STRUCTUAL REPRESENTATION OF MACHINE AND TOOL MACHINERY FOR KINEMATIC CHIP METAL BREAKING

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Annotation

The paper deals with research of the various aspects of kinematic metal chips breaking techniques in multi edge machining. The adaptive type machinery scheme synthesis is developed to clear the adaptive links role in the kinematic chips breaking process. The morphological characteristics analysis of chips breaking schemes is performed that makes it possible to design the new principal equipment constructions for the chip cutting and breaking when using the adaptive links between the separate cutting elements. The results of the mentioned synthesis are gathered in the table form and are described in detail. The integral logic function of the discrete cutting schemes is proposed to use in the choosing process of the necessary machinery.

Key words: *kinematic metal chips breaking, machines and tool equipment, multi edge machining, adaptive link, synthesis.*

Introduction

Manufacturing processes intensification in metal machining leads to the sharp increase in the mass of metal chips removing from the surface. Sometimes depending on the machining material the chips output goes up to 35.6% of the work piece mass.

In the machining process of the cementing and refractory materials (such as stainless, high-alloy and speed steels) as well as a lot of nonferrous alloys the metal chip takes a shape of a long continuous strip or spiral. In practice one cannot predict even the direction of its flowing. Such metal chip was named “continuous chip”. Its presence is the negative factor of the metal cutting machining [1].

The complexity of the chips breaking problem led to the various methods and techniques of it solving. Analyzing and systematization of the chip breaking and cutting methods allowed joining them into two large groups: natural and artificial. Natural methods examination gives it possible to discover the chip breaking mechanism and set a lot of purposeful ways to improve the most perfect of the artificial techniques that are more numerous.

Actuality and investigation main goal

So as it was discovered the search of new design and technology solutions of the methods and machinery for the chip breaking presents the actual engineering and scientific problem. Among the modern and effective chip cutting methods the kinematic chip breaking is of prominent value. This method allows reaching the stable forming of the chips elements of the calculated length not in regard with the material type. Essence of the kinematic chip breaking methods in the machining process with varying parameters lies in the periodical interruption of the machining process due to the setting some or that of cutting tool movement regularities relatively to the machined work piece.

Almost all of the known methods of kinematic chip breaking are based on the vibration cutting. That means that the cutting feed of constant value is imposed by the additional tool oscillation movements. In this way it can be advised to use in the internal surfaces machining the tool linear oscillations as the additional vibration movements as well as in the machining of the external surfaces – either the linear or swinging oscillations.

The investigations of the vibration machining processes are widely discussed in a number of the scientific and applied papers. These researches deal with the advantages of the vibration cutting in regard to the traditional schemes of the materials machining [1]. The results of the manufacturing implementation approved the effectiveness and prospective character of this kind of metal cutting machining as well. At the same time cutting with vibrations has some shortcomings dealing with the additional dynamic loadings on the cutting tools and all the machine tool systems as a whole [2, 3].

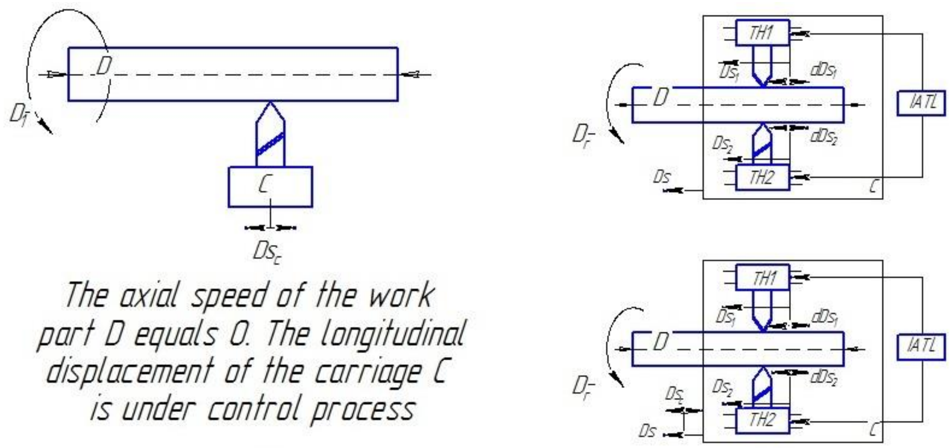
The total elimination of these disadvantages is impossible but it is necessary to find in theoretical and experimental research of the vibration cutting process the optimal schemes, conditions and regimes that minimize the negative effects. In this way these tasks form the integrated problem to be solved [4].

