EFFECT OF THE MICRORELIEF OF RUBBING FACES OF SEALED REFRIGERATION COMPRESSORS ON THEIR WORKING LIFE

Yu. G. Shneider and Ya. V. Guzok

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Test use of sealed refrigeration units has shown that certain rubbing faces of the compressors of these units operate with insufficient lubrication, which leads to scoring and to seizure of the rubbing surfaces. The possibilities of constructional change to improve the oil supply to the rubbing surfaces without complicating the compressor design have been almost exhausted. The only solution is to improve the retention of the oil on the rubbing surfaces. A partial solution to this problem is to optimize the microrelief of the working surfaces of the rubbing components by using, in place of the traditional cleaning and finishing treatment, the technique of vibration burnishing [1-3], providing an almost unlimited means of controlling all the geometric parameters of the microrelief. In order to show the possibilities of using vibration burnishing in refrigeration equipment an investigation was made of the component of the FG 0.7 ~ 3 sealed refrigeration compressor which is subject to the greatest frictional wear, the piston crank pin and the connecting rod.

In order to study this friction couple a special friction machine based on the motor/weights principle was designed and made. The friction force moment was measured by the angle of rotation of a pendulum system, also including the electric motor. When the electric motor was switched on, all the pendulum system was deflected by the reactive moment through an angle proportional to the coefficient of friction at the rubbing faces; the angle of deflection was recorded. Using calibration equations, the moment and the coefficient of friction for the given conditions of load and lubrication were determined from this angle.

The testpieces were a piston crank pin of steel 20 with surface hardness HRC 55, and a segment (internal diameter 12 mm, external diameter 24 mm, height 9 mm) of Br.OTsS 5-5-5 bronze, simulating the upper connecting rod head. Two holes were drilled in the bronze segment; one for lubrication, the other for the thermocouple junction.

Vibration burnishing was carried out on a type 1K62 turning lathe in a special universal-vibration head attachment. The hardened piston crank pins were machined by means of a diamond point with a spherical radius of 1 mm (a point of 2 mm spherical radius was used for smoothing), and a ball of 4 mm diameter was used for machining the bronze segments. In order to create the different forms of microrelief the feed rate of the deforming element and the number of revolutions of the workpiece were varied. The vibroburnishing force was unchanged, being 30 kgf for the crank pins and 25 kgf for the segments. The initial roughnesses of the crank pins and segments were checked by the Kalibr-201 profilograph/profilometer.

The depth of the grooves formed during the vibroburnishing was 6 μ on the crank pins and 15 μ on the segments. These values were chosen so as to maintain the dimensions of the piston crank pins and the gap in the upper connecting rod heads in the allowed range after vibroburnishing. With a smaller depth of groove, the oil capacity is increased with a smaller effect, while, with a greater groove depth, the projections formed (particularly on the bronze connecting rods) are considerably greater than the maximum height of the initial surface microirregularities, as a result of which the dimensions of the vibroburnished components fall outside the allowable range.

In order to find the optimum microrelief of the contacting surfaces for given friction conditions, different friction couples were tested:

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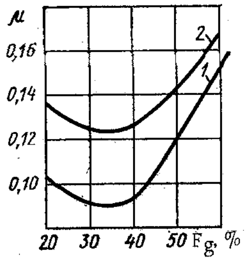

Fig. 1

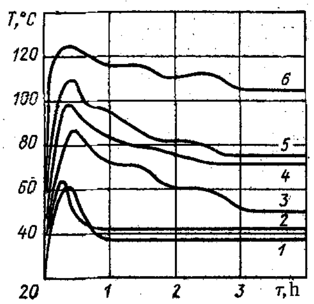

Fig. 2

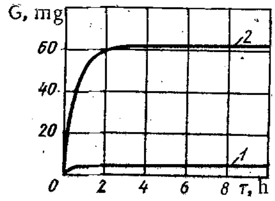

Fig. 3

Fig. 1. Coefficient of friction μ as a function of groove area F_g for different friction couples: 1) planished crank pin and vibroburnished segment (type-I microrelief); 2) ground crank pin and vibroburnished segment (type-I microrelief).

Fig. 2. Relation between the temperature T close to the friction zone and the duration τ of the initial running-in for different friction couples: 1) planished and subsequently vibroburnished crank pin (type-I microrelief, F_g = 20%) with vibroburnished segment (type-I microrelief, F_g = 35%); 2) planished crank pin with vibroburnished segment (type-I microrelief, F_g = 35%); 3) planished crank pin with bored segment; 4) ground crank pin with vibroburnished segment (type-I microrelief, F_g = 35%); 5) vibroburnished crank pin (type-I microrelief, F_g = 20%) with bored segment; 6) ground crank pin with bored segment.

