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QUALIMETRIC INDEXES DETERMINATION OF ADAPTIVE TYPE LIMITED MECHANISMS FOR MATERIAL MACHINING

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Summary

The design modular principle of adaptive limited mechanisms is put forward. The structure of adaptive type metal cutting tools as technical systems is given in the context of their main functions partition. The basic qualimetric criteria of these mechanisms functioning are preceded as well as the generalized structural and flow graph of the technical system “adaptive limited mechanism”. Basing on the mentioned criteria the structural synthesis modular principle is developed exemplifying adaptive type metal cutting tools. Furthermore the determination considerations of main modules transformation coefficients with regard to the adaptive limited mechanisms for material machining are put up.

Keywords: adaptive limited mechanisms, surface quality, qualimetric index, drill with hydraulic inter edge link, multi edge head, design modular principle, transformation coefficient

Wyznaczenie współczynników ograniczających mechanizmów adaptacyjnych dla obróbki skrawaniem materiałów

Streszczenie

W pracy podano zasadę modułowej budowy adaptacyjnych mechanizmów ograniczających. Przedstawiono opis struktury narzędzi skrawających adaptacyjnych z uwzględnieniem rozdzielania ich głównych funkcji jako systemów technicznych. Podano główne kryteria funkcjonowania danych adaptacyjnych mechanizmów ograniczających, a także uogólniony strukturalny i parametryczny system techniczny "Mechanizm adaptacyjny ograniczający". Wykonano analizę głównych kryteriów jakości funkcjonowania adaptacyjnych mechanizmów ograniczających dla obróbki skraw-aniem. Sformułowano zasadę modułowej strukturalnej syntezy mechanizmów adaptacyjnych ograniczających na przykładzie adaptacyjnych narzędzi skrawających z uwzględnieniem zapewnienia jakości ich funkcjonowania. Zaproponowano główne kryteria wyznaczenia współczynników transfor-macji elementów głównych modułów adaptacyjnych mechanizmów ograniczających dla obróbki skrawaniem materiałów.

Słowa kluczowe: adaptacyjny mechanizm ograniczający, jakość powierzchni, wskaźnik jakości, wiertło z wewnętrznym układem hydraulicznym, głowica wieloostrzowa, zasada modułowa budowy, współczynnik transformacji

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1. Formulation of the problem

The operation of multi edge and multi tool accessories rests on using limited mechanisms as technical systems of cutting process regulation and self-adjustment. Therewith in the process of multi edge accessories design developing the large quantity of possible functional scheme and construction variants arise. The design objective of such limited mechanisms is the technical system optimal design decision making in order to provide the increasing of adaptive limited mechanism technical-and-economic indexes as compared with the corresponding analogs.

To define the modules of the adaptive limited mechanism (ALM) let us consider it as a technical system (TS) and identify its main elements. Further, it is necessary to distinguish main, basic and additional functions and basing on functional interrelations of the ALM elements - to determine basic functional-design modules and corresponding qualimetric indexes.

2. Analysis of previous research

The theory of technical systems [1] allows developing new approaches in the design of machines and metalworking equipment [2-4]. Many modern mechanical constructions deal with the progressive scientific research that provides the modular design approach [2, 4 and 5]. In this way the machine design considers the design features of a set of new constructions. The main feature of these structures lies in a separate testing each of their elements in the design process that makes easier to determine the mutual interrelations of technical systems elements [6]. So the quality of the system elements interaction defines the quality of its operation. In this case to provide the design process it is necessary to determine the quality indexes of the technical system elements interaction.

3. Some views explanations

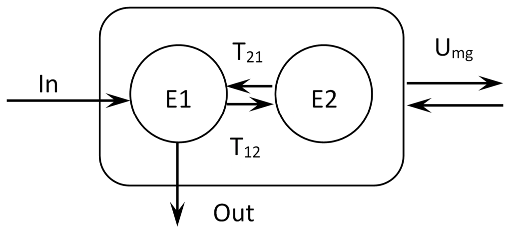
The substance of the adaptive type technical systems for materials cutting [7-10] comes down to providing their working elements (that are turning tools, cutting edges, etc.) interrelation. As far as in the process of the adaptive cutting tool functioning then process of adjusting loads restricting is taking place then the technical system named as the adaptive tool can be considered as a limited mechanism of adaptive operation principle. There way the main function of the ALM is to limit adjustably the values of the axial and radial forces. The process of loading restriction on the working elements is based on the principle of their mutual equalization and compensation.

4. ALM for metal cutting qualimetric indexes determination

According to the TS ALM graph (Fig. 1a) two elements of the system are present: the working element E1 and the transmission-and-transfer element E2. Throughout the flows T_{12} and T_{21} the energy exchange between the working and transmission-transfer elements takes place. In the given system the influence of the surrounding U_{mg} as well as the input (In) and the output (Out) flows are in the picture too.

