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IMPROVING THE EFFICIENCY OF THREAD ROLLING WITH MANAGEMENT OF TECHNOLOGICAL CONNECTIONS

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A B S T R A C T

The formation of threads by plastic deformation is one of the most effective ways of forming threads, which determines their high performance characteristics; Increasing the accuracy of thread manufacturing is especially important for organizing an effective process of automating the assembly of threaded connections. The article analyzes the mechanism of thread accuracy formation during thread rolling with radial feed on two-roll roll forming machines and with the help of tangential thread rolling heads with tangential feed. Connections between input and output parameters are revealed, a new method of thread rolling with tangential feed is presented, which practically without reducing the productivity of the technological operation (feed) determine the direction of reducing the knurling force, as also proposed ways to improve the accuracy of rolled threads.

K E Y W O R D S

Thread;
Rolling;
Radial;
Tangential;
Feed;
Accuracy of parameters;
Technological connections.

Introduction

Threaded connections are widely used in various designs. The reliability and efficiency of threads formed by plastic deformation of the material is higher than threads obtained by cutting. Increasing the efficiency of any technological operation is the main task of engineering technologies. Modern requirements for the technical level and quality of products, their components, surfaces that form parts, as well as the competitiveness of products require an increase in the efficiency of their production, which is an integral part of the efficiency of their use. Thread rolling is one of the methods that ensures high quality and productivity of its formation is characterized by a high degree of suitability for automation. Improving the accuracy of thread manufacturing is especially important for organizing an efficient automatic assembly of threaded connections. Based on the foregoing, increasing the accuracy and efficiency of the formation of threads by plastic deformation of the material is of great technological and operational importance. The formation of threads by this method on two-roller profile rolling machines is the most common for workpieces made of viscous-plastic materials [1-5].

Tangential heads also are very effective for formation threads on lathe machines by plastic deformation. Formation of threads with high productivity, possession of high performance characteristics of rolled threads make the use of thread rolling with tangential heads very relevant. It seems to be very effective and profitable to form threads by rolling on the details of equipment for oil production and transportation. Unfortunately, one of the main disadvantages of thread rolling with tangential thread rolling heads is the impossibility of thread rolling on workpieces with relatively low stiffness and great length [1, 3]. Since, as a result of the presence of a large nominal contact area «tool-workpiece» (fig. 1, the profile of rolled threads is not shown conventionally in the figure), too much rolling force acts on the workpiece the stresses on the surface are equal to and higher than the yield strength of the material. In particular, due to the low radial stiffness of hollow blanks, large plastic deformations occur along the inner diameter of the blank. Sometimes it is possible to carry out the rolling process at very low feed rates (in most cases this is also impossible), which, leads to an increase in the time the rolling and thread rolling becomes in not effective.

The aim of the work is to analyze the mechanism for forming the accuracy of threads formed by plastic deformation by radial feed on two-roller profile rolling machines and by tangential feed with tangential heads, to identify connections between the output and input parameters of technological systems, to develop ways to increase the accuracy of the

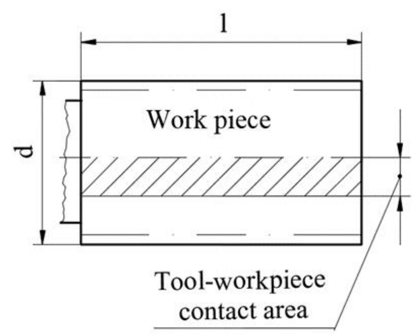

Fig. 1. Scheme of the fields of action of the rolling force when rolling threads by traditional methods

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parameters of rolled threads and features of a new method of rolling threads with tangential feed.

Research method

The solution to this problem is carried out on the basis of the analysis and control of technological connections between the output and input parameters of the technological system during the formation of threads on two-roller profile rolling machines with radial feed also the rolling threads with tangential head with tangential feed.

Formation of threads on two-roller profile rolling machines with radial feed. To implement thread rolling, the workpiece (3) is freely installed above the support knife (not shown in the figure), between the rolling rollers (1 and 4) (fig. 2a). Thread rolling is carried out with the coordinated rotation of the rollers (1 and 4) and the radial movement of one of them (4). With the radial feed of the movable head (6), the roller (4) mounted on its spindle (5) presses the workpieces (3) against the roller (1) mounted on the spindle (2) of the fixed head. Due to the torque created by the frictional forces between the rollers and the workpiece, the workpiece rotation is realized, which is linked to the rotation frequency of the rollers (1, 4). When the pressure on the surface of the workpiece is higher than the yield point of the material, the latter deforms plastically, fills the interturn grooves of the tools and the profile of the rollers is transferred to the workpiece [1-4].

