DEVICE FOR THE STUDY OF THE PUNCHING PROCESS

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Abstract: *Punching is a cold deformation process by which holes are obtained in the workpiece in sheets or plates. The part of interest is the separate part of the workpiece or that which remains after separating an area from the plate or sheet. A systemic analysis of the punching process was first performed to investigate the punching processes better. The analysis revealed the parameters of interest in the case of such processes and the factors that influence the values of the parameters of interest. The use of the first axiom in the axiomatic design facilitated the identification of some components of a device that would fulfill the different functional requirements of the device. A variant of the device was designed to facilitate a more detailed study of the material's behavior in the area affected by the plastic deformation process. The device considers the specific components of a die, being adaptable to some of the existing universal machine tools in a mechanical workshop.*

Keywords: *punching, parameters of interest, influence factors, axiomatic design, device.*

1. Introduction

A group of machining processes used in the machine manufacturing field is based on deformation and cutting processes, without generating chips, at a temperature corresponding to that of the ambient and generating parts with few or no additional machining operations. They could be grouped under the name of cold pressing processes. Such processes use complex punching tools, and the most commonly used processing equipment is the press.

Punching is a cold-pressing process that generates a closed inner contour or a cavity in a sheet metal blank [Emche, 2012; Rîpanu, 2013; Soares, 2013; Wojtkowiak, 2019].

It is found that punching and other cold pressing processes ensure high dimensional accuracy and high productivity, which has led to the use of such a process, especially in series and mass production.

In principle, the separation of a part of the workpiece occurs as a result of the development of a shearing process by the action on the workpiece of the sharp edges of a moving tool with the sharp edges of the die.

Although known for quite some time, punching processes are still objectives of the activities of researchers in the field of machine manufacturing. Attention is paid to the possibilities of improving the tools used, identifying new elements related to the active edges of the tools, optimizing the cutting parameters, better understanding how the process of material separation is initiated and developed, etc.

Thus, Emche and Kandalkar addressed the issue of designing a punch for obtaining oval holes in sheet workpieces [Emche, 2012]. They have developed a set of considerations to help the designer in selecting the best solutions for the punch able to generate the oval holes.

Neugebauer et al. investigated the influence exerted by a preload of the workpiece on the stress state of the workpiece material in the case of a precision stamping process [Neugebauer, 2013]. They noticed that the width of the material flow area in the processing area is different in the case of workpieces made of steel and aluminum alloys.

Kadarno et al. proposed a punching process involving the thickening of a hole edge by using a punch with a conical area, which improved the fatigue strength of the punched sheet [Kadarno, 2014].

Moreno et al. approached the problem of interactive simulation of the behavior of the punching machine in the context of its use in a manufacturing line [Moreno, 2017]. They highlighted the help that can be offered by developing software that allows taking into account several factors in the virtual perforation.

The modification of some sheet material properties when obtaining some inclined surfaces by perforation was studied by Katoh et al. [Katoh, 2016]. They used in this sense the variation of the Vickers hardness of authentic stainless steel in a cross-section through the sheet subjected to the punching process.

Gupta investigated the variation of quality parameters when using perforation in washers [Gupta, 2918]. He used, in this case, DMAIC to identify the main factors capable of affecting the variation of some quality parameters of the processed surfaces.

2. Analysis of the operating conditions of a device for the study of the punching process

Punching processes are applied on processing equipment in the press category to ensure high efficiency.

The tools used to materialize the punching processes are the dies. They usually have a fixed subassembly located on the press table and a mobile subassembly attached to the mobile component of the punching equipment. During the punching process, the mobile subassembly moves to ensure the separation of a part of the workpiece material by the sharp edges of the two components involved directly in the development of the shear process.

In principle, a punch with a predetermined cross-section and sharp edges moves and in a hole found in the active plate (die) which in turn has a cross-section with a shape correlated with the shape of the cross-section of the punch. Clearance of a specified value can be defined between the side surface of the punch, at its active edges, and the hole in the die.

Note that the sheet or strip-type workpiece is frequently immobilized by various means on the surface of the die to avoid the occurrence of processing errors due to an uncontrolled flow of the workpiece material during the plastic deformation process.

