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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

AUTOMOBILE INDUSTRY

(SELECTED ARTICLES)

FOREIGN TECHNOLOGY DIVISION

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UNEDITED ROUGH DRAFT TRANSLATION

AUTOMOBILE INDUSTRY (SELECTED ARTICLES)

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RELATIVE EFFECTIVENESS OF VARIOUS TYPES OF CHROMIUM COATINGS

P. I. Zemskov (Kharkov Tractor Plant)

At the auto-tractor industry chromium coating finds broad application to increase the wear resistance of friction details, especially in these cases, when the details function under difficult conditions, for example upper compression piston rings, valve rods, shafts of water pumps etc.

Chromium coating of such a mass detail, as the shell case of a clinder block, could have brought a greater increase in engine resource, but because of greater energy capacity of the chromium plating process new shell cases are so far not chromium plated. For the purpose of repair at small programs the list of details, subjected to chromium plating, is considerably expanded, including also the shell case.

Chromium coating can be divided into two stages:

1) porous chromium coatings (point, channel and spotty,) obtainable by electric pickling;

2) dense chromium coating.

In recent years greater attention is devoted to the porous coating mainly of channel type.

But basically the retention of grease is investigated, but omitted are the antifriction properties of the coating, much depending upon the width of the channels, dimensions of the plateau, upon the tapering, irregularities etc.

The experiments carried out on dense chromium plating over the rolled surface showed a series of advantages of same before porous chromium plating. Coating with dense chromium posses a poor oil wettability. Retention of the oil is obtained by the process of porous chromium coating, and in this case a surface roughness of the detail is created. But, in spite of the abrasion, the rough surface of the porous chromium layer affects negatively the wear of the conjugated detail, while the coating of the chromium applied surface has no roughness in this case, it possesses much higher antifriction properties, and wears less on the conjugated surface.

Wear of porous chromium is unequal, in the form of shearing action, and the chromium plated surface wears off uniformly, the grease on the surface retained till total wear of the chromium coating layer.

The process of porous chromium coating has a series of technological defficiencies: to obtain an optimum network of cracks of channels or a definite point porosity it is necessary to strictly observe the definite regime by temperature, current density and electrolyte composition.

Optimum channel coating is considered such a coating, which has 15-25 plateaus per 1 mm^2 at a width of the channels of 0.04 - 0.06 mm and chromium layer thickness of 0.15 - 0.16 mm. Actually considerable retrogressions are obtained from optimum channel porosity, which leads to a reduction in antifriction and antiwear properties of the given coating.

The mechanical method of obtaining porosity of chromium coating is simple and gives the possibility of having constant porosity regardless of the chromium plating condition.

In the given investigations antifriction properties of various chromium coatings were compared and their workability was checked for various components of auto-tractor engines: cylinder, piston rings, crank and distribution shafts etc.

Prepared was a series of samples, coated with channeled and point porous chromium. The total thickness of the chromium layer was $\delta = 160 \div 180$ microns, thickness of porous chromium layer $\delta_1 = 40 \div 50$ microns, samples were coated with spotty chromium and chromium according to knurled surface.

In the latter case deepenings were arranged in checkerboard order at a distance of 2 mm from each other. The form of the hollows was - tetrahedral pyramid with 0.5 X 0.5 mm base.

At engine cylinders diagonals of knurling squares were situated along the axis of the cylinders. The depth of the hole equalled 0.18 -

0.25 mm.

Selection of depth volume and knurling step was made with consideration of the thing, that a sufficient amount of grease should be assured and minimum detail wear.

The value of the specific oil capacity was figured with consideration of the volume of hollows and knurling pitch and it was adopted as equal to 0.9 - 1.0 mm^3/cm^2 [1.]

The technology of chromium coating over the knurled surface of the cylinder consisted in the following:

1) ungriding of cylinders under chromination;

2) knurling of hollows;

3) honing to remove hollows burrs;

4) chromium plating (250 g/l of chromium anhydride, 25 g of sulfuric acid, current density D_k = 50 a/dm^2; temperature T = 55°.)

5) thermal treatment (T = 250°, time 2.0 - 2.5 hrs);

6) honing up to 10-11 class;

7) washing.

Porous chromium plating was carried out by the technology adopted at the plant.

To improve the work-in nonchromium, plated cast iron details underwent a sulfocyantion process in a bath of composition [2]: 50% potassium chloride, 40% sodium sulfate, 10% sodium cyanide at a temperature of 560-580° for a period of 2 hrs and subsequent oiling at an oil temperature of 110-125° for a period of 6 hrs. The chromium plated details under went a tinplating process. Tests were carried out under laboratory conditions on the stand (engine SMD) and under exploitation conditions.

Laboratory tests. Laboratory tests of antifriction and wear resistance of various coatings were carried out on the friction machine MT at a pressure of p = 600 kg/cm^2, rates of v = 0.6 m/sec at a limited (8-10 droplets per min) and sufficient (1 drop per sec) grease.

