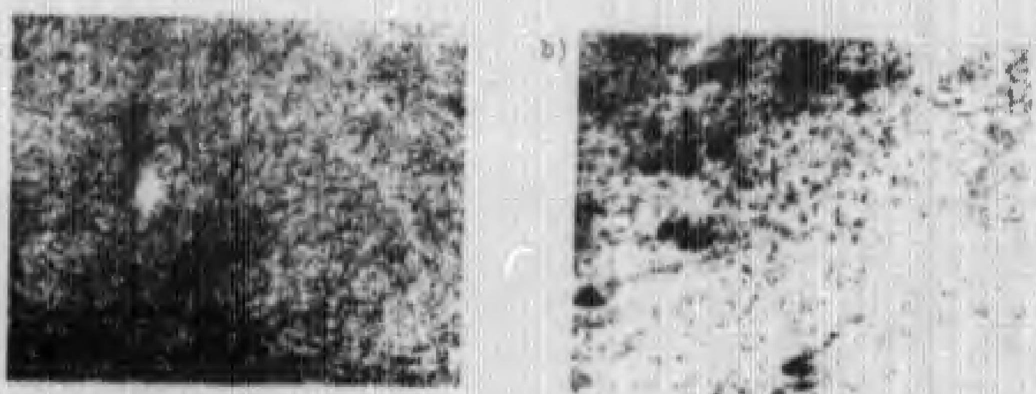


Fig. 8. Macro- and microstructure of alcusip instead of bronze: a) Pb — 1.01%; b) Pb — 1.58%.

However, regarding microstructures of unetched samples of alcusip, they have solid solution of copper in aluminum characterized by basic light background, and crystals of lead — dark color.

Table 10. Reagents for Exposure of Microstructures of Alcusip

Reagent	Content, %	Time of etching, sec	Method of etching
NaOH crystal H_2O	1 99	10	To rub in process of etching
NaOH H_2O	10 90	2	To dip into solution heated to 70°C
HNO_3 concentrate H_2O	25 75	40	To dip into solution heated to 70°C
H_2SO_4 concentrate H_2O	10 90	5	To dip into solution heated to 60-70°C
HNO_3 concentrate H_2O	15 85	40-60	To dip into solution heated to 60-70°C

In Table 10 there are enumerated reagents for exposure of microstructures of alcusip.

Microstructure of etched samples of alcusip usually a represent solid solution of copper in aluminum (light background) + crystals of lead (dark color) + (eutectic mottled field).

10. Foundry Shop in the Production of Alcusip

Experience has shown that after first positive results of exploitation of alcusip on repaired equipment, plants and repair-mechanical workshops assign separate foundry sections for smelting alcusip.

However, creation of small specialized foundry shops or sections for production of alcusip is the most rational.

Thus, petroleum production administration of "Ordzhonikidze oil" in Baku-Surakhany, following a specialized handicraft foundry section for alcusip, transfered its production to well equipped foundry-heat treatment shops of compressor economy, equipped with electric furnaces.

At the same time, by order of the same administration, a small experimental foundry shop of alcusip was designed for 100 t of casting in a year.

Workshop has an area 117 m^2 with distribution of necessary equipment. Accepted equipment ensures not only fulfillment of annual program – 100 t of casting, but also provides for possibility of its increase.

By this plan, melting is conducted in crucible furnaces operating on petroleum gas with artificial draft. Melt of master alloy is poured into casting moulds. Ingot of master alloy should have fullerings, facilitating its breaking into pieces weighting 3-4 kilograms.

Charge materials are stored on racks.

For removal of liquation in castings with large lead content, installation of chill molds is provided for during pouring on table, top of which constitutes a 1200 × 600 × 30 mm box, water-cooled from within. Assembly of chill molds under pouring, knockout of castings from chill molds, and operations of trimming and fettling are executed on tables.

Quality and more accurate rapid testing of released production are produced according to Brinell hardness.

For drying of potash and preheating of chill molds, a 1200 × 1000 × 1000 mm

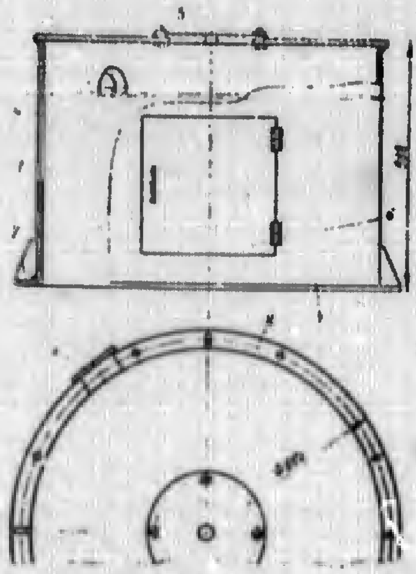


Fig. 9. Vent hood: 1 — branch connection; 2 — flange of hood; 3 — handle; 4 — door; 5 — cover; 6 — door hinge; 7 — frame of hood; 8 — top of hood.

furnace, consisting of two sections, is provided. In section for preheating of chill molds there is located a gas burner; other section is for drying of potash. Temperature in furnace is controlled by thermocouples.

In such specialized workshops it is desirable to have possibility of production of bushings both in sand molds and by means of pouring them into chill molds, and also by centrifugal method. Unconditionally, for guarantee of serial production of bushings, such workshops or sections should be maximum mechanized with directed freight flows of both initial materials and finished production.

With respect to conditions of hygiene of labor and requirements of safety technology, any installation for castings from alcusip, even with lowered content of lead, should be equipped with draw ventilation or, as a minimum of requirements, a vent hood (Fig. 9), without which meltings of alcusip are not allowed since besides carbon monoxide fumes of lead there occurs its evaporation, which is harmful to health of worker.

11. Methods of Control of Articles from Alcusip and Conditions of Their Usage in Machines

a) Methods of Control

1. One of the basic requirements of imposed on parts from alcusip is their corresponding Brinell hardness, of which during replacement of high-tin babbitt B83 and B90 by alcusip should be from 28.0 to 35.0, and during replacement of bronze by alcusip — 50-60.

2. Microstructure of alcusip should be uniform with respect to distribution of lead in aluminum base.

3. It is possible to manufacture alcusip both solid and macroporous. For determination of porosity it is recommended to use scale of All-Union Scientific Research Institute of Aviation Materials (VIAM), which is presented in Table 11.

Table 11. Standards of Degree of Porosity of Alloys

No. of standard	1	2	3	4	5
Quantity of pores on 1 cm^2	up to 5	up to 10	up to 15	up to 20	up to 25
Diameter of pores in mm	up to 0.1 100%	up to 0.1 80% up to 0.2 20%	up to 0.3 80% up to 0.5 20%	up to 0.5 70% up to 0.1 30%	up to 0.5 60% up to 1.0 40%

It is possible to use standards of degree of porosity regardless of brand of alloy.

4. Every melting of alcusip should be checked by chemical analysis for Cu, Pb, Si, Fe, and Al with check of chemical composition for Brinell hardness. For chemical analysis shavings are taken from a special sample.

5. Ultimate tensile strength in kg/mm^2 and elongation per unit length are determined on standard samples.

6. During mastering and introduction of alcusip on new objects, it is recommended to expand laboratory tests by determination of following additional physical constants:

1) proportional limit during compression;
2) upsetting during compression;
3) resilience;
4) coefficient of linear expansion;
5) linear shrinkage;
6) thermal conduction;
7) fluidity;
8) coefficient of friction with lubricant;
9) coefficient of friction without lubricant.

7. Measurement of macro- and microporosity of alcusip is produced by optical instruments, and during rapid-tests — with application of magnifier. Quantity of pores and their diameter, fluctuating from 0.1 to 0.2 mm, depend upon dosage of potash. Besides, total microporosity on 1 cm^2 area should be calculated by finding out percent of porosity with respect to measured area with indication of class of porosity.

8. In case of necessity, anticorrosive stability of alcusip is determined by loss of weight of samples after their 60 hour stay in artificially oxidized lubricating oil.

9. Bearings poured with alcusip (with application of solder) are checked on absence of trembling sound by means of blows on suspended bearings or by other acoustic method.

b) Conditions of Usage

1. Usage of different machines, in which it is possible to apply bearings from alcusip, should be preceded by running at idle and working movement or running in according to a special program including cold running, hot running without load and under a load. This running in occurs on the average of 1.5 times longer than usual because of more prolonged fitting of alcusip to journals of shaft.

2. Due to raised thermal conduction of alcusip, during assembly of machines and mechanisms it is necessary to make oil gaps on the average of 1.5 times larger as compared to those which are applied in machines and mechanisms working on tin bronzes.

3. Work of friction, characterizing intensity of work of bearings, for alcusip inserts should generally oscillate from 180 to 300 kg-m/cm^2·sec.

For the case of sharply variable and impact loads, work of friction of alcusip oscillates within limits of 250-600 kg-m/cm^2·sec.

4. For low-speed motors and for any metal-working machines work of friction of alcusip can be allowed up to 800-1000 kg-m/cm^2·sec at specific pressures from 180 to 220 kg/cm^2.