Investigation results

The scheme synthesis of machinery for the chip breaking can be developed as a result of several procedures: at first – by integrating the kinematic features of the well-known schemes of discrete cutting; secondly – by defining the role of adaptive type links in these processes and at last by rationalization of the scheme variants regarding to the necessity of the certain machining conditions. In the given aspect only those schemes of chip breakage are discussed that directly include the axial oscillations of the manufacturing system elements in the feed direction taking into account that these oscillations make no influence on the machining accuracy.

The methods and machinery of kinematic chip breaking in metal cutting with axial oscillations can be composed in the integrated system basing on the principle kinematic schemes using (fig. 1-4).

At first let us compare four scheme variants of the kinematic chip cutting and breaking without using the adaptive links between the separate tools and in a case of adaptive type breaking.



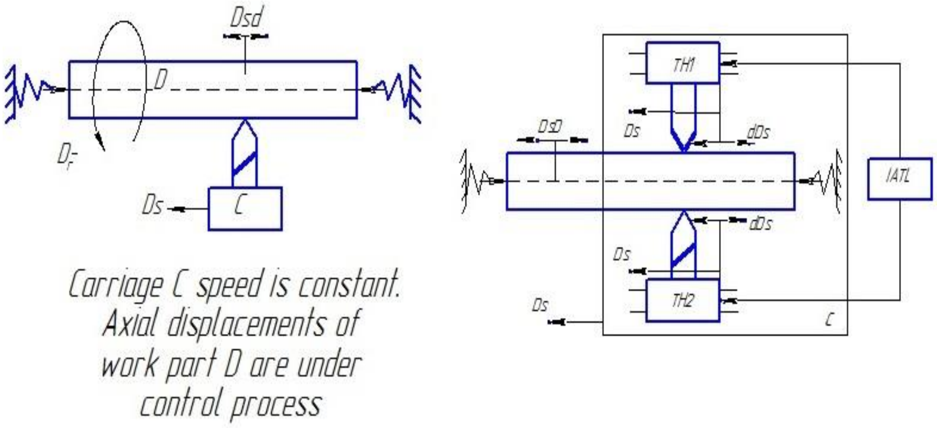
a) b)

Fig.1. Comparison of structural and kinematic schemes of chip breaking in a case when the axial speed of work piece equals 0

In a first case (fig. 1) the work part in the process of machining is non movable in the axial direction and the forced oscillations *Dsc* are imposed on the lathe slide carriage steady motion *Ds*. Such integrated motion allows periodically cutting tool stopping and as a result chip cutting off. The scheme of adaptive discrete cutting is of different kind from the given one. It provides the chip breaking using only the interlinked oscillation motions ∂Ds_1 and ∂Ds_2 of cutting tool holders (THi, i=1,2) as a result of the inter-tool adaptive type link (IATL) operation as well as the combining the movement *Dsc* with vibrations and oscillations dDs_1 and dDs_2.

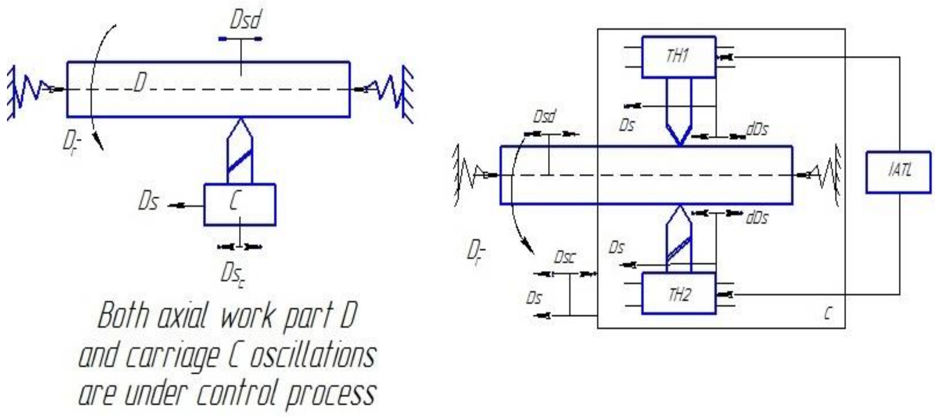
Some kinematic methods of chip breaking in the process of turning are used in a case of the constant feed speed value as a result of the controlled work part axial displacements (fig. 2). As an alternative to the given one the scheme of the chip breaking using inter-tool adaptive links can be discussed. In this case the working part is oscillated in the axial direction as well. It is easily can be noted that not taking into consideration the motion *Dsd* the proposed scheme is transferred to the similar scheme at the fig. 1.