In these investigations the effect of the value of porous chromium plating on wear was tested. Experiments were made at 15, 20, 30, 40, 50, and 60% porosity; the effect of porosity on the wear of the detail and on the wear of the conjugated with the detail was investigated.

The work of the samples with chromium plated surface after knurling was investigated in pair with counter body made of cast iron, babbit, ASM alloy and steel 45.

Laboratory tests showed, that at a small porosity (10-15%) the chromium layer after 3-5 thousand revolutions wear away and can no longer serve as a reservoir for supplementation of the grease. On the chromium plated surface appears lines, which indicate the insufficient amount of grease on the friction surface.

If the porosity is made greater than 50%, the mechanical strength of chromium is reduced - the coating gives lesser service (for example, in piston rings instead of 60 thousand km of automobile run there is only 35-40 thousand km,) and by virture of the appearance of irregularities over the chromium surface there is a sharp increase in friction coefficient and in the wear of counter bodies (engine cylinders.) Consequently, the optimum porosity of point and channel coating with chromium appears to be porosity constituting 30-35% of the chromium layer thickness.

In fig. 1-3 data is given of friction coefficients and wear resistance of various chromium coatings in dependence upon the summary number of revolutions Σ.

Results of laboratory tests showed, that coating with point and channel chromium have antifriction properties, poorer, than dense chromium applied over a knurled surface. Coating with spotty chromium even though it has better qualities in comparison with qualities of the mentioned coatings, but its friction coefficient is almost the same, as in channel and point chromium.

For cylinders and piston rings, the reduction in the friction coefficient is of special importance. According to laboratory tests, surfaces, chromium plated during knurling, have all advantages over porously chromium plated surfaces. Point and channel types of coatings permit introduction of sharp ejections and sharp edges of the channels into the conjugated surface and promote an increase in its wear.

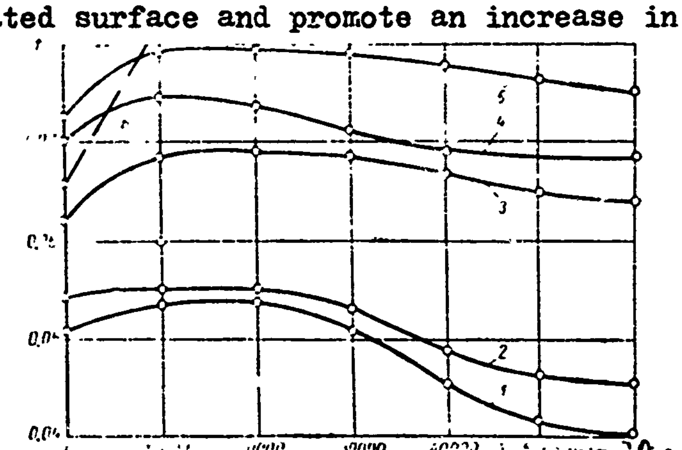

Fig. 1. Antifriction properties of various chromium coatings (tinned): 1 - dense chromium after knurling during work with babbit insert; 2 - dense chromium after knurling during operation with cast iron PK insert; 3 - spotty chromium; 4 - channel chromium with 30% porosity; 5 - point chromium with 30% porosity; 6 - point chromium with 65% porosity.

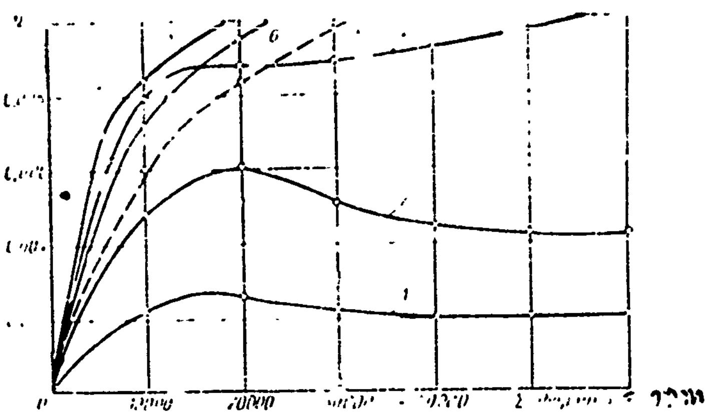

Fig. 2. Wear resistance of various chromium coatings (tinned): 1 - dense chromium after knurling during operation with babbit inserts; 2 - dense chromium after knurling during operation with inserts from cast iron: 3 - spotty chromium; 4 - channel chromium; 5 - point chromium with 30% porosity; 6 - point chromium with 65% porosity.