Dealing with the main ALM functioning criteria we can distinguish main quality criteria QE_1 and QE_2 of the E1 and E2 corresponding elements as well as main channel (flow) criteria Tin1E1, Tin2E1, … , Tin n Em (Fig. 1b).

a)



b)

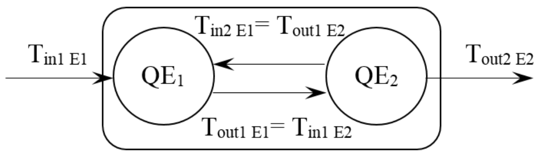


Fig. 1. Generalized structural (a) and flow (b) graphs of the “Adaptive limited mechanism” technical system

As far as the TS each element performs the certain determined main function to provide the TS main function operation it can be considered in its turn as separate TS. Each of the elements is characterized by certain criteria of their functioning quality (stability, reliability, etc). In this way the energy flows are characterized by the following (channel) criteria (force, velocity, quantity, etc) trough that the possibility of the elements interlinks intensity defining exists.

To realize the modular approach to the analysis and synthesis of the ALM TS exemplifying the multi edge head (MH) let us consider in detail the corresponding graph (Fig. 2). The given ALM consists of the working module M1 (cutting elements) and the transmission-and-transfer module M2. Additionally the transmission-and-transfer module M2 includes the transmission M3 and the transfer M4 modules. The element E3 providing the working element in the zero position and the working element drive E5 belong to the transmission module. The element E2 of information reading and transfer regarding the working element behavior as well as the software and technical support (personal computer PC) element E4 belong to the transfer module.

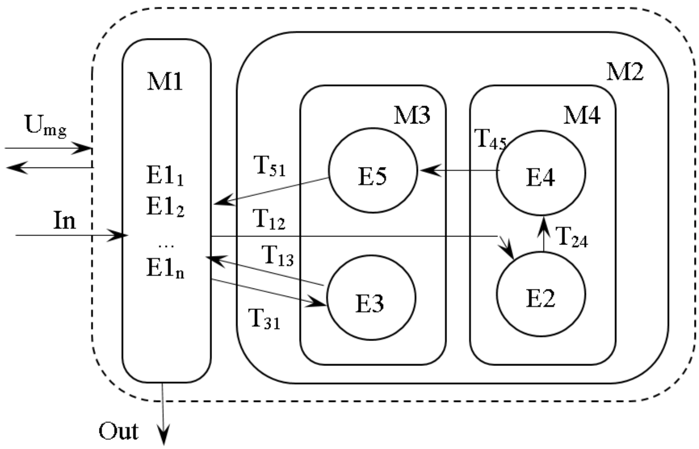


Fig. 2. Graph of the ALM TS exemplifying the multi edge head (MH) with adaptive computer control

When MH functioning the energy from the module 1 working element (turning cutting tool) transfers through the channel T12 to the module of information reading and transfer (regarding the working element behavior) and through the channel T13 to the element E3 providing the working element in the zero position. In this way the element E3 is characterized by the direct opposite flow T31 through which the energy is transferred to the working module M1. The main function of the working module M1 is to remove the metal layer in the process of machining of the cylindrical surface. The M2 main function is to equalize the working module loadings by reading, changing and transferring information regarding the working element behavior. Using the element E2 of information (regarding the working module M1 behavior) reading and transfer the linear motion energy turns to the signal that is transferring to the element of the module E4 of the software and technical support. The element of the software and technical support represents the computer with the corresponding program to control the movement of the working element (cutting tool) in the process of machining. Its main function is the input information processing in regard to the determined algorithm and generation of the corresponding signals for the transmission module that is the E5 drive element. The E5 drive element is used to regulate the working module E1 accordingly to the input signals that are submitted from the transferring module M4 that is from software and technical support element E4. In its turn the inverse process of energy transformation takes place in the module M3. In a case of implementation the given module in a form of the solenoid the signal transforms into the electromagnetic impulse signal and therefore into the linear motion energy.

Basing on the TS graph of the multi edge head ALM with adaptive computer control (Fig. 3) the design of the multi edge head with elastic adaptive type guides was proposed. The Fig. 3 presents the operational functional scheme of the multi edge head for the finish turning. The head consists of the house, the control block, three cutting elements and their drives. The cutting element in a form of straight turning tool operates in a work piece axis direction with a help of solenoid. The control signal to the cutting elements drive is going from the control block and depends from the value of the cutting elements displacement in the detail axis direction in the operation process.

