The structure of a mathematical algorithm and software for geometric and strength analyses, and the working diagram of multiple-pair meshing for GT are presented. Methods are considered for improving the reliability and quality of GT on the basis of multiple-pair meshing, which can be expanded to bevel GT with straight and spiral teeth, and cylindrical worm GT.

Requirements are being raised for the strength and time-to-overhaul of gear trains (GT) in mechanical transmissions of chemical and oil-and-gas equipment. As a component part of power-generating sets, GT exert a major influence on their basic technico-economic indicators: mass, overall dimensions, time to overhaul, vibroacoustic activity, cost, etc. The cost of the GT may amount to 30% of the overall cost of the power-generating set. Enhancement of the reliability and quality of the GT, for example, their strength, is therefore a component part of the total problem of improving the reliability of the drive systems of any machine set.

Basic causes of GT failures are: design errors, errors in fabrication and assembly, and violation of operating conditions. Traditional means of improving the reliability and quality of GT (an increase in dimensions, and improvement in fabrication precision, use of high-strength materials, surface hardening, etc.) have little effect in many cases, since they are associated with significant material outlays, and do not always lead to desirable results. A significant reduction in expenditures and, at the same time, improvement in quality indicators of the GT can be achieved by automating their design process. Computer technologies make it possible to shorten the time required for GT design, and essentially eliminate errors, as well as produce an optimal design in terms of strength conditions and time to overhaul, including designs based on new technical solutions.

The following are basic attributes of the mathematical algorithm and software (MA and SW), which can be used, for example, for geometric and strength calculations of GT: a developed network of data bases; invariance with respect to parameters of the original profile; possibility of analyzing machined meshing and the fillet curve of the teeth, and also the stress-strain state of the teeth at all points of the profile; multicriterial optimization of transmission parameters; and communication between individual applied programs in a single processing network. Figure 1 shows the typical structure of the MA and SW employed for geometric and strength analyses of GT.

It is expedient to execute the computer design of GT in both the package, and also dialogue modes. The package mode is used to determine parameters of the GT in first approximation. The dialogue mode makes it possible to optimize parameters of the GT in conformity with assigned reliability and quality criteria.

Use of GT with multiple-pair meshing can be referred to as a new technical solution (Fig. 2). As a result of simultaneous contact between several pairs of gears (in contrast to standard GT with single-pair meshing), these GT possess high-
er strength, longer time-to-overhaul, and noise-emission indicators. The transverse overlap $\varepsilon_\alpha$ – the ratio of the length of action $AD$ to the normal base pitch $AB$ – is used as a characteristic of multiple-pair meshing. GT with multiple-pair contact are designed by determining the parameters of the meshing geometry with the condition that $\varepsilon_\alpha > 2$. (1)

Here, requirements regarding the contact and bending strengths of the teeth should be met with minimal possible overall dimensions of the GT. Solution of this problem is possible primarily by use of special computer programs. The geometry of multiple-pair meshing is synthesized on the basis of high-profile modification of the teeth as a result of negative shifts of the original profile with reduced or zero helix angles.

The following original-profile parameters are assumed for multiple-pair trains: generating pressure angle $\alpha \leq 20^\circ$; and, addendum $h^*_a \geq 1.2$. An increased flank with an addendum $h^*_a \geq 2.65$ may serve as a distinguishing external feature of multiple-pair GT. The transverse overlap of the GT is independent of the value of the module $m$; it is therefore expedient to synthesize the geometry of a multiple-pair GT for $m = 1$. This makes it possible to formulate the geometry of the multiple-pair meshing initially, and then enter increases in the module to the assigned center-to-center distance of the GT.

Table 1 presents values of the transverse overlap $\varepsilon_\alpha$, which were obtained by numerical realization of condition (1) for external spur GT with multiple-pair meshing and initial data, which exclude both undercut and interference: $m = 1$; $z_1 = 23$; $z_2 = 23–115$; $x_1 = -0.045$; $\alpha = 20^\circ$; and, $h^*_a = 1.3$.