The chip breaking in non-adaptive single tool machining can be also achieved by simultaneous velocities changing both axial displacements of the carriage and work part (fig. 3). This combination can be applied to the case of multi edge turning in the process of machining with inter-tool adaptive type links using.



a) b)

Fig. 2. Comparison of structural and kinematic schemes of chip breaking in a case when the carriage speed is constant



a) b)

Fig. 3. Comparison of structural and kinematic schemes of chip breaking in a case when both work piece and carriage oscillations are under control process

Another variant of discrete machining process using two or more single point tools is possible. In this case the feed speed of one of the tools is constant and the additional carriage drive (drives) is used to produce the additional oscillations of the tool (tools) (fig. 4). In a case of multi tool cutting with adaptive links the chip breaking scheme can be proposed in which the feed speed of one of the cutting tools is of constant value($Ds_1 = const$), but the next part of the total feed is divided between another tools (motions ∂Ds_2, ∂Ds_3 etc.) in a process of adaptive links functioning.

The given schemes combining in the integrated one makes it possible to discuss their advantages and unsatisfactory features as well as prove the actuality of adaptive type links using in the chip breaking methods. It is also important to analyze the effectiveness of such techniques in combination with other motions of the machining system components.

The development of new schemes machineries for kinematic chip breaking using the links of adaptive type between separate cutting elements in the machining process of revolution surfaces is convenient to analyze in an easy-to-use form by means of morphological synthesis method.

To carry out this method let us differentiate the machinery's morphological characteristics. In this way let us take into account only the most fundamental ones that make the significant influence on the process of chip breaking. Besides that let us consider that the discussed synthesis deals with only the machining method of feed division because the feed division actually provides the inter-linked cutting elements oscillations in the process of adaptive type links functioning.

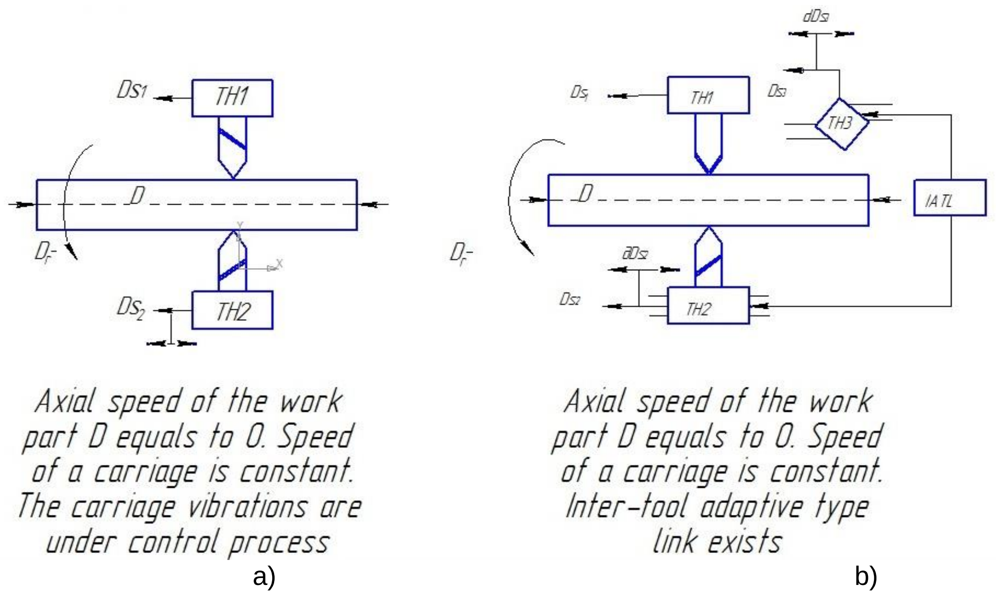


Fig. 4. Comparison of structural and kinematic schemes of chip breaking in a case when the axial speed of work piece equals 0 and the speed of the carriage is constant. The additional carriage vibrations are under control process

All the morphological features set of the chip breaking schemes with the adaptive links use it is convenient to distribute into 5 groups.

Herewith the first group of characteristic features (typ) (see table 1) relates to the number of cutting elements (edges) that take a rate part in machining as well as to the links between these cutting elements

Table 1

Morphological characteristic features first group (typ) of chip breaking schemes

Characteristics of multi edge machining (typ)	
1. Number of cutting edges (tools) (no)	2. Links between cutting edges (lk)
1.1 One	2.1 Without
1.2 Double	2.2 Using adaptive links only
1.3 Three and more	2.3 One tool is rigidly fixed, adaptive links exist between others

The second group of factors (kin) (table 2) deals with the cumulative action of motions carrying out by elements of machine tool accessories (MTA) in chip cutting and breaking. The comparative analysis of the necessary motions and their correlation with the well-known kinematics of chip breakage was illustrated in figures 1-4. These motions realization can be provided by additional drive that gives the useful oscillation to the machining system. Such a vibration can be different in the shape mode being sinusoidal and harmonic or in the impulses shape of squire pulse, triangular or parabolic form.

