Generation of precessional gear teeth by plastic deformation

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Abstract. The correct choice of the dimensions of the workpiece product is one of the main problems, the solution of which depends on the reduction of the consumption of materials and energy, as well as the quality of the wheels obtained by plastic deformation. Referring to the manufacture of conical wheels with convex-concave profile of the teeth by knurling, the height of the teeth is determined by the condition of the equal volume of metal that moves from the gaps between the teeth to their tip during the plastic deformation by rolling. The use of methods for the manufacture of teeth without chipping will allow the increase of the utilization coefficient of expensive materials.

1. Introduction

Gears are machine parts that occupy an essential place in the operation of various mechanical constructions. The execution of the gears at a high-quality level and at a low cost, puts in front of the specialist multiple problems.

From the design stage, the specialist must take certain measures to achieve a high reliability of the designed gears. Shapes of teeth profiles that can be obtained by plastic deformation [1, 2] for use in precessional multipliers are presented. Starting from the correct choice of materials and dimensions of the workpiece product, the designer must adopt constructive solutions of the gears that can be made in the most economical conditions. Previous research by the author has been presented in [3, 4, 5].

2. Determination of the displacement value of the deformation node in the direction of the axial feed

Based on the computerized model of the toothed wheel plastic deformation device, the working strokes (vertical table feed), the number of revolutions of the main machine tool shaft, were analyzed to ensure the deformation speed prescribed by the technical literature.

Determination of the vertical feed of the table is necessary for the complete teeth formation [3, 4, 6].

Determining the total stroke of the plastic deformation rollers in order to obtain the full height of the teeth requires the determination of the height of the teeth, which is calculated from:

$$h_{th} = R_{out} \cdot tg2\theta \tag{1}$$

where: R_{out} is the outer conical radius of the blank, mm;

θ is the angle of nutation, degrees.

The height increase of the tooth according to the vertical advance of the plastic deformation node, in which the plastic deformation rollers are fixed, was determined according to the relation:

$$\Delta h_{pc} = s_{pc} \cdot cos(\delta + \beta + \theta) \quad (2)$$

where: δ is the angle of the conical axoid, degrees;
s_{pc} is the advance of the plastic deformation node to a precession cycle, mm;
β is angle of conicity of the rollers, degrees.

The value of the stroke of the plastic deformation node in which the plastic deformation rollers are fixed:

$$s_t = \frac{h_{th}}{cos(\delta + \beta + \theta)} \quad (3)$$

According to the literature recommendations for the total teeth profile formation [5], the summary advance was divided into steps, measured by the digital indicator. The results of calculating the penetration advance according to tooth height are presented (see table 1).

Table 1. The advance depending on the height of the teeth.

Step No	The angle of nutation θ, degrees	Angle of the conical axoid δ, degrees	Angle of conicity of the rollers β, degrees	Height of the teeth h_i, mm	The advance, S_{pci}, mm
1.				13.72	13.73
2.				14.22	14.23
3.	3.0	0	3.5	14.72	14.73
4.				15.22	15.23
5.				15.52	15.53

3. Forces determination for plastic deformation with precession tool

Knowledge of the forces necessary for the formation of the teeth is an important factor for the calculation of the plastic deformation of toothed wheels. It should be noted that in all of the conceptual developed diagrams the plastic deformation tool performs sphero-spatial motion, which reduces by about 60% the value of the forces required for tooth deformation due to the reduction of the instant contact surface of the tool with the blank. The progressive plastic deformation aims to reduce the deformation pressure by dividing the deformation width into several sectors. The plastic deformation of the teeth with a precession tool and deformation with i rolls is further examined. In figure 1 (a) the action of the deformation rollers on the blank is replaced by an equivalent roll. The torque transmission (forces) from the main shaft is carried out with arms help $F_{hi}=f(e)$ figure 1 (b), measured in the planes passing through the application points of the F_{rhi}, levers L_1 şi L_2: $F_{r_{hi}} \cdot L_1 = R_m \cdot L_2$. The deforming forces acting on the workpiece, when the deformation process is already stabilized, are shown in figure 1 (c). The deformation rolls act with the normal force F_n and the tangential force F_t, and R_m is their result.

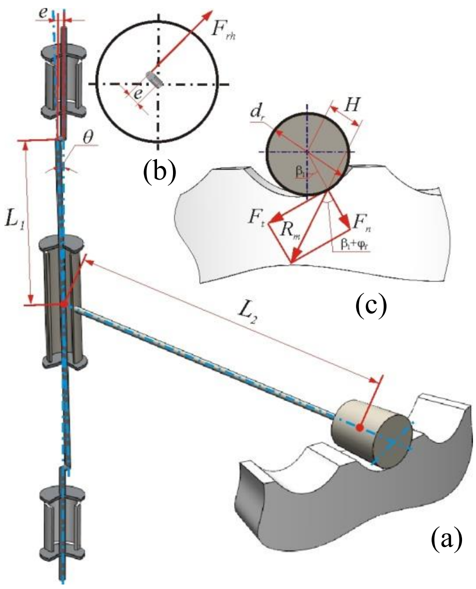

Figure 1. Scheme for determining the applied torque to the main shaft.

The normal force, being the sum of the elementary forces relative to the surface unit of the deformation zone, results from the relation: $F_n = AP_m$ where A is the contact surface in the deformation zone, and P_m is the mean pressure in the deformation zone. From figure 1 (c) results: