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University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

METHOD OF KINEMATIC SYNTHESIS FOR THE FEED AND THREAD BOX OF THE CONVENTIONAL LATHES

Dumitru DUMITRU

Abstract: *The kinematic synthesis of the adjustment mechanisms, feeds and threads boxes type, supposes the determination of some transmission ratios for a big number of gears, which to meet simultaneously two conditions: when the motion is transmitted in one direction, the transmission ratios, necessary for the obtaining of the Metric or Module threads pitches, to be provided and when the motion is transmitted in the opposite direction, the transmission ratios, necessary for the obtaining of the Whitworth and Diametral Pitch threads pitches, to be provided. In this paper, for the kinematic synthesis of the feeds and threads boxes from the machine-tools structure, a new method is shown, which contributes to the achievement of their kinematic and constructive parameters optimization.*

Key words: *kinematic synthesis, threads and feeds box.*

1. INTRODUCTION

In the case of the universal machine-tools, especially of the engine lathes, the feed linkage and the threading linkage are adjusted by a common adjustment mechanism, in order that a fast and easy programming of the outputs typical to those two linkages to be made, [1].
On the engine lathes, the threads generation is achieved for the work pieces of individual and small - scale production, where both the threads type (Metric, Whitworth, Module, Diametral Pitch) and the threads specific elements are often modified. As a result, the threading linkage adjustment is obtained by means of threads boxes type adjustment mechanisms, their programming for the given conditions (the thread type, the thread features, the spiral sense) being convenient and fast.

Concomitantly, for the engine lathes, the threads box is the adjustment mechanism of the longitudinal and cross linkages, too, because of this being named threads and feeds box (TFB). Its kinematics allows both the possibility of any thread type generation in a certain range of the specific geometric elements and the obtaining of the feeds (longitudinal and cross) ranges, which are imposed by the cutting process.

2. THE KINEMATIC SYNTHESIS OF THE FEEDS AND THREADS BOXES FROM THE LATHES

Each thread type is defined through a specific geometric element:

- Metric thread, by pitch: p_M;
- Whitworth thread, by the number of pitches/inch – N_p for this the pitch p_W is:

$$p_W = \frac{25.4}{N_p}\,; \qquad (1)$$

- Module thread, by the Module – m, for this the pitch p_m is:

$$p_m = \pi \cdot m\,; \qquad (2)$$

- Diametral Pitch thread, by the number of modules/inch – DP, for this the pitch p_{DP} is:

$$p_{DP} = \frac{25.4 \cdot m}{DP}\,. \qquad (3)$$

The adjustment mechanism of the threading linkage, therefore the threads and feeds box (TFB), must be conceived as a combined construction (fig. 1). The change gears A/B provide the obtaining of the basis threads features (Metric, Whitworth, Module or Diametral Pitch). The up-to-date threads and feeds boxes, have in their structure, in place of the change gears A/B, an adjustment mechanism with sliding gears, included in TFB, which provide a much easier selection of the thread type.

The input block in TFB is a multiplying and reducing box with sliding gears or in meander, with the transfer ratio i_{BM} and usual values of 1/4, 1/2, 1/1, 2/1, which allows the generation of the threads having their geometric features (p_M, N_p, m, DP) as multiples or submultiples of the basis threads features. Depending on the thread type, which is generated, (Metric or Module, respectively Whitworth or Diametral Pitch), the switch position is selected: M, m or W, DP.

In the TFB kinematic structure, a pitch selector is included. By means of this and according to the coupling position of the switch K, the position M/m, respectively W/DP (fig. 1), the variable transfer ratio i_{ps} (for the Metric or Module threads) and its reverse $1/i_{ps}$ (for the Whitworth or Diametral Pitch threads) are achieved.

When the pitch selector is traversed in the direction of the Metric or metric threads obtaining, its total $i_{tot}^{M/m}$ transmission ratio is:

$$i_{tot}^{M/m} = i_1 \cdot i_{ps} \cdot i_2 \qquad (4)$$

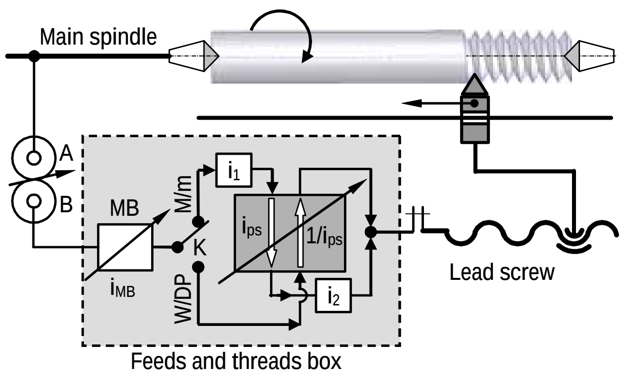

Fig. 1. Block scheme of a threading linkage for an engine lathe.

