The Dnepropetrovsk Chemical Engineering Institute carried out research work on the dynamic behavior of a ZG-83-10/320 high-pressure reciprocating compressor in order to investigate the possibility of increasing its output by raising the suction pressure of the first stage.

The ZG-83-10/320 compressor (V = 83 m³/min; P_{in} = 10 atm; P_{ex} = 320 atm; n_0 = 125 rpm; N = 906 kW) intended for the compression of nitrogen-hydrogen mixture (75% H₂ and 25% N₂) is a horizontal machine with in-line cylinders; its four compression stages are arranged in a differential block with a receiver (p = 1 atm) between the first and the third stages. Using as a basis the strength calculations carried out in designing compressor parts by the Leningrad Scientific Research Institute of Chemical Engineering (NIKhimmash), we determined the most critical cross sections in the main parts of the machine's mechanism (main shaft, connecting rod, coupling, and piston rod) and developed a method for the investigation of the dynamic behavior of the compressor. In carrying out this investigation 200-Ω resistance wire strain gauges with a length of 20 mm were bonded to the essential parts of the machine at several critical points (Fig. 1). In order to reduce the movement of strain gauges and to obtain stable results they were bonded by BF-2 glue which was subsequently polymerized by heating the parts concerned [1]. The strain gauges were stabilized (by repeated loading of parts concerned) by starting the compressor. The strain gauges were calibrated on parts of the assembled compressor, for which purpose the pressure valve of the first stage was closed by a blind flange while the equalizing cavity was connected to atmosphere. Nitrogen at a pressure of up to 30 atm was then admitted into the first stage and produced, in the elements of the mechanism, stresses equal to those occurring in operation; this method also eliminated errors common to ordinary calibration methods [2].

The stresses in the main shaft were not measured directly with strain gauges because of considerable errors introduced by the electric contacts. These stresses were determined from the torque measured on the driving motor shaft which, in turn, was calculated from the power recorded by the wattmeter loop of the oscillograph. Forces and stresses produced in the mechanism elements were measured by means of strain-gauge amplifiers and recorded on the film of the MPO-2 oscillograph.

The tests also involved the measurement of gas pressure and temperature in the compressor cylinders and in the suction and delivery connections. Changes of gas pressure were measured by means of pressure strain gauges developed at the Dnepropetrovsk Chemical Engineering Institute. All parameters characterizing the working of the machine were recorded simultaneously during the starting of the compressor, in stable operation, and during its stopping.

Figure 2 gives the oscillogram of forces acting in connecting rod ends. The recording was made during the stable operation of the compressor with a film speed of 100 mm/sec. The processing of oscillograms reproduced the action of forces in the big and small ends and also in the central part of the connecting rod (Figs. 3 and 4).

The curve representing the variation of forces in the connecting rod is the algebraic sum of gas pressures acting on the piston, of inertia forces of the reciprocating masses, and of the friction forces of the reverse motion. When the piston moves away from the front dead point (FDP) towards the rear dead point (RDP) the connecting rod is subjected to a compressive force while during the reverse stroke it is subjected to a tensile force.
Fig. 1. Schematic diagram showing the arrangement of sensing elements on the mechanism of the compressor: 1-10) strain-gauge bridges for measuring stresses; 11-13) strain-gauge bridges for measuring pressures; 14-15) thermocouples; 16) magnetoelectric oscillograph; 17) strain-gauge amplifier.

Fig. 2. Oscillogram of forces in connecting rod ends: 1, 2, and 3) forces in top, end, and bottom parts of the big end respectively; 4, 5, and 6) forces in the top end and bottom parts of the small end respectively.

The graph of Fig. 2 shows that at the FDP the force acting in the connecting rod is 18 tons; thereupon, it sharply decreases, passes through zero and, after changing sign, begins to increase. At about the middle of the stroke the force reaches its maximum (36 tons) and subsequently decreases to 7 tons. During the motion of the piston from the RDP to FDP the compressive force decreases to zero and subsequently changes to a tensile force. The maximum tensile force of 32 tons is also produced approximately in the middle of the stroke with the result that here the inertia forces are zero and the force in the rod represents the algebraic sum of only two forces: the gas pressure on the piston and the friction force. During the rest of the stroke the inertia forces increase thus reducing the total force in the connecting rod.

It should be pointed out that in the region of compressive forces the curve representing the variation of forces in the connecting rod changes relatively smoothly whereas in the tensile region, commencing in the second half of the stroke, the amplitude of vibrations on the curve reaches about 9 tons. This can be explained by the fluctuations of pressure in the communicating lines and by the vibration of valves [3]. The variation of forces in the lower part of the big end in the compressive region remains similar in character and numerical values to that in the small end but in the tensile region its character changes. The tensile force of about 18 tons sharply decreases to zero while the compressive force begins to act quarter of a stroke earlier than in the connecting rod. In the end portion of the big end the compressive forces are practically absent while the tensile forces exceed the forces produced in the connecting rod by about 6 tons due to the effect of impact forces. In the lower part of the big end and in the connecting rod the compressive forces act at the time when the tensile forces act in the top part of the big end.

Figures 2 and 3 show that the forces acting in the top and bottom parts of the big end are opposite in phase. Consequently, the connecting rod bends under compressive forces in such a manner that the material in the top part