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CHEMICAL AND CHEMICAL TECHNOLOGY, PART II. TRANSACTIONS (SELECTED ARTICLES)

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MODERN METHODS OF INVESTIGATING LIQUID FRICTION BEARINGS WORKING IN AGGRESSIVE MEDIA

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ABSTRACT: The article deals with the study of the wear of metals in an aggressive medium. This study requires the application of a special method and devices. To investigate the wear of metals in an aggressive medium M. M. Khrushchov and M. A. Babichev developed a special laboratory friction machine, the X2-M. This machine permits carrying out investigations on the friction scheme of a solid disk or a sample of the investigated metal, whereby the disk and sample are submerged in a liquid medium bath. I. V. Vasilyev and A. D. Gopins performed operations on the selection of material for friction pairs working in an alkaline medium in weak sulfuric acid. These operaions were performed on the MT-1 friction machine. During 1953-56 Ye. V. Lyalin was engaged in the study of slide bearing operation in lubrication with 92% sulfuric acid. He also investigated hardness and friction surface purity changes. It was established that the corrosive medium appears to be the basic factor reducing the surface hardness. Orig. art. has 1 figure and 8 formulas. English Translation: 9 pages.

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(09)English Title
DETERMINING THE MECHANICAL PROPERTIES OF METAL OF WELDED LOW ALLOYED SEAMS BY THEIR CHEMICAL COMPOSITION

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ABSTRACT: It is established that the mechanical properties of welded seam metal in a thermially non-developed state are subject to the additiveness law with the investigated concentrations of the alloying elements. Formulas are given for an approximate calculation of mechanical properties of seam metal by their chemical composition. It was established that molybdenum, at a content of up to 1%, not only raises the strength characteristics of seam metal, but also increases δ and Ψ. The positive effect of aluminum on plastic properties of seam metal. A check of formulas (1), (2), and (3) after Langer and Frumin data (5) (with an introduction of corrections for the cooling rate, because in the mentioned work the cooling rate on the axis of the seam equals $4.2^{\circ}C/s$) has shown that deviations of calculation values from the actual ones do not exceed 10%. Orig. art. has 2 figures, 5 tables, and 5 formulas. English Translation: 11 pages.

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MODERN METHODS OF INVESTIGATING LIQUID FRICTION BEARINGS WORKING IN AGGRESSIVE MEDIA

L. I. Mamon and D. V. Galivets

In operation, at chemical plants, are machines and devices with friction units, lubricated by an aggressive medium. These are inserts of slide bearings, interstage bushings of multi-stage centrifugal pumps atec.

By studying the operation of slide bearings in aggressive media many authors (M. M. Khrushchov and M. A. Babichev, 1955) have noticed that the problem about wear resistance of metals in the presence of aggressive liquid media has almost not been investigated (1).

In this connection this problem represents greater practical and scientific interest in connection with the introduction of mechanization into various technological processes. The study of wear of metals in an aggressive medium requires the application of a special method and devices. The effect of an aggressive liquid medium may differ substantially in dependence upon the amount and method of supplying the medium to the friction surface, upon the temperature of that medium and many other conditions.

M. M. Khrushchov and M A. Babichev to investigate wear of metals in an aggressive medium created a special laboratory friction machine X-2-M. This machine allows to carry out investigations by the friction scheme of a solid disk or a sample of the investigated metal, whereby the disk and sample are submerged in a bath with liquid medium. For this the spindle, on the lower end of which is available the disk from ultrahard alloy, situated vertically, and the bath with aggressive medium can be fed downwards; under the bath is situated an electrical heater, allowing to maintain the temperature of the liquid medium at a desired level.

At the NIIKHIMMASHE I. V. Vasilyev and A. D. Gopius carried out operations on the selection of material for friction pairs, working in an alkaline medium and in weak sulfuric acid. The operations were carried out on the friction machine MT-1, imitating real working conditions of a bearing. Used was also the generally known friction machine by Amsler and the X2-M machine, on which preliminary tests of bearing materials were carried out.

I. V. Vasilyev proposes in addition to mechanical characteristics of the friction process (wear, friction coefficient etc) to consider also the electrochemical processes, taking place on the surfaces of friction materials and characterized by the change in electrode potentials.

If the friction surface is covered with protective films, is observed a jump in potential into negative side, and if on the friction surface are no protective films, then the metal dissolved, the electrode potential remains constant in the friction process (2).