In figure 2a schematically shows the mechanism of the formation of an error in the shape of the rolled threads due to the turn of the movable head (the value of Δ at the length l_1 of the head) and due to the bending of axes spindles (rotation of the roller axis by the angle α). A guaranteed gap (δ) is provided between the guides of the machine (7) and the sliding elements-slide of the movable head (8) (fig. 2a). The angle of turn of the head (β) is also a function of the reference length of the contact (b) of the guide-slide on the plane of rotation.

In figure 2b shows the diagrams of the transmission of drive mechanisms of rotation of the spindle and the acting forces (rolling, friction and engagement) in the movable head of a two-roller profile rolling machine, where the following are indicated: 9. Spline connection, 10. Worm gear, 11. Spindle gear, 12. Hydraulic cylinder, 13. Detail, carrying guides for the movable head.

On the basis of the analysis of technological connections, acting during the formation of threads on two-roller profile rolling machines with radial feed, it was revealed that there are the following functional connections between the output and input parameters of the technological process:

$$\Delta P = f(\Delta P_t, \Delta P_{ta}, \Delta P_k, \Delta P_s, \Delta P_{bt}, \Delta P_{tt}, P_{bp}, \Delta P_{ht}), \quad (1)$$

$$\Delta\alpha = f(\Delta\alpha_t, \Delta\alpha_{ta}, \Delta\alpha_k, \Delta\alpha_s, \Delta\alpha_{bt}, \Delta\alpha_{tt}, \Delta\alpha_{ht}, \Delta\alpha_{bp}), \quad (2)$$

where ΔP and $\Delta\alpha$ – are the errors of the pitch and the profile angle of the rolled threads, respectively;

ΔP_t and $\Delta\alpha_t$ – are the errors of the pitch and angle of the thread profile rollers-of tools, respectively;

ΔP_{ta} and $\Delta\alpha_{ta}$ – are the errors of the pitch and angle of the thread profile from the error of matching the tool profiles when adjusting the positions of the tools;

ΔP_k and $\Delta\alpha_k$ – are the errors of the pitch and angle of the thread profile, caused by the deviation of the working surface of the knife-support from the horizontal position;

ΔP_s and $\Delta\alpha_s$ - are the errors of the pitch and angle of the thread profile due to bending of the axes of the spindles, under the action of the force rolled;

ΔP_{bt} and $\Delta\alpha_{bt}$ – are the errors of the pitch and angle of the thread profile due to thermal deformations of the workpiece;

ΔP_{tt} and $\Delta\alpha_{tt}$ – are the errors of the pitch and angle of the thread profile due to uneven thermal deformations of the material of the working parts of the tools;

ΔP_{bp} and $\Delta\alpha_{bt}$ – are the errors of the pitch and angle of the thread profile caused by the position of the workpiece;

ΔP_{ht} and $\Delta\alpha_{ht}$ – are the errors of the pitch and angle of the thread profile, caused by turn of movable head.

Formation a threads with tangential head with tangential feed. For thread rolling, the tangential head is mounted in a tool holder (or turret) of a lathe machine, and the workpiece is fixed in the spindle of machine. After giving the workpiece a rotational movement, the head is given a feed movement in a direction perpendicular to its axis. The thread-rolling rollers come into contact with the workpiece and, having entered into engagement with it, begin to rotate and, due to the radial feed, roll the workpiece and gradually form a threaded profile on it. When the vertical axes of symmetry of the rollers and the workpiece are aligned, the tool feed stops and it is retracted.