5. General operational efficiency and stability of alcusip in all calculations can be taken 2 times greater than in cases of use of babbitt, high-tin, and other antifriction bronzes in machines.

6. During usage of motors with bearing inserts from porous alcusip less abundant lubricant is needed than with solid alcusip.

7. Properties of bearings with inserts from porous alcusip remain stable and do not change during heating up to +200°C.

12. Area and Experiment of Application of Alcusip

Alcusip-1 was tested for the first time as material of bearings by the author as far back as 1948-1949 on ZIL-5, ZIL-150, and other trucks in exchange for sharply deficient and expensive B83.

Later alcusip was applied in transport workshop of enterprise of petroleum production administration of "Ordzhonikidge oil" in Baku-Surakhany.

After two years of work the transport workshop of this enterprise equipped over 40 trucks of types GAZ-51, ZIL-150, AYaZ-200, MAZ-200 with inserts from alcusip; many from them completed a run over 50 thousand kilometers without repair. Main and connecting rod alcusip inserts turned out to be not only considerably more stable as compared to babbitt B83, but journals of crankshaft wear out less. Petroleum production administration of "Ordzhonikidze oil" spread experience of its own motor transport men on introduction of alcusip to other objects of its own extensive economy. Here many machines and mechanisms work successfully on alcusip inserts. Thus, in compressor workshop, 2 brand 8Kh compressors with alcusip bushings in connecting rod ends work a prolonged time. In oil-water transfer workshop 20 centrifugal pumps (throttle and pouch type) operate exclusively on alcusip sliding bearings. In reconditioning shop for wells over 20 swivels with load capacity 75 t operate unfailingly on alcusip bushings. In shop for underground repair of wells, on many tractors-hoists there are installed alcusip bushings in rollers under caterpillar tracks; the same 16 tractors-hoists operate with gearboxes completely assembled on alcusip bushings. Besides, many lathes of the same transport shop operate on inserts from alcusip.

In trades of the same administration 12 batching pumps and several DGR scum pumps operate completely on alcusip bearings; over 300 valves manufactured from alcusip are applied in trades, in gas and repair-assembly shops.

Field of application of alcusip in Azerbaidzhan Republic, as is covered by "Technical economic bulletin of Azerbaidzhan Sovnarkhoz (Baku, 1960, March, No. 3) is expanded all the time. After only one year, as a result of use of alcusip, economic effect composed 60 thousand rubles for petroleum production administration (NPU) of "Ordzhonikidze oil."

In the Novocherkassk electric locomotive building plant, from alcusip there were manufactured inserts for motor-axle bearings of electric motors of electric locomotives, which earlier were prepared from B16 babbitt. Here there is applied alcusip for inserts and bushings of lathe and grinding machines. From alcusip there are made nuts of actuating screw of turret lathe without splines, nuts of actuating screw of turret lathe with splines, bushings of shears, bushings of presses, and other objects of plant equipment. Workers of this plant in their conclusions consider alcusip a good substitute for babbitt, bronzes, and brasses; its use in exchange for babbit is considered possible only with the presence of pores and capillary paths in it, since as a result of their own tests they established that coefficient of friction of movement of alcusip with lubricant after fitting of unit of friction varies from 0.0035 to 0.0045 and depends on macroporosity and capillarity of alcusip. They also experimentally established that the more lead in alloy, the less is the coefficient of friction and the better alcusip works on abrasion.

Alcusip instead of bronze was tested for the first time with positive results and applied in Orotukansk repair plant of mountain-concentrating equipment in bearing bushings of lower rollers of S-80 tractors, where it was used to replace expensive sharply deficient high-tin bronzes Br. 010, Br. OTs10-2, and Br. OTs8-4.

Due to high antifriction properties, alcusip can be applied instead of bronze for various kinds of bushings and strongly loaded parts operating in heavy conditions and subjected to intense wear. This antifriction alloy, possessing good foundry properties, permits its usage for light, average, and large shaped casting even in instrument-making. However, this question requires further study.

Alcusip-2, by possessing porosity with best antifriction and mechanical properties, can replace the following pseudo alloys:

1) antifriction cermet based on iron with porosity 20-25%;

2) the same with copper base;

3) iron graphite with posority 20-30%;

4) bronze graphite with porosity 18-20%.

Bearings from alcusip-2 are characterized by following data:

1) 50-60 HB hardness gives possibility to apply bearings for hardened and non-hardened shafts;

2) properties of bearings based on aluminum are not changed during heating up to 200°C;

3) coefficient of expansion is the same as for standard cast bearings;

4) coefficient of friction with abundant lubricant is less than for bearings from cast tin bronze; coefficient of friction drops with increase of load on bearings;

5) wear is less, since dry friction is absent;

6) wear of bearings is several times less than bearings from tin babbitt;

7) fitability of bearings is inferior to that of babbitt bearings.

Whereas mechanical properties of porous bearings from pseudo alloys depend on porosity, and with its increase by 1% these properties are worsened by 3-10%, bearings from alcusip-2 with micropores scattered throughout entire thickness do not change mechanical properties.

Experience of Novocherkassk electric locomotive building plant confirmed that alcusip is a good substitute for antifriction bronzes and brasses, and can be recommended for wide introduction in machine building. Presence of pores and capillary paths in castings from alcusip alloy permits improving lubricant of rubbing parts, which in separate cases gives possibility to use it instead of babbitt.

In the Novocherkassk electric locomotive building plant it was proposed to divide alcusip into four brands: alcusip-1 instead of babbitt, alcusip-2 instead of bronzes, alcusip-3 for replacement of brasses, and alcusip with 30-35 Brinell hardness with large percent of lead content.

According to this plant, coefficient of friction of movement of alcusip instead of bronze with lubricant after fitting in of unit of friction varies within limits of 0.0035-0.0045 and depends on macroporosity and capillarity. During fitting in of unit of friction, coefficient of friction of movement is not constant and depends on specific pressure, type of lubricant, accuracy of treatment; this fitting factor can vary from 0.20, 0.10, to 0.076.

However, there were such experimental meltings in this plant, which gave unsatisfactory results — sometimes ingots were obtained nonuniform with respect to chemical composition and with great liquation of lead.

Presence of positive and negative results of production and application of alcusip in industry indicates that with further introduction of alcusip into industry much scientific, research, and experimental work is still required, which it is necessary to continue on the jobs. Testing of alcusip-2 is conducted in Leningrad plant "Krasnyy Treugol'nik," where it is applied in bushings of shafts of bearings of small-size rollers.

Besides, porous alcusip-2 starts to find application in instrument manufacture and in mechanisms of precision mechanics. So, Leningrad Scientific Research Institute (NII) of polymerizational plastics tests porous alcusip for stuffing box seals of reducing gears and in particular reducers of colloidal mills.

It is natural that every enterprise, becomming familiar with alcusip, introduces something new not only in foundry technology, but also in machining of alcusip, in assembly, and bench tests of articles made from alcusip.

Only the combined work of designers, mechanics, technologists, and metallurgists will help to rapidly and correctly solve the questions appearing during introduction of alcusip into production.

13. Technical Conditions for Alcusip

In all cases technical conditions primarily provides for obtaining of desirable Brinell hardness of alcusip, depending upon which brand of alcusip and its chemical composition are selected. There is also indicated the brand of other material, paired with which it should work.

In view of the fact that in very many cases during repair there is required solid alcusip without its treatment by potash, in technical conditions it is necessary to make the corresponding stipulations.

For porous alcusip the class of porosity is indicated.

During mass production of alcusip parts macroporosity of 3rd class is preferable.

Conditions and requirements of designers are indicated with respect to efficiency of alcusip, character and kind of loads, and also range of specific pressures and linear speeds.

There is indicated temperature of which alcusip should work and also specific conditions of medium, as for example water or raised humidity.

Indication of desirable mechanical properties of alcusip is necessary.

There are indicated kind and character of lubricant or impregnation of alcusip if it is necessary to apply porous alcusip, and also there is indicated desirable emergency supply of oil and periods of work of alcusip with this emergency supply.

Requirements are advanced in technical conditions for treatment, assembly, and testing of a part from alcusip, depending upon equipment.

14. Alcusip in Hydrotechnical

By order of "State All-Union Design and Planning Institute of the Ministry of Ferrous Metallurgy," in connection with application of alcusip for inserts in support hinges for segment gate of Krasnoyarsk Hydroelectric station (Fig. 10),

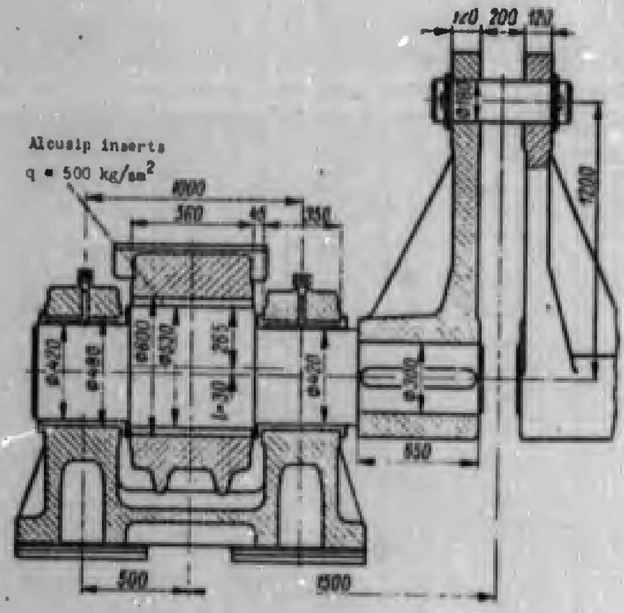


Fig. 10. Alcusip inserts in support hinges.

working with specific pressure 500 kg/cm^2, the author made calculated and experimental work, basic results of which are expounded below.