The third group of characteristic features (sys) (table 3) relates to the manufacturing system breakage setting. Thus item is discussed because the cutting elements setting for machining can be different for various cases. For example the setting can be the same for different tools (edges). Alternatively the cutting edges can be set into different cut depths as well as with the height errors or non-uniformly of the work piece circumference. Besides that the work piece can be fixed with eccentricity as well as with an error when its longitudinal axis straddles with the spindle (tool) rotation axis.

The fourth features group (cut) (table 4) regards to the geometry of cutting edges taking into account the differences in major and minor cutting edges angles as well as in the face and clearance angles and in the cutting edge angle.

The fifth features group (mec) (table 5) discusses the construction design characteristics of the adaptive type mechanisms that fulfill the function of oscillations operation. They can include the control system but the control system can be off of the process of chip breaking. The mentioned characteristics can be exemplified with the leveling devices using lever mechanism, differences in screw kinematic pairs as well as in cone-ball or cone-pin type mechanisms or in hydraulic system of adaptive type.

Table 2

Second group (kin) of chip breaking schemes morphological factors

Breaking kinematics characteristics (kin)		
1. Oscillation motions in breaking (mo)	2. Additional drive (dr)	3. Shape of additional oscillations (os)
1.1 Motions are off	2.1 Without additional drive	3.1 Oscillations are off
1.2 Adaptive type mechanisms motion only	2.2 Using additional drive	3.2 Harmonic
1.3 Carriage slide motion (tool unit)		3.3 Impulse of squire pulse shape
1.4 Work piece motion		3.4 Impulse of triangular shape
1.5 Both carriage slide (tool unit) and work piece motion		3.5. Impulse of parabolic shape

Table 3

Third group (sys) of chip breaking schemes morphological features

System setting (sys)	
1. Tools setting (to)	2. Work piece setting (de)
1.1 Equal	2.1 Ideal
1.2 Different cut depths	2.2 With eccentricity
1.3 Errors in height	2.3 Straddles with the spindle axis

Table 4

Fourth group (sys) of chip breaking schemes morphological features

Cutting edges geometry characteristics (cut)	
1. Edges angles (an)	2. Cutting edges sharpening (sh)
1.1 Equal	2.1 The same
1.2 Different major or minor angles	2.2 Different point radius values
1.3 Different face angles	2.3 Different edges sharpening angles
1.4 Different cutting edges inclination	2.4. Other

Table 5

Fifth group (sys) of chip breaking schemes morphological features

Adaptive type link irregularities (mec)	
1. Control system is off (uc)	2. With control system (wc)
1.1 Symmetry of the inter-tool link	2.1 Control system with actuators
1.2 Different levers of the leveling system	2.2 Control of levers length
1.3 Different screws pitches	2.3 Control of rotating speed
1.4 Different characteristics of cone-ball and other mechanisms	2.4 Control of tools feed
1.5 Differences in hydraulic devices parameters	2.5. Control of system components rigidity
1.6 Other	2.6. Other

Integrating all these characteristics in a total system provides deriving the basic morphological model. Combinations of the model components develop the set of chip breaking schemes in multi-edge cutting with the adaptive type links using. The general logic function of the discrete cutting in chip breaking can be written as follows:

$$\tau = typ \Lambda kin \Lambda sys \Lambda cut \Lambda mec. \quad (1)$$

The connecting links between the characteristic features of different groups cannot be derived as single-valued. But the morphological matrix is developed in such a form that in a general case the following equalities can be obtained:

$$typ = no \Lambda lk\,;\; kin = mo \Lambda dr \Lambda os\,;\; sys = to \Lambda de\,;\; cut = an \Lambda sh\,;\; mec = uc \Lambda wc\,.$$

Correspondingly the general formula of the schemes is:

$$\tau = (no \Lambda lk) \Lambda (mo \Lambda dr \Lambda os) \Lambda (to \Lambda de) \Lambda (an \Lambda sh) \Lambda (uc \Lambda wc). \quad (2)$$

For the separate features groups it can be written also:

– Group typ:; $no = \underset{j=1}{\overset{3}{V}}(no_i)$; $lk = \underset{k=1}{\overset{3}{V}}(lk_k)$.

