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Problems of Lead Screw Accuracy made by turning

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Abstract. The accuracy of closing and opening of gate valves or taps, and accordingly the efficiency of energy saving, largely depends on the accuracy of the lead screw. Lead screws are mostly made using lathes. The accuracy of the thread of the lead screw is primarily the accuracy of the thread profile. Basically, the shape and profile of the screw must meet the standards of the trapezoidal thread and, accordingly, with the Archimedean form. However, based on the real conditions of the turning process, the shape of the thread will have a convoluted character, which functionally depends on the accuracy of the setting of the needle relative to the part. Taking this approach into account, it is possible to effectively apply the calculation algorithm, which provides for the maximum possible accuracy of the actual production of a lead screw with a trapezoidal or triangular profile.

Keywords: turning process, manufacturing of machine, thread accuracy.

1. Introduction

The production of lead screws for power needs (taps and gate valves), as well as for drives for machine tools and mechanical jacks, is usually carried out on lathes. To increase the accuracy of strength and stability in conditions of aggressive environments, special materials are used for the production of lead screws, their special thermal treatment processing, and sometimes, in addition to turning operations, they also use thread grinding. However, additional grinding operations reduce the production of lead screws performance. Replacing the grinding process with only turning operations can, of course, significantly speed up the production of lead screws manufacturing. However, there is a problem of accuracy, because cutters for turning thread-part made from hard and strong materials require different geometric parameters in their working part than usual tools, which actually reduce accuracy. To prove the possibility of using such cutters with changed geometric parameters, the shape of the helical surfaces obtained in the turning process should be analysed.

2. Literature Review

According to standards [1,2], lead screws for energy shut-off fittings, and especially for machine tools, are produced with a given trapezoidal profile, which is regulated by a profile angle of 30° [1] or 29° [2] (fig.1). It is clear from the standard that the axial profile of the side surfaces of the threads is a straight line.

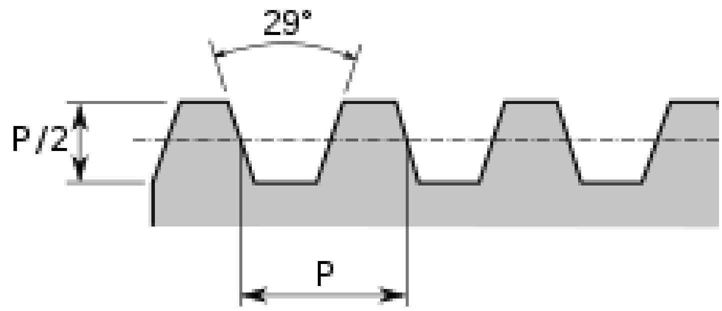

Figure 1. Lead screw profile schema ANSI/ACME. P - thread pitch.

The standard [2] regulates the accuracy of the semi-profile angle as a function of the number of thread threads per 1 inch length. Therefore, the tolerance for the semi-profile angle of 29° is in the range from 47' to 12'.

TABLE 8 TOLERANCES ON 14.5 deg FLANK ANGLE FOR EXTERNAL AND INTERNAL PRODUCT THREADS

	14.5 deg Variation	
Threads/in.	deg	min
16	0	47
14	0	44
12	0	41
10	0	39
8	0	35
6	0	30
5	0	27
4	0	25
3	0	22
2.5	0	20
2	0	18
1.5	0	16
1.33	0	15
1	0	12

Figure 2. The accuracy tolerances of the angle of the half-profile of the thread according to the ASME standard

Today, the most productive method of thread screw manufacturing is whirling process. It is obvious that with an increase in the strength and hardness of a screw with a trapezoidal profile, as well as an improvement in the accuracy of the threaded profile, its service life will increase [3] (Fig. 3).