The basic problem of all investigations by the NIIKHIMMASH method, is the selection of a material of satisfactory wear resistance in the given aggressive medium. The magnitude of friction coefficients, consumption of energy, hydrodynamic factors are not considered by the NIIKHIMMASH method.

At the Moscow Institute of Chemical Machine Construction, Ye. V. Lyalin in 1953-56 was occupied in the investigation of slide bearing operation at a lubrication with 92% sulfuric acid (3). The delivery of lubricant, i.e., sulfuric acid, into the friction unit when testing various combinations of metals of friction pair, was by drops (60 drops per minute), which gave the possibility of obtaining comparative data. Tests were carried out with insert samples of "kolodka = Lock" type without upper cover. The pressure to the bearing was realized from below upwards through a loaded device system, made in form of a movable parallelogram. To measure the friction moment was accepted a weighting device with horizontal deflection of the yoke, which were measured with an indicator by the scheme adopted at the Skoca plant. By the obtained friction moments were carried out determinations of the conditional friction coefficients.

Ye. V. Lyalin mentions, that for all combinations of materials of friction pairs (steels and chromous cast irons), the friction coefficients have, approximately, one and the same value.

The friction coefficients f = 0.0019 - 0.007 which points toward the operation of the friction pairs at a liquid friction condition.

The temperature of the insert was measured with thermometer, inserted in the opening in the insert at a distance of 2 mm from the working surface of the sample. After the operation the samples were subsequently washed in a hot solution of calcinated sodium, water, alcohol, and then desiccated in the air, afterwhich they were measured with a micrometer in two mutually perpendicular directions. The testing of bearing materials in the stand after determining the friction coefficient and wear was carried out with a total duration of 30 hours.

The weighty wear of journals at all other conditions equal for one and the very same metal is greater, than the weighty wear of the insert.

Ye. V. Lyalin also investigated hardness and friction surface purity changes. Hardness was determined by the method of impressing a diamond pyramid prior and after the testing.

It was established, that the corrosive medium appears to be the basic factor, reducing the surface hardness. Lubrication with high concentration sulfuric acid is due for the rapid processing of friction pairs.

Independent from the basic purity of the friction surface (from fifth to tenth class) which was determined on the Abbots profilometer within a certain time (20-60 minutes) the surface acquires irregularities, corresponding to 6 + 7 class of purity, which remains stable during the period of the entier further operation.

Ya. V. Lyalin only established, that the wear of the journal was greater than the wear of the insert, without explaining the causes of this phenomenon, although it is generally known, that in slide bearings the journal remains practically unworn. This also pertains to the operation in an aggressive medium (2).

To investigate slide bearings, working at nitric acid solutions of various concentrations, at the "equipment of chemical plants" faculty DKHTI was mounted an experimental installation, schematically depicted in the drawing. From the known experimental installations our installation differs by the driving originality and by the delivery of lubrication.

Investigation of sliding bearing operation during their rotary movements with a nitric acid lubrication on the given installation allows to determine:

(1) forces, moments and friction coefficients;

(2) wear in the friction pairs;

(3) hydrodynamics of the bearing - pressure in the lubricating layer and film thickness.

To assure testing of several samples, which is very important at long lasting experiments the installation was made with two perfectly identical bearings.

The tested bearings are situated on conical parts of cantilever ends of the lower guided shaft, which was maintained in the center part by two auxiliary sliding bearings with fluoroplastic bushings 4. The lower slave shaft 1 and the upper master shaft 2 were made with high accuracy and have a pulsation relative to the centers of no more than 0.015 - 0.02 mm; the shaft material - stainless steel EI-654, is stable in nitric acid.

Rotation by the electric motor to the upper shaft and from the latter to the lower slave shaft is transmitted respectively by two pairs of wedges shaped belts. The center pulley of the upper shaft and the pulley of the lower shaft are made from individual disks, connector with each other by adjusting bolts, which gives the possibility of controlling belt tension at constant intercentral distance. Controlling the revolutions of the lower shaft is carried out in stages by changing the pulleys of the upper shaft of the installation and the shaft of the electric motor. An AC motor is mounted, with a capacity of 7.5 kw and 1415 rpm-s.

