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Comparison and substitution of conventional processes of plastic forming applying hydroforming

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1. Introduction

Hydroforming and other actions of plastic forming are based on the laws of plastic theory, balance of forces that are opposite to deformation. The success of hydroforming action depends on the processing parameters: forming force, the force of sheet metal holder, the frame, dimensions of workpiece and friction.

Hydroforming analysis at the plasticity area is possible because of actual knowledge application on deformation processing for conventional or unconventional processings as the values of individual parameters [1-7] can be compared.

2. Conventional procedures (treatments) of plastic forming

One of the most important processes of thin wall elements (sheet of metal) deformation is deep drawing out. The deep drawing out can be made by hard tool or under the action of transmission environment (unconventional treatments).

The conventional processing of deep drawing out (Fig. 1) shows that by the same tool depending on punch wreath part or a part without wreath can be obtained.

The height of workpiece is increased by h_1 to h, acted by punch since the workpiece wreath is decreased by the height increasing.

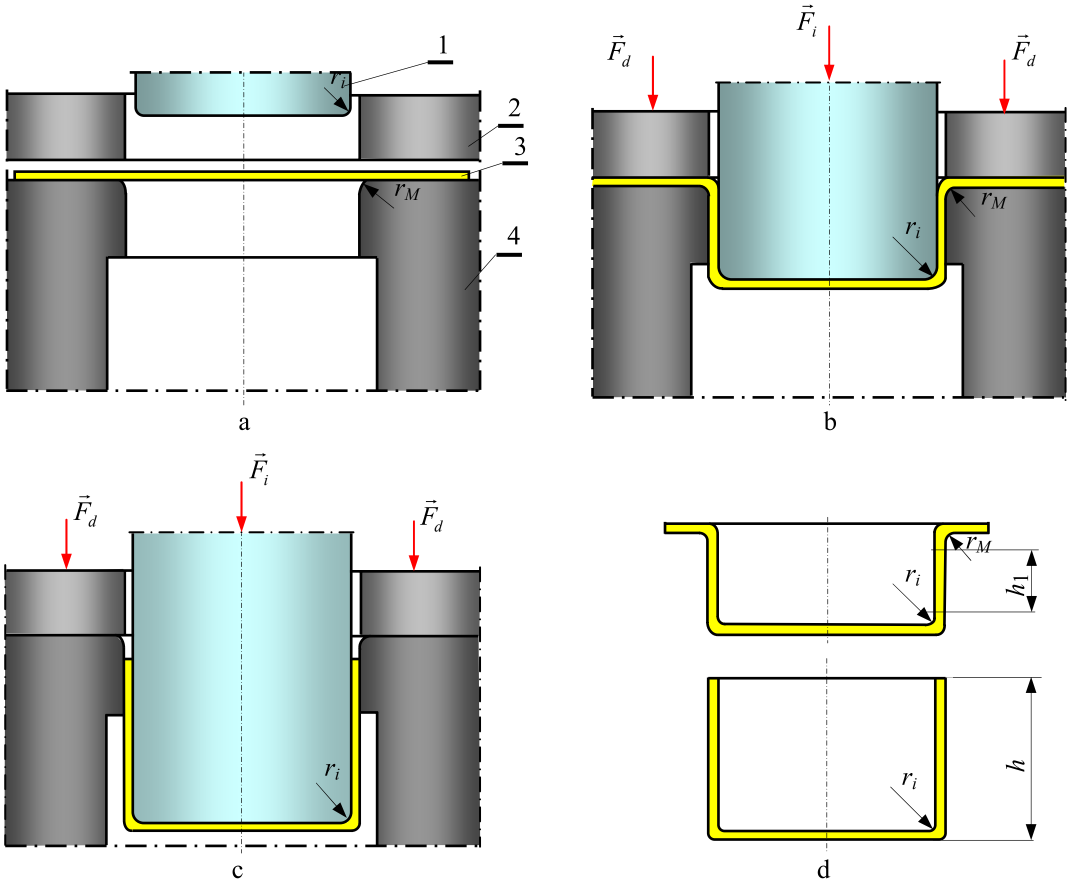


Fig. 1 Conventional processing of deep drawing out

By full drawing in of a sheet metal into ring hole, the wreath is lost and steel piece of the desired height h is gotten (Fig. 1, c) [4,5,7,8].