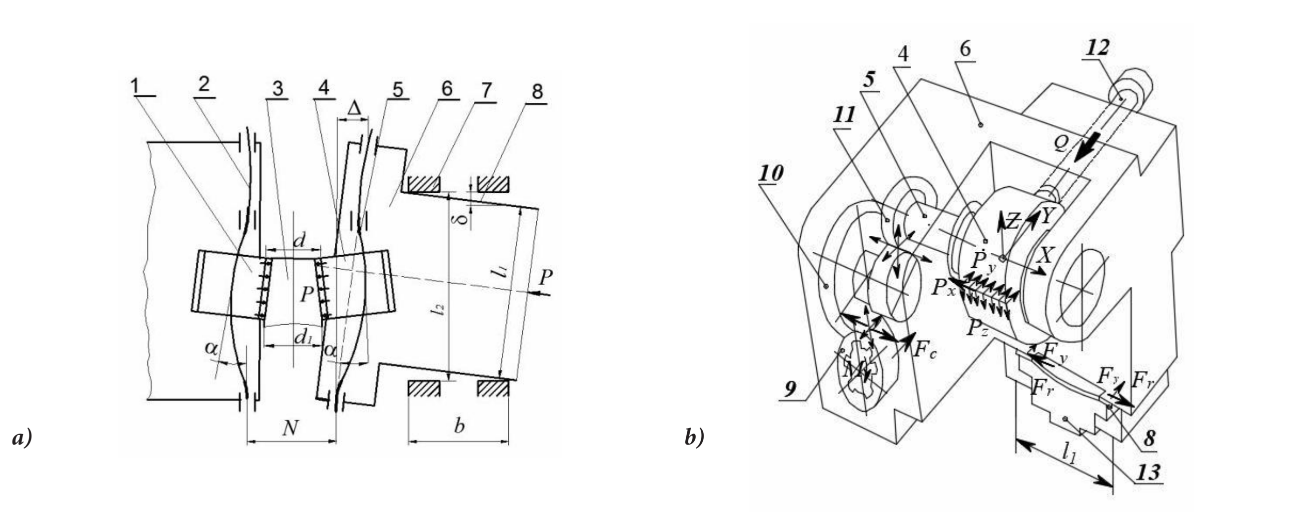

Fig. 2. Schemes of rolling thread (a) and the movable head of a two-roller profile rolling machine (for example, machine model A2528) (b)

In order to solve the problem posed, we investigate the rolling force formed during thread rolling with a tangential head. It is known that the force acting on the workpiece from the side of the knurling rollers acts throughout the entire length of the roller-workpiece contact in the form of a distributed load (force) (fig. 1). The stress that occurs along the contact area, taking into account also the thickness of the deformable layer of the material, is equal to the yield strength of the material. Thus, the radial and tangential forces acting on the workpiece depend on the size of the «workpiece-tool» contact area. And the size of the contact area depends on the diameters of the tool, the rolled thread, the thread pitch.

The functional relationship between the thread profile angle and the initial technological factors can be expressed as follows:

$$T_{zyx} = f(d_2, D_2, P, S_t, \sigma_t) \quad (3)$$

here, d_2 – average diameter of the rolled thread,

D_2 – average diameter of the tool (roller);

P – thread pitch;

S_t – tangential feed;

σ_t – yield strength of workpiece material.

m – other influencing parameters according to the conditions of the thread rolling process.

Based on the analysis of the mechanism for the formation of thread parameters, and the search for ways to control the connections acting between the input and output parameters when rolling threads with radial feed on two-roller profile rolling machines, also with tangential head with tangential feed have been developed ways to improve the accuracy of rolled threads and thread rolling with tangential heads.

When thread rolling with tangential heads, the angle of the workpiece wrap in relation to the tool and the thread length l, during the rolling process, we can say thatremain constant and reach large values (fig.1, conditionally, the thread profile is not indicated). As a result, the force of rolling reach high values.

Based on the analysis of the mechanism for the formation of thread parameters, and the search for ways to control the connections acting between the input and output parameters when rolling threads with radial feed on two-roller profile rolling machines, also with tangential head with tangential feed have been developed ways to improve the accuracy of rolled threads and thread rolling with tangential heads.

Improving the efficiency of thread rolling

Increasing the accuracy of threads parameters when her rolling with radial feed.

The following paths have been defined and proposed increasing the accuracy of threads parameters when her rolling with radial feed on two-roller profile rolling machines:

1. A technique is proposed for determining the diameter of the workpiece ($d_{w\min}$ and $d_{w\max}$) on the basis of dimensional relationships between the under-thread surface and the average diameter of the rolled threads [7]:

$$d_{w\min} = d_{2\min} + A + 3\sigma - 3\sigma_0$$

$$d_{w\max} = d_{2\max} + A - 3\sigma + 3\sigma_0 - mT_{d2}$$

where $d_{2\min}$ and $d_{2\max}$ – are the smallest and largest allowable average thread diameters;

A – correlation relationship between the diameter of the workpiece and the average diameter of the thread, determined by the difference in the coordinates of the centers of the grouping of their scattering curves;

σ – is the standard deviation of the mean diameter of the rolled threads;

σ_0 – standard deviation of the workpiece diameter;

T_{d2} – average thread diameter tolerance;

m – is a coefficient that takes into account the proportion of the form deviation tolerance in the tolerance of the average thread diameter.