Support-revolving hinges of segment or sector gates, made from alcusip, can work in conditions:

1) large loads, prolonged with respect to time and of vibrational character;

2) environment — air of considerable humidity with temperature gradient from -40° to +40°C;

3) insignificant angle of rotation (less than 90°);

4) extremely low speeds on conjugated surfaces of friction;

5) thick lubricant under pressure.

Support hinges of these locks experience extremely high pressures, magnitude of which attains 1500 t, and diameter of axis of hinge is 500-600 mm.

Total load on two legs of segment composes 2520 t, consequently, on each bearing of 420 mm diameter (see Fig. 10) there occurs force

$$Q = \frac{P}{4} = \frac{2520}{4} = 630\ T,$$

and on each support of 530 mm diameter —

$$N = \frac{P}{2} = \frac{2520}{2} = 1260\ T.$$

Maximum specific pressure in bushing

$$p = \frac{N}{dl} = \frac{1\,260\,000}{53 \cdot 56} = \frac{1\,260\,000}{2968} \approx 425\ \text{kg/cm}^2.$$

Speed on surface of friction is 1 mm/sec. Duration of turn of lock by 50° is 4 minutes. Duration of cycle (raising + lowering) is 8 minutes. Hypothetical condition: quantity of cycles per twenty-four hours: 1. Quantity of cycles per year: 300. Character of load is constant both during movement and stationary.

Temperature gradient is from -5° to +40°C. Work is outside water, but in conditions of strong humidity, air medium is contaminated (sporadically) by abrasives (sand storms).

Installation of antifriction bearings having large dimensions in support hinges weights the construction and increases its dimensions. Check, repair, and replacement of antifriction bearings are extremely difficult also; therefore, application of alcusip inserts exceptionally rational and economical. Replacement of antifriction bearings by sliding bearings from alcusip monometallic inserts will also lower weight of entire construction, will facilitate operation and repair. Application of alcusip bushings in exchange for bushings from DSP wood or on running wheels of gates in exchange for antifriction bearings is especially rational, since installation of antifriction bearings requires surmounting of a number of difficulties of structural order.

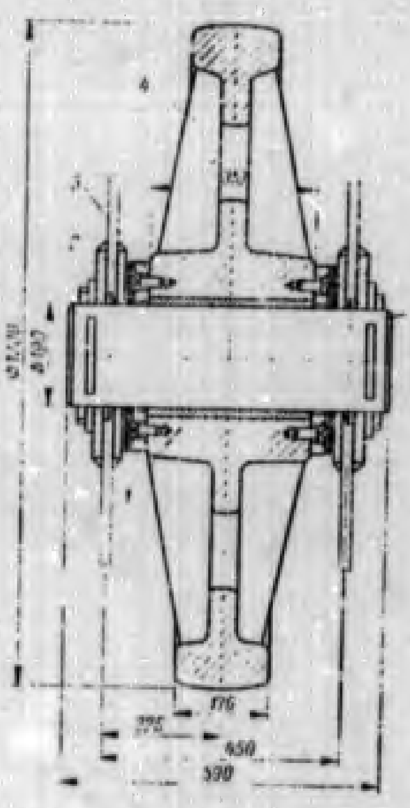


Fig. 11. Alcusip bushing in running whell of working gate. 1 — alcusip bushing; 2 — washer; 3 — ring; 4 — wheel; 5 — axis.

Running wheel of working gate (Fig. 11) with 1200 mm diameter will operate in water. Load on wheel is 115 t.

Then we obtain specific pressure on bushing

$$p = \frac{P}{dl} = \frac{115000}{22 \cdot 19} \approx 275 \quad \text{kg/cm}^2.$$

Fifty percent overload is possible, then specific pressure

$$p = \frac{115000 \cdot 1.5}{22 \cdot 19} - 400 \quad \text{kg/cm}^2.$$

Rate of slip on surface of friction is 0.015 m/sec.

Operating conditions of running wheels of gates are assigned the pursue following technical requirements:

1) environment — water with possible inclusion of abrasive particles and air (when gate is lifted above water) with temperature gradient from +40° to -40°C. At lower temperatures the gate does not work and support carriages can be covered with ice;

2) character of load — constant with stationary gate (pressure of water) and variable during its movement; possibility of vibration is not excluded;

3) operating conditions of gates in overwhelming majority — sporadic, with the exception of ship passing facility, where there is produced up to 30 cycles of locking in twenty-four hours.

It is possible to use alcusip for all supports which are now more often made on antifriction bearings. By applying alcusip, we thereby will replace rolling friction by sliding friction, inasmuch as alcusip possesses small coefficient of friction. It works well in transmissions with from 75 to 1500 rpm reducing gears and with transmissions with smaller rpm, made open on antifriction bearings or sliding bearings.

Alcusip instead of bronzes is freely substituted in sliding bearings DSP or bronze Br. AZh9-4, and also antifriction cast iron applied at low specific pressures.

Alcusip instead of bronzes satisfies all technical requirements with respect to allowed specific pressures, peripheral speeds on surface of friction, and efficiency, which do not emerge from norms of general machine building permitted for bearings with bronze inserts and bushings.

Alcusip instead of bronzes will cover allowed specific pressures assigned for DSP in following dimensions:

Bushings of blocks, drums, journal boxes . .	300 kg/cm^2
Intermediate shafts.	150 kg/cm^2
Hinges with relative turn 360°	400 kg/cm^2

Alcusip permits increasing the life of separate units of mechanisms, particularly sliding bearings, on the average of 2 times thanks to sharply lowered coefficient of friction.

Alcusip can be applied both in high speed closed gears and in open gears with low rpm up to 100 rpm and diameter of journals under supports 60-80 mm.

Air medium surrounding bearing with temperature gradient from -40° to +40°C, considerable humidity with possible penetration of bearing shell by atmospheric precipitation in the form of snow and rain, and also dust penetration are totally permissible for alcusip, especially as alcusip does not change its properties in temperature range from -65° to +200°C.

General technical requirements presented to alcusip in units of hydromechanical equipment are also easily feasible with respect to all positions, namely:

1) for bearings of mechanism drives alcusip will be suitable not only because it will be equivalent to bronze of brand Br. AZh9-4 with more optimum antifriction properties inherent to it, resistance to wear, fitting ability,

plasticity, mechanical strength, corrosion-resistance, and fatigue strength, but also because it will possess great efficiency;

2) where shaft and axis are made of brand St. 45 steel, alcusip will also work well; coefficient of sliding friction will not sharply differ from that of static friction;

3) alcusip of all brands possesses good anticorrosive properties; therefore, work of alcusip parts is freely allowed even in water;

4) alcusip-1 and alcusip-2 can also be applied for support-undercarriages with diameter of axes from 100 to 250 mm, reverse and side wheels with diameter of axes from 50 to 100 mm, flat gates, experimental-revolving hinges, segment and sector gates with diameter of axes up to 600 mm, and undercarriages of roll away gates with diameter of axes up to 250 mm.

According to technical requirements imposed on alcusip utilized in mechanical equipment of hydrotechnical installalions at large specific pressures, and also for the purpose of preservation of minimum coefficient of friction, taking into account possible inferior conditions of lubricant without scoring of metal between rubbing surfaces, the author conducted experimental work on manifestation of efficiency of alcusip, results of which are brought forth in Table 12.

Table 12. Regularities in Efficiency of Alcusip

Specific pressure kg/cm^2	Speed m/sec	Efficiency $\frac{kg\cdot m}{cm^2\cdot sec}$	Specific pressure kg/cm^2	Speed m/sec	Efficiency $\frac{kg\cdot m}{cm^2\cdot sec}$	Specific pressure kg/cm^2	Speed m/sec	Efficiency $\frac{kg\cdot m}{cm^2\cdot sec}$
100	0,6	60	100	1,2	120	100	2,4	240
150	0,4	60	150	0,8	120	150	1,6	240
200	0,3	60	200	0,6	120	200	1,2	240
250	0,24	60	250	0,48	120	250	0,9	240
300	0,20	60	300	0,40	120	300	0,8	240
350	0,17	60	350	0,34	120	350	0,7	240
400	0 15	60	400	0,30	120	400	0,6	240
450	0.135	60	450	0,27	120	450	0,53	240
500	0,120	60	500	0,24	120	500	0,48	240
550	0,110	60	550	0,22	120	550	0,44	240
600	0,100	60	600	0,20	120	600	0,40	240
700	0,085	60	700	0,17	120	700	0,34	240
800	0,075	60	800	0,15	120	800	0,30	240
900	0,066	60	900	0,13	120	900	0,27	240
1000	0,060	60	1000	0,12	120	1000	0,24	240

By experimental data the dependence of change of coefficient of friction f on specific pressure p was established; for solid alcusip working without lubricant the coefficient of friction was equal to 0.30-0.32. During running in of unit of friction, coefficient of friction of motion is not constant and depends on specific pressure, type of lubricant, accuracy of treatment, and therefore can oscillate from 0.010 to 0.076; coefficient of friction of microporous alcusip with lubricant is equal to 0.003; for lubricant there is recommended primarily lubricating oil of All-Union Government Standard 1862-57 with specific gravity 0.914, and any type of oils and lubricant including water.