The limited element is used in the given design in a form of the in mounted automatic control system with the manufacturing process actuators. In this way it makes the mechatronic head intellectual, autonomous and able to create the metal cutting units perspective designs.

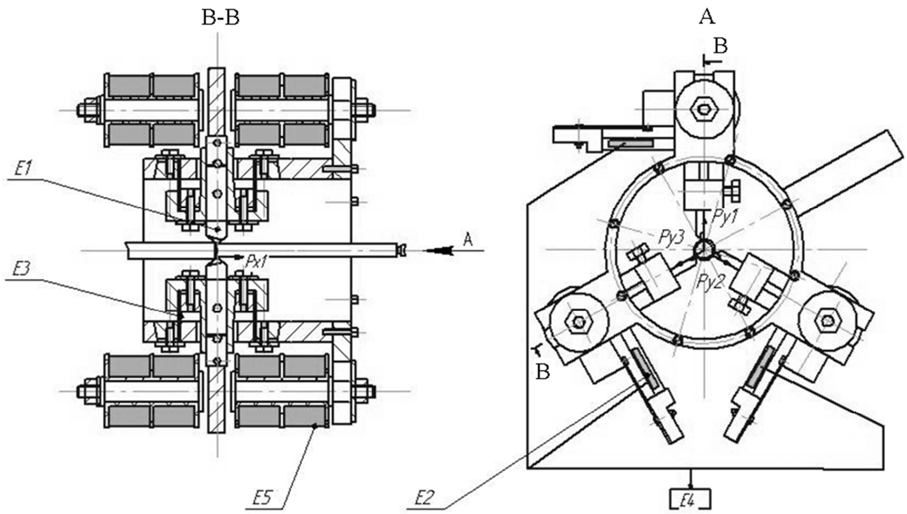


Fig. 3. Design of the multi edge head with elastic adaptive type guides

The determination of the main functioning qualimetric criteria of the multi edge head ALM is based on the quality criteria of its basic elements. For example for the multi edge ALM the basic elements of the working module M1 are the turning tools. Their main quality criteria Q_{ME} are their cutting-tool life T (Table 1).

In this way the cutting force $P_{z(x,y)}$ is the main of the given system element input flow criterion Tin_{ME}. According to the flow transformation coefficients set K_{trME} the adaptive restriction process of cutting forces on the working elements takes place. In each element of the corresponding modules the transformation coefficient is to transform the input signal of the given element Tin_{ME} into the output signal $Tout_{ME}$. The quality of such transformation is determined by the corresponding quality criterion Q_{ME}.

Table 1. Main criteria of the multi edge head ALM

Element name	**Symbolic notation**	**Realization**	**Main criteria**	
			Qualitive Q_{ME}	**Flow Tin_{ME}, $Tout_{ME}$**
Working	E1	Turning cutting tool	Tool life $Q_{M1E1} = T = \left(\frac{1}{m} - 1\right) t_{ch}$ t_{ch} – time to tool removal; m – slope of curve (tangle angle)	Cutting force $Tin_{M1E1} = P_{z(x,y)} = 10 C_p t^x S^y V^n K_p$ Force acting on the tension sensor and elastic guide $Tout_{M1E1} = Tin_{M1E1} \cdot K_{trM1E1}$ K_{trM1E1} – coefficient of flow transformation of the element E1 (module M1)
Reading and transfer of information regarding working element behavior	E2	Tension sensor	Response $Q_{M4E2} = Ч_m = \frac{\left[(R - R_0)/R_0\right]}{\xi}$ in which R_0 – tension sensor resistance without deformation; R – tension sensor resistance with relative deformation ε; ξ – conversion coefficient; $\xi = \frac{\Delta R}{R_0}$ ΔR – resistance deviation	Force acting on the tension sensor: $Tin_{M4E2} = Tout_{M1E1}$ Sensor output signal (resistance deviation ΔR): $Tout_{M4E2} = Tin_{M2E2} \cdot K_{trM4E2}$ K_{trM4E2} – coefficient of flow transformation of the element E2 (module M2)
Working element support in the zero position	E3	Elastic plate guides	Rigidity $Q_{M3E3} = c = \frac{F_{pr}}{l_{pr}}$ F_{pr} – force acting on the elastic guide; l_{pr} – deformation of the elastic guide under the force F effect	Force acting on the elastic guide: $Tin_{M3E3} = Tout_{M1E1}$ Strength of the elastic guide: $Tout_{M3E3} = -Tin_{M3E3} \cdot K_{trM3E3}$
Software and technical supply (PC)	E4	Program of information processing and PC	Response speed (rapidity coefficient): $Q_{M4E4} = k_{пк} = \frac{Q_{\inf}}{\Delta t_{\inf}}$ $Q_{\inf}$ – quantity of processing information (signals); $\Delta t_{\inf}$ – time of control signal forming (time between signal input and output)	Output signal of the tension sensor (resistance ΔR deviation): $Tin_{M4E4} = Tout_{M4E2}$ Control signal for the tool drive: $Tout_{M4E4} = Tin_{M4E4} \cdot K_{trM4E4}$

Table 1 (cont.)