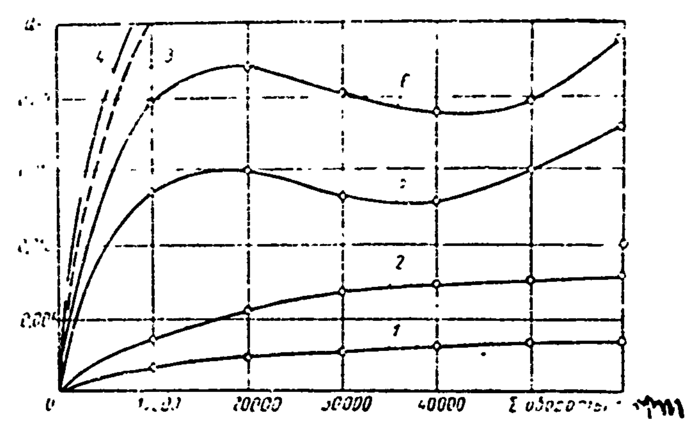

Fig. 3. Wear of counter body by samples with different chromium coating (tinned): 1 - dense chromium after knurling during operation with babbit inserts; 2 - dense chromium after knurling during operation with cast iron inserts; 3 - spotty chromium; 4 - channel chromium; 5 - point chromium with 30% porosity; 6 - point chromium with 65% porosity.

In spotty chromium increased wear is caused by the chipping of chromium particles from irregularly corroded parts of points and abrasive action of these particles.

Dense chromium coating eliminates the possibility of corrosion of chromium particles and introduction of a material into the conjugated surface, by virtue of which it gives a reduced friction coefficient and small wear. After laboratory tests all chromium coatings were subjected worked themselves in well during the rolling. In details without soft coatings after the rolling were here and there observed lines and gripping traces. All this indicates the necessity of applying tinning, sulfocyanation or phosphatization. But preference should be given to the first two processes - tinning is irreplaceable when working in steel and cast iron details, sulfocyanation not only improves the working in, but further reduces wear of cast iron details.

After the tests have been carried out it was explained, that the smallest wear is observed during laboratory tests, in details with chromium coating after knurling; in piston rings (0.002 mm); in cylinders - 0.04 - 0.063 mm. A considerably greater wear was in piston rings - 0.007 mm, in cylinders the wear of 0.10 - 0.12 mm was obtained at point and channel chromium plating (table 1, 2, fig. 4.)

Table 1.

Form of chromium coatings of piston rings	Average wear of first compression ring after 60 hrs of rolling in mm	Average wear of one compression ring after 1000 of testing in mm	Maximum wear of cylinders after 1000 hrs of testing in mm
Point coating:			
porosity 15%	0.007	0.14-0.15	0.10-0.12
porosity 25-30%	0.C06	0.12-0.14	0.10-0.12
porosity 40%	0.008	maximum wear	0.14-0.16
porosity 65%	0.01	ditto	0.20-0.22
Chromium coating after rolled surface	0.002	0.04-0.05	0.04-0.06

In this way, wear of point and channel coating was almost 1.4 - 1.6 times greater than the wear of chromium coating after knurling.

In several cylinders, where piston rings stayed with point chromium worked themselves in well during the rolling. In details without soft coatings after the rolling were here and there observed lines and gripping traces. All this indicates the necessity of applying tinning, sulfocyanation or phosphatization. But preference should be given to the first two processes - tinning is irreplaceable when working in steel and cast iron details, sulfocyanation not only improves the working in, but further reduces wear of cast iron details.

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In several cylinders, where piston rings stayed with point chromium coating, were deep longitudinal lines - traces from wearing and chipping chromium.

Table 2.

Form of chrom... coatings of cylinders	Wear of cylinders after 1000 hrs testing in mm	Wear of piston rings after 1000 hrs of testing in mm	
		First compression RC 48-50	Oil removable
Channel coating:			
porosity 15%	0.10-0.12	0.14-0.16	0.18-0.20
porosity 25-30%	0.08-0.10	0.10-0.12	0.14-0.16
Spotty coating	0.06-0.08	0.06-0.08	0.12-0.14
Chromium coating over knurled surface	0.04-0.05	0.05-0.06	0.10-0.12

It is also characteristic, that wear of cylinders with piston rings coated with channel chromium was also found to be 1.3 - 1.5 times greater than with piston rings with chromium coating after knurling, because chromium coating on rings had entirely no burrs or sharp projections.

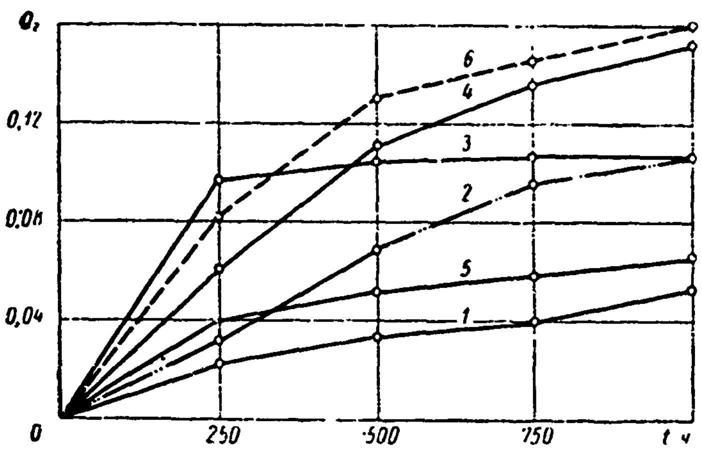

Fig. 4. Wear of piston rings in cylinders with channel chromium plating - of the first compression rings: 1 - chromium after knurling; 2 - spotty chromium; 3 - channel chromium with a porosity of 30%; 4 - channel chromium with 15% porosity; 5 - chromium after knurling (of oil removal rings); 6 - channel chromium with 45% porosity.