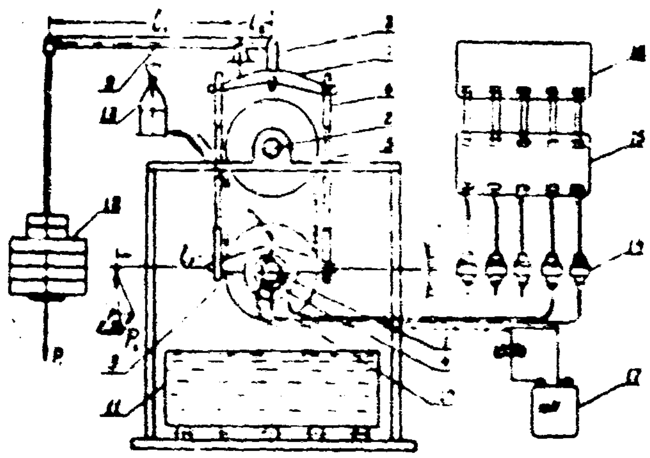

Figure 1. Scheme of installation for testing sliding bearings, working in aggressive media.

KEY: (1) lower slave shaft; (2) upper master shaft; (3) yoke; (4) bushing; (5) suspension (6) & (8) sleeve pieces; (7) beam; (9) lever; (10) disassembling pulley; (11) bath with aggressive medium; (12) weights; (13) flask with lubrication; (14) mess doses; (15) booster; (16) oscillograph; (17) milli-voltmeter.

The shaft journals in the tested bearings are detachable, formed by bushings, sitting on cone ends of the lower shaft, on a shaft fixed stationary by clamping nuts.

The loads to the tested inserts are applied with the aid of two parallel lever systems, each one of which consists of: yoke 3 with pressed in insert 4, two suspensions 5, consisting in turn, of end hooks 6, connected by a control pin with right and left threads at the ends, upper yoke 7, suspended in the center from ear 8, connected with lever 9, on the other end of which are suspended gyros.

To reduce friction all conjugated yokes with suspensions and of the latter with yoke and ear right made on solid knife prisms. The accuracy of measuring friction parameters in the investigated bearings depend in many respects upon the proper adjustment of the mentioned conjugations, so that the contact should be only over the line of knife sharpness.

During the measurements is necessary, that the yokes with inserts should turn perpendicularly to the axis of the shaft at a small angle, in order that the inserts should work by their treated part, to avoid sharp jumps in the fixed values - forces moments and friction coefficient.

Since the bearing load is broad through the movable parallelogram, consisting of yoke, suspensions and beam, then the insert with yoke during the rotation of the journal, originating by the friction force, turns in direction of motion of the journal.

Measurement of the friction moment is realized by equilibrating the yoke with the aid of a set of weights, placed on small cups, suspended from the lever-dial rigidly connected with the yoke. This equilibration is carried out in such a way, that the lever was always in one and the same position.

The lead value of the set of weights - is the value of the friction forces.

When deriving an equation for the calculation of the friction coefficient we base ourselves upon a position, that the suspensions of the parallelogram are equal between themselves, and the beam and yoke are situated in horizontal position.

The friction moment in this case, affecting the bearing, equals

$$M_{mp} \approx Q.f.r$$

where Q - radial load on bearing, f - friction coefficient, r - radius of tested journal. Q - is determined from equality (Fig. 1)

$$P_1 . l_1 = Q . l_2,$$

$$Q = \frac{P_1 . l_1}{l_2},$$

where P_1 - load on the lever; l_1 - and l_2 - arms of applying load.

To equilibrate the friction moment is necessary to apply an equal to it moment

$$M_{ur} = P_2 . l_3,$$

where P_2 - value of equilibrating set of weights, suspended at a distance l_3 from the center of the journal.

$$M_{tr} = M_{ur}$$

$$\frac{P_1 . l_1 . f . r}{l_2} = P_2 . l_3$$

Hence the friction coefficient equals

$$f = \frac{P_2 . l_3 . l_2}{P_1 . l_1 . r} = K . \frac{P_2}{P_1},$$

where $l_2 . l_3$ constant value for the given dimensions of levers and journal $l_1 . r$.

The natural weight of the levers is not considered in calculations, because it is compensated by counterweights.

The installation allows to carry out measurements of hydrodynamic pressure distribution over the surrounding of the bushing. For this purpose in the bushing were drilled five openings with a diameter of 0.4 mm. To measure the pressure in each point are used electrohydraulic mess dosages of membrane type with wire resistance elements, which consist of an assembled cylindrical body with threaded connections in the center of the working element - membrane. In the mess doses are placed four wire resistance elements at 200 ohms each, two of which appear to be working and are glued on the membrane. Two other sonsing elements, glued on the body of the sensing elements, appear to be compensating (temperature) and are not subjected to deformation.