Element name	Symbolic notation	Realization	Main criteria	
			Qualitive Q_{ME}	**Flow Tin_{ME}, $Tout_{ME}$**
Working element drive	E5	Solenoid	Inductance $Q_{M3E5} = L = \dfrac{\sqrt{\left(\dfrac{U_m}{I_m}\right)^2 - R^2}}{2\pi\upsilon}$ I_m, U_m – electric current force and voltage amplitude values; R – active resistance; v – alternating current frequency	Control signal for the tool drive (current, voltage, current frequency): $Tin_{M3E5} = Tout_{M4E4}$ Solenoid force action on the tool: $Tout_{M2E5} = Tin_{M3E5} \cdot K_{trM3E5}$

Now we can repeat like in the case of multi edge tool head ALM the definition of the ALM main quality metric factors of the inner surfaces machining. The inner surfaces machining as a whole and deep holes machining in particular is characterized by the necessity of the high productive drilling process. In this case the stable chip removal, enough cooling fluid supply to the cutting zone, manufacturability, high tool life, minimal errors of holes accuracy parameters as well as low production costs are needed.

The main engineering problem in the deep holes machining ALM design is to ensure minimum error values of the geometric shape and deep hole dimension as well as the drill run. This factor deals with the tool rigidity decreasing when the tool cutting part length enlarging. In addition we have different obstacles in lubricating as well as cooling fluid supply and metal chip removal. One of the effective methods of this problem solving is to emplace in the drill design the adaptive kinematic link of the working elements to provide equalization of the cutting forces on the drill edges.

To realize the adaptive drill for deep holes machining analysis and synthesis procedures it is desirable to use the modular approach. In this way let us consider the corresponding graph (Fig. 4) of the given technical system. Such an ALM similarly to the previous one consists of the working module M1 (cutting elements) and transmission-and-transforming module M2. The last one also comprises transmission M3 and transforming M4 modules. The elements of energy transfer in a form of two hydraulic cylinders E2 and E4 belong to the transmission module. The liquid E3 that fills in the system is acting as an element of transforming module.

In the process of ALM technical system functioning the energy from the working element E1 (cutting edge) of the working module M2 is transferring through the channel T12 to the transmission-and-transforming module M2, that is to the element E2 (hydraulic cylinder 1) of the transmission module M3. Thereafter through the channel T23 by the main element E3 (liquid of the hydraulic system) of the transforming module M4 as well as through the channel T34 the energy is transferring to the working element E4 (hydraulic cylinder 2) of the transmission module M3. After that through the channel T45 the energy is transferring to the working element E5 (cutting edge 2) of the working module M1. In this case the corresponding inverse energy flows T21, T32, T43 and T54 are present too. These flows are the result of the resistant force factors (friction forces, inertia, nominal loads, etc.).

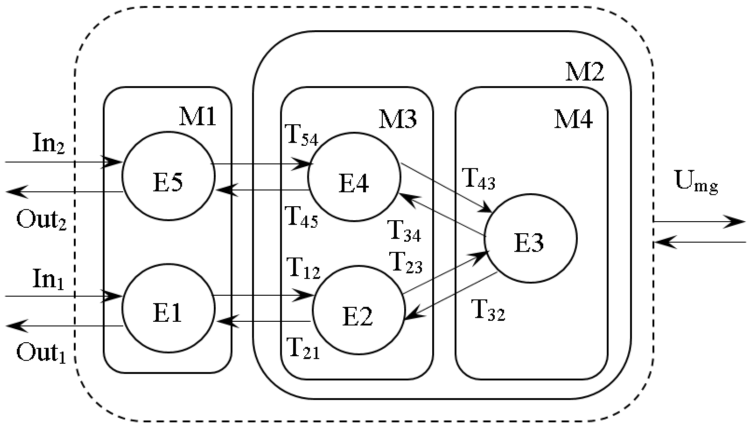


Fig. 4. Graph of the ALM technical system exemplifying the drill design with the hydraulic inter edge link used for the deep hole machining

The drill design with the hydraulic inter edge link developed on the base of the given graph (Fig. 5) consists of the drill tool body and cutting elements moveable in the axial direction. These cutting elements in a form of wide-ranging and narrow-width edges through the plunger and hydraulic channel are joined with each other by the hydraulic kinematic link. To locate the drill in the hole three hard alloy guide plates are used. In the process of the hole machining the automatic loadings equalization between the cutting edges takes place by the relative displacement of plungers-pistons. The forces acting on the plungers due to the direct hydraulic link remain equal as before.

The two cutting elements E1 and E5 of the drill with the hydraulic inter edge link used for the deep hole machining are the main elements of the ALM working module. These elements main quality criteria Q_{ME} is represented by the tool life T_A (Table 2). The cutting force $P_{z(x,y)}$ is the main flow criteria $Tout_{\mathrm{M1E1}}$ of the T12 channel on the E1-E2 section. This force is being changed according to the transformation coefficient Ktr_{M1E1}. Further on the output energy flow of the element E1 (module 1) is the input one for the element E2 in a form of the hydraulic cylinder piston of the transmission module M3 that in its turn is a part of the transmission-and-transforming module M2. The liquid volume compression coefficient β_s is the main quality criterion Q_{M4E3} of the corresponding element: hydraulic liquid E3. In this way it is necessary also to take into account the system liquid losses under the working pressures. Being transformed in the elements E2, E3 and E4 of the transmission-and-transforming module M2 the energy flow through the channel T45 is transmitted to the output working element E5 in a form of the cutting edge of the working module M1. In this way using the deep hole drill with inter edge hydraulic link we achieve the adaptive restriction of the forces resulting on the ALM working elements.

The integrating ALM quality index of the multi edge head and deep hole drill with the hydraulic inter edge link is a quality of the machining surface. This index is expressed by the machining accuracy figures as well as surface profile deviation. In this way the integrating ALM quality index can be estimated by the following dependence

$$Q = \begin{cases} Q_M = f\left(Q_{ME}\right) \\ Tout_M = f\left(Tin_M, K_{trM}\right) \end{cases} \tag{1}$$

Therefore the integrating quality index for the ALM in a form of the multi edge head takes the form of:

$$Q = \begin{cases} Q_M = f\left(Q_{M1}, Q_{M2}\right) \\ Tout_{M1} = f\left(Tin_{M1}, K_{trM1}\right) \\ Tout_{M2} = f\left(Tin_{M2}, K_{trM2}\right) \end{cases} = \begin{cases} Q_M = f\left(Q_{M1}, Q_{M3}, Q_{M4}\right) \\ Tout_{M1} = f\left(Tin_{M1}, K_{trM1}\right) \\ Tout_{M3} = f\left(Tin_{M3}, K_{trM3}\right) \\ Tout_{M4} = f\left(Tin_{M4}, K_{trM4}\right) \end{cases} \tag{2}$$