Also, when the pitch selector is traversed in the opposite direction, the Whitworth or Diametral Pitch threads are obtained and the transfer ratio of the selector is:

$$i_{tot}^{W/DP} = \frac{1}{i_{ps}} \tag{5}$$

From mechanical standpoint, it is known that the utilization of the mechanism with Norton cone, an easy variant for designing, was nearly total eliminated, because of its very low stiffness. In order that this disadvantage to be eliminated, the mechanisms with sliding gears are nearly exclusive used at the up-to-date threads and feeds boxes. From standpoint of stiffness, these are very good, but from standpoint of kinematic synthesis, their designing is more difficult.

In this paper, it is shown a new method of kinematic synthesis for the threads and feeds boxes from lathes, by means of this, the optimization of their kinematic and constructive parameters being achieved.

The difficulty of the kinematic synthesis achievement for the pitch selector arises from the necessity of obtaining, without error, between the same two shafts, by using cylindrical gears with straight teeth, of a number of transmission ratios which to be equal with the number of the basis pitches [3].

3. A KINEMATIC SYNTHESIS METHOD OF THE THREADS AND FEEDS BOX FROM ENGINE LATHES

If the equations of the transfer function for the obtaining of the Metric, respectively Whitworth pitches, are written on the basis of the block scheme shown in figure 1, the following are successively obtained:

$$p_M = i_{A/B} \cdot i_{MB} \cdot i_{tot}^{M/m} \cdot p_{ls}\,, \tag{6}$$

$$p_W = \frac{25.4}{N_p} = i_{A/B} \cdot i_{MB} \cdot i_{tot}^{W/DP} \cdot p_{ls}\,, \tag{7}$$

where:

- p_{ls} is the lead screw pitch;
- $i_{A/B}$ – the transfer ratio of the change gears;
- i_{MB} – the transfer ratio of the multiplying/reducing box;
- i_{ps} – the transfer ratio of the pitch selector;
- i_1, i_2 – the transfer ratios of the gears which provide the traverse of the motion direction between the two shafts of the pitch selector for the obtaining the Metric and Module threads.

If the relations (6) and (7) are written as follows:

$$\begin{aligned} p_{ls} &= \frac{1}{i_{A/B}} \cdot \frac{1}{i_{MB}} \cdot \frac{1}{i_{tot}^{M/m}} \cdot p_M = \\ &= \frac{1}{i_{A/B}} \cdot \frac{1}{i_{MB}} \cdot \frac{1}{i_1} \cdot \frac{1}{i_{ps}} \cdot \frac{1}{i_2} \cdot p_M\,, \end{aligned} \tag{8}$$

$$p_{ls} = \frac{25.4}{N_p} \cdot \frac{1}{i_{A/B}} \cdot \frac{1}{i_{MB}} \cdot \frac{1}{i_{tot}^{W/DP}} = \frac{25.4}{N_p} \cdot \frac{1}{i_{A/B}} \cdot \frac{1}{i_{MB}} \cdot i_{ps} \tag{9}$$

and the relations (8) and (9) are equalized, it is obtained:

$$p_M \cdot N_p = i_1 \cdot i_2 \cdot i_{ps}^2 \cdot 25.4\,. \tag{10}$$

Therefore, the transfer ratios of the pitch selector can be calculated with the relation:

$$i_{ps} = \sqrt{\frac{p_M \cdot N_p}{i_1 \cdot i_2 \cdot 25.4}}\,. \tag{11}$$

For an adjustment step provided by the pitch selector, it is obtained – when the pitch selector is coupled on one direction (the switch K, on the position M/m, fig. 1) – for example, the Metric thread of p_M pitch, and when the pitch selector is coupled on the opposite direction (the switch K, on the position W/DP), the Whitworth thread of p_W pitch.

By analyzing the relation (11), one can easy notice the following aspect, as the kinematic deviation of pitch to be reduced, by the obtaining of some transfer ratios i_{ps} of some common fractions form, it is necessary as the ratio $(p_M \cdot N_p)/(i_1 \cdot i_2 \cdot 25.4)$ to be perfect squares. These conditions are easy achieved for the first product ($p_M \cdot N_p$), but much more difficult for the second because of the decimal number 25.4. For all that, the ratios i_1 and i_2 can be so selected that the kinematic deviation of pitch to be a minimum one.

In the Fig. 2, the skeleton diagram of a threads and feeds box for an engine lathe is shown. This is achieved in accordance with the block scheme from the figure 1.