In view of the fact that actual value of efficiency of alcusip should in the end be expressed through specific work of friction, it awaits to conduct experiments on determination of magnitudes of coefficient of friction, depending upon specific pressure during growth of latter to the maximum possible limit.

15. Investigations and Testing of Alcusip

Author's first investigations and tests of alcusip, conducted in central plant laboratory of automobile repair plant in Magadan in 1950-1951, were standard plant tests and chemical analyses with detailed metallographic investigations.

On their basis it was established that alcusip, with hardness similar to B83 (30 HB), should have following chemical composition: copper – 2.4-3.4%; lead – 6-8%; silicon – 0.1-0.2%; iron – 0.1-0.15%; remaining – aluminum.

High requirements with respect to hardness of alcusip were confiremed during test 11 of ZIL-120 auto engines, which verified that alcusip instead of B83 on motor vehicles should have hardness higher than 30 HB, especially for main bearings. Later alcusip inserts with hardness 36-38 HB were applied in auto engines.

It was established that hardness of alcusip is increased considerably with increase of percent of copper, iron, and silicon. Together with their increase, naturally, mechanical properties are also changed, which was confirmed later in Novocherkassk electric locomotive building plane (see Table 13).

Table 13. Influence of Copper Content on Mechanical Properties of Alcusip

Chemical composition, %					σ_b, kg/mm^2	δ, %	HB
Cu	Pb	Si	Fe	Al			
2,1	4,5	0,21	0,29	Remaining	14,5	6,8	47,8
3,2	4,56	0,18	0,27		14,8	4,1	48,9
4,15	4,61	0,19	0,30		15,0	2,5	50,1
5,05	4,9	0,22	0,25		15,2	1,5	51,5
6,1	5,5	0,17	0,28		16,4	1,3	60,2
7,2	5,3	0,20	0,26		16,5	0,6	69,1
7,5	3,5	0,19	0,30		16,7	0,6	69,2

At the same time, after operation of first ZIL-120 auto engines in which alcusip inserts of connecting rod and main bearings were used, it was established that insignificant increase of iron sharply increases wear of shaft. Therefore, subsequently during all meltings the author considered and considers iron in alcusip instead of B83 as an undesirable impurity and allows it only in virtue of necessity during charge preparation or at special singular requirements for instance when mechanics and fitters request to manufacture alcusip inserts that are well resiling during assembly of engines.

It was also established that maximum copper content in alcusip should not be more than 5-5.5%, since greater content of it worsens antifriction properties of alloy and may cause break of oil layer during operation in elevated temperature range.

Mechanical properties of first samples of alcusip, showing positive results during tests of ZIL-150 trucks are given in Table 14.

Table 14. Mechanical Properties of Alcusip with Chemical Composition: Al — 91.5%; Cu — 3.0%; Pb — 5%; Fe — 0.3%; Si — 0.2% with Different Hardness

No. of sample	Diameter, mm	Area of cross section mm^2	Length, mm	Length after elongation, mm	Elongation, mm	Load, kg	Temporary breaking strength, kg/mm^2	Elongation, %	Brinell hardness
1	8,96	53,05	50	54	4,0	920	14,5	8	44
2	13,72	147,60	50	53,1	3,4	2160	14,6	6,8	40,1[1]
3	14,20	158,40	50	56,5	6,5	2070	13,1	13	37,2
4	14,34	161,50	50	58,0	8,0	2320	14,4	16	35,8
5	14,68	169,50	50	56,3	6,3	2300	13,6	12,6	37,2

[1]Break of sample for nonstandard mark.

As fluxes during experimental meltings of alcusip, in Dal'stroya in 1948-1950 the author tested F-1, F-3, VIAM-5, Na_2CO_3, NaOH, NaCl, and K_2CO_3.

Application of potash as flux gave the best results, namely: alcusip was not only cleaned from slag and dirt, but was obtained softer with lowering of hardness to 8 HB.

Thus, for creation of conditions of formation of eutectic alloy Pb-Al, for its purification, and also for lowering hardness of porous alcusip potash is applied in quantity from 2 to 5% of weight of charge.

Porosity of alcusip will be formed at the expense of separation of carbon dioxide, since during heating of potash its thermal dissociation starts to occur.

It was established that the biggest mass of alloy hardens in temperature range 623-621°C; in this range there also occurs beginning of formation of solid eutectic solution with its subsequent completion at 545-540°C.

With different var tions of chemical composition of alcusip, some deviations from above mentioned hardening temperatures of alloy will be obtained.

During operation of first trucks with alcusip inserts its microporosity was regulated as a rule by dosages of potash that were 3% of overall weight of charge, which made alcusip porous according to 3rd class of standard scale of porosity. During comparative running tests of ZIL-150 trucks it was established that from the point of view of microwear of main and connecting rod journals of shaft, identical results turned out after the following runs: trucks ZIL-150 with inserts from B83 passed 22 thousand km, with inserts from solid alcusip – 34 thousand km, with inserts from porous alcusip – 42 thousand km.

First performance tests of alcusip instead of bronze Br. OF10-1 were conducted by the author in 1951 in Protukan repair plant of mining-concentrating equipment. Here from alcusip there were cast bearing bushings on lower rollers of S-80 tractors of the following chemical composition: Al – 92-93%, Cu – 5-5%, Fe – 0.5-0.6%, Si – 0.4-0.5%, Pb – 1.0-1.5%.

Before assembly of machined bushings, manufactured without any changes on plant drawing, we checked mechanical properties of alcusip, which turned out to be the following: 1) ultimate tensile strength 22 kg/mm^2; 2) elongation per unit length – 6%; 3) Brinell hardness – 50-60.

Allowances on free dimensions, play of butt surface, conditions finishing after pressing were identical to bushings from Br. OF10-1, with the exception of insignificant increase of gaps.

Performance tests passed successfully and later alcusip instead of bronze began to be applied in other frictional parts and in wider scales than alcusip instead of babbitt.

Influence of heating on resilience and hardness of alcusip, given in Tables 15 and 16 according to Novocherkassk electric locomotive building plant, shows that physical-mechanical properties of alcusip scarcely change during heating to 200°C.

Table 15. Influence of Heating on Resilience of Alcusip

Resilience a_k, kg-m/cm² of alcusip samples			
without notch		with notch	
$t=18°$	$t=200°$	$t=18°$	$t=200°$
0,75	0,8	0,64	0,60
1,4	1,36	0,6	0,58
1,6	1,47	1,05	0,96
1,4	1,58	1,21	1,18
1,59	1,70	1,17	1,16
1,74	1,28	0,58	0,58
1,36	1,30	0,58	0,58
1,25	1,18	0,6	0,58

Table 16. Influence of Heating on Hardness of Alcusip

Brinell hardness			
$t=18°$	$t=200°$	$t=18°$	$t=200°$
47,5	43,7	50,2	47,0
49,0	44,0	45,0	41,0
52,0	48,0	44,0	40,0
54,0	50,0	46,0	41,0
56,0	52,0	42,0	38,0

Conclusions

Work of connecting rod inserts of crankshaft bearings of automotive engines occurs in extremely heavy conditions, caused by presence of forces of inertia and dynamic loads, acting both on bearings and on their inserts. With respect to conditions of operation, automotive engines also work in heavy conditions. Therefore, by showing good results in process of tests of motor vehicles on bad roads, it is favorable to apply alcusip as a substitute for high-tin babbitt B83 and B90. This material is cheaper than sharply deficient tin bronzes and babbitts of other brands.

Alcusip, as an antifriction alloy, can improve its antifriction properties if its structure will consist of comparatively soft inclusions of defined dimensions and in a specific quantity, evenly scattered in a relatively harder base.

Introduction of potash in quantity 1-5% permits obtaining equal distribution of lead in aluminum base. Besides, with increase of introduction of potash, lead is adopted in alcusip in greater quantity. Articles from alcusip not only have capillary paths, along which lubricating oil penetrates, decreasing friction in bearings, but also possess porosity, due to which inserts from this alloy receive properties of reticular bearings.

It is necessary to consider that during operation of engines in which inserts from solid alcusip are applied, more abundant lubricant is needed.

Lead entering alcusip in the form of fine inclusions with the absence of lubricant is a unique additional lubricating substance.