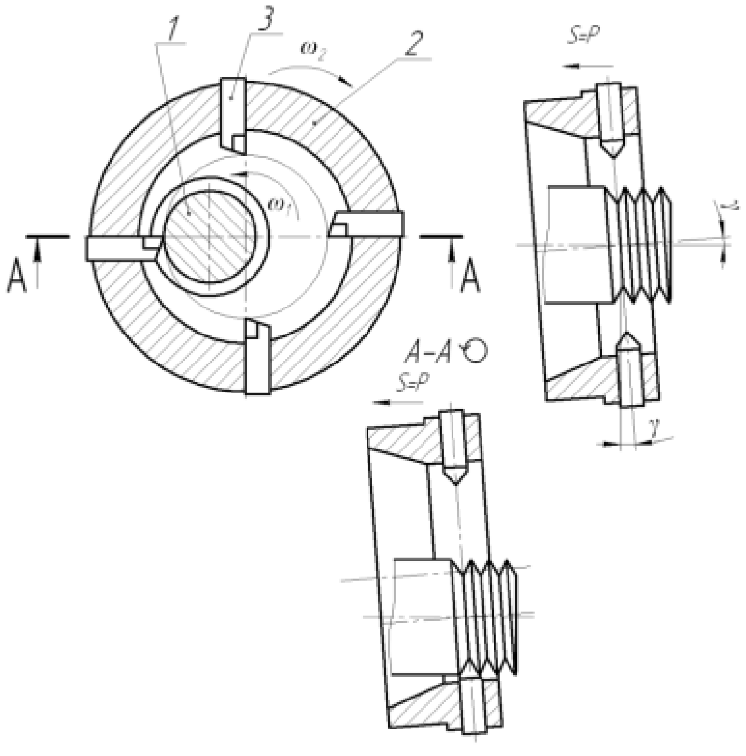

Figure 3. Schema of whirling process: 1-workpiece, 2- whirling head вихрова головка, 3-cutting tool.

This method consists in the fact that during the rotation of the processed workpiece and the parallel movement of the cutter head along its axis with a certain step in one rotation of the workpiece, the resulting movement is carried out along a helical line. The axis of the cutter head is shifted parallel to the axis of the processed workpiece by the special amount, so the cutting process is intermittent.

The cutter head is a disk milling cutter of internal contact with two, four or six cutters inserted into it, the profile of which corresponds to the profile of the thread being cut.

However, the study [3] of whirling process of threads, it is not about a change in the profile of the obtained thread as a result of multi-turning.

At the same time, studies of the kinematic influence indicate a change in the resulting profile [4] (Fig.4). According to their results, the profile acquires an asymmetric curve character [5] (Fig.5).

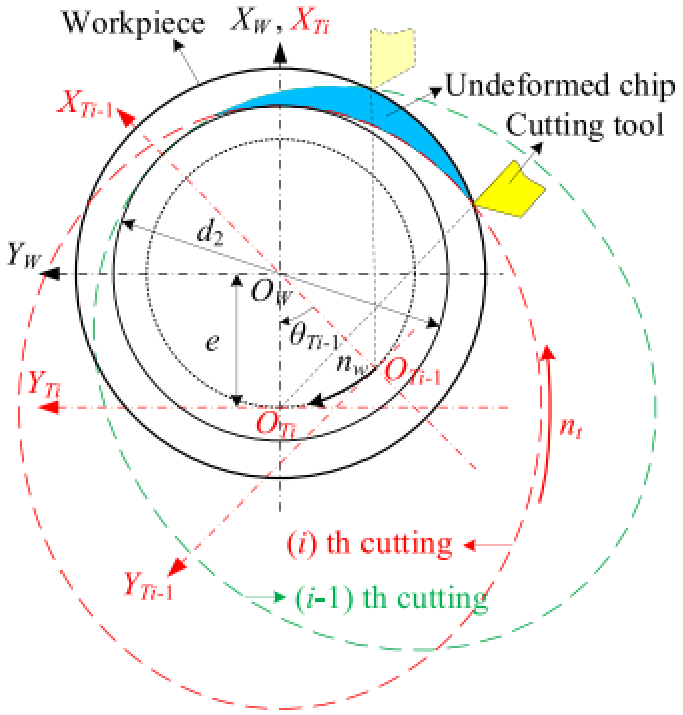

Figure 4. Kinematic scheme explaining the occurrence of chip removal-non-removal zones

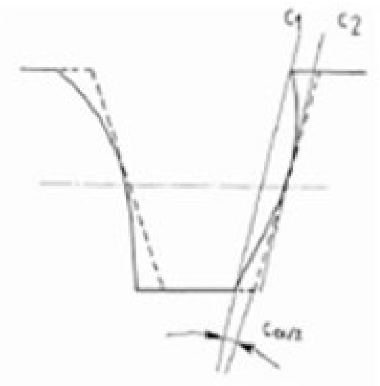

Figure 5. The result of the study of the predicted deviation of the profile of the trapezoidal cutting of the propeller in the MATLAB environment

3. Research Methodology

Virtual and analytical studies of turning of conical drill bits, including a small diameter of 25 mm, which is close to the diameter of the lead screw of a machine tool or a large gate valve show the suitability of the convolute shape of the screw obtained by a cutter with a non-zero character of its geometric parameters: the rake angle and the inclination angle of the cutting edge [6,7]. According to the standards, the shape of the screw is defined as an Archimedean screw, that is, with a rectilinear side profile in the axial section. Moreover, this Archimedean profile (1-2-3-4) is symmetrical (Fig. 6). The study indicates a significant influence of the front angle on the deviation of the profile of the obtained thread by 19’-31’ from the nominal value of the half -profile angle 30°'.