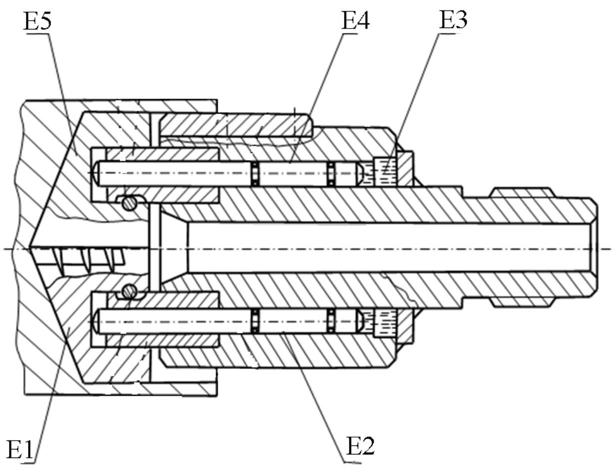


Fig. 5. The drill design with the hydraulic inter edge link

Table 2. Main criteria of ALM exemplifying by the deep hole drill

Element name	**Symbo-lic notation**	**Realization**	**Main criteria**	
			Qualitive Q_{ME}	**Flow Tin_{ME}, $Tout_{ME}$**
Working	E1	Cutting edge	Tool life (the total service duration): $Q_{M1E1} = T_A = T(i+1)$ In which T – the tool operation time duration till dulling; i – number of repoints; $i = \frac{L_{st}}{c_0}$ in which L_{st} – total permitted sewing-up value; c_0 – sewing-up value The sewing-up value of the hard alloy edge of the drill clearance surface is = 0.4mm	Cutting force: $Tin_{M1E1} = P_{z(x,y)} =$ $= pa^{1-m} b k_v k_1 k_{col} k_h k_b$ In which p is the specific cutting force, N/mm^2; a, b are thickness of cut and width of cut; m is index of power; K is coefficient regarding different condition of cutting; Force acting on the tension sensor and hydraulic cylinder piston: $Tout_{M1E1} = Tin_{M1E1} \cdot K_{trM1E1}$ K_{trM1E1} – coefficient of the element 1(module1) flow transformation
Energy flow transmission between cutting edges	E2	Hydraulic cylinder and guides	Friction force: $Q_{M3E2} = F_{fr} = k_{fr2} N_2$ k_{fr2} – coefficient of friction in the element E2; N_2 – normal force in the element E2; $P = \frac{F_g}{Sk_{mp}}$ in which F_g – is a force transmitted from the working element to the hydraulic cylinder piston; S – active area of the hydraulic cylinder piston; k_{mp} – coefficient regarding friction losses	Force acting on the hydraulic cylinder piston: $Tin_{M3E2} = Tout_{M1E1}$ Liquid pressure in the hydraulic system $Tout_{M3E2} = Tin_{M3E2} \cdot K_{trM3E2}$
Energy flow transmissions and transformations between cutting edges	E3	Hydraulic liquid	Coefficient of liquid volume compression: $Q_{M4E3} = \beta_{s3} = 1\frac{1}{V_3}\left(\frac{\partial V_3}{\partial p_3}\right)_s$ V_3 – liquid volume in the element E3; p_3 – pressure acting the liquid in the element E3;	Force acting on the hydraulic cylinder liquid (element E3): $Tin_{M4E3} = Tout_{M3E2}$ Liquid pressure in the hydraulic system $Tout_{M4E3} = Tin_{M4E3} \cdot K_{trM4E3}$

Table 2 (cont.)

Element name	Symbolic notation	Realization	Main criteria	
			Qualitive Q_{ME}	**Flow Tin_{ME}, $Tout_{ME}$**
Energy flow transmissions between cutting edges	E4	Hydraulic cylinder and guides	Friction force: $Q_{M3E4} = F_{fr} = k_{fr4} N_4$ k_{fr4} – coefficient of friction in the element E4; N_4 – normal force in the element E4; $P = \frac{F_g}{Sk_{mp}}$ in which F_g – is a force transmitted from the working element to the hydraulic cylinder piston; S – active area of the hydraulic cylinder piston; k_{mp} – coefficient re-garding friction losses	Liquid pressure in the hydraulic system $Tin_{M3E4} = Tout_{M4E3}$ Force acting on the hydraulic cylinder piston: $Tout_{M3E4} = Tin_{M3E4} \cdot K_{trM3E4}$
Working	E5	Cutting edge	Tool life (the total service duration): $Q_{M1E5} = T_A = T(i+1)$	Force acting on the hydraulic cylinder piston: $Tin_{M1E5} = Tout_{M3E4}$ Force acting from the hydraulic cylinder piston on the cutting edge: $Tout_{M1E5} = Tin_{M1E5} \cdot K_{trM1E5}$

Taking into account the main ALM modules elements the equation (2) takes on the expression:

$$Q = \begin{cases} Q_{ME} = f(Q_{M1E1}, Q_{M3E3}, Q_{M3E5}, Q_{M4E2}, Q_{M4E4}) \\ Tout_{M1E1} = f\left(Tin_{M1E1}, K_{trM1E1}\right) \\ Tout_{M3E3} = f\left(Tin_{M3E3}, K_{trM3E3}\right) \\ Tout_{M3E5} = f\left(Tin_{M3E5}, K_{trM3E5}\right) \\ Tout_{M4E2} = f\left(Tin_{M4E2}, K_{trM4E2}\right) \\ Tout_{M4E4} = f\left(Tin_{M4E4}, K_{trM4E4}\right) \end{cases} \tag{3}$$

Writing the quality indexes as the corresponding criteria the ALM integrating functioning quality index for the multi edge head can be derived in a form:

$$Q = \begin{cases} Q_{ME} = f(T, c, L, Ч_m, k_{пн}) \\ Tout_{M1E1} = f\left(P_{z(y,x)}, K_{trM1E1}\right) \\ Tout_{M3E3} = f\left(P_{z(y,x)} \cdot K_{trM1E1}, K_{trM3E3}\right) \\ Tout_{M3E5} = f\left(P_{z(y,x)} \cdot K_{trM1E1} \cdot K_{trM4E2} \cdot K_{trM4E4}, K_{trM3E5}\right) \\ Tout_{M4E2} = f\left(P_{z(y,x)} \cdot K_{trM1E1}, K_{trM4E2}\right) \\ Tout_{M4E4} = f\left(P_{z(y,x)} \cdot K_{trM1E1} \cdot K_{trM4E2}, K_{trM4E4}\right) \end{cases} \quad (4)$$