Alcusip-2 (in exchange for bronzes) is not only simpler with respect to foundry technology, but also can be prepared with sharply increased mechanical properties, which was confirmed during manufacture of bearing bushings of lower rollers of S-80 tractor instead of bronze OF10-1 (Fig. 12).

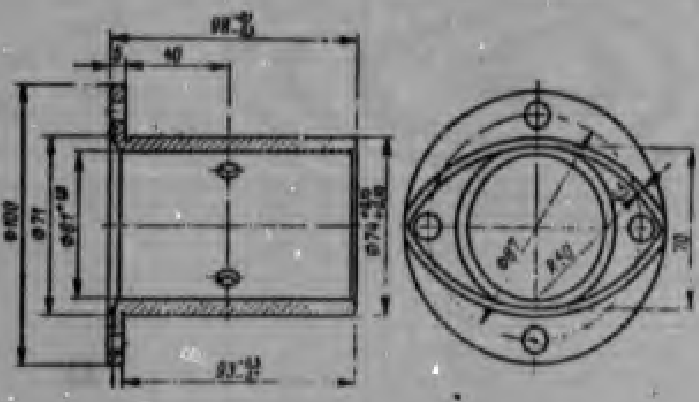


Fig. 12. Alcusip bearing bushing of lower rollers of S-80 tractor.

Additions of titanium in alcusip even in small quantities on the order of 0.05-0.1% improve its mechanical and technological properties.

Alcusip with titanium content from 0.2 to 1% represents not only good antifriction, but also qualitative structural material with high mechanical properties with ultimate tensile strength from 25-30 kg/mm^2 and compression strength 1500-2000 kg/cm^2.

Titanium is introduced into alcusip in the form of aluminum-titanium alloy of the following chemical composition: titanium 2-4%, aluminum 98-96%.

It is necessary to prepare master alloy aluminum - titanium in graphite crucibles in a high-frequency induction furnace, and not to melt in iron and cast-iron crucibles in avoidance of its saturation by iron. Even for stirring of liquid alloy it is necessary to take only graphite mixers.

For charge preparation there is applied spongy titanium of brand TR-1 and aluminum of brand A00.

Spongy titanium is introduced after melting of aluminum and bringing temperature of liquid metal to 1250°C. To avoid ejection of metal titanium is introduced by separate portions of 50 g, which are preliminarily turned into aluminum foil, pressed, and heated to 200°C.

After melting of entire charge the alloy is thoroughly stirred, brought up to 900°C, and then poured into chill molds. Obtained ingots of aluminum-titanium master alloy are remelted a second time with heating up to 900°C and with refining by manganese chloride, which is preliminarily dried at 100-120°C. Then the alloy is poured into shallow casting molds or chill molds with preliminary cleansing of alloy from slag.

Alcusip yields well to machining by cutters of R9 high-speed cutting stee without application of cutters with tips from hard alloys.

Alcusip is a good substitute for any antifriction bronzes and brasses and can find application in machine building and instrument manufacture thanks to low coefficient of friction.

Alcusip, as an antifriction material, also finds application in hydrotechnical installations as bearing supports, where large specific pressures are encountered; thus, for example, bushings of blocks, drums, journal boxes experience specific pressure 300 kg/cm^2; intermediate shafts — up to 150 kg/cm^2; hinges with relative rotation 360°-400 kg/cm^2 and with speeds fluctuating from 0.02 to 2.4 m/sec experience pressure up to 400 kg/cm^2.

At the same time, alcusip in units of hydromechanical equipment should work in conditions of great wear resistance, good fitting, proper plasticity and mechanical strength, corrosion-resistance, and assigned fatigue strength.

Efficiency of bearings is determined by necessity of tolerance of maximum specific pressures while maintaining minimum coefficient of friction and calculation of possible inferior conditions of lubrication without scoring of metal between rubbing surfaces. Besides, for production of technological-economical effect during application of alcusip it is required to have maximums of pressures 500 kg/cm^2 with negative sliding speeds, close to zero.

Alcusip can have solid castings (without potash) in those cases when it is applied as a structural material, especially in instrument making, for manufacture of almost all parts of instruments from plates to small pinions.

Markability of alcusip is established depending upon technical conditions, on which also depends manufacture of alcusip without its treatment by potash.

In distinction from producing alcusip with high percentage of lead 5-5.5%, presenting great difficulty, producing it in castings of 15-20 mm thickness when casting in chill mold, casting of alcusip instead of bronze does not present difficulties under any technical conditions, since it, as an alloy with smaller lead content, is obtained uniform during the most elementary foundry technology. However, in all cases for the purpose of obtaining a more uniform alloy with respect to lead, one should not pour it into intensely heated chill molds, but pour into cold molds with possibly good mixing in ladle with rapid cooling and fast knockout of castings from molds.

Comparative data of physical-mechanical properties of alcusip-2 (instead of bronze) and bronzes are shown in Table 17.

Table 17. Physical-Mechanical Properties of Antifriction Bronze and Alcusip-2

Brands of bronzes	Ultimate tensile strength, kg/mm^2	Elongation per unit length, %	Brinell hardness	Linear shrinkage, %	Coefficient of friction with lubricant	Specific gravity, g/cm^3
Br. 0.10 . . .	20-25	3-10	70-80	1.28	0.0056	8.8
Br. OTs-2 . . .	20-25	2-10	80-90	1.45-1.50	0.006	8.8
Br. OTs-4 . . .	20-25	4-15	75-85	1.54	0.008	8.78
Alcusip instead of bronze . .	22-28	6-12	50-60	1.5-1.8	0.005-0.0055	2.8

Introduction of alcusip will give the people's economy considerable savings, calculated on many tons of sharply deficient tin and millions of rubles.

CHAPTER II

ANTIFRICTION POROUS CAST IRON

17. Description of Antifriction Cast Irons

Recently in units of friction for replacement of bronze we find the application of antifriction cast iron of different brands.

It is well-known that for certain bearings there are applied high-quality gray cast irons with pearlite base and raised content of free graphite. Graphite is a lubricant and simultaneously absorbs lubricant itself, thus lowering coefficient of friction between journal of shaft and wall of bearings.

Besides gray cast iron, malleable and high-strength cast irons are applied for bearings.

Antifriction cast irons should satisfy the same requirements as other antifriction alloys.

Antifriction properties of cast iron to a considerable degree cause the presence of free carbon (graphite) in mass of metal; therefore, with respect to lubricant metal becomes porous to a certain degree.

Figure 13 shows different forms of separation of graphite.

Ferritic gray cast iron is the softest of all antifriction cast irons and therefore is easier fitted to journal of shaft. It possesses low wear-resistance and is applied in those cases when journals of shaft have low hardness.

Pearlitic gray cast iron is applied when journals of shafts possess great hardness due to hardening. This cast iron is used for manufacture of bushings of lathes, planers, drills, milling machines, roller tables, electric motors, and other various equipment.

a) b)

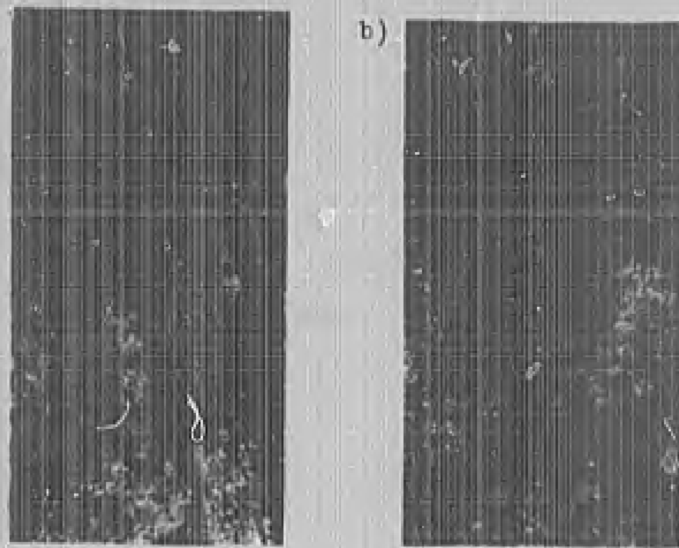


Fig. 13. Microstructure of cast iron with different form of graphite; a) laminar; b) flaky.

Ferritic malleable cast iron possesses good fittability, high strength, and ductility. Its properties are better than ferritic gray cast iron, but its wear-resistance and hardness are insignificant. Specific load during operation should not exceed 40 kg/cm^2 at speeds 1-1.5 m/sec.

Pearlitic malleable cast iron possesses high mechanical properties. Due to its high hardness it is more difficult to fit to journals of shaft than ferritic malleable cast iron and therefore requires more thorough bench running before putting into operation.

Pearlitic-ferritic malleable cast iron is considerably more wear-resisting than ferritic malleable cast iron. In operation it allows specific pressure up to 60 kg/cm^2 at sliding speeds not exceeding 2-3 m/sec.

Chemical composition and mechanical properties of antifriction cast iron are shown in Table 18.

Majority of parts from antifriction cast iron are bushings and inserts for bearings. During the last few years there were established several brands of bearing cast iron; namely: cast iron with laminar graphite (gray antifriction cast iron); cast iron with graphite in the form of temper carbon (malleable cast iron); cast iron with spheroidal graphite (high-strength cast iron).

Table 18. Chemical Composition of Antifriction Cast Irons

Designation	Components, %									Brinell hardness	Ultimate tensile strength kg/mm²	Elongation per unit length, %
	C_{total}	Si	Mn	P	S	Cr	Ni	Cu	Al			
Ferritic gray cast iron . . .	3,3–3,6	3,0–3,5	0,4–0,6	0,8 1,0					—	150 160		—
Pearlitic gray cast iron Ts1	3,2–3,6	2,2–2,4	0,6 0,9	0,15–0,20	Up to 0,12	0,2–0,35	0,3 0,4	0,2–0,3	0,1–0,15	170–230	—	—
Pearlitic gray cast iron Ts2	3,2–3,6	2,2 2,1	0,6–0,9	0,15–0,30	Up to 0,12	0,2–0,35	0,3–0,4	—	—	170–23	69	—
Pearlitic gray cast iron Ts3	3,2–3,6	2,4–2,9	0,8 1,0	0,15–0,20	Up to 0,12	0,2–0,35	0,3–0,4	0,7–0,9	0,1–0,15	170–230	—	—
Ferritic malleable cast iron	2,6	1,0	0,8	0,07	0,075				—	140–190	30	7
Pearlitic malleable cast iron	—	—	0,7–1,0	—	—		—	—	—	180–200	48–60	15–20
The same	—	—	1,1–1,4	—	—		—		—	240–260	70–80	4–7
Pearlitic-ferritic malleable cast iron . . .	2,6–3,0	1–1,10	0,9–1,0	Up to 0,07	0,008		—	—	—	100–200	49–53	6–7

Cast iron with laminar graphite is subdivided in turn into brands:

a) chrome-nickel pearlitic class SChTs-2 (All-Union Government Standard 1585-57);

b) chrome-nickel pearlitic class, additionally alloyed with copper and aluminum SChP-1 (All-Union Government Standard 1585-57);

c) titanium-copper.

Antifriction malleable cast iron is subdivided in the following manner:

a) pearlitic and pearlitic-ferritic malleable cast iron (unalloyed);

b) copper malleable cast iron;

c) titanium-manganesse malleable cast iron.

For successful use of antifriction cast irons of all types in bearings, reliable lubricant, precise machining, and thorough assembling are required.

An important distinctive feature of cast iron as antifriction material is its prolonged fittability, requiring application of special measures, for example, running in of parts under idling or eased conditions.

Good results are given by special lubricants for running in, etching of surface, and covering of surface of cast iron bearing by plastic metals.

In cases of heavy working conditions and necessity to increase wear-resistance, preference is devoted to cast iron with spheroidal graphite with smallest possible content of ferrite.

However, all above-described antifriction cast irons cannot completely replace tin bronzes since they can work during gentle load and peripheral speed not exceeding 0.25 m/sec, and during specific loads 400-450 kg/cm^2. If, however, peripheral speed is equal to 1 m/sec, specific pressure should not exceed 100-120 kg/cm^2, and with peripheral speed 3 m/sec specific pressure should not be more than 20 kg/cm^2. Besides, during application of these antifriction cast irons lubricant should be supplied continuously and in large quantity, and journals of shafts or axes should have greater hardness than for cast-iron bushings.

18. Chemical Composition of New Antifriction Cast Iron and Technology of Its Production

By latest investigations and experimental data the following regularity is established between coefficient of static friction and elastic modulus (in Table 19).

Table 19. Coefficients of Static Friction

Material of surface	Coefficient of static friction	Elastic modulus E/2.5 kg/cm^2
Lead	3.31	780
Tin	1.11	1810
Aluminum	0.94	2700
Glass	0.94	2900
Brass	0.63	3500
Copper	0.60	4700
Platinum	0.46	6200
Steel (soft)	0.41	8100
Steel (hard)	0.39	8900

From the table one may see that in materials arranged in order of decrease of coefficient of static friction, elastic modulus or shear modulus increases correspondingly regularly. By this is also explained application of medium-dry lubricants with graphite, since displacement for graphite occurs easily and graphite is a good lubricating substance; during crushing it is easily destroyed, dividing into laminae, which very freely slide along each other.

In practice because of roughness of rubbing surfaces, contact occurs only in a small number of points, on which all the pressure is transmitted, in consequence of which wear and friction become excessive. Therefore, plastic materials are desirable which under pressure can take the form of projection and increase contact surface area.

Porosity of antifriction material, including porosity of antifriction cast iron, ensuring rational and full heat exchange of lubricant by means of seepage of oil through pores, are necessary qualities of good antifriction alloy.

On the basis of what was said, antifriction, porous, high-strength cast iron was proposed.

For formation of pores and improvement of antifriction properties of cast iron, lead and potash were applied.

Antifriction porous cast iron has following chemical composition:

$C_{общий}$ – 2.2-2.8%, Si – 3-4%, Mn – 0.2-0.4%, P – 0.5-1%, S – up to 0.12%, Pb – 0.5-1%.

Melting of cast iron is produced in usual cupola furnaces. Other melting units ensuring the most reliably assigned chemical composition can be used. Preparation of charge on assigned chemical composition of porous antifriction cast iron is conducted similar to that of standard cast iron. During calculation of charge, gray and mottled cast iron with addition of 10-20% steel scrap should be taken for a base.

Regarding phosphorus and lead, they are introduced in ladle with liquid metal before filling of molds. Besides, metal is treated in ladle with potash

Thus, for each 100 kilograms of liquid melted cast iron during charge preparation there should be:

1) phosphorus 0.5-1 kilogram (with increase for waste);

2) lead 1-2 kilograms, i.e., 2 times more than assigned with respect to chemical composition, proceeding from calculation of its intense burning out and evaporation;

3) potash 0.5 kg in heated powdery form.

In view of the fact that potash is introduced in ladle before the actual filling of molds, it is necessary to preliminarily suspend it with respect to quantity for each ladle and with help of foundry "bells" (copes) to lower to bottom of ladle.

In runner of cupola furnace it is desirable to have temperature of metal 1370-1380°C.

Immediately after withdrawal of cast iron, phosphorus, which is thoroughly mixed, is loaded into ladle, then after some standing slag is removed from surface of ladle and ladle with metal is transported to pouring place.

Before the actual filling of molds, into ladle there are introduced cut pieces of lead, which are mixed together with hot cast iron, and the finished metal is poured into molds.

Entire further process of foundry technology (knockout of molds, cleaning, and fettling of castings) is produced by usually accepted methods.

19. Heat Treatment of Antifriction Porous Cast Iron

Heat treatment of antifriction porous cast iron CAPCh is produced depending upon what microstructure there should be with respect to technical conditions of usage of parts.

Thus, with necessity to have a perlitic structure with ferrite content not more than 15%, APCh is subjected to normalization, and for production of ferritic-pearlitic structure APCh is subjected to annealing.

Normalization gives APCh a fine-grained structure that is uniform for a given batch of parts, since during normalization pearlite obtains a thin fine-grained structure.

Cooling of parts from APCh after heating and holding during normalization is produced in air.

Despite the fact that at present normalization is more widely spread in machine building than annealing, since it is a much more productive operation, requires smaller industrial areas, less equipment and manpower, in production of small parts of bushings and inserts from antifriction porous cast iron one should issue preference to annealing of these parts.

During heat treatment of castings from antifriction porous cast iron it was accepted to produce their annealing in sand, where microstructure of castings was obtained uniform over entire section. Pearlite-graphite, antifriction, porous cast iron possesses high mechanical properties and wear-resistance and at the same time is machined well by a cutting tool, especially in cases of fine-laminar structure of pearlite and fine graphite separations.

Besides, during annealing there is an increase of diameter of pores of cast iron from 1.0-1.25 mm to 1.5-1.75 mm.

Heat treatment — annealing in sand of castings from antifriction porous cast iron is produced under following conditions.

1. Castings after their fettling and cleaning are packed into iron boxes, poured over with dry sifted silica sand, and loaded into special furnace for annea ng.

2. During first 2-4 hours there occurs heating of castings loaded in furnace to 850-900°C.

3. In subsequent 12-16 hours at constant temperature 850-900°C there occurs annealing of cast iron.

4. Then castings in boxes are cooled together with furnace to room temperature.

After cooling castings are cleaned and sent for machining.

Thermal condition of annealing of castings from antifriction porous cast iron can be represented by curve (Fig. 14).

In the given diagram, curve abcd, illustrating change of temperature in time, is constructed by theoretical method, since quantity of hours required for heating, annealing, and cooling will be changed depending upon size and weight of castings. Cooling of castings should be conducted as slow as possible. Temperature of annealing can be increased for the purpose of acceleration of heat treatment process; however, it is necessary to consider that during high-temperature annealing a ferritic structure of cast iron is obtained, lowering wear-resistance and mechanical properties of APCh.