The membrane with the aid of threaded conncection with lead pressing of the bits between two halves of mess dosage bodies. In the first half of the mess dosage are placed sensing elements and connecting wires. In the second half of the dynamometer (mess dosage) is supplied over small pipes the lub (acid) under a pressure from each point over the circumference of the bearing. The working and compensating sensing elements of the dynamometer appear to be arms of a sensitive measuring bridge of AC current, which serves for the conversion of mechanical deformation into electric oscillations, and are connected to the inputs of an electron amplifier.

The set of the measuring apparatus includes:

1. Electrohydraulic mess doses (dynamometers);
2. six channel electron amplifier (booster) TU-6M;
3. voltage stabilizer;
4. magnetoelectric oscillograph MPO-2.

The wear of the bushings is determined by the method of the cut out holes. For this purpose is used the UPOI-6 instrument. The method of determining the wear of the holes by the arrangement in length normally in direction of the friction.

For the concave internal surface of the bushing the value of the linear wear is determined as difference in depth of the hole which was initially applied and remaining after the wear, i.e.:

$$\Delta h = h_1 - h_2 = 0{,}125\,(l_1^2 - l_2^2)\cdot\left(\frac{1}{r} - \frac{1}{R}\right)$$

where l_1 - length of initial hole; l_2 - length of hole after wear, r - radius of diamond cutter of the instrument. R- radius of tested bushing.

Linear wear of the outer surface of the removable bushing, serving as shaft journal, is determined by formula

$$\Delta h \quad 0.125(l_1^2 \quad l_2^2)\cdot\left(\frac{1}{r}+\frac{1}{R}\right)$$

The installation of the equipment with a supplying system of the investigated bearings with a dosaged amount of lub (nitric acid), which is fed to the friction surfaces by gravity flow from a specially mounted bottle. On the journal the lub goes in drops into the center of its part.

Since the ratio of journal length to the diameter equals in our case 40/70 $\approx$ 0.6, then the delivery of lub in one point is perfectly sufficient.

Investigation of slide bearings from various journal and bushing materials is carried out at various specific pressures on the friction surface and at various rates of journal rotation. From literature data is known, that at identical wear conditions (friction materials, condition, lub) after treating in a friction pair is established a definite optimum surface roughness, which does not depend upon the initial and can be smaller or larger than the initial. Knowing same, it is possible to fix the processing and to reduce wear.

For the purpose of changing the nature of change in microgeometry of journal and bushing surfaces in the process of working in an aggressive medium as up to the test as well as after the test are taken profilograms of surface quality - on the BEI caliber profilogram.

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DETERMINING THE MECHANICAL PROPERTIES OF METAL OF WELDED LOW ALLOYED SEAMS BY THEIR CHEMICAL COMPOSITION

B. D. Lebedev

The mechanical properties of seam metal appears to be one of the important characteristics of a welded joint, and they should be considered when developing technological processes. This acquires special importance when new types of steel are welded, the assortment of which is continuously expanding. At present time there is no method of determining the mechanical properties of welded seam metal by calculation and in each individual case is necessary to follow the experimental selection method of the welding technology. This is explained by the fact that the mechanical properties of welded seam metal depend upon many mutual factors the main ones of which are: chemical composition and rate of cooling.

The effect of ehcmical composition of the metal of seams on their mechanical properties have been investigated in several operations (1, 2, 3, 4, 5, 6). When carrying out the experiments in the mentioned investigations the seam metal, in addition to the alloying element, had a maximum amount of admixtures, always present in steel: C, Si, Mn, S, P and, in this way, the phenomenon of alloying elements was investigated on compositions, taking place during the welding. But not all authors observed an identical picture, but nonetheless it can be considered, that the nature of the effect of manganese, silicon, chromium, nickel, molybdenum and copper on the mechanical properties of seam metal in initial state (without thermo processing) has been qualitatively determined.

For the purpose of establishing quantitative dependences was conducted this examination. The published data appear to be a part of the calculation method to determine the mechanical properties of welded seam metal and their utilization should be preceded by a calculation of the obtained chemical composition. To exclude from investigating the cooling rate in the subcritical range of temperatures affecting the mechanical properties the entire work was carried out at a constant welding condition on samples of identical dimensions (q/v = 7500 cal/cm). The cooling rate on the axis of the welded seam, calculated by N. N. Rykalin (7) equations at an instantaneous temperature of 600°C, equaled 2°C/sec (method of determining the effect of cooling rate on the mechanical properties of the metal of the seam is proposed to explain in a separate report).