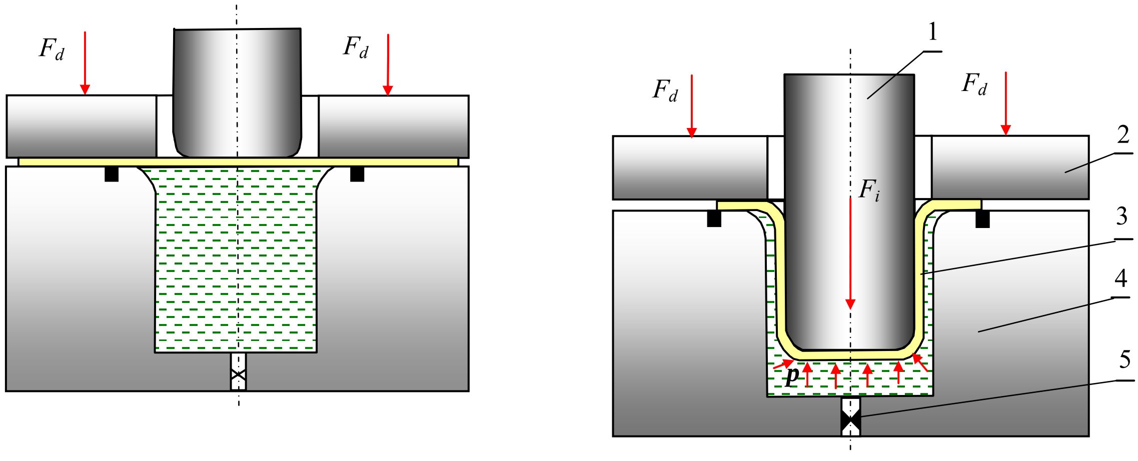
The parts produced by this action can have different forms (cycled, squared, rectangle ellipse or the combination of these forms). Their deformation processes as well as stresses states are different and they depend on the part form.

3. Hydroforming

Plastic material forming depends on the process kind and forming regime. Long ago there was an understanding that plastic forming of sheet metal elements is made by hard tools over 1000 pieces. By occurring of unconventional processes such as hydroforming, the same element can be made by one or by another method.

The choice of technology process depends on the analysis of influencing process parameters of sheet metal forming. The way of fluid forming is classified into the process of hydromechanical forming and hydroforming. At hydromechanical forming, the forming of final piece is defined by hard tool since the strain force is achieved by fluid. At hydroforming, impressed fluid is the carrier of strain force since the form is defined by cast geometry.

According to classical drawing out, where there is contact between the tool and working piece, at hydroforming the presence of unpressed fluid between metal sheet and the tool prevents the surface of metal sheet from damaging so the parts with quality outside surface or the parts with protection and with covering of outside surface can be made. In this way the form and part dimension accuracy is increased, and total drawing out stresses are decreased. The example of deep drawing out is presented in Fig. 2.



a b

Fig. 2 Hydromechanical deep drawing out

The prepared metal sheet part of is placed at the down part of the tool at which is working chamber *4*. The sheet of metal holder *2* serves for closing of working chamber. Through the valve *5* the working chamber is filled with unpressed fluid and pressure *p* of unpressed fluid is regulated. By moving down hard punch *1* drawing out of part *3* is made, that holds drawing out form. The wrinkle occurrence at the wreath prevents the sheet of metal holder.

At the complex form production, hydro mechanical deep drawing out offers the advantages of operation number decreasing. At Fig. 3, hydro mechanical drawing out of semisphere at the first operation, by boring of a hole at the bottom is shown. By classical deep drawing out it must be made by two operations.

At the second example of complex part production it can be noticed the production of bulb throat. Acting by the unpressed fluid on the hard punch form, the desired form at the one operation is obtained, since by classical processes should be made two operations: deep drawing out and screw thread producing.