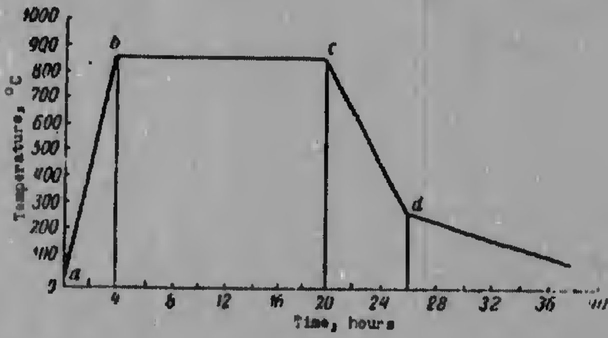


Fig. 14. Curve of annealing of parts from antifriction porous cast iron.

Annealing of parts from APCh during mass production can be produced in ordinary compartment-type furnaces, furnaces of continuous action with protective atmosphere, and also in electric furnaces.

In furnaces with protective atmosphere APCh castings can be annealed without packing and filling with sand, which permits reducing duration of annealing and decreasing fuel consumption.

20. Machining and Assembly of Parts from Antifriction Porous Cast Iron

APCh billets are poured in the form of solid cylinders (ingots), bushings, and shaped billets.

Machine treatment of billets from antifriction porous cast iron should be conducted at high rpm with maximum speeds of cutting and small feeds on the order of 0.1 mm.

Regarding cutting depth, it is applied the same as for treatment of standard cast iron.

Machining should ensure cleanness of working surface of bearing not lower than ∇6.

During assembly of bearings with APCh bushings, observance of following conditions is required.

1. To avoid scoring edge, sliding surfaces should be rounded, and in order not to break oil layer, edges of lubricating grooves should not be sharp.

2. Gap between bushing and journal of shaft should be 20-50% greater than during application of bronze bushings, where magnitude of gap usually composes about 0.003 of diameter of shaft.

3. During assembly it is necessary to especially thoroughly trim working surface of cast-iron bushings by scraping and to polish journal of shaft; besides, it is impossible to permit misalignments, at which due to decrease of gap part of rubbing surface will appear without lubricant, as a result of which scoring and rapid wear will appear.

4. Lubricant should be supplied with force in sufficient quantity; preference should be given to thick lubricant. Grooves for lubricant should be cut on unloaded side of bearing, usually in upper half.

5. For prevention of scoring of journal of shaft preliminary running in of bushings is necessary both at idle and during load. Running in time depends on power of mechanism in which given bushings are installed, and varies from 4 to 12 hours. For improvement of fittability of cast-iron bearing it is recommended to produce pickling of its surface with a 10-15% solution of nitric acid for 2-3 minutes with subsequent washing in running water, neutralization, and penetration in oil at 120-130°C for 1-2 hours.

6. It is necessary to conduct running in of bushings on lubricant with addition of 0.1-0.3% graphite.

7. After running in of bushings, it is necessary to change lubricant for removal of mechanical impurities formed in running in process.

Connecting rod bearings, in view of especially heavy conditions of their operation at sharply variable loads of crankshaft, should not be assembled on bushings or inserts from antifriction porous cast iron, since this creates premature wear of expensive shaft and possible scoring during operation.

21. Physical-Mechanical Properties and Metallographic Peculiarities of Antifriction Porous Cast Iron

Properties and quality of APCh are characterized by following data:

Specific gravity	7.1-7.15 g/cm^2
Diameter of pores.	0.75-1.5 mm
Temporary breaking strength.	40-50 kg/mm^2
Brinell Hardness	100-120
Coefficient of friction with lubricant . .	0.004-0.005
Microstructure	Pearlitic-ferritic, pearlitic, and pearlitic-graphite.

Table 20 shows hardness of APCh as compared to hardness of other antifriction cast irons. Hardness is one of the basic additional control factors for evaluation of qualities of microstructure and also operational qualities of antifriction materials.

Analysis of given table shows that APCh possesses lowered hardness as compared to other antifriction cast irons.

Another no less important factor of porous cast iron, as any antifriction material, especially from the point of view of its operating conditions, is intensity of work of bearings, determined, as it is known, by magnitude of specific load and peripheral speed.

Permissible specific pressures and speeds for different brands of antifriction cast iron are selected by Fig. 15.

On the figure curve 1 corresponds to SChTs-1 and SChTs-2; 2) titanium-copper; 3) with spheroidal graphite and unalloyed malleable cast iron; 4) antifriction porous cast iron.

Thus, from the point of view of permissible specific pressures and speeds APCh can be applied in all units of friction, including parts subjected to heating

Table 20. Hardness of Antifriction Cast Irons and APCh

Group	Brand	Brinnell hardness (upper limit)
Cast iron with laminar graphite	SChTs-1 SChTs-2 Titanium-copper	229
Cast iron with spheroidal graphite	In poured state	229
	After normalization	269
Cast iron with graphite in the form of temper carbon (malleable cast iron)	Unalloyed, pearlitic-ferritic	229
	Copper	260
	Titanium-manganese with spheroidized pearlite	200
Antifriction porous cast iron	APCh pearlitic and pearlitic-ferritic	120

up to 300°C with specific pressure up to 90 kg/cm^2 and peripheral speeds up to 4 m/sec; efficiency of bearings from antifriction porous cast iron, as follows from curve 4 (Fig. 15), will be 90 kg-m/cm^2·sec.

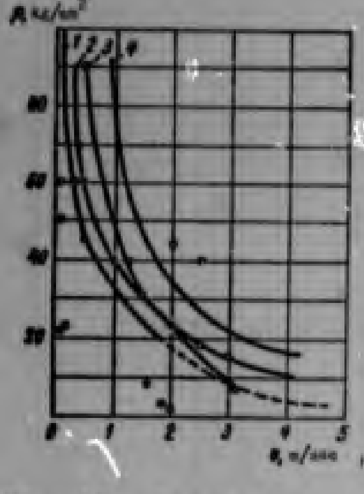


Fig. 15. Permissible values of specific pressure and peripheral speed for antifriction cast iron.

Antifriction porous cast iron, as was shown above, depending upon its assignment can be obtained with pearlitic, pearlitic-ferritic, and in certain cases ferritic-graphite microstructure. The most desirable from the point of view of mechanical properties is a pearlitic structure and pearlitic-ferritic with ferrite content not more than 15%.

As it is known three basic varieties of pearlite are distinguished in metallography, namely: fine laminar pearlite (Fig. 16a), coarse-laminar (Fig. 16b), and very coarse-laminar (Fig. 16c), of which the fine-laminar variety is given preference. Pearlitic cast iron does not require annealing; for production of a pearlitic antifriction porous cast iron, its normalization is sufficient. By virtue of great resistivity to friction, pearlitic APCh can be applied with success for those parts which accomplish considerable work of sliding friction, as for example pistons, piston rings, cylinders, pinions, and carriage. Pearlitic APCh is easily machined.

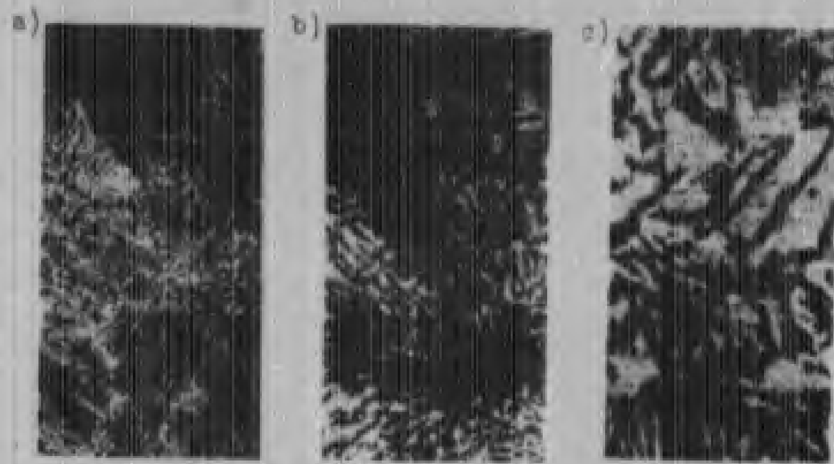


Fig. 16. Microstructure of pearlitic cast irons.

A flaw of microstructure of finished parts from APCh is presence of cementite — it leads to raised hardness and brittleness, and is due to insufficient annealing or a raised content of manganese in cast iron. Presence of laminar graphite also worsens microstructure of APCh.

If parts from APCh have to be subjected to sharp abrasion in operation, pearlitic structure on surface of APCh is extremely useful since it increases wear-resistance of cast iron.