Before the work was carried out it was established by preliminary investigations, that reinfrocement of the metal of welded seams at simultaneous alloying of same with several elements in small amounts is approximately subject to the law of additiveness. Alloying of seams is realized during the welding with powder wire, having in its composition the investigated elements. We investigated the effect of C, Mn, Si, Ni, Cr, Mo, W, Cu, Al and Ti. When the first series of experiments was being carried out the wire was prepared with various content of one of the alloying elements: in the other series each wire contained in its composition two alloying powders in various amounts. The alloying elements were combined into groups by the following manner: Mn-Si, Cr-Ni; C-Cu, Al-W, Ti-Mo.

For each combination of elements were prepared 9 wire compositions, whereby the constant composition of one element corresponded to three different concentrations ot another element. In Table 1 are given calculated contents of alloying mixtures in the metal of seams, which should be obtained during the welding with chromium nickel wire. It is evident from the table, that the mentioned method allows to examine the change in the mechanical properties of the metal of the seams when the chromium concentration for three different by nickel seam groups and to establish on these samples the sought for law at an increase in nickel concentration for different by chromium compositions.

Samples for welding were prepared from boiling steel type St 3 with a thickness of 8 mm with V-shaped division of edges (angle of exposure 60°) and truncation of 2 mm. The dimension of the samples 165 X 100 mm. Welding was carried out with the ADS-000-2 automat at constant flow of reverse polarity at the condition following: I_{sv} = 290 - 310 a, I_d = 33-35 v; V_{sv} = 9.36 m/hr, flux AN-348 A. The process began and ended on the derived plates. From the seam metal of each plate in thermally unprocessed state were cut out two proportional quintuple samples with a diameter of 3 mm for testing of elongation, three samples with a section of 5 X 10 mm for testing impact bending and one sample to determine the hardness of the seam metal. All samples and testing methods corresponded to requirements of GOST 6996-54. The metal composition of each welded seam was determined chemically and by spectral analysis.

By results of mechanical tests of samples were formulated graphs, showing the change σ_B, δ , a_k at an increase in concentration of the investigated alloying element in the seam metal. For each element on the graph, as a rule, were applied three-four curves, on which one was constructed by results of the first series of investigations and the remaining by results of the second series. On the graphs, characterizing a change δ and σ_b, each point represents an average of arithmetical results of testing two samples, on the graphs "a_k - alloying element" - of three samples. The arrangement of experimental results for each group of samples, in a majority of cases, are sufficiently close to rectangular, which gives bases for the replacement of curves, connecting experimental points, with straight lines, equally distant from the applied points, with the aid of the method of smallest squares.

The change in mechanical characteristics with an increase in concentration of alloy in elements by the straight line offers the possibility of evaluating the degree of reinforcement (degree of reducing the plasticity) of the seam metal with the tangent of inclination angle of straight lines to the axis of the abscissa. The actual tangent of the inclination angle represents a coefficient showing the value of change in corresponding mechanical characteristic when into the seam metal is introduced 1% of the alloying element. The values of the tangences for straight lines on one graph are close to each other and this allows to speak about the adherence to the law of additiveness at given concentrations of the alloying elements, considering, that all direct lines are formed for various chemical compositions of seam metal. The sought for coefficient for each element was determined as an average value of tangents of the inclination angle of all straight lines. Drawing 1, showing the effect of carbon concentration, copper, titanium and molybdenum concentration on the strength limit of welded seam metal, illustrate the indicated positions.

Table 1

Recognition Symbols of the Wires	Computed Content of Alloys of the elements of the seams %	
	Cr	Ni
Cr-Ni I	0,5	0,5
Cr-Ni II	1,0	0,5
Cr-Ni III	1,5	0,5
Cr-Ni IV	0,5	1,0
Cr-Ni V	1,0	1,0
Cr-Ni VI	1,5	1,0
Cr-Ni VII	0,5	1,5
Cr-Ni VIII	1,0	1,5
Cr-Ni IX	1,5	1,5

