ANALYSIS OF THE CONSTRUCTION, ASSEMBLY AND USAGE OF SPECIALIZED FIXTURES ILLUSTRATED WITH AN EXAMPLE OF MACHINING A LEVER

Analiza konstrukcji, montażu i użytkowania uchwytów specjalnych na przykładzie obróbki dźwigni

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Abstract: The paper presents a method of quantitative assessment of manufacturability of the construction of specialized fixtures used in machining. The assumed, simplified assessment criteria include both the complexity of the construction with respect to time-consumption of manufacturing the components and their assembly, as well as the features of the usage of fixtures. The paper contains a study case connected with variably designed functional hardware for machining a cast-iron lever.
Keywords: mechanical engineering, machining fixtures, manufacturability of construction, assessment

Streszczenie: W artykule przedstawiono sposób ilościowej oceny technologiczności konstrukcji obróbkowych uchwytów specjalnych. Przyjęte uproszczone kryteria oceny uwzględniają zarówno złożoność konstrukcji w aspekcie czasochłonności wykonania elementów składowych i ich montażu, jak i cechy użytkowania uchwytów. W pracy zamieszczono studium przypadku związanego z zaprojektowanym wariantowo oprzyrządowaniem przedmiotowym do obróbki dźwigni żeliwnej.
Słowa kluczowe: inżynieria mechaniczna, uchwyty obróbkowe, technologiczność konstrukcji, ocena

Introduction

Manufacturability of construction comprises an important criterion of assessing any product. It can be defined as a feature of construction solution that ensures achieving a set of imposed requirements for a specific batch, technological, organizational and manpower conditions in a company, with minimizing the production costs [7,9,13,15,17]. Design process involves the application of the general rules of typification, unification and normalization of components. Possible reduction of mass, selection of a semi-finished product, essential requirements for machining and assembly, as well as utility features [4,6,16,18,19] are also taken into consideration.

In relation to a specialized machining hardware, it is important to provide its basic functions, hence, correct setting and gripping of the element, decreasing the usage of construction materials and ensuring the required degree of precision of a manufactured fixture [12]. During the design, one should also consider the technical possibilities of a tool shop, as well as the ease of service and possible repairs of a fixture. The same functional range of a piece of hardware can be achieved by various construction solutions and, consequently, technological solutions, in terms of their labour intensity, material consumption, i.e. cost consumption. Beneficial conditions of producing fixtures can be ensured by an appropriate composition of the design team – including highly trained, qualified and experienced personnel [2,3].

n the process of engineering education of students, within the scope of team design of machining hardware, there is a need for a simplified assessment of the prepared construction variants and selection of the best solution. The problem has been illustrated with an example of 5 variably-designed fixtures for machining a lever [14].

Design construction of fixtures

Machined element consists in a lever made of cast iron EN-GJL-150 (Fig.1). Machining involves face surfaces (3 mm offset on each side), two openings with 16H8 mm diameters and a central opening with 30H8 mm diameter (roughly made during casting). Milling of the face surfaces and final machining of the openings are conducted on the VF-2YT machining centre produced by Haas, equipped with the worktable whose dimensions are 914x356 mm (T-slots width: 16 mm).

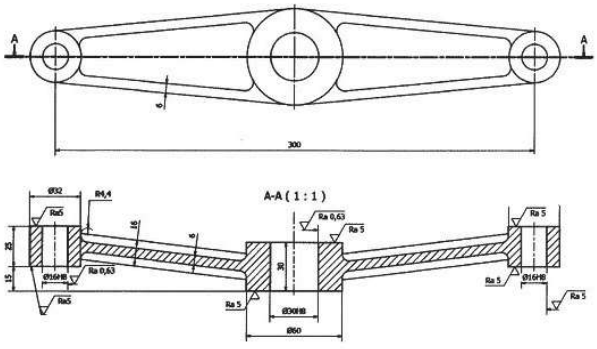

Fig.1. Design of the machined element

• Fixture U1

In the first design variant of the fixture two levers (in two holders) are machined at the same time – Fig. 2.