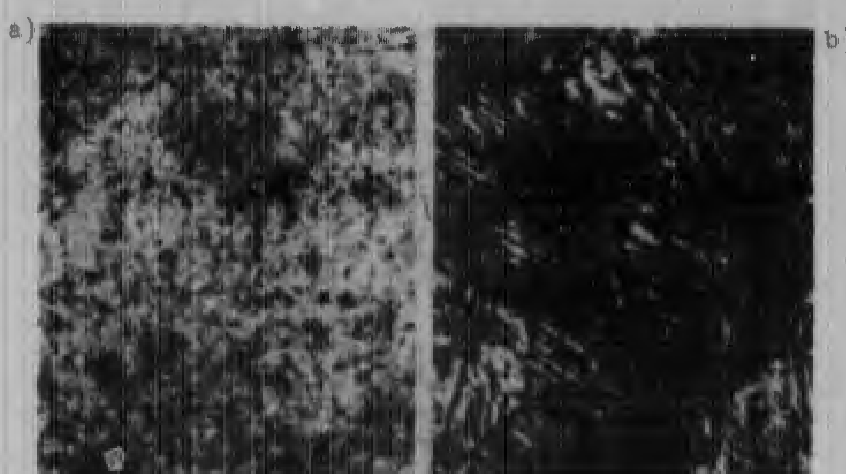


Fig. 17. Microstructure of pearlitic antifriction porous cast iron.

APCh with fine separations of laminar graphite, structure of thin sorbitic pearlite (Fig. 17), and raised hardness resists wear well, and therefore can be applied as antifriction material for sliding bearings. However, it is necessary to consider that plates of graphite may cause chipping of metallic base of cast iron and its destruction under friction. In this respect APCh with spheroidal graphite possesses best antifriction properties, since by virtue of spherical form of graphite it scarcely bothers metallic base of cast iron. Therefore, modification of antifriction porous cast iron by magnesium is a problem of paramount importance. It is necessary to note that it is possible to give desirable porosity to any kinds of antifriction cast iron by means of introduction of potash.

22. Field of Application of Antifriction Porous Cast Iron

With respect to its antifriction and operational qualities, APCh is designed primarily for replacement of sharply deficient and expensive tin bronzes.

Table 21 contains a list of operation tested parts from antifriction porous cast iron applied instead of other materials with indication of character of load.

Table 21. List of Operation Tested Parts from Antifriction Porous Cast Iron

Designation of machine	Name of part	Material of replaceable part	Character of load
S-80 tractor	Roller bushing	Br OTsS6-6-3	Impact
ZIL-150 and ZIL-5 automibles	Main bearing (insert)	B83	The same
Gear milling machine	Bushing	Br.OF10-1	Gentle
Machine for cutting level pinions	The same	Br.OF10-15	The same
Cam press	Connecting rod bushing	Br.OF10-0.5	The same
Grinding machine	The same	Br.OF10-0.5	The same
Forging machine	Insert of cam of transverse slider	Br.OF10-0.5	The same

During manufacture of bearings from antifriction porous cast iron instead of bronze, it is necessary to ensure proper machining, gaps, and their thorough assembling. Besides, it is necessary to consider such elements of operating conditions as specific pressure, speed, conditions of lubricant, and state of conjugated part.

Antifriction porous cast iron, along with other anti-fiction cast irons, can find application in following machines and mechanisms:

1) lathes, milling, worm cutting, grinding, sharpening, drilling, and slotting machines;

2) hammers, presses, and other forging and pressing equipment;

3) crushing equipment (runners, crushers, rollers, ball mills);

4) lifting and transport mechanisms (bridge cranes, turning mechanisms,

hydraulic mechanisms, railroads, excavators, winches, electric locomotives);

5) mechanisms and undercarriage of tractors;

6) steam turbines, pumps, and compressors;

7) in mining and metallurgical industry.

APCh along with other described porous alloys can replace cermet antifriction materials during manufacture of sliding bearings.

Quality of contact surface of insert from APCh for journal of shaft is determined by color and is measured by number of spots on 1 cm^2 of surface. With precise scraping there should be not less than 10 spots on 1 cm^2, during rough scraping 3-5 spots on the same area.

APCh, by possessing lowered hardness as compared to other antifriction cast iron, is scraped well and can go for manufacture of inserts.

Application of antifriction porous cast iron in the form of cast bushings or inserts will sharply expand region of its use in machines and mechanisms both during gentle and impact loads.

Preliminary Inferences

Method of production of antifriction cast iron for the purpose of increase of its antifriction properties by means of introduction of up to 10% lead is known by author's certificate No. 64138 on class 18,1/20, issued to H. H. Sirot on order No. 85/322661 from 9 Aug 1943. However, it did not receive practical application till now.

Increase of antifriction properties of APCh (author's requisition No. 558054/22, registered by Committee on matters of inventions and discoveries attached to the Council of Ministers of USSR, 28 September 1956, class 18, subclass d, group 1/20) occurs mainly due to its microstructure, porosity, heat treatment, and insignificant introduction of lead. The most desirable is a pearlitic structure and pearlitic-ferritic with pearlite content not more than 15%.

If till now such additions as Na_2CO_3, $BaCO_3$, and $CaCO_3$ were applied only for the purpose of desulfurization of cast iron, in production of APCh its treatment by potash is intended primarily for obtaining its porosity.

Recently in units of friction in machines, antifriction cast irons of different brands find application for replacement of bronze.

However, they cannot completely replace tin bronzes since they are applicable only during gentle load and in restricted limits of pressure and peripheral speed.

With peripheral speed not exceeding 0.25 m/sec, bushings from antifriction cast iron can work at specific pressure 400-450 kg/cm^2, and with increase of speed to 1 and 3 m/sec pressure should be lowered to 100-120 and to 20 kg/cm^2. Good antifriction material in addition to low coefficient of friction and sufficient strength should have proper porosity, ensuring seepage of lubricant.

There is developed a method of manufacture of antifriction porous cast by means of introduction of lead into it and its treatment by potash. Chemical composition and conditions of heat treatment of such cast iron are selected with calculation of production of sufficient porosity and antifriction ability, high strength of pearlitic and ferritic-pearlitic structure

Gaps between APCh bushings and journals of shaft should be made 15-20% greater than in bronze bushings.

Antifriction porous cast iron is primarily designed for replacement of bronzes of brands Br.OTsS6-6-3, Br.OTsS5-5-5, and Br.OF10-1. In recent years APCh began to be applied also for worm pinions in low-speed transmissions with the most viscous lubricant at which losses of power on stirring and spraying of oil are not too great, and also for replacement of aluminum bronzes and even low-tin babbitt.

Physical and technical properties of antifriction porous cast iron are characterized by following data: specific gravity 7.1-7.15 g/cm^3; ultimate tensile strength 40-50 kg/mm^2; hardness HB — 100-120 kg/cm^2; coefficient of friction with lubricant 0.004-0.005.

Field of application of APCh is wider than that of known antifriction cast irons, characterized by following data:

Specific pressure . . 80; 40; 32; 24; 20 kg/cm^2

Peripheral speed. . . 0.1; 0.5; 1.0; 1.0; 2.5 m/sec

Efficiency. . . . . . 8; 20; 32; 48; 50 kg-m/cm$^2\cdot$sec.

Hardness of shaft or another surface operating in conjunction with APCh should always be considerably higher than the latter. It is possible to also apply steel bushings poured with APCh by centrifugal method, which is hardly economical however. Monometallic inserts from APCh alone, without any base, is preferable.

Conclusion

Among antifriction materials, alloys based on iron and aluminum occupy an even greater place. Cast iron and aluminum satisfy in the very best manner ever increasing requirements of designers in obtaining necessary mechanical properties, lightening weight of parts, and also of technologists in their tendency to apply metals that are machined well by cutting tool with good foundry qualities.

At the same time ever increasing speeds of machines and mechanisms with growing loads and specific pressures place questions of temperature condition of work of bearings first.

Cermet pseudo alloys, along with positive factors, possess less strength as compared to cast alloys. Besides, they require expensive pressing equipment and dies, especially for large parts.

In light of everything presented, it is possible to say that among bearing alloys, which include babbitt (tin, lead, and aluminum), bronze (tin, lead-tin, and lead), powder pseudoalloys from iron or bronze powders with graphite, antifriction porous alloys described by us, (alcusip and antifriction porous cast iron) can find application primarily as bushings and inserts in units of friction of machines and mechanisms. Application of alcusip in a wider scale requires further study.

Antifriction porous alloys based on aluminum and iron not only are substitutes of above-enumerated alloys, but possess best parameters and best antifriction properties with lowered coefficients of friction.

Antifriction porous alloys considered by us exclude necessity of their application on a steel band, since they are simpler and more economical to apply in the form of completely cast bushings, inserts, or shaped billets.

Porosity of considered antifriction alloys this is such a factor that very favorably affects lubricant, assignment of which is not only decrease of friction of conjugated parts, but also removal of products of wear cooling of journal and inserts, and protection of treated surfaces from corrosion.

Practice of operation of different machines and mechanisms in which alcusip and antifriction porous cast iron were applied, clearly confirms exclusively the important value of porosity of antifriction alloys.

Manufacture of rubbing surfaces of machine parts and mechanisms from porous alloys practically will lead not only to decrease of forces of friction, but also to increase of life of machines and mechanisms, and also to decrease of their weight, which will give considerable economy of means and materials to our People's economy. For more successful and rapid introduction of the described new antifriction porous alloys, friendly combined work of designers, mechanics, technologists, and metallurgists of enterprises is required.

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