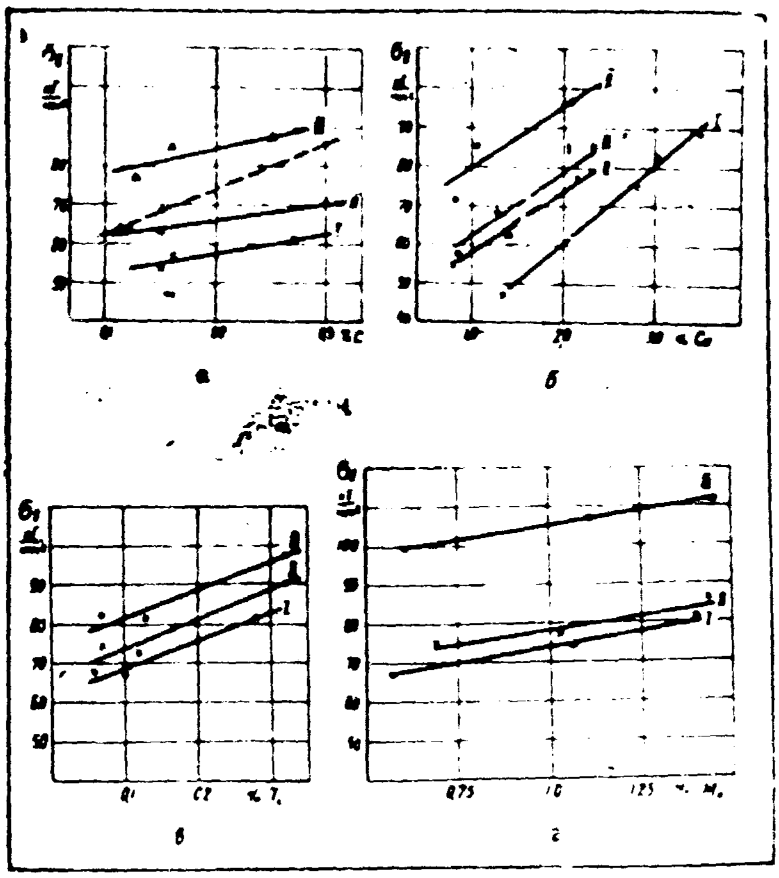

Fig. 1. Effect of concentration of alloying elements on the strength limit of seam metal of various compositions.

а)	I	Cu – 0.85%	Mn – 1.12%	Si – 0.35%	
	II	Cu – 1.3%	Mn – 1.08%	Si – 0.27%	
	III	Cu – 2.15%	Mn – 1.1%	Si – 0.27%	
б)	I	C – 0.10%	Mn – 0.75%	Si – 0.15%	
	II	C – 0.13%	Mn – 1.1%	Si – 0.3%	
	III	C – 0.16%	Mn – 1.15%	Si – 0.35%	
	IV	C – 0.27%	Mn – 1.45%	Si – 0.41%	
в)	I	C – 0.11%	Mo – 0.6%	Mn – 1.13%	Si – 0.43%
	II	C – 0.12%	Mo – 1.05%	Mn – 1.26%	Si – 0.40%
	III	C – 0.12%	Mo – 1.43%	Mn – 1.16%	Si – 0.40%
г)	I	C – 0.11%	Ti – 0.07%	Mn – 1.15%	Si – 0.45%
	II	C – 0.11%	Ti – 0.12%	Mn – 1.4%	Si – 0.6%
	III	C – 0.12%	Ti – 0.31%	Mn – 1.45%	Si – 0.5%

The formula to determine the strength limit of welded low alloy seam metal by their chemical composition has the following form:

$$\sigma_{в} = 4{,}8 + 50 \cdot C + 25{,}2 \cdot Mn + 17{,}5 \cdot Si + 23.9 \cdot Cr + 7{,}7 \cdot Ni + \qquad (1)$$
$$+ 8 \cdot W + 70 \cdot Ti + 17{,}6 \cdot Cu + 2{,}9 \cdot Al + 16{,}8 \cdot Mo \text{ кг/мм}^2$$

In formula (1) the indices of chemical elements indicate the content of corresponding elements in percentages.

Elements, which appear to be energetic deoxidizers (Ti, C, Al, Si) raise the intensity of the silicon - and manganese restoration processes, which leads to a rise in Mn and Si concentration in the welding bath and in seam metal. During the formulation of graphs for elements - deoxidizers the mentioned phenomenon was considered with the aid of coefficients, found in the given work, and value σ_{B} decreased (values δ and a_k increased) by a value, depending upon Δ Mn and Δ Si.

As an example, we will examine a straight line II in Fig. 1 a. The rise in concentration of manganese and silicon at an increase in carbon concentration in the samples, by the test results of which was formulated straight line II, is evident from Table 2. There is placed the actual value σ_b for all three samples. The actual values σ_b are designated in Fig. 1, bv black circles and the dotted line is guided by them. In order to change from the dotted straight line to straight line II were determined values Δ Mn and ΔSi for samples No. 2 and 3 in comparison with sample No. 1.