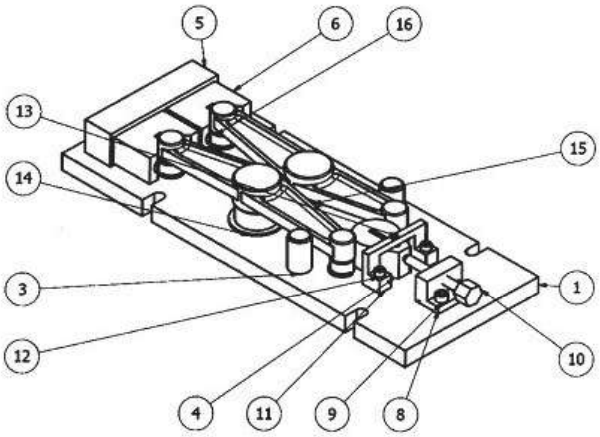

Fig. 2. Construction design of fixture U1

Each machined element is set by a fixed V-block (6), support bushings (14), (15) and (16) and a stop pin (3). Fixed V-blocks are attached with bolts (2) that are not visible in the drawing to the intermediate block (5) joined with the fixture base (1) with bolts (7) that are not visible in this projection. The levers are affixed by means of a slider (4) moving in a clamping ring (11) joined with the base (1) by means of bolts (12) and through a notch in the slider (4) with a special screw (13) – by turning the screw (10) in the block (8) attached to the base (1) with bolts (9). An advantage of this solution consists in the possibility of machining two levers at the same time and quick fixing, while its flaw rests in relatively high number of specialized components in the construction.

• Fixture U2

In this design solution (Fig. 3) the machined lever is supported with two bushings (10) and with a center bushing (3) which sets the element in linear plane X-Y, while the occurring play ensures the freedom of fixing towards Z axis, including the precision of the semi-product. Another degree of freedom is removed by the stop pin (4). Location of the element (10) is regulated by a spring (9) covered with a cover (5) which is attached with bolts (6) to the fixture body (1). The blockade of the bushing (10) is ensured by a lateral screw (2) – invisible in this drawing. Two clamps (8) are used to fix the machined element. The advantage of this concept lies in relatively low number of components, while its disadvantage is the weight of the body, caused by spring-loaded adjustment of the central support (3) and more difficult removal of the shavings from its vicinity.

• Fixture U3

In this concept (Fig. 4) the lever is affixed using a pair of lateral clamps (6). Setting elements in this design are: a support (5) attached to the block (4) and two supports (2) placed in the wall (1) fixed with bolts (7) and, also, support bushings (10) set in the base (3). The block (4) is attached to the base (3) with two bolts (8) that are not shown in the drawing; similarly to the clamp (6) that is attached with bolts (9) that are not shown in the drawing. The advantages of this fixture consist in quick fixing of the lever without the need of using extra tools and relatively low number of components.

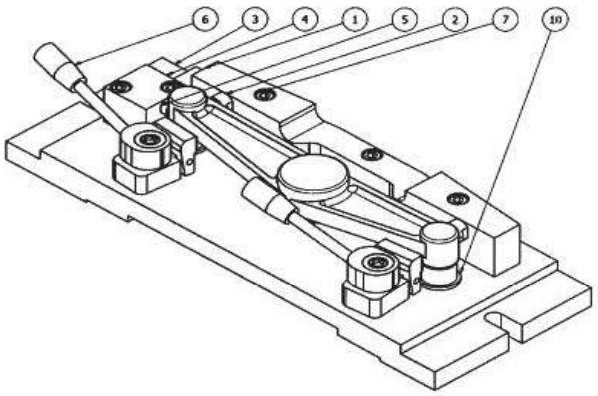

Fig. 4. Design of fixture U3

• Fixture U4

In this case (Fig. 5) a pair of horizontal clamps (7) fixing the machined lever from the top and attached with bolts (10) that are not visible in the drawing. A support beam (6) attached to the base (2) with bolts (13) was

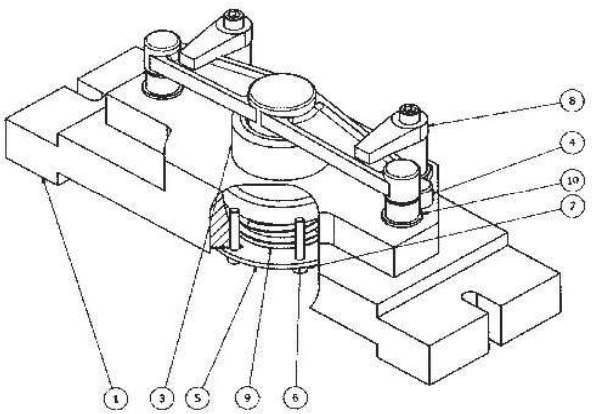

Fig. 3. Design of fixture U2

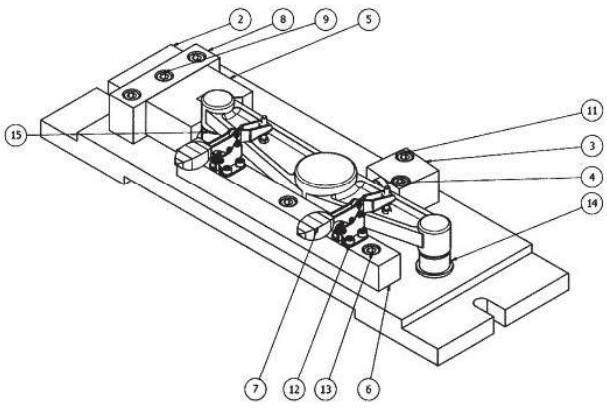

Fig. 5. Design of fixture U4

applied in this solution. Machined element is set by means of a fixed V-block attached to the block (8) with bolts (1) that are not visible in this drawing. Block (8) is attached to the base (2) with bolts (9), while block (3) is attached with bolts (11). Block (3) features a stop pin (4). Machined element is supported with flanged bushings (14) and (15). The advantage of this solution is quick fixing of the machined element, while its disadvantage lies in a high number of specialized and normalized elements, hence a high number of machined surfaces.

• Fixture U5

This version of the equipment (Fig. 6) features a pair of V-blocks – fixed one (2) attached to the block (3) with bolts (12) that are not visible in the picture, and a sliding one – joined with the slider (4). The slider runs through clamping rings (5) and is moved by a screw (6) attached with the aid of a cotter pin (7). The screw is driven into an angular support (9) attached to the base of the grip (1) with bolts (10). The machined lever rests upon two flat supports (13) connected with the base (1). The advantage of this grip consists in its low weight and easy operation, while its flaw rests in a relatively high number of precise special elements.

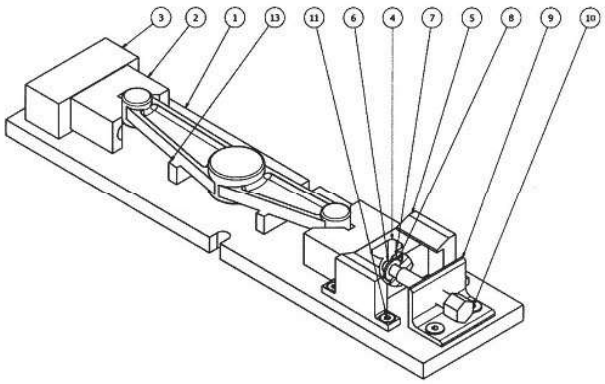

Fig. 5. Design of fixture U4

Assessment of the manufacturability of the proposed designs of fixtures

In the assessment of the manufacturability of a design, three groups of analysed features connected with the manufacturing of the fixture – group X_1 (assumed importance factor w_k = 0.35), usage and operation –X_2 (w_k = 0.45) as well as transport and regeneration – X_3 (w_k = 0.2).

Final assessment O_{Tk} is determined as:

$$O_{Tk} = \Sigma\ wk \cdot O_{Tx} \quad (1)$$

where O_{Tx} is the value of the factor in each of the three analysed groups and is:

$$O_{Tx} = \Sigma\ wc \cdot O_x \quad (2)$$

where wc denotes the assumed importance factor for a specific feature, while O_x is the numerical value of the feature. The higher the O_{Tk} value is, the more manufacturable is the design.

Features regarding the manufacturing of a fixture

These features influence the machining and assembly costs as well as the material consumption of the fixture (Tab. 1). In the case of assessing the costs of manufacturing of special elements, a simplification that they are proportional to the number of machined surfaces of a fixture was introduced. During the calculation it was assumed that threaded openings are treated as two surfaces (boring of an opening and threading), the calculations excluded the bottom sections of deepened openings and it was assumed that grooves are singular surfaces. Machined surfaces also include welds.

Table. 1. Indicators of the manufacturability of a design - X_1 group of features

Specification	Determination method	Importance factor w_c
Number of components	$O_{Ex} = C_{Emax}/C_{Ex}$	1
Share of normalized components	$On_x = C_{nx}/C_{Ex}$	1.2
Cost of normalized components	$O_{nkx} = K_{nmax}/K_{nx}$	1.5
Cost of manufacturing specialized components	$O_{swx} = N_{max}/N_x$	1.5

O_{Ex} – indicator of the number of components in a fixture,
C_{Emax} – maximum number of elements among analysed fixtures,
C_{Ex} – number of components in the analysed fixture,
O_{nx} – indicator of the share of normalized components,
C_{nx} – number of normalized components in the analysed fixture,
O_{nkx} – indicator of the cost-consumption for the normalized components,
K_{nmax} – maximum total amount of costs of normalized components among analysed fixtures,
K_{nx} – cost of the normalized elements of the analysed fixture,
O_{swx} – indicator of the cost-consumption of manufacturing specialized elements,
N_{max} – maximum number of the machined surfaces among analysed fixtures,
N_x – number of the machined surfaces in the analysed fixture.

Table 2. Values of the indicators of the assessment of manufacturability of the fixtures

Specification	U1	U2	U3	U4	U5
O_E	1.120	1.330	1.867	1.000	1.217
O_n	0.624	0.856	0.800	0.943	0.626
O_{nk}	2.815	4.582	1.969	2.637	1.599
O_{sw}	2.757	2.508	1.962	1.500	1.561
Summary O_{Tx1}	7.316	9.277	6.598	6.080	5.003

Tab. 2 contains the collected results of the assessment of manufacturability of the five analysed fixtures, determined on the basis of the dependencies listed in Tab. 1 and multiplied by the assumed importance factor w_c.

Features regarding the operation and usage of a fixture

Features associated with the usage of the fixture regard the reduction of the fixing time (including, among others, handling the fixing assemblies, removing and mounting the machined element, as well as removing the chippings with compressed air), necessity of using additional tools and the number of elements mounted at the same time (Tab. 3).

Table 3. Indicators of manufacturability of a design - X_2 feature group

Specification	Determination method	Importance factor w_c
Time of mounting the machined element	$O_{mx} = t_{mmax}/t_{mx}$	2
Number of additional tools required to operate the fixture	$O_{dx} = 1 - 0.25n_{dx}$	1
Number of elements mounted in the fixture at the same time	$O_{lx} = 1 - 0.25n_{lx}$	1

O_{mx} – indicator of mounting the machined element in the analysed fixture,
t_{mmax} – maximum time of mounting the machined element among analysed fixtures,
t_{mx} – time of mounting the element in the analysed fixture,
O_{dx} – indicator of the number of additional tools required to mount the element in the fixture,
n_{dx} – number of additional tools used to mount the machine element,
O_{lx} – indicator of the number of elements mounted at the same time in the analysed fixture,
n_{lx} – number of elements mounted at the same time in the analysed fixture.

Determined collected results of the assessments of features in group X_2 are listed in table 4 (considering the assumed importance factor w_c).

Table 4. Values of the indicators of the assessment of operation and usage of the fixtures

Specification	U1	U2	U3	U4	U5
O_{mx}	4.518	2.000	4.518	4.518	2.838
O_{dx}	0.75	0.75	1	1	0.75
O_{lx}	1.25	1	1	1	1
Summary O_{Tx2}	6.518	3.750	6.518	5.518	4.588

Features regarding transport and regeneration of a fixture

The method of the assessment of features associated with transport and regeneration of fixtures is defined in Tab. 5.

Table 5. Indicators of the manufacturability of a design – X_3 feature group

Specification	Determination method	Importance factor w_c
Weight of the fixture	$O_{Mx} = M_{max}/M_x$	1.25
Overall dimensions of the fixture	$OG_x = G_{max}/G_x$	1.1
Number of movable pairs of friction surfaces in the fixture	$O_{px} = 2 - C_{px}/C_{pmax}$	1.2

O_{Mx} – indicator of the weight of the analysed fixture,
M_{max} – weight of the lightest fixture among the analysed ones,
M_x – weight of the analysed fixture,
O_{Gx} – indicator of the overall dimensions of the analysed fixtures,
G_{max} – maximum overall dimension of the fixture among the analysed designs,
G_x – maximum overall dimension of the analysed fixture,
O_{px} – indicator of the number of pairs of friction surfaces in analysed grips,
C_{px} – number of pairs of friction surfaces in the analysed fixture,
C_{pmax} – maximum number of pairs of friction surfaces among analysed fixtures.

Determined assessment of features in X_3 group are listed in Table 3 – considering the value of the assumed importance factor.

Table 6. Values of the indicators of the assessment of transport and regeneration of fixtures

Specification	U1	U2	U3	U4	U5
O_{mx}	1.343	1.250	2.455	2.368	2.646
O_{dx}	1.155	1.308	1.359	1.260	1.100
O_{lx}	1.440	1.920	2.400	2.400	1.200
Summary O_{Tx3}	3.938	4.478	6.214	6.027	4.946

Final assessment of the manufacturability of the fixture designs

Considering the dependency listed above (1) after including the assumed importance factor wk, summary values of the indicator of manufacturability O_{Tk} were determined for the designs of fixtures U1 – U5 (Tab. 7).

Table 7. Summary values of the indicators of manufacturability of designs for the analysed specialized grips for machining a lever

Specification	U1	U2	U3	U4	U5
O_{Tk}	6.281	5.830	6.485	6.267	4.805

Summary

Manufacturability of a construction can be assessed descriptively, however, it requires detailed, specialized knowledge. A common criteria of assessment can be total cost, time for preparing the production and manufacturing time (machining or assembly), or a stipulated complex criteria. Time and cost criteria are difficult to apply when a specialized hardware is produced in limited numbers.

In the case of quantitative assessment of the manufacturability of a design, there is a possibility of adopting complex, hence multifaceted, criteria, as well as a possibility of selecting the method of a common scale (monetary or point), method of a function of weighted sum or product, quantitative determination of the level of modernity, value analysis, comparative method and others, using, among others, fuzzy logic [1, 5, 8, 10, 11].

The method proposed in the paper can be useful in the work of less-experienced constructors, so the ones who begin their professional career, or in the very process of educating mechanics and process engineers.

The assumed, simplified assessment criteria include both the complexity of the construction with respect to time-consumption of manufacturing the components and their assembly, as well as the features of the usage of fixtures.

The results of the conducted analysis of the specialized fixtures indicate that the design marked as U3 was given the highest mark. This mark results from the short time of mounting the machined element, easy operation of the fixture, as well as its relatively small dimensions and weight. The advantages of this fixture consist in quick fixing of the lever without the need of using extra tools and relatively low number of components.

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