– Group kin: $mo = \left[\underset{l=1}{\overset{5}{V}}(mo_1)\right] V \left[\underset{r=1}{\overset{3}{V}}(mo_2 \Lambda mo_{2+r})\right]$; $dr = dr_1 V dr_2$; $os = \underset{m=1}{\overset{5}{V}}(os_m)$.

– Group sys: $to = \left[\underset{n=1}{\overset{5}{V}}(to_n)\right] V \left[\underset{s=1}{\overset{2}{V}}(to_2 \Lambda to_{2+s})\right]$; $de = \left[\underset{g=1}{\overset{4}{V}}(de_g)\right] V \left[\underset{p=1}{\overset{2}{V}}(de_2 \Lambda de_{2+p})\right]$.

– Group cut: $an = \left[\underset{t=1}{\overset{3}{V}}(an_t)\right] V \left[\underset{f=1}{\overset{3}{V}}(an_2 \Lambda an_{2+f})\right]$; $sh = \left[\underset{e=1}{\overset{3}{V}}(sh_e)\right] V \left[(sh_2 \Lambda sh_3)\right]$.

– Group mec: $uc = \underset{0=1}{\overset{5}{V}}(uc_0)$; $wc = \underset{v=1}{\overset{5}{V}}(wc_v)$.

The analysis of tables 1-5 as well as of the given logical regularities shows that in the limits of the developed general formula some combinations are not real and they must be excluded. For example the drill has only two cutting edges, not more; the additional drive is off in any way when the oscillation motions are off and so on. Thus we can also write the logic limitations that are to be considered in the schemes developing, for example:

$$lk_1 \Lambda mo_2 = false;\ lk_2 \Lambda mo_1 = lk_2 \Lambda mo_3 ... lk_2 \Lambda mo_5 = false$$

$$lk_1 \Lambda mo_1 \Lambda dr_2 = false;\ uc_i \Lambda wc_j = false;\ (i = \overline{1,5};\ j = \overline{2,5});\ \text{etc.}$$

The variants with these limitations are to be excluded from consideration.

In this way the schemes variants set can be represented by formula

$$\tau_p = [true(\tau)]. \quad (3)$$

By the way it is clear that the given tables also represent the schemes that are functionally operative and effective but do not achieve the chip breaking. So according to the formulas

$$lk_1 \Lambda mo_1 \text{ or } lk_2 \Lambda mo_2 \Lambda dr_1 \Lambda os_1 \Lambda to_1 \Lambda de_1 \Lambda an_1 \Lambda sh_1 \Lambda uc_1 \Lambda wc_1,$$

the schemes set also cannot be discussed, because these schemes regard to the variants of single point or multi edge stable type cutting without adaptive links and kinematic oscillations.

Applying other additional limitations the morphological set is to be narrowed. Thus exemplifying the two edge lathe machining with adaptive links using the lever force leveling mechanism the following alternatives can be proposed:

$$\tau_T = no_2 \Lambda lk_2 \Lambda mo_2 \Lambda dr_1 \Lambda os_1 \Lambda (to_1 V to_2) \Lambda dr_1 \Lambda (an_1 V am_1) \Lambda sh_1 \Lambda (uc_1 V uc_2) \Lambda wc_1. \quad (4)$$

So in result we obtain in this case that the kinematic chip breaking comprises such schemes as: 1) lathe machining by equal tools being set for different dimensional allowances removal; 2) cutting tools machining with different major cutting angles; 3) different arm levers leveling mechanism using as an adaptive type link; 4) combination of these techniques.

Conclusions

1. As an investigation result of the various aspects of kinematic metal chips breaking techniques in multi edge machining the adaptive type machinery scheme synthesis is developed to clear the adaptive links role in the kinematic chip breaking process.

2. The morphological characteristics analysis of chips breaking schemes is performed. The represented logic operations with the morphological matrixes give the possibility to design the new principal equipment constructions for the chip cutting and breaking when using the adaptive links between the separate cutting elements. The results of the mentioned synthesis are gathered in the table form and are described in detail.

3. The given systematic approach makes it possible to develop the effective strategy for choosing a lot of functionally operative accessories for turning, drilling, boring machining followed by guaranteed continuous chip cutting and breaking. As a result of applying the additional limitations that exclude the contradictive and nonoperational variants the developed morphological set can be narrowed to the reasonable mathematical form. Thus the actually proposed variants of effective chip breaking in machining process comprise the ease methods of system setting and adjustment, as well as right tools geometry choosing.

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