Sample No. 2	Δ Mn = 0.12%	Δ Si = 0.13%
Sample No. 3	Δ Mn = 0.47%	Δ Si = 0.20%

With the aid of coefficients of formula (1) we determine the strengthening, caused by an increase in manganese and silicon contents.

Table 2

SAMPLE #	CHEMICAL SUBSTANCE %			σ_B FACTUAL
	C	Mn	Si	
1	0,12	1,08	0,27	64,7
2	0,15	1,20	0.40	68,7
3	0,20	1,55	0,47	86 0

Sample No. 2 $\quad 0.12 \times 25.2 + 0.13 \times 17.5 = 5.3$ kg/mm^2
Sample No. 3 $\quad 0.47 \times 25.2 + 0.20 \times 17.5 = 15.3$ kg/mm^3

The actual values σ_B for samples No. 2 and 3 are reduced to the found values of strengthening and in this way are found the given values σ_B for the formulation of straight line II

Sample No. 2 $\quad 68.7 - 5.3 = 63.4$ kg/mm^2
Sample No. 3 $\quad 86.0 - 15.3 = 70.7$ kg/mm^2

The investigated method was used for carbon, silicon, aluminum, titanium for the formulation of graphs of change in σ_B, δ and a_k with an increase in concentration of the alloying element.

The alloying elements present in the metal of welded seams do somewhat differently affect the strength limit and the yield point, i.e., they change the ratio [illegible], but for approximate calculations, as in the given case, it can be adopted:

$$\sigma_T = 0,73 \cdot \sigma_B \text{ кг/мм}^2 \qquad (2)$$

In this report under σ_T it is necessary always to understand the conditional yield point, because on elongation diagrams of all samples there was no yield area.

Between the hardness of the metal of the welded seams and the ultimate strength was established the following dependence:

$$HB = 3.16 \cdot \sigma_B \qquad (3)$$

The coefficients in formulas (2) and (3) were checked by data, published in reports (5, 6, 8) where the ratios between σ_B and σ_T and HV were found to be on an average th: same.

To establish the dependence between plastic properties and chemical composition of welded seam metal was used the above described method. The dependence between relative elongation δ and concentrations Ti and Mo is evident from Fig. 2. On this drawing two graphs show the effect of chromium and copper concentration on the impact viscosity a_k. Formulas to determine plastic properties of the metal of welded seams have such a form:

$$\delta = 50{,}4 - (21{,}8 \cdot C + 15 \cdot Mn + 4{,}9 \cdot Si + 2{,}4 \cdot Ni + 5{,}8 \cdot Cr + 6.2 \cdot Cu + 2{,}2 \cdot W + 6{,}6Ti) + 17{,}1 \cdot Al + 2{,}7 \cdot Mo\,\%; \quad (4)$$

$$\psi = 2{,}32 \cdot \delta\,\%;$$

$$a_k = 23{,}3 - (25{,}7 \cdot C + 6{,}4 \cdot Mn + 8{,}4 \cdot Si + 2{,}4 \cdot Cr + 1{,}6 \cdot Ni + 4 \cdot Cu + (\ 5 \cdot W + 1{,}4 \cdot Mo + 15{,}4 \cdot Ti) + 18{,}0 \cdot Al \text{ кгм/см}^2. \quad (5)$$