The increased wear of piston rings in cylinders with channel chromium plating was observed especially at the time of work-in, which was almost unavailable during the work of rings in cylinders with chromium plating after knurling of the working surface. In fig. 4 the wear of such rings is depicted by a curve with smooth rise in contrast to the curve of ring wear in cylinders, covered with spotty and channel chromium.

Distribution shafts. Distribution shafts of given engines with chromium plated necks and cams were worked in very well also at the time of work-in.

After 1000 hrs of testing the wear of chromium plated necks of the small distribution shafts was almost equal to zero. Slight wear has shown on the cams of the small shafts (0.03 mm) and especially chromium coated cams, working in pairs with sulfocyanated pushers from gray and high strength cast iron.

Chromium coated cams, working with chromium plated pushers, had a somewhat greater wear, apparently, by virtue of the inherent to chromium nonwettability with oil. This should be kept in mind during the restoration of the given detail with chromium plating - simultaneous chromium plating of two details should not be conducted.

At present time to restore the dimension of piston fingers is needed chromium coating with subsequent anode process to obtain channel porosity, necessary for the improvement of finger work in to the lugs of the piston and bushing of the connecting rod.

Porous chromium plating (channel and point) in the work-in process leads to an intensified wear of surfaces - the surface of the chromium as well as the surface of the details conjugated with it.

During the sometimes originating grasping process between a porously chromium plated pin and aluminum alloy of the cam the friction coefficient may reach up to 0.4, and between porous chromium and bronze up to 0.2. Such coefficients even for dry friction are considered considerable.

Chromium plated in that way wears pins more intensively, than nonchromium plated ones, whereby the wear of the pin is different at various places. On the conjugation section with piston cam the pins wear by 45% more, and on the conjugation section with bronze bushing of coupling rod by 33% more, than nonchromium plated pins, while the surface of the cam wear off by 85% more, than during work with nonchromium plated pins. In addition, such a porosity net is rapidly worked up and it cannot serve as an oil reservoir.

A chromium plated surface works considerably better with a porosity net, applied prior to chromium plating of the detail by a mechanical way (knurling.)

Investigations on SMD engines show that after 1000 hrs of tests, the wear of the pin with a chromium plated surface, after knurling, and conjugate with surfaces (the smallest in comparison) with a channel chromium coating.

Various chromium plated details were also tested under exploitation conditions on three MZMA and two GAS-51 engines after capital repair. A part of the cylinders of these engines underwent chromium plating after the knurling, part was chromium coated with channel porosity, part with spotty chromium and some cylinders remained not-chromium coated. In this case hardened rings were used (RC 48-50) from gray and high strength cast iron and unhardened (RB 98-1000.)

Chromium plated piston rings, distribution shafts and crankshafts with various types of chromium plating were also submitted to testing. The work of chromium plated necks of crankshafts during the work with various bearings was checked simultaneously - babbit type and ASM alloy.

In vestigations of ring wear, established in the cylinder with various types of chromium plating, showed the following. The chromium layer with point porosity on the piston rings and the chromium layer with channel porosity on the cylinders wore rapidly and did not serve as a reservoir for the feeding of lubrication and for reduction of friction coefficient between friction surfaces. In some cases such a porosity led to the appearance of grooves on the mirror of cylinders and on the working surface of piston rings due to chipping of chromium particles. Deep point channel porosity led to notching of the chromium layer, toward local chipping and scaling.

The best results, as well as during lab tests, were yielded by chromium plating by knurling. With this type of chromium plating the grooves on the details were absolutely absent and the wear of both conjugated surfaces decreases quite noticeably. And so, wear of chromium plating after knurling cylinders, after the first change of rings, compiled for engines GAZ-51 is 0.04 - 0.06 mm, while the wear of cylinders with channel porosity is 0.10 - 0.12 mm.

Approximately the very same thing was also observed on other chromium plated details. Data on component wears of engines GAZ-51 and MZMA, having various chromium coating, are given in table 3.

In this way, the wear of cylinders, chromium plated after knurling, is lesser than the wear of cylinders, covered with channel and spotty chromium, by 1.7 - 2.5 times.

Table 3.

Friction couples	Wear of GAZ-51 engines (run 65-67 thousand km) in mm				Wear of MZMA engines (run 60 thousand km) in mm	
	Cylinders	Upper compression rings	Cam tips of distribution shafts	Pusher plates	Cylinders	Upper piston rings
Cylinder, chromium coated after knurling, and compression rings from high strength cast iron (RC 48-50)..........	0.04-0.06	0.04-0.06	-	-	0.03-0.04	0.05-0.06
Cylinders, covered with channel chromium, and piston rings from gray cast iron, top hardened (RC 48-50).................	0.10-0.12	0.14-0.16	-	-	0.11-0.14	0.15-0.16
Cylinders, covered with spotty chromium, and piston rings from gray cast iron, top hardened (RC 48-50).	0.08-0.09	0.06-0.08	-	-	0.8-0.10	0.06-0.08
Cylinders from cast iron type SCH 21-40 and compression rings with Cr after knurling...........	0.08-0.10	0.04-0.05	-	-	0.8-0.10	0.03-0.05

Cylinder from cast iron type SCH 21-40 and compression rings with point Cr.......	0.12-0.14	0.10-0.12	-	-	0.11-0.12	0.10-0.12
Distribution shaft with cams, chromium coated after knurling, and steel pushers without coating.....	-	-	0.04	0.02	-	-
Distribution shaft with cams, coated with channel Cr, and steel pushers with out coating.........	-	-	0.07	0.05	-	-

Piston rings in this case wear by 2-3 times lesser, than in cylinders, coated with channel chromium. A set of rings with a chromium coated upper piston ring in cast iron cylinders wears out more rapidly, than nonchromium coated rings in cylinders with chromium coating.

Conclusions

1. Dense chromium coating after knurling possesses good antifriction properties.

2. Dense coating after knurling has high wear resistance and wear off little of the surface conjugated with it. Servicelife of chromium coating after knurling is 2.0 - 2.2 times greater than the servicelife of channel coating, and is by 1.5 - 1.7 times greater than the servicelife of spotty coating. In comparison with hardened cast iron surface the channel type of chromium plating raises the wear resistance of the mirror by 3-4 times, spotty - by 5 times and dense chromium plating - by 8-10 times.

3. Dense coating protects the detail against corrosion. Point and channel types of chromium plating are dangerous by the fact, that acids, forming at definite working conditions of the engine, may penetrate under the chromium layer, forming there oxides, leading to peeling of the chromium.

4. The process of dense chromium plating after knurling is technologically simple, while the process of porous chromium plating is carried out by a strictly definite regime and the slightest deviations from same lead to a reduction in antifriction and wear resistant properties of the given coating. Spotty type of chromium plating has no deficiencies, inherent to channel chromium plating, and is technologically simpler, but its antifriction properties are approximately the same as in channel type chromium plating.

5. The use of dense chromium plating gives an economy in chromium expenditure of from 30 to 50% in comparison with other types of coatings.

6. The chromium plating regime after dnurling can be selected in conformity with the desired hardness and antifriction properties of the chromium, while other coatings do not posess these properties.

7. Dense coating gives the possibility of controlling the oil capacitance of the surface.

In this way, good antifriction quality and high wear resistance of chromium coatings after knurling, allow to recommend them instead of porous chromium.

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HIGH ENERGY IGNITION SYSTEM FOR STARTING A GAS TURBINE ENGINE

Cand. of Techn. Sc. A. S. Shteynberg

At the present time low power gas turbine engines characterize the use of a spark plug, mounted directly in the combustion chamber. Such an igition system of a fuel air mixture (without starting igniter) appears to be simple and convenient in exploitation, but it causes additional difficulties, connected with the possibility of formation of scale on the spark plug electrodes and their overheating.

As is known, the minimum ignition energy is required in this case, when in the zone of the plug is situated at an optimum amount of mixture, close to stoichiometric, and the rate of the stream is small. But it is not always possible to attain these conditions in the combustion chamber, consequently to start the engine, especially under conditions of negative temperatures, and increased discharge energy is needed.

In the practice of planning gas turbine engines a low voltage system of ignition with spark plug of surface discharge is widely used, to the basic advantages of which should be added: relatively low voltage of all elements and communications; the possibility of obtaining a powerful condensed discharge, the energy of which exceeds by hundreds of times the discharge energy of an ordinary high voltage system; the insensitivity of the spark plug of the surface discharge to scale formation, because the discharge in it passes not through the spark gap, but over the surface of a semi-conductor.

As an example of a low voltage system of high energy ignition can serve the ignition system of the English firm Rotaks, used in the Rover gas turbine engine and in engines of other companies.

The principal electrical diagram of the Rotaks ignition system is given in fig. 1. In succession with primary winding 1 of the induction coils are connected vibrator contacts 2 with the spark extinguishing condensator 3 connected parallel to them. When vibrator contacts are opened a pulsation current originates in the primary winding, which transforms into secondary winding 4 into a high voltage pulse current. Transformation of the variable impulse current into constant (DC) is realized with the aid of one semi-periodic rectifier 5. The obtained energy creates a charge in the accumulation capacitor 6 with a capacity of 6 microfarads.

Parallel to accumulation capacitor 6 is connected a blocking resistance 7, through which takes place the capacitor discharge after disconnection of the ignition, thanks to which the possibility of injuring the service personnel with the current is cut off.

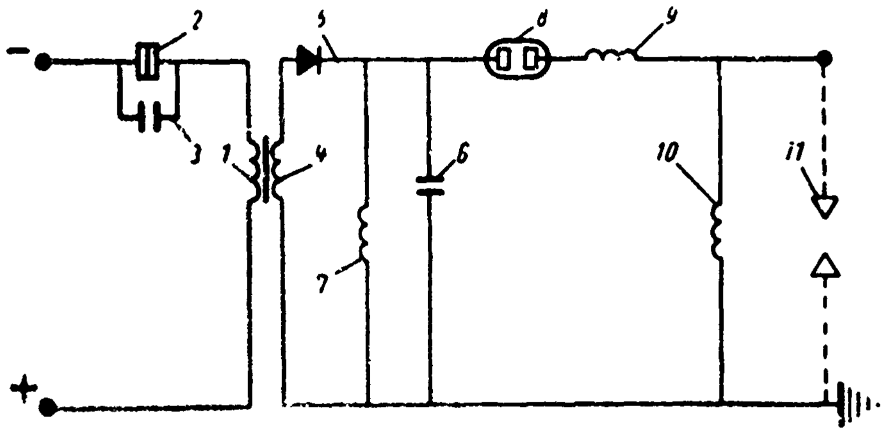


Fig. 1.

The magnitude of the charge, obtained by the capacitor, and the voltage on its terminals, increases in the vibration process of the contacts until it reaches 2 kv. At this voltage occurs the puncture of the spark interval of the gas filled discharger 8 and a high energy spark will pass over the surface of the semiconductor of the ignition spark plug, included between the electrodes.

The presence of rectifier 5 protects the accumulation capacitor against discharge, which may take place in the interval between the pulses.

In the first stage of the process on the surface of the semiconductor are formed incandescent filaments - conduction channels, causing its heating. Since the semiconductor has a positive electroconductivity coefficient, then in proportion to its heating conductivity rises, which causes a further increase in the heating of semiconductor surface. Upon the attainment of a definite temperature comes evaporation of the semiconductor material, and the space between electrodes ionizes. In the second stage of the process an electric discharge between electrodes above the surface of the semiconductor take place.

The ignitability of the ignition system is affected by the duration or time of existence of the discharge spark stage τ_{raz}.

As is known, introduction of inductance into the discharge circuit leads to an increase in the duration of discharge processes in the second spark stage of the process at simultaneous reduction of maximum discharge current value. Consequently the ratio between the duration of the discharge and maximum value of discharge current is selected experimentally, on the basis of conditions of obtaining maximum inflameability of the discharge.

In the Rotaks ignition system the inductance value was selected with such a calculation, that the duration of spark formation would constitute $\tau_{times} \approx 100$ msec. This value was found to be optimum for ignition of the mixture.

To assure the given time of spark formation into the circuit successive to the discharge a small inductance was connected in the form of a throttle-coil 9. When the voltage is fed to the throttle an accumulation of electromagnetic energy takes place in its winding. The piercing voltage, conducted from spark plug electrodes, is delayed and an implication of the discharge processes takes place. The frequency of spark formation constitutes 60 imp/min.

The protective resistance 10, in-parallel connected to the high voltage drive and mass, to which spark plug 11 is connected, protects the accumulating capacitor against possible overloads (overvoltages) in case spark plug contacts have been disrupted.

The energy, reserved in the capacitor Q_{res}, constitutes

$$Q_{зап} = \frac{C u_{пр}^2}{2} = \frac{6 \cdot 10^{-6} \cdot 2^2 \cdot 10^6}{2} = 12 \text{ дж},$$

where C - capacitor capacitance, equalling 6 microfarads; u_{pr} - piercing discharge voltage, equalling 2 kv.

The characteristic of the Rotaks ignition block are small overall dimensions and weight. This determines to a considerable degree the small dimensions of the capacitor. The length of the block is 180 mm, width 141 mm, height 97 mm. Weight of the block is 2.9 kg. The block is intended for one spark plug and is fed from a DC network with a voltage of 24 v.

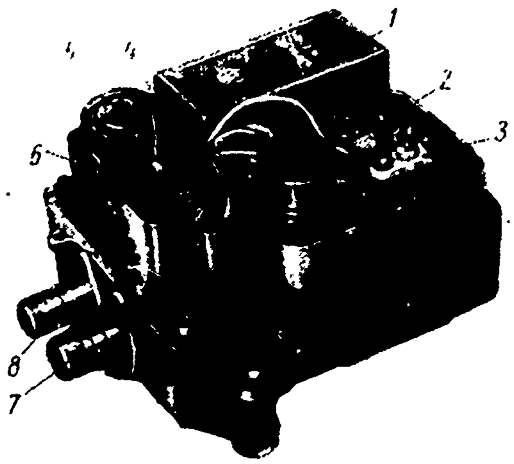


Fig. 2.

The general view of the Rotaks ignition block without cover is given in fig. 2. Block details are found in the magnesium alloy housing, protecting the radio technical devices against the effect of radio interferences, caused by elements of ignition system. Resistance of the ignition block amounts to 500000 ohms.