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By analyzing the relation (11), one can remarked that the grouping of the two value pairs $p_M \cdot N_p$ will bring the key for the product $i_1 \cdot i_2$.

Virtually, the grouping of these values in pairs, starts from the scale of the pitches that must be obtained by means of the threads and feeds box being designed, but for an optimum grouping, some experience in the synthesis of the gear transmission is necessary, too.

Also, the geometrical features of the threads can be grouped in two fields: with basic values and with increased values. So, a great number (practically a fourfold increase) of values for the threads performed by the threads and feeds box having a minimum size, can be obtained.

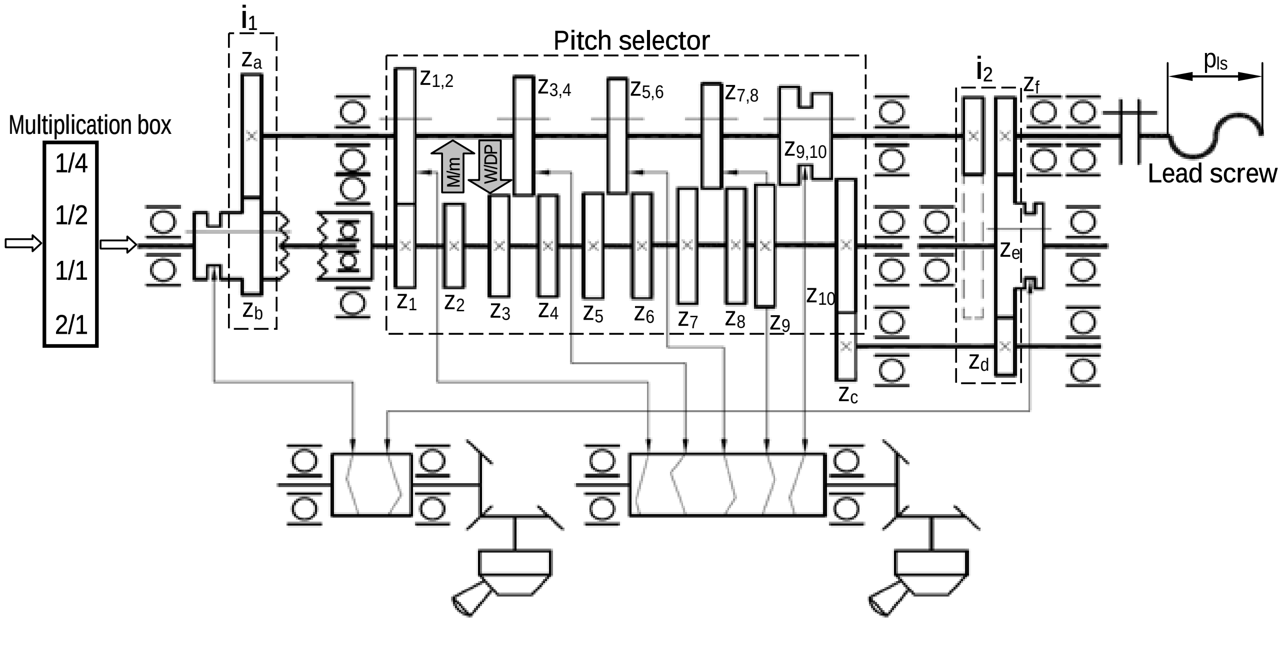

Fig. 2. Skeleton diagram of a threads and feeds box for an engine lathe.

Table 1

Two value pairs p_M and N_p

No	p_M	N_p	$p_M \cdot N_p$
1.	1.125	9	10.125
2.	1.1875	9.5	11.28125
3.	1.25	10	12.5
4.	1.375	11	15.125
5.	1.4375	11.5	16.53125
6.	1.5	12	18
7.	1.625	13	21.125
8.	1.6875	13.5	22.78125
9.	1.75	14	24.5
10.	2	16	32

For the threads and feeds box from this paper, 10 pairs of basic values $p_M \cdot N_p$ were selected, these being itemized in the Table 1.

The values from the Table 1 correspond to the basic value (1/1) of the multiply factor that featuring the multiplying box. The other values of the pitches p_M and N_p corresponding to the multiply factors, 1/4, 1/2 and 2/1, of the multiplying box (Fig. 2), are obtained by multiplying the values from the Table 1 with the appropriate multiply factor.

Must be also pointed that the $p_M \cdot N_p$ product values will have the same values for the similar positions of those four series of values, respectively 1/4, 1/2 1/1 and 2/1.