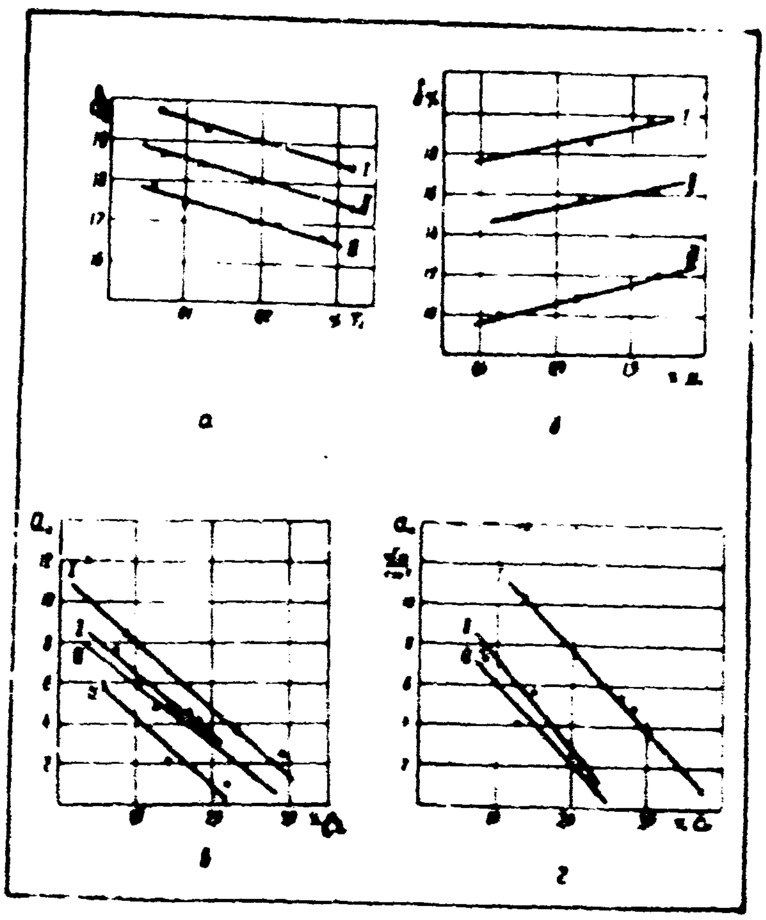

Fig. 2. Effect of concentration of alloying elements on relative elongation and impact strength of seam metal of various compositions.

а)	I	C = 0,11%;	Mo = 1,43%;	Mn = 1,16%;	Si = 0,40%;
	II	C = 0,12%;	Mo = 1,05%;	Mn = 1,26%;	Si = 0,48%;
	III	C = 0,11%;	Mo = 0,6 %;	Mn = 1,13%;	Si = 0,43%;
б)	I	C = 0,11%;	Ti = 0,07%;	Mn = 0,15%;	Si = 0,45%;
	II	C = 0,11%;	Ti = 0,12%;	Mn = 1,4 %;	Si = 0,6 %;
	III	C = 0,12%;	Ti = 0,31%;	Mn = 1,45%;	Si = 0.8 %;
в)	I	C = 0,11%;	Mn = 1,1 %;	Si = 0,4 %;	
	II	C = 0,10%;	Mn = 1,1 %;	Si = [illegible];	Ni = 1,15%;
	III	C = 0,09%;	Mn = 1,0 %;	Si = 0,25%;	Ni = 1,95%;
	IV	C = 0,10%;	Mn = 1,1 %;	Si = 0,25%;	Ni = 3,2 %;
г)	I	C = 0,10%;	Mn = 0,75%;	Si = 0,15%;	
	II	C = 0,13%;	Mn = 1,1 %;	Si = 0,3 %;	
	III	C = 0,16%;	Mn = 1,15%;	Si = 0,35%;	

Attention is attracted by the fact, that aluminum and molybdenum raise the relative elongation (4) and aluminum the impact strength (5). During the welding the positive effect of aluminum is darkened by the effect of other elements, the conversion of which into seam metal Al increases (we keep in mind Si, Mn, C). As result of total effect of aluminum, silicon, manganese and carbon the plastic properties of the seam metal deteriorates. In this way during the alloying of welded seams with aluminum its favorable action on δ, ψ, a_k is brought to an unavoidable increase in Si, Mn, C concentrations.

The formulas given in this report are true (valid) for cases, when the concentration of alloying elements does not exceed values, shown in Table 3, and the summary concentration of all elements, present in the seam metal, equals or is smaller than 6%.

When studying the secondary structure of seam metal the presence of Martensite components has never been detected. A confirmation of this appear to be also mechanical properties of samples. In this way, the formulas derived are applicable to perlite structures of different degree of dispersion.

Table 3

ALLOY ELEMENT	MAXIMUM CONCENTRATION ON METAL SEAMS %
C	from от 0,09 до 0,3
Cr	до 3
Ni	до 3
Mn	from от 0,7 до 2,5
Si	от 0,25 до 1,0
W	до 2,0
Al	до 0,75
Cu	до 3,0
Mo	до 1,0
Ti	до 0,35

to

Conclusion

1. It has been established, that the mechanical properties of welded seam metal in thermally non-developed state are subject to the additiveness law at the investigated concentrations of the alloying elements.

2. The proposed formulas for an approximate calculation of mechanical properties of seam metal by their chemical composition.

3. It was established, that molybdenum at a content of up to 1% not only raises the strength characteristics of seam metal, but also increases δ and ψ.

4. Revealed was the positive effect of aluminum on plastic properties of seam metal.

5. A check of formulas (1), (2), and (3) by Langer and Frumin data (5) (with introduction of corrections for the cooling rate, because in the mentioned work the cooling rate on the axis of the seam equals 4.2°C/sec) has shown, that deviations of calculation values from the actual ones do not exceed 10%.

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