EXPERIENCE IN ASSIMILATING PRODUCTION OF
STANDARDIZED CENTRIFUGAL COMPRESSOR
MACHINES IN THE KAZAN' COMPRESSOR PLANT

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The Kazan' Compressor Plant has gone into the mass production of standardized centrifugal compressor machines [1] developed by the Special Construction Office for Compressor Building (SKBK, Kazan').

The building of standardized centrifugal compressor machines and putting them into production was preceded by a complex of work which can arbitrarily be divided into four stages.

In the first stage, the main functional aggregates and subassemblies of centrifugal machines were determined: the compression housing, the gear-type boosters, the gas and oil coolers, the bearings, the torsion clutches, the lubricating and packing system, the automation system, etc., the determination of their parametric order and development of the actual typical constructions.

In the second stage, experimental samples of typical representatives of the functional aggregates and subassemblies of their determining elements were prepared and subjected to exhaustive tests. The principle of geometric similitude of the constructions made it possible to extend the characteristics obtained to the remaining standard types of subassemblies and aggregates. For example, as a result of the testing of 16 typical stages of compression housings, the characteristics of the stages of the remaining 64 standard types were determined, which considerably reduced the volume and time of the experimental work.

In the third stage, in the SKBK a system of programs and subprograms was set up embracing the whole process of machine development. The calculation results, printed out by the computer, are included in the calculational-explanatory description without any additional analysis or reformation. These programs consist of complex engineering calculations, including the following operations:

- the use of nomograms to select several competing schemes of the future schemes;
- the use of an ES-1020 computer in accordance with a given program for selection of the nominal (calculated) parameters optimal for each scheme of the flow-through part on the basis of the characteristics of standard sets of stages and gas coolers stored in the memory;
- selection of the best scheme of the machine for a given order on the basis of an economic comparison;
- determination, in accordance with a program, of the actual head—mass-flow-rate dependence and the limits of stable work of the compressor, disclosure of the stage worsening the overall characteristic of the machine, and its replacement;
- determination, in accordance with specialized programs, of the axial forces, the critical frequencies of the transverse and torsional vibrations of the rotors connected by gear-type clutches, the friction losses in the bearings and seals, and other parameters.

The SKBK is carrying out work on the total automation of the design of standardized centrifugal compressor machines, including the computer specification and design of a minimal number of constituent parts.

In the fourth stage, work was started and continued on the development of the aggregates entering into the system of standardized centrifugal compressor machines, their preparation, and the equipment for their production. This work is based on previously planned constructional standardization, making it possible to create typical technological processes and equipment, to considerably shorten the fabrication times, and to improve the quality of the machines.

The most complex technical problem was the building of a standard series of compression housings. The solution of this problem served as the start of a systematic approach to the production of standardized centrifugal compressor machines.

With the construction of the cylinders of standardized centrifugal compressor machines, account was taken of experience in the operation of machines with diffusor helixes cast in the housing.

To the end of an increase in the rigidity of the cylinders, the bearing journals are brought out of the chambers to the flange of a horizontal joint, as a result of which cases of uncentering of the compressors during the process of operation are eliminated. Actual strain-gage measurement of the cylinders made it possible to bring out their safety factor and to raise the permissible working pressure. During the process of the reconstruction of the casting line, there was a considerable increase in the degree of mechanization of all the operations of the casting of the cylinders of standardized centrifugal compressor machines (the largest parts in the nomenclature of the plant) from sand preparation to the electrohydraulic knocking-out of the billets.

The construction of the flow-through part of standardized centrifugal compressor machines, in spite of the high degree of standardization, assures a high efficiency of the compression of various gases. It must be noted that the transition to the production of standardized centrifugal compressor machines coincided with the introduction of more efficient, but more complicated, flow-through parts, which permitted a 3-5% increase in the efficiency of the compressor machines, and brought them to a high technical level. In collaboration with the M. I. Kalinin Leningrad Polytechnic Institute (LPI) work is going forward on the building of the flow-through part of a second generation of standardized centrifugal compressor machines, based on a comparative evaluation of the losses of head using a calculation of a three-dimensional boundary layer, taking account of secondary flows in accordance with a method and a program developed at LPI.

As the result of the introduction of vacuum welding of working wheels of steel 09Kh15N8Yu, proposed by the All-Union Scientific-Research Institute of Compressor Machinery, the strength characteristics of the wheels were raised, which made it possible to decrease the thickness of the blades by 1.5 times and to increase the working velocities up to 320 m/sec. In the plant, two vacuum furnaces are in operation for the welding of wheels with a diameter up to 480 mm and a furnace is being built for the welding of wheels with a diameter up to 640 mm.

Particular attention is being paid to increasing the reliability of compressor machines from the point of view of assuring the vibrational stability of rotors working at speeds of 16,000 rpm or more, as well as the strength of elements of machines with long-term operation. In this direction the SKBK and the Kazan' Compressor Plant have carried out work including a computer method for calculating critical conditions of rotors rotating in sliding bearings; the introduction of stage-by-stage balancing of flexible rotors in resonance balancing stands with a magnetic frame (according to an SKBK method), and static balancing of wheels on an air cushion (in accordance with a method of the Kazan' Institute of Chemical Engineering); the introduction of a new enterprise standard for high-precision gear-type clutches with gapless centering around the rim of the gear; a complex of apparatus has been built for monitoring the vibrational state of the machines by a contactless method during the tests.

Traditional cylindrical or "lemon" bearings have been found unsuitable for standardized centrifugal compressor machines as not assuring the stability of the shaft journal in a wide range of conditions. The SKBK, on the level of the enterprise standard, has developed, investigated, and introduced five-wedge sliding thrust bearings, a special characteristic of which is the presence of symmetrical (reverse) shoes, with a temperature oil wedge (Fig. 1). Such bearings work stably at any given rates of rotation, as well as in conjunction with small-gap slit-type seals. To raise the quality and to improve the structure of the babbitt layer of the shoes, the unit for the centrifugal lining of the bearings is provided with a practical cooling system and the optimal volume of the melt of babbitt for one batch of bearings is determined. Work is being done on reinforcement of the babbitt layer.

As a result of a complex of work done on improvement of the elements of the rotor-bearing system, the efficiency of machines put out after 1975 has increased substantially.

To increase the wear resistance of the parts of oil slit-type seals in standardized centrifugal compressors designed for the compression of poisonous and explosive gases, experimental work is being done on implementation of the method of the plasma-spray deposition of a hard-alloy powder SNGN-50 on the surfaces of the necks of the rotor. The friction pair SNGN-50-babbitt B-83 is outstanding for high wear resistance. A complex of technical equipment for the plasma spraying of mass-produced parts is being built in the plant.

The enterprise standard provides for the fabrication of gas coolers with water cooling of 8 standard types, instead of the old apparatus with 30 designations. The cooling surfaces of the gas coolers consist of efficient all-rolled finned tubes, recommended in the investigations of the Leningrad Scientific-Research Institute of Chemical Machinery. The principal advantages of the new gas coolers are simplicity of construction