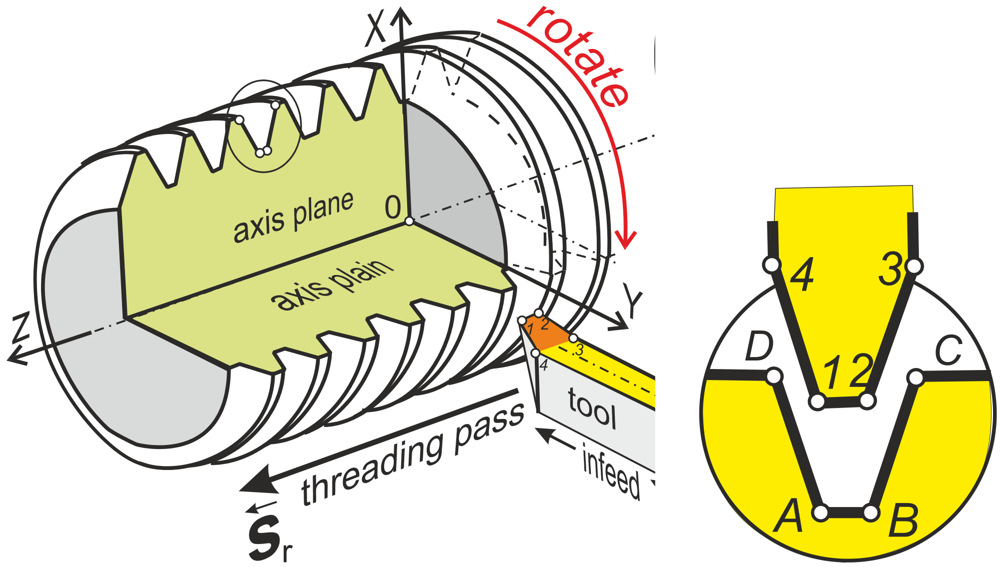

Figure 6. Shema of the turning of screw by using cutter with non-zero rake angle.

In the study, the rake angle is equal to 12°, according to recommendations for turning threads from stainless steel. In the figure, the front surface of the cutter is shown in orange to emphasize its inclination relative to the yellow main plane. (Fig. 6, 7).

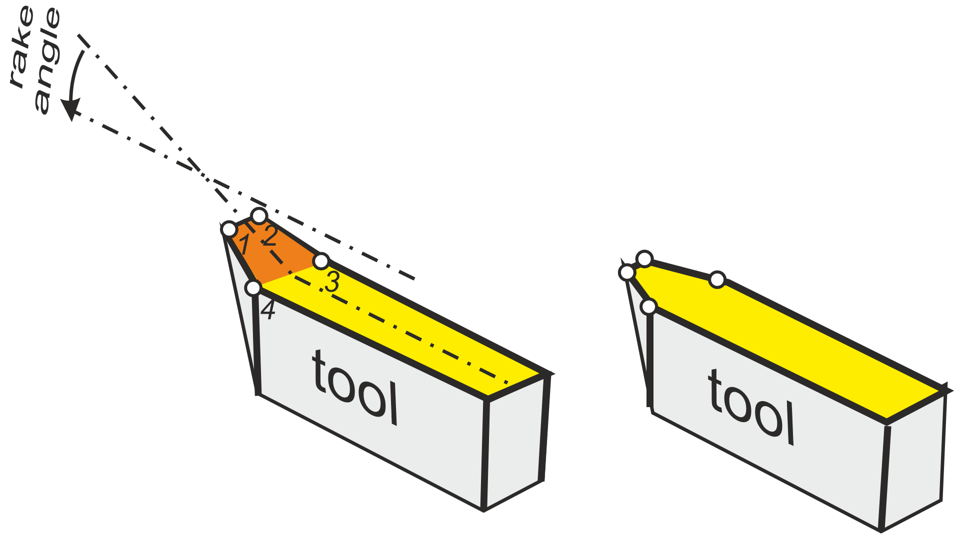

Figure 7. Shema of the turning-tool used for screw -making by using cutter non-zero (left) and zero rake angle (right).

Non-zero values of the rake angle are recommended for turning difficult-to-machine materials with an ultimate strength of more than 1200 MPA.

The following expressions are the theoretical basis of the method of calculating of the convoluted screw axial profile (Fig. 6) [7]:

$$Z(x) = tg(\alpha)x\frac{\sin\tau}{\sin\gamma} - \frac{P\tau}{2\pi} \tag{1}$$

Where:

$$\tau = \gamma - \arcsin\left(\frac{d_{\min or}}{2x}\sin\gamma\right) \tag{2}$$

α- half-profile of cutting edge. (the same as thread half profile).

4. Conclusion

The axial profile of the lead screw obtained by turning and whirling are:

- -curve,
- asymmetric,
- largely depends on the location of the cutters relative to the part and the value of their rake angle.

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