In line with the accumulating capacitor 1 is mounted induction coil 2 with vibrator 3. To them adjoins the insulating housing, divided into three sections, in which are placed discharger 4, throttle 5 and protective resistance (situated in section 6.) The block is connected into the network with the aid of two plugs 7 and 8.

To investigate the ignitability of the Rotaks ignition system was selected a direct flow combustion chamber of a gas turbine engine with a diameter of 140 mm and 250 mm in length. Through a blade vortex device of the chamber entered about 3.5% of air, through fine openings of the head - about 8%. The total area of chamber openings constituted 71 cm^2. The plane of **spark plug mounting was at a distance of 42 mm from the** sprayer.

The temperature of the air, going into the combustion chamber from a centrifugal compressor, in dependence upon air consumption varied between 30-60°. The outlet from the chamber was open, and that is why the pressure in it approached atmospheric.

Tests were carried out on a cold Diesel engine (GOST 4749-49) at its temperature of 20°.

Parameters	Basic data of fuel spray				
p_m в кг/см²	1,0	2,0	3,0	5,0	10,0
G_m в кг/ч	9,1	13,2	16,9	21,5	30,0
β в град	50,0	60,0	[illegible]	72,0	78,0

A single channel centrifugal fuel sprayer gave a satisfactory fine droplet diffusion of the fuel, beginning with a pressure p_m = 2 kg/cm². In the table are given data on the spraying angle β and timely fuel consumption G_m at various fuel pressures p_m.

During the tests was used a surface discharge spark plug SE-15B (fig. 3,) placed in the chamber at a depth h - 25 mm.

The semiconductive element 1,

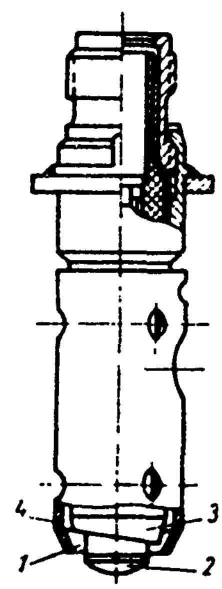


Fig. 3.

was included between the central electrode 2 and body 3, made in form of a segment from ceramic material with a partial content of restored titanium dioxide. The spark discharge of the plug Se-15B was concentrated in the place of installing the semiconductor segment, which faced in direction of the sprayer, which assured better ignition of the mixture.

To feed cooling air in the protective housing of plug 4 an oval cut out is provided.

Test on the evaluation of the ignitability of the ignition system were reduced to depicting the dependence characteristics of minimum fuel pressure before spraying p_m, at which ignition of the mixture took place from the center rate of air in w_o openings.

The tests were carried out in the following order:

1. Constant rate of air was set in the holes.

2. A definite fuel pressure was created before the spraying (fuel was not fed through it.)

3. Opening the electromagnetic valve before the spraying for a time of not more than 5 sec to the moment of mixture ignition.

If within the period of 5 sec. there was no ignition, the starting of the engine was considered as not existing.

4. To remove fuel residues and to cool chamber walls within a period of 2 min before each start the engine was air blasted.

5. At each regime were carried out three engine starting tests, whereby the starting was considered successful, if the ignition of the mixture took place no less than in two cases.

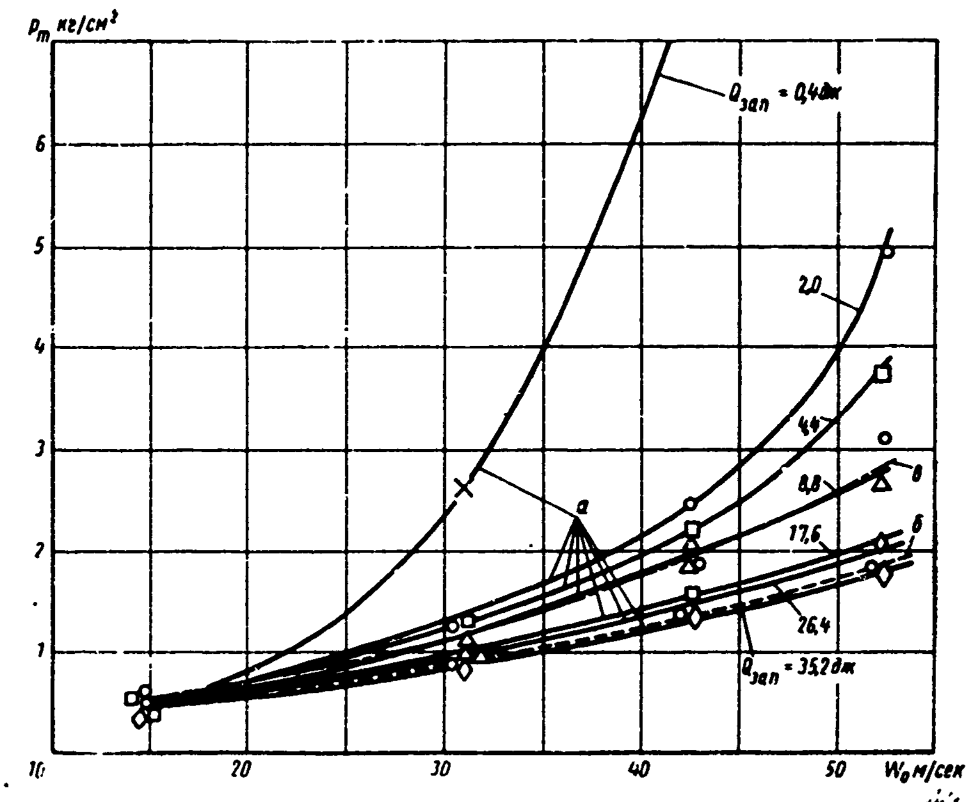
To test the ignition of the Rotaks system an investigation was carried out on the energy effect of the discharge capacity on the ignition of the mixture. For this purpose an experimental laboratory type ignition system was used, developed by N. G. Maksimov and B. M. Smushkowich, which allowed with the aid of taking on various capacitances by the capacitors and discharges with different piercing voltage to change the accumulated energy Q_{zat} in wide limits.