2. Rational dimensions of the adjustment of the technological system when processing the under-thread surface: the smallest set-up size and the moment when the tool is removed from machining due to its wear (or its readjustment) [8]:

$$H_{\min} = d_{2\min} + 3\sigma_0$$

$$T_H = d_{2\max} - 3\sigma_0 - H_{\min} - U_{u\min}$$

where T_H – is the tolerance for setting up the technological system; $U_{u\min}$ the minimum allowable wear of the cutting tool, ensuring the efficiency of processing.

3. The design of a self-adjusting thread-rolled device under the action of force of rolled has been developed and a patent AP has been obtained (fig. 3), achieveds of promotion the accuracy of the shape and parameters of the rolled threads, and simplifies the adjustment of the tecnolojical sistem of rolling process [9].

When thread rolling is performed under the action of rolling force P, roller 2 mounted on spindle 1, between elastic washers 3, self-adjusts until the uniform distribution of force along the roller-workpiece contact length is ensured (fig. 3).

4. On the basis of theoretical studies, it was revealed that for studs it is important which of the sides: – long or short threads to roll in the first place.

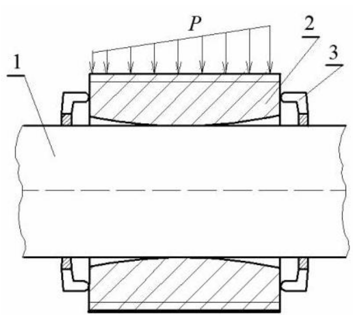

Fig. 3. Scheme of the design self-adjusting thread-rolled device

Experiments were carried out under production conditions to determine the effect of the sequence of rolling of long and short threads on the accuracy of half-angles of the profile of rolled stud threads.

The results of measurements of half-angles of profiles of rolled threads and their processing statistical given in the table

It was found that for almost all samples, both on long and short threads, the accuracy of the thread profile parameters rolled first with a long thread, is higher than for samples rolled first with a short thread. It should be noted that the lengths of the long threads were about half the length of the studs.

Formation a threads with tangential head with tangential

feed.

To decrease the rolling force acting on the workpiece, it is offered to position the axis of the knurling rollers of the tool in relation to the axis rolled thread at a certain angle β (fig. 4).

At a certain position of the tool, it comes into contact with the workpiece and, with radial movement, begins to roll the thread. When the outer diameter of the roller is reached at position 2, the length a shows the length of the section of the rolling force generated, and the shaded section shows the section of the rolling force formation (for simplicity, the thread profile is not shown) (fig. 4). When the outer diameter of the roller reaches position 3, the «tool-workpiece» contact area moves and is the length *b*. Thus, much smaller rolling forces act on the workpiece, depending on the angle of inclination of the tool β relative to the workpiece axis. It should be noted that the design of the thread rolling roller differs from the traditional one. When the thread is rolled using the developed method, the movement of the head in the radial direction increases, however, it must be taken into account that the formation of a thread by rolling takes much less time than cutting. But it increases the possibility of rolling a longer threads with a lower rigidity of the workpiece.

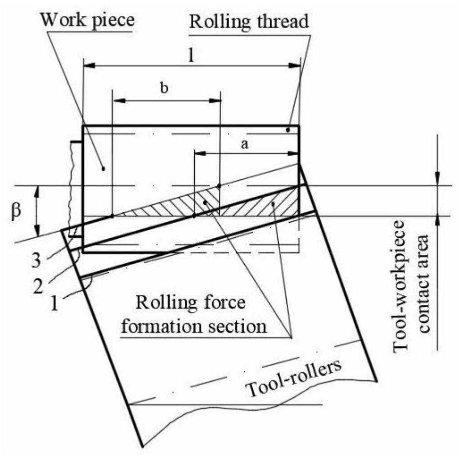

Fig. 4. Diagram of the fields of action of the rolling force when rolling a thread with an improved head