The integrating quality index for the ALM in a form of the deep hole drill with the hydraulic inter edge link can be expressed as the following dependence:

$$Q = \begin{cases} Q_M = f\left(Q_{M1}, Q_{M2}\right) \\ Tout_{M1} = f\left(Tin_{M1}, K_{trM1}\right) \\ Tout_{M2} = f\left(Tin_{M2}, K_{trM2}\right) \end{cases} = \begin{cases} Q_M = f\left(Q_{M1}, Q_{M3}, Q_{M4}\right) \\ Tout_{M1} = f\left(Tin_{M1}, K_{trM1}\right) \\ Tout_{M3} = f\left(Tin_{M3}, K_{trM3}\right) \\ Tout_{M4} = f\left(Tin_{M4}, K_{trM4}\right) \end{cases} \quad (5)$$

Taking into account the main ALM modules elements the equation (5) takes on the expression:

$$Q = \begin{cases} Q_{ME} = f(Q_{M1E1}, Q_{M1E5}, Q_{M3E2}, Q_{M3E4}, Q_{M4E3}) \\ Tout_{M1E1} = f\left(Tin_{M1E1}, K_{trM1E1}\right) \\ Tout_{M3E2} = f\left(Tin_{M3E2}, K_{trM3E2}\right) \\ Tout_{M4E3} = f\left(Tin_{M4E3}, K_{trM4E3}\right) \\ Tout_{M3E4} = f\left(Tin_{M3E4}, K_{trM3E4}\right) \\ Tout_{M1E5} = f\left(Tin_{M1E5}, K_{trM1E5}\right) \end{cases} \quad (6)$$

In this way writing the quality indexes as the corresponding criteria the ALM integrating functioning quality index for the deep hole drill with the hydraulic inter edge link makes the following set of equations:

$$Q = \begin{cases} Q_{ME} = f(T_{AE1}, T_{AE5}, \beta_{sE2}, \beta_{sE3}, \beta_{sE4}) \\ Tout_{M1E1} = f\left(P_{z(y,x)}, K_{trM1E1}\right) \\ Tout_{M3E2} = f\left(P_{z(y,x)} \cdot K_{trM1E1}, K_{trM3E2}\right) \\ Tout_{M4E3} = f\left(P_{z(y,x)} \cdot K_{trM1E1} \cdot K_{trM3E2}, K_{trM4E3}\right) \\ Tout_{M3E4} = f\left(P_{z(y,x)} \cdot K_{trM1E1} \cdot K_{trM3E2} \cdot K_{trM4E3}, K_{trM3E4}\right) \\ Tout_{M1E5} = f\left(P_{z(y,x)} \cdot K_{trM1E1} \cdot K_{trM3E2} \cdot K_{trM4E3} \cdot K_{trM3E4}, K_{trM1E5}\right) \end{cases} \quad (7)$$

Analyzing the dependences of the input and output flows of the investigated ALM it is possible to make a conclusion about clear sequential or parallel interdependence between the force perturbing factors and the elements transformation coefficients of the corresponding modules. In this way this points to the fact of the preferred modular approach using to design different kinds of ALM taking into account the modular energy flows sequences with corresponding transformation coefficients. The given transformation coefficients consider:

- energy transformation into another kind (mechanical force into the electric signal; electric signal into the magnetic field),
- energy losses (friction power, conductors resistance, etc.),
- weakening or strengthening of the energy flow force factor due to the characteristics of the corresponding modules elements (speed displacement increasing of the hydraulic cylinder rod when force relaxation),
- changing of the energy transfer direction (energy flows distribution).

Depending on the determined ALM functioning conditions the certain design decisions of its construction are used. In this way each variant of design decisions is characterized by the set of quality characteristics that define in general the ALM functioning quality. For example, depending on the values of loadings acting on the working elements of the multi edge head ALM for different work piece diameters we can obtain the corresponding graph of its main quality characteristics range (Fig. 5). Hereby let us consider three design variants of the multi edge head and three design variants of the deep hole drill for the different diameters work pieces machining: (a) I variant – work piece machining of 15-30 mm in diameter; II variant – for 50-75 mm and III variant – for 60-85 mm as well as (b): I variant – hole diameter of 10-20 mm in diameter; II variant – for 25-35 mm and III variant – for 40-65 mm.