The engine starting characteristics given in fig. 4 were obtained at constant values of the accumulated energy Q_{res} = 0.4; 2.0; 4.4; 8.8; 17.6; 26.4 and 35.2 joules. The frequency of the discharge pulses constituted in this case 2-4 per sec.

When examining the characteristics given in fig. 4 of the experimental ignition system (a,) of the Rotaks system (b,) of the Rotaks system without throttle (c) it follows, that in the area of slow stream velocities (w_0 = 15 m/sec) where the most favorable conditions do exist for ignition of the mixture, the effect of discharge energy is practically not exerted on the poor boundary of the ignition zone. But in ratio to increase in velocity the effect of discharge energy begins exerting itself very sharply, especially in the area of its low values. At high discharge energy values the change in its energy has very little effect on the ignition boundary, consequently, apparently, the creation of an ignition system with accumulated energy of more than 10-12 joules appears to be unrational.

The present experiments were made on an experimental igition system of larger overall dimensions. The creation of an industrial sample of an ignition block of small dimensions appears to be a complex electrotechnical problem.

In fig. 4 the starting characteristic of the engine with Rotaks ignition block (curve b) is given. At an accumulated energy of 12 joules this system behaves as the experimental with an accumulated energy of 35 joules. This is explained by the presence in the Rotaks system of a throttle, which allows to increase the duration of spark formation to 100 msec. i.e. to a value, considerably exceeding the time of spark formation in the experimental system. Ignition of the mixture, as a rule, took place with the Rotaks system immediately after the first discharge pulse, so that the small frequency forming frequency was fully compensated by its greater duration.



During the disconnection of the throttle from the Rotaks system (curve b) the ignitability of the system decreases considerably and it becomes equal to the ignitability of the experimental system.

As is known, in proportion to a reduction in depth of submerging the plug in the combustion chamber ignition, the condition of the mixture becomes deteriorated and the rate of the stream increases. For the purpose of explaining the effect of plug submersion depth on the ignitability of the Rotaks ignition system additional tests were carried out at a plug submersion depth h = 5 and 15 mm. Tests have shown, that a change of h within limits of 5-25 mm has no effect on engine starting characteristics. That is why in the Rover engine with Rotaks ignition system the plug is not at all submerged in the chamber, and is situated along side with its wall. The plug requires no special measures for cooling, which were provided in the SE-15B spark plug.

In the carried out experiments with SE-15B spark plug the spark discharge of the plug, passing over the surface of the segment from a semiconductor, was oriented in direction of the sprayer. Displacement of the spark discharge from this position made the engine start worse. A poorer result was obtained when the spark discharge was displaced by 180°, which, apparently, is explained by the effect of electrode form and by the presence of the screen.

In addition to the tests with SE-15B spark plug a part of the experiments was carried out with a semiconductor plug of the Lodz company, intended for operation from the Rotaks ignition system. Engine starting characteristics with Lodz spark plug are in no way different from the starting characteristics, obtained with plug SE-15B when the latter is placed by a spark discharge to the sprayer. But in contrast to plug SE-15B the Lodz plug was found to be insensitive to the position of the spark discharge relative to the sprayer, which is explained by the form of electrodes, at which the spark as if extends outwards from the body of the plug.

Conclusions

1. To improve starting characteristics of a gas turbine engine it is advisable to use a low voltage ignition system of high energy capacitance type (10-12 joules.) A further increase in discharge energy appears to be irrational, because the starting of the engine does not essentially improve.

2. As an example of a successful structural execution of a high energy ignition system (12 joules) can serve the Rotaks system, in which thanks to the use of a low overall capacitor of greater capacity (6 microfarads) and compact arrangement of other elements it was possible to considerably reduce the overall dimensions and weight of the ignition block.

3. The use in the Rotaks ignition system of additional throttle inductance allows to increase the time of flow through of the discharge current through the spark plug and to improve the ignitability of the discharge.