For the kinematic synthesis of the pitch selector, with 10 distinct transfer ratios, the option was for the fixed ratios i_1 and i_2 of equal values:

$$i_1 = \frac{z_a}{z_b} = \frac{34}{29}, \qquad (12)$$

$$i_2 = \frac{z_c}{z_{10}} \cdot \frac{z_e}{z_d} \cdot \frac{z_f}{z_e} = \frac{32}{32} \cdot \frac{33}{18} \cdot \frac{17}{33} = \frac{17}{18}. \qquad (13)$$

For probation, taking into consideration the first two value pair from the Table 1, it is obtained:

$$p_M \cdot N_p = 1.125 \cdot 9 = 10.125, \qquad (14)$$

$$i_{ps} = \sqrt{\frac{p_M \cdot N_p}{i_1 \cdot i_2 \cdot 25.4}} = \sqrt{\frac{10.125}{\frac{34}{29} \cdot \frac{17}{18} \cdot 25.4}} = \sqrt{0.36000122}, \qquad (15)$$

and consequently the kinematic deviation will be:

$$\frac{0.36000122 - 0.36}{0.36} \cdot 100\% \cong 0.00034\%, \qquad (16)$$

therefore a deviation much smaller than the admissible limit, even for the accurate threads.

For the products of $p_M \cdot N_p$ form, the condition of perfect square can be easy observed by an appropriate grouping of the values for the Metric threads pitches with the number of pitches/inch for the Whitworth threads.

Further on, each of those 10 ratios – i_{ps} – is calculated with the above relation (11), the following approximation being made:

$$i_1 \cdot i_2 \cdot 25.4 = 0.36. \qquad (17)$$

After the assignation of the values for the transfer ratios i_1 and i_2, the main problem is the finding of those ten transfer ratios i_{ps} for the pitch selector.

For the two value pairs $p_M \cdot N_p$ already assigned (according to the Table 1), those ten values of the transfer ratios for the pitch selector i_{ps} being found with the

Table 2

Transfer ratios, i_{ps}, of the pitch selector from the threads and feeds box structure

No	$p_M \cdot N_p$	i_{ps}	Module	Gear symbol, (figure 2)
1.	10.125	$\frac{18}{30}$	3	z_1 / $z_{1,2}$
2.	11.28125	$\frac{19}{30}$	3	z_2 / $z_{1,2}$
3.	12.5	$\frac{20}{30}$	2.75	z_3 / $z_{3,4}$
4.	15.125	$\frac{22}{30}$	2.75	z_4 / $z_{3,4}$
5.	16.53125	$\frac{23}{30}$	2.75	z_5 / $z_{5,6}$
6.	18	$\frac{24}{30}$	2.75	z_6 / $z_{5,6}$
7.	21.125	$\frac{26}{30}$	2.5	z_7 / $z_{7,8}$
8.	22.78125	$\frac{27}{30}$	2.5	z_8 / $z_{7,8}$
9.	24.5	$\frac{28}{30}$	2.25	z_9 / $z_{9,10}$
10.	32	$\frac{32}{30}$	2.25	z_{10} / $z_{9,10}$

relation (11), are shown in the Table 2. The variant of some ratios with constant denominator was chosen, because so the calculus is simplified. Of course, this variant supposes the module finding of the gear transmission with the ratio i_{ps}, too, because in the conditions of the same distances between axes, the module will be dependent on the total number of gearing teeth and the specific addendum of the teeth profile, too.

4. CONCLUSIONS

Essentially, the feed and thread boxes are separate discrete speed variators that have a typical kinematic structure in their construction: the pitch selector. The fundamental condition to achieve by means of an appropriate number of cylindrical gears, without kinematic error, more partial transmission ratios between the same two shafts, needs a special theoretical tackling. The computer use can simplify the optimum solution determination, according as there is a typical mathematical algorithm for the calculation of these ratios.

In order that a simple method of kinematic synthesis for the threads and feeds boxes from the engine lathes to be elaborated, in paper, a block scheme was firstly shown, which was the basis for the writing of the transfer equations related to the obtaining of the pitches for those two fundamental threads types: Metric and Whitworth.

Beginning from these equations, some calculus relations were determined for the transfer ratios of the pitch selector, for the obtaining of the basis pitches. By using this methodology of calculus, the kinematic synthesis of a threads and feeds box – its skeleton diagram being shown in the figure 2 – was achieved.

The proposed method has the advantage that is a simple one and offers the possibility as the kinematic deviation of the values for the obtained threads pitches related to the standard values to be minimized from the synthesis stage.

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Author:

PhD, Dumitru DUMITRU, Lecturer, VALAHIA University of Târgovişte, Mechanical Department
E-mail: ddumitru@valahia.ro