Fig. 3. Relation between the wear G of the bronze segment testpiece and the duration τ of the initial running in with the crank pin for different friction couples: 1) planished crank pin with vibroburnished segment (type-I microrelief, F_g = 35%); 2) ground crank pin with bored segment.

segmented testpieces, the surfaces of which were bored (by an effective method) to an 8th-class finish, together with crank pins the surfaces of which were machined by different means: by grinding to 9th-class finish (by an effective method); by planishing to an 11th-class finish; by vibroburnishing to form microrelief of types I, II, and III [2, 3], with a groove area equal to 20, 25, 30, 50, and 60% of the nominal surface area; by vibroburnishing to form type-IV microrelief and planishing with subsequent vibroburnishing;

segment testpieces with surfaces vibroburnished to form microrelief of types I, II, and III with groove areas equal to 20, 25, 35, 50, and 60% of the nominal surface area together with crank pins ground to a 9th-class finish;

segmented testpieces with surfaces vibroburnished to form microrelief of types I, II, and III with various groove areas F_g, together with crank pins vibroburnished to form type-I microrelief (F_g = 20%), planished, and planished with subsequent vibroburnishing to form type-I microrelief (F_g = 20%).

The crank pin was rotated at a speed of 700 rpm, oil was fed dropwise (~1 drop per min), the pressure was held at 20 kgf/cm^2. The temperature in the vicinity of the friction zone (at a distance of 0.5 mm from the contact surface) was measured by a Chromel—Copel thermocouple, the values being recorded on a chart by a PS1-08 potentiometer. In each case three pairs were investigated.

A comparison of the test results provided a means of finding the best friction couple in terms of the coefficient of friction, the temperature in the vicinity of the friction zone, and the duration of running-in. The two best couples consisted of a planished piston crank pin with a vibroburnished segment (type-I microrelief, F_g = 35%), and a planished, and subsequently vibroburnished crank pin (type-I microrelief, F_g = 20%) with a vibroburnished segment (type-I microrelief, F_g = 35%).

The coefficient of friction of these couples up to the end of running-in was 0.09, whilst it was 0.182 for the couple with the ground crank pin and bored segment. It was noted that the coefficient of friction is essentially a function of the groove area (Fig. 1). Both decreasing and increasing the groove area on the working surface of the bronze segment increases the coefficient of friction: the optimum is a groove area $F_{g.opt}$ equal to 32-35% of the area of the bearing surface.

If the groove area on the working surface of the bronze segment is less than $F_{g.opt}$ the bearing surface is increased but its oil capacity is decreased, as a result of which the possibility of maintaining a stable oil film between the rubbing faces is impaired. If the groove area is greater than $F_{g.opt}$ the bearing surface is decreased, so that the contact pressure is increased and, in spite of the increased oil capacity of the surface, the possibility of maintaining a stable oil film is impaired.

It was also established that having the optimum area of the grooves of the oil system decreases the temperature in the friction zone. Accordingly, the temperature close to the friction zone of the couples consisting of the planished crank pin with the vibroburnished segment and the planished and subsequently vibroburnished crank pin with the vibroburnished segment were respectively 42 and 37°C, but the temperature near to the friction zone of the series-produced couples consisting of a ground crank pin and a bored segment was 105°C.

The thermal conditions of some of the couples investigated are characterized by the curves recorded by the potentiometer (Fig. 2).

Since under the given conditions, the differences in the temperatures close to the friction zone are not large for the selected couples, further testing was carried out on the wear resistance of the more easily produced couple, that consisting of a planished piston crank pin together with a vibroburnished segment. Wear resistance testing was carried out under the same conditions as for friction. The couples under test were worn out over a period of 10 h, the major wear taking place on the bronze segment. The wear on the bronze segment was determined by weighing it before and after testing on an ADV-200 analytical balance. As is evident from Fig. 3, the planished piston crank pin had a higher wear resistance and longer running-in time than the series-production couple.

The results of the laboratory testing allowed the planished piston crank pin and vibroburnished upper connecting-rod head (type-I microrelief, F_g = 35%) to be recommended for testing under operating conditions. In order to exclude or weaken the effect of variables depending on the working conditions and individual features of compressors, the wear of a couple consisting of the planished piston crank pin and the vibroburnished connecting-rod head was compared to the wear of a series-produced couple on the same compressor. For this purpose, in ten compressors for VN-0.35 and VS-0.7 units, one of the cylinders was fitted with a couple consisting of a planished middle part of the piston crank pin and vibroburnished connecting-rod head, the other with a series-production couple.

After assembly, the units were mounted in ShKh-0.8 and T-120 refrigerators and low-temperature counters, where they worked for more than 2000 h. The refrigerators operated under normal conditions. After stripping down the compressors, the wears of the connecting-rod heads and the piston crank pins were measured, comparing their dimensions and weights before and after testing.

The operational-test results confirmed the results of the earlier tests. The wear of the planished piston crank pins after working for 2000 h with vibroburnished connecting rods was on average 0.0259 g, whilst the wear of series-production piston crank pins was greater by a factor of 1.8-2.0.

The linear wear of the vibroburnished upper connecting-rod clearances was, on average, 5-6 μ; the wear of the series-production connecting-rod clearances was greater by a factor of 2-2.5.

Accordingly, the vibration burnishing method, providing the possibility of controlling the bearing surface and the oil capacity of the rubbing surfaces, is very promising for machining the surfaces of the piston crank pin–upper connecting-rod head couple, and also for other friction couples in sealed compressors, crankshaft–lower connecting-rod head, cylinder–piston, etc.

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