Table

Experimental results deviations the half-angle of profile in rolled threads

Thread of hairpin (Material)	First rolling thread	Indicators of deviations of half of the profile angle $\alpha/2$, minutes, not less than							
		long thread				short thread			
		$(\alpha/2)_{max}$	ω	a	σ	$(\alpha/2)_{max}$	ω	a	σ
		Indicators of deviations of the right half-angle of profile, $(\alpha/2)_r$							
M27-6gx75 (steel Ст 35)	short	+38	40	17.985	6.671	+36	42	+15.018	7.012
	long	+21	31	+5.511	5.158	+24	34	+7.011	5.670
M27-6gx80 (steel Ст 40X)	short	+32	34	+15.021	5.662	+34	35	+16.492	5.838
	long	-13	25	-0.465	4.165	-17	26	-3.989	4.342
M16-6gx55 (steel Ст 35)	short	+41	39	+21.532	6.496	+38	41	+17.504	6.861
	long	+28	32	+14.103	6.330	+20	35	+2.493	5.901
		Indicators of deviations of the left half-angle of the profile $(\alpha/2)_l$							
M27-6gx75 (steel Ст 35)	short	-23	39	-3.485	6.513	-25	43	-3.518	7.512
	long	-15	29	-0.509	4.829	-21	36	-2.987	6.008
M27-6gx80 (steel Ст 40X)	short	+22	39	+2.499	6.501	-32	41	-11.515	6.834
	long	+18	30	+3.045	4.990	+21	28	+7.103	4.671
M16-6gx55 (steel Ст 35)	short	-30	42	-8.978	7.032	+22	44	0.026	7.325
	long	-21	30	-6.021	5.019	+17	32	0.991	5.342

Note: $(\alpha/2)_{max}$ and $(\alpha/2)_{min}$ – the largest and smallest values of the profile half-angle in the samples-parties; ω – scattering interval of half of the profile angles; a – coordinate of the parameter distribution center; σ – standard deviation of half of the profile angles.

Conclusion

1. A technique is proposed for determining the diameter of the workpiece on the basis of dimensional relationships between the under- threads smooth surface and the average diameter of the rolled threads, and the rational adjustment dimensional of the technological system.
2. The design of a self-adjusting thread-rolling device has been developed, and the accuracy of the shape and parameters of the rolled threads is improved.
3. It is proposed to first roll long, and then short threads on the studs.
4. The method of thread rolling with tangential heads does not provide an opportunity to roll threads on hollow, relatively non-rigid workpieces. A way for rolling threads with tangential heads has been developed, which allows to increase the length of the rolled thread and reduce the rigidity of workpieces in comparison with the traditional method.

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Повышение эффективности накатки резьбы с управлением технологическими связями

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Реферат

Формирование резьб пластическим деформированием является одним из наиболее эффективных способов формирования резьб, что определяет их высокие эксплуатационные характеристики; повышение точности изготовления резьбы особенно важно для организации эффективного процесса автоматизации сборки резьбовых соединений. В статье анализируется механизм формирования точности резьбы при накатывании резьбы с радиальной подачей на двухроликовых профиленакатных станках и с помощью тангенциальных резьбонакатных головок с тангенциальной подачей; выявлены связи между входными и выходными параметрами, представлен новый способ накатки резьбы с тангенциальной подачей, который практически без снижения производительности технологической операции (подачи) обеспечивает снижения усилия накатки, а также предложены пути повышения точности накатанной резьб.

Ключевые слова: резьба; накатка; радиальная; тангенциальная; подача; точность параметров; технологические связи.

Texnoloji əlaqələri idarə etməklə yivdiyirləmə səmərəliyinin yüksəldilməsi

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Xülasə

Yivlərin plastik deformasiya ilə formalaşdırılması onları formalaşdırmanın ən səmərəli üsullarından biri olub, həm də onların yüksək istismar göstəricilərini təmin edir; yiv birləşmələrini avtomatlaşdırılmış yığma prosesinin səmərəli təşkili üçün yivin formalaşdırılma dəqiqliyinin artırılması xüsusilə vacibdir. Məqalədə iki diyircəkli profil diyirləyən dəzgahlarda radial verişlə yiv diyirləmə zamanı və tangensial verişlə tangensial başlıqlarının köməyi ilə yivin dəqiqliyinin təmin edilməsi mexanizmi təhlil edilir; giriş və çıxış parametrləri arasında əlaqə aşkar edilir, məhsuldarlığı praktiki olaraq azaltmadan tangensial verişlə yiv diyirləmənin yeni üsulu təqdim olunur, demək olar ki, texnoloji əməliyyatın məhsuldarlığını azaltmadan diyirləmə qüvvəsinin azaldılması təmin edilir, həmçinin yivi diyirləmə dəqiqliyini artırmaq yolları təklif olunur.

Açar sözlər: yiv; diyirləmə; radial; tangensial; veriş; parametrlərin dəqiqliyi; texnoloji əlaqələr.