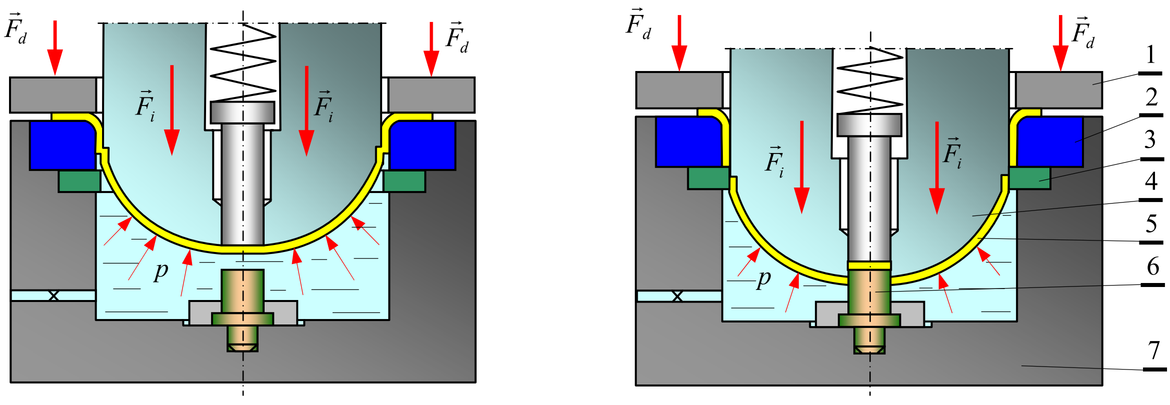


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Fig. 3 Hydro mechanical deep drawing out of semi sphere: *1* - blank holder; *2* - drawing ring; *3* - cutting ring; *4* - punch; *5* - blank; *6* - punching tool; *7* - lower of tool (container)

In Fig. 4 the tool for hydro mechanical drawing out is shown with drawing through of throat so that we can get throat height the same as at classical drawing through [6,7].

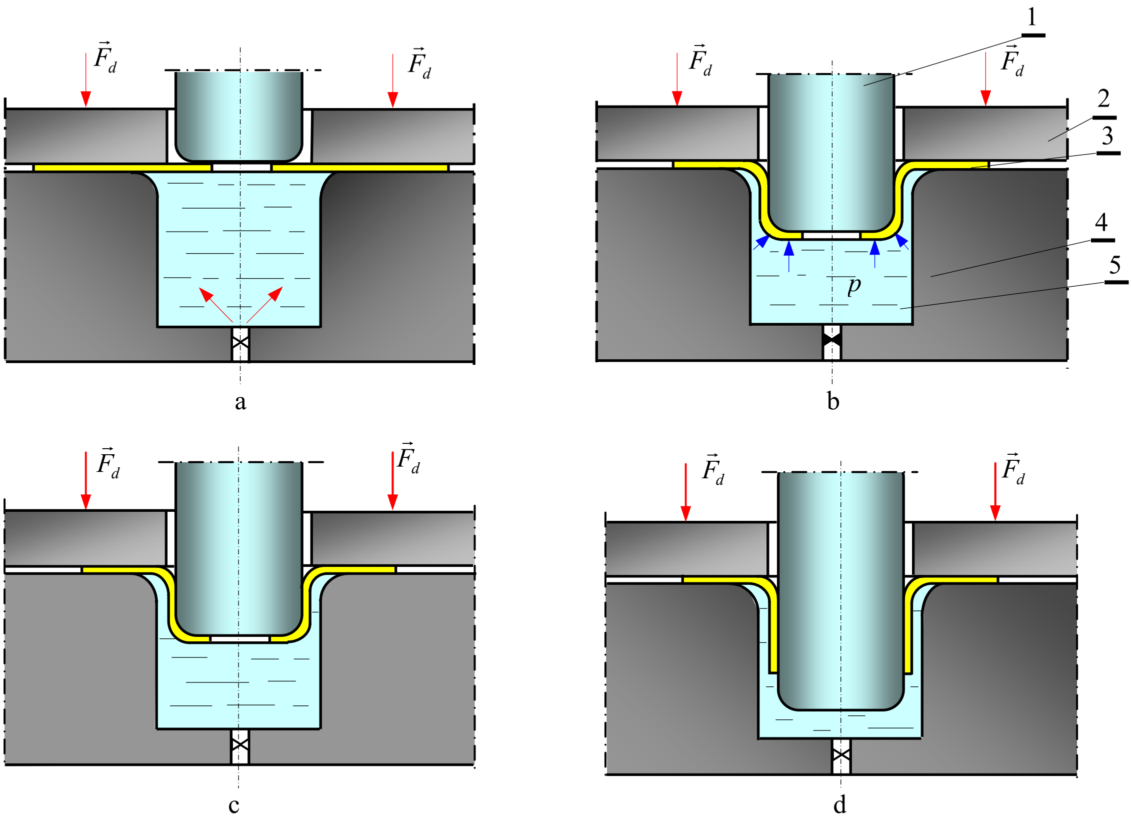

Fig. 4 Tool for combined drawing: *1* - punch; *2* - blank holder; *3* - blank; *4* - die; *5* - fluid

4. Comparing of conventional and hydro forming

Comparing the conventional forming actions with hydroforming there can be noticed the differences:

- tools;
- tribology of producing process;
- product quality;
- producing technology;
- machining systems.

The compared values of individual parameters either at conventional or unconventional processes can be obtained by theoretical or experimental ways.

Hidro forming process conditions influence on the quality of processed surface significantly that gives better quality than classical processes [6,9].

4.1. Comparison of process parameters of conventional and hydroforming of metal sheet.

In the paper are compared the following process parameters:

- stand at the contact surface;
- process distortion force;
- stress-strain stand;
- strain work;
- tribology stand;
- process quality and stability;
- tool worn-out and existence;
- product geometry.

4.1.1. Stand at the contact surface

At the conventional forming process, the influence of friction at the contact surface between the tool and preparing piece or preparing piece and the ring forecasting depends on lubrication means. Forming process unpressed by fluid does not require the application of lubricating means at the preparing piece surface or the ring for cast drawing out.

As an unpressed fluid an oil is used and it serves as lubricating means. Friction influence on the contact surface is smaller what directly influences on the forming force value and on the holder of metal sheet.

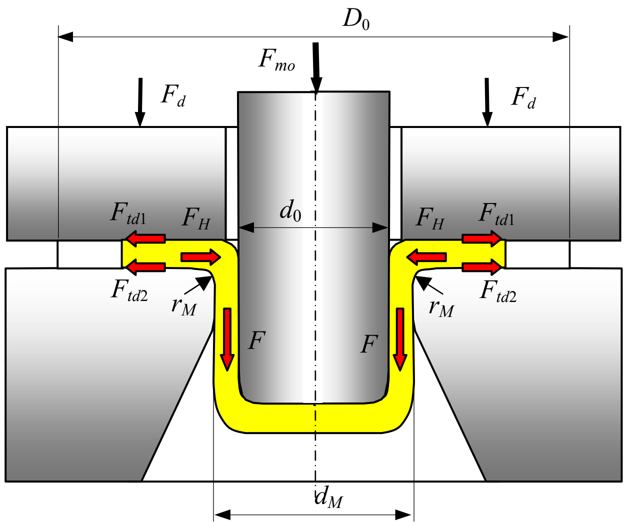

Fig. 5 Friction force at the deep drawing out

4.1.2. Stress strain stand

At the part wreath, formed by unpressed fluid, stress-strain stand does not differ significantly from the stand formed by classical drawing out, except when bigger transformed areas in case of classical forming are expected.

4.1.3. Process strain force

At the hydroforming process the force or strain depend on the unpressed fluid pressure and contact surface at which the fluid acts.

Pressure force can be obtained from the equation

$$F_{pf} = p\,A_p \tag{1}$$

where p is pressure, N/mm^2; A_p is surface drawing, mm^2.

Since at the mechanical forming, the force in common case is

$$F = k_{sr}\,A \tag{2}$$

where k_{sr} is mean specific resistance, N/mm^2; A is contact surface, mm^2.

According to higher contact friction and smaller level of process energy utilization, at the classical process of deep drawing is needed higher intensity of strain force than at the hydroforming can be expected.

Comparing strain force we need to notice axial force at the hydroforming. For the process of deep drawing out by hydroforming smaller strain work than at the classical process of deep drawing out is needed.

4.1.4. Tribology stand

At the process of metal sheet forming by deep drawing out, when the friction is observed, there is not possible to choose one value for friction coefficient μ, that is adopted to all points of working piece at the strain process. During the deep drawing out forming it comes between sheets of metal:

- for drawing out (castings);
- sheet of metal holder;
- ring radius for drawing out;
- punch.

At the mechanical process of deep drawing, the friction force of sheet of metal holder is

$$F_{td} = F_{td1} + F_{td2} = 2\,\mu\,F_d \tag{3}$$

Since the total force caused by friction

$$F = F_H\,e^{0.5\pi\mu} = \left(F_p + F_{td}\right)e^{0.5\pi\mu} =$$

$$= \left(1.1 k_s\,d_s\,\pi\,s\,ln\frac{D}{d_s} + 2\,\mu\,F_d\right)e^{0.5\pi\mu} \tag{4}$$

At the process of deep drawing out by unpressed fluid, the friction force F_t is constituted of

$$F_t = F_{\mu d} + F_{\mu k} + F_{\mu m} + F_{\mu i} \tag{5}$$

where $F_{\mu d}$ is friction force between the sheet of metal and the sheet of metal holder, N; $F_{\mu k}$ is friction force between the sheet of metal and flat ring surface for casting, N; $F_{\mu m}$ is friction force between the sheet of metal and matrix radius of drawing out matrix, N; $F_{\mu i}$ is friction force between the sheet of metal and the punch, N.

4.1.5. Force of sheet of metal holder

Pressure stresses at the part wreath in the angle area can cause metal sheet bending or wrinkle occurrence. When the wrinkles are too large and they can not be flattened at the cycled edge of drawing out ring, material flow into the ring opening (cast) can be stopped and the part destructed. To prevent wrinkle occurrence at the wreath volume, it must be acted by defined pressure of metal holder sheet. The specific pressure of sheet of metal holder can be changed in the defined limits.

The value lower than the limit is defined by wrinkle occurrence and the one upper the limit by destruction. By equation (6) the values of specific pressure can be defined in the zone of holder at the drawing out hydroforming process with unpressed fluid [2, 10]

$$p_d = 0.025\left[\left(m-1\right) + 0.5\frac{d_0}{100\,s_0}\right]\sigma_m \tag{6}$$

where m is drawing out level ($m = d/d_0$); d_0 is piece radius that is drawn out, mm; s_0 is metal sheet thickness, mm; σ_m is material hardness, MPa; p_d is metal holder sheet pressure, N/mm^2.

The force of metal holder sheet can be achieved by simple formula

$$F_d = p_d\,A_d = p_d\left[D_0^2 - \left(d_M + 2\,r_M\right)^2\right]\frac{\pi}{4} \tag{7}$$

where A_d is the surface of metal holder sheet, mm^2; D_0 is platinum diameter, mm; r_M is radius of cycled matrix edge, mm, d_M is diameter of matrix opening, mm.

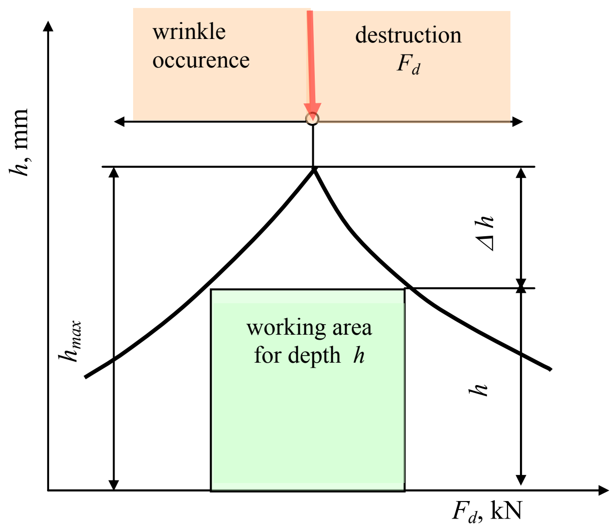

Fig. 6 The influence of holder force on the drawing out depth

The optimal value of holder must satisfy the conditions that are needed wrinkles or piece cutting not to occur. The influence of holder force on drawing out depth is presented in Fig. 6. [6,11,12].

4.1.6. Total force of the process

- The force at the mechanical forming

$$F_{mo} = F_p + F_{td} + F_{tk} + F_s \quad (8)$$

where F_p is plastic forming force, N; F_{td} is friction force because of metal holder sheet, N; F_{tk} is splitting friction force of metal sheet over the radius of cycled ring, N, F_s is bending force over the ring radius, N.

- The force at the hydroforming.

At the hydroforming, the forming force is placed in the function of part height increasing. Because of strain latency in the area of radius according to the middle side of the part, of maximum forming force value is needed to be known.

It is obtained in the case of hydromechanical forming and the following bending process (strain at the middle of outer side) that it finishes before the occurrence of maximum forming force. At the definition of maximum forming force the form of final piece at define areas as e.g. cylindrical part for deep drawing out: radius area and the area of straight side must be taken into attention.

To hydroforming force all forces needed for forming at the areas shown in Fig. 1 are summed

$$F_{ho} = F_p + F_{td} + F_{tk} + F_s + F_{pf} \quad (9)$$

where F_{ho} is total hydroforming force, N; F_{pf} is pressure force of unpressed fluid, N.

4.1.7. Process quality and stability

Either it is conventional or unconventional metal plastic processing, the process quality and stability depend on numerous process parameters (influences, friction, sheet of metal holder application, and so on). At the hydroforming, the significant influence on quality and forming stability has the relation of axial strain force and internal fluid pressure.

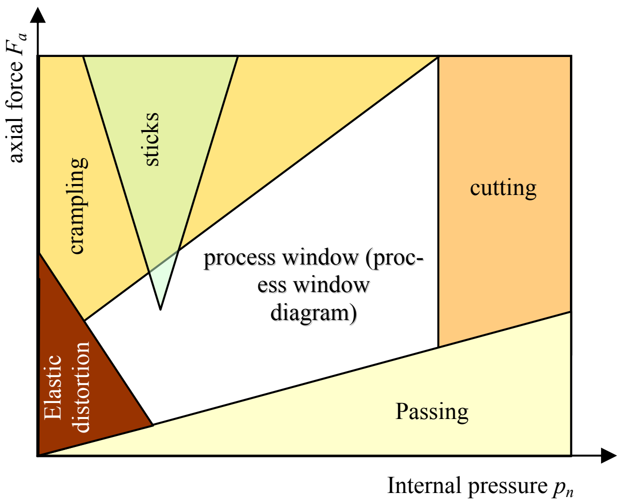

Fig. 7 Dependence of axial force on internal pressure

Forming process needs to have such combination of forming process parameters that are inside the process window (process window diagram).In this case stable and successful forming process (Fig. 7) is obtained.

Outside the defined area errors on final piece occur regardless it is the matter of sticks, crumpling or destruction. At the mechanical forming, process stability depends mostly on tribology conditions of real process.

Lubrication intensity and defined mean quality can make the process stable. But with the changes of tribology stands the increase of contact tangential stress can appear (friction force) that leads the process into unstable area when it comes to holes and cutting out of working piece material [6,10].

4.1.8. Tool wear

As contact friction is decreased at the hydroforming process significant to compare with the friction force in mechanical forming, it is not difficult to conclude that the lower tool wear will be at the forming process with fluid. This is because the surfaces are in contact with fluid.

4.1.9. Working piece geometry

Fluid plastic forming previously analyzed has shown the defined advantages according to classical metal forming depending on working piece geometry and sizes [2, 9-12].

5. Advantages of hydroforming

The plastic material forming processes by hydroforming has defined advantages according to conventional treatments and there are:

- decreasing of operations number, in one step it is made deep drawing out and engraving of different forms and needed hole boring;
- simple tool production and the possibility of different thickness metal sheet parts production with the same tool;
- cheap tool, because it is made by half of hard tools, and the other part of tool is fluid;
- more betterment tribology, lower contact friction;
- obtaining quality inside part surface, because only outside part surface touches hard ring of drawing out;
- possibility of complex larger dimensions element production (car industry, ship building, military equipment);
- economy increasing, because it is possible to produce parts of different forms and dimensions that at the same tool cast changing at the defined size frames is made;
- make parts, which are not possible to produce by classical processes.

6. Conclusion

In the last decades unconventional processing substitutes the conventional processing actions. Though the fluid processing is applied since 70' years theoretical or experimental research of it is still necessary.

In the developed countries hydroforming is increasing 5-10% per year to compare with classical plastic processing.

The given advantages, allow automation and action optimization what the top of plastic forming processes make hydroforming.

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ĮPRASTINIO PLASTINIO FORMAVIMO PROCESO, TAIKOMO HIDRAULIŠKAI ŠTAMPUOJANT, PALYGINIMAS IR PAKEITIMAS

R e z i u m ė

Rinka reikalauja nuolat keisti produktų asortimentą, taikant naujas technologijas. Kompiuteriai padeda panaudoti naujas technologijas, kurios užtikrina modernios produkcijos sąlygas: platų gaminių asortimentą, eksportinę kokybę. Hidraulinis štampavimas priskiriamas prie nevaržomo apdirbimo, kai gaminio formavimo metu tarp įrankio ir apdirbamos detalės nėra tiesioginio kontakto. Nevaržomas plastinis formavimas ir hidraulinis štampavimas gali būti lyginami pagal technologinį apdirbimą, įrankius ir apdirbimo sistemas, apdirbtų paviršių kokybę, apdirbimo proceso trilogiją ir kt. Straipsnyje parodyta keletas skystojo formavimo pranašumų, palyginti su tradiciniais procesais. Pateikta keletas įprasto plastinio formavimo ir hidraulinio štampavimo lyginimo pavyzdžių.

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COMPARISON AND SUBSTITUTION OF CONVENTIONAL PROCESSES OF PLASTIC FORMING APPLYING HYDROFORMING

S u m m a r y

The market demands for continuous changes of product assortments require the application of new technologies. The computer aided new production technologies witchsatisfy conditions of modern production as: wide product assortment and quality export. Hydroforming is unconventional processing where there is no direct contact between the tool and working piece during the product forming. The comparisons of unconventional plastic forming processes with hydroforming can be made by technological processing, tools and processing systems, the quality of processed surface, tribology of production process and so on. In the paper some of advantages of fluid forming according to conventional processes are given. Therefore some of examples of substitutions of conventional processes of plastic forming and applying hydroforming are provided.

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СРАВНЕНИЕ И ЗАМЕНА ОБЫЧНОГО ПЛАСТИЧЕСКОГО ПРОЦЕССА ФОРМИРОВАНИЯ ПРИМЕНЯЕМОГО В ГИДРОШТАМПОВАНИИ

Р е з ю м е

Рынок постоянно требует изменения ассортимента продуктов, применяя новые технологии. Компьютеры способствуют внедрению новых технологий обеспечивающих условия современной продукции: широкий ассортимент изделий и экспортное качество. Гидроштамповку причисляют к нестесненному способу обработки, когда нет прямого контакта между инструментом и обрабатываемой деталью во время формирования изделия. Сравнение нестесненного пластического формирования с гидроштамповкой можно осуществить по технологическому процессу, качеству инструментов и производственных систем, обрабатываемой поверхности, трибологией производственных процессов и т.д. В статье показаны некоторые преимущества жидкостного формирования по сравнению с традиционными процессами. Представлено несколько примеров сравнения обычного пластического процесса формирования с процессом гидроформирования.

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