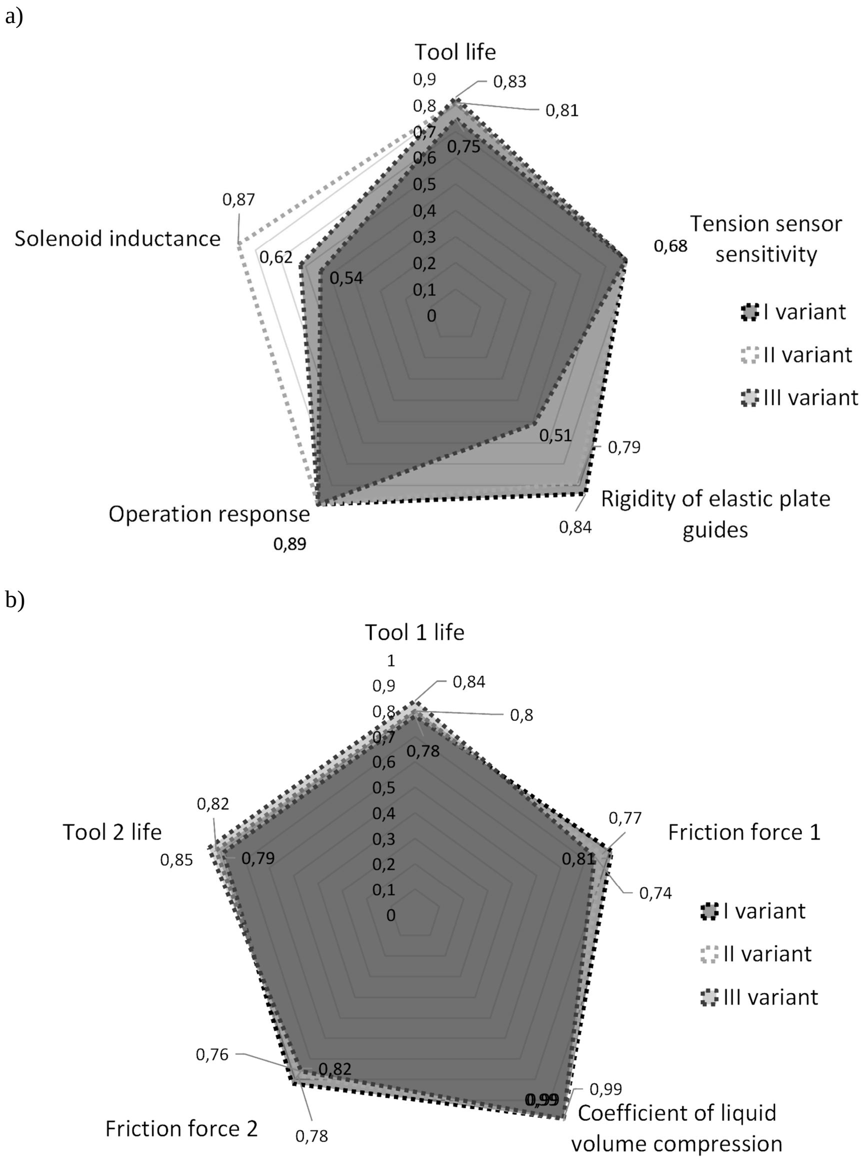


Fig. 5. Main quality characteristics range graph of ALM in a form of:
a) multi edge head, b) deep hole drill

In investigation of the ALM for materials cutting it can be observed the simultaneous changes of the quality indexes of its main elements both positive and negative. In this way it is important to determine the generalized quality index that characterizes the ALM functioning as a technical system as a whole one. The main values of these ALM generalized qualimetric indexes that are determined as the square areas pictured on the corresponding graphs are presented in the Table 3.

Table 3. ALM generalized qualimetric indexes for the metal cutting machining

ALM name	**ALM generalized qualimetric index value**			**ALM generalized qualimetric index minimum value**
Calculated variants	**I variant**	**II variant**	**III variant**	
Multiedge head	$Q_{1.1} = 1.29$	$Q_{1.2} = 1.56$	$Q_{1.3} = 1.16$	$Q_{1.gn.min} = 1.04$
Deep hole drill	$Q_{2.1} = 1.67$	$Q_{2.2} = 1.64$	$Q_{2.3} = 1.65$	$Q_{2.\ gn.min} = 1.56$

As a result of the performed investigations it is possible to prove that the minimum values of the ALM generalized qualimetric indexes for the metal cutting machining are the following: for the multi edge head $Q_{1gn.min} = 1.04$, and for the adaptive drill – $Q_{2.\ gn.min} = 1.56$.

Conclusions

To construct the adaptive limited mechanisms the modular principle is used exemplifying the design of the adaptive metal cutting tools. The given limited mechanisms modular design theory is based on the structure conception of the adaptive type metal cutting tools in the context of these technical system objects main functions partition. Hereby for each element of the ALM corresponding module the certain quality criteria of its functioning exist. In their turn these criteria depend on the energy channels characteristics. Such factors can be defined by transformation coefficients used. The given formalization of the RM elements transaction allows proposing the new approach to their optimization in the design process aiming on optimal quality indexes.

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