The analysis of the conditions in which the shearing process developed by separating a part of the workpiece takes place reveals the existence of at least several sequences with distinct characteristics (fig. 1):

a) The contact between the active edges of the punch and the immobilized workpiece on the surface of the die takes place first;

b) In a second sequence, if the movement of the punch continues, a process of elastic deformation of the workpiece material is initiated;

c) The continuation of the punch movement results in the initiation of a process of plastic deformation of the workpiece material;

d) If the active edges of the punch and those generated by the intersection of the hole in the die with the flat surface are sufficiently sharp, a shearing process is initiated, with the first appearance of a new surface, with a lower roughness and which highlights the existence of flow lines of the semi-finished material;

e) The continuation of the movement of the punch facilitates the development of the cracks previously primed in the workpiece material and the promotion of the process of separation of a part of the workpiece, possibly until the complete separation of the part with the resulting waste;

f) If the material of the workpiece has high plasticity and the clearance between the punch and the active plate is large enough, a variable-height burr may appear at the contour of the spare part and the edge of any part of the workpiece.

Several factors can influence the accuracy and roughness of surfaces made by using the punching process.

Efficient analysis of the quality of surfaces obtained by punching processes can be performed using *the systemic approach*. In such an approach, the drilling process is considered a system to which input factors and output parameters are defined.

Taking into account the parameters that define the quality of surfaces generated by punching processes (dimensional accuracy, shape accuracy, reciprocal position accuracy, corrugations, roughness characterization parameters, properties of the surface layer generated by punching and different from those of the base material of workpiece), the following *groups of input factors* can be defined in the punching process and which could affect the values of *the output parameters*:

1. Physical-mechanical properties of the workpiece material;
2. Physical-mechanical properties of the punch material;
3. Thickness of the workpiece;
4. Shape and dimensions of the orifice to be obtained by punching;
5. The clearance between the side surface of the punch and the hole in the die and the length of the zone in the die hole on which this clearance is maintained;
6. Sharpening radii at the active edges of the punch and the die.
7. The relative speed of movement between the punch and the active plate will be decisive for reaching a certain speed of flow of the workpiece material and the development of cracks that will eventually lead to the separation of a part of the workpiece.

Conducting an experimental research activity on the influence that some input factors exert on the values of some of the output factors of the punching process highlighted the possibility of designing and making a device to allow a more detailed investigation of how it is initiated and the process of separating a part of the workpiece during the punching process develops.

3. Formulation of functional requirements for a device for studying the punching process by taking into account the first axiom of axiomatic design

Axiomatic design is a way of approaching design problems so that the design activity has a more systematic character and becomes more efficient. The axiomatic design was proposed by Professor Nam Suh while working in a manufacturing engineering department at the Massachusetts Institute of Technology in the U.S.A. [Suh, 2001; Slătineanu, 2019]. The uses of axiomatic design must ensure the efficient design of manufacturing processes.

Subsequently, the axiomatic design would be used with positive results and for solving constructive design problems, but also in areas that did not have direct connections with engineering activities (in medicine, road traffic problems, environmental protection, architecture, etc.).

In principle, axiomatic design involves the use of two axioms, namely:

a) The axiom of independence of the functional requirements that the design objective must meet;

b) The axiom of information, according to which among several alternatives for solving a problem, the one that involves the use of the least information will be preferred. A more nuanced wording of this axiom calls, in fact, for the use of that alternative solution to the problem addressed, which is most likely to be successful;

c) The application of the first axiom requires a successive definition of the functional requirements for several successive levels of approach to the problem;

d) Thus, in the case of the need to design a device for a more detailed investigation of the processes that occur and take place in the specific space of a punching process of a strip-shaped workpiece, the zero-order functional requirement could be formulated as follows: *FR*0: design a device that allows a clearer demonstration of how transformations evolve in the workpiece into the working area of a punching process.

As functional requirements of the first order could be considered:

*FR*1: ensure that the device is used in a mechanical workshop;

*FR*2: Ensure conditions for meeting or simulating the specific requirements of a drilling process;

*FR*3: provide opportunities for direct observation, possibly photography or filming of the evolution of processes in the punching area.

For each functional requirement of the first order, it is necessary to have analyzed and selected appropriate ways to fulfill them. In the case of axiomatic design, these ways will be called *design parameters* and it could be, for example, those mentioned below, taking into account each functional requirement of the first order:

*DP*1: a drilling machine, i.e., a relatively simpler machine tool compared to other machine tool categories and found in every mechanical workshop;

*DP*2: a die including the components necessary to carry out a process of separation of a part of the workpiece material as a result of its plastic deformation;

*DP*3: an arrangement of the components of the die so that it is possible to observe directly the processes in the punching area.

The use of axiomatic design can be continued by the successive formulation of some functional requirements and respectively of some identification of some design parameters for more and more detailed aspects of the pursued objective.

4. The solution identified for the device for studying the shear-cutting process

Addressing the problem of identifying a device solution that facilitates the observation and possibly recording by photography or filming of the processes that take place in the workpiece in the punching area led to the design of the principle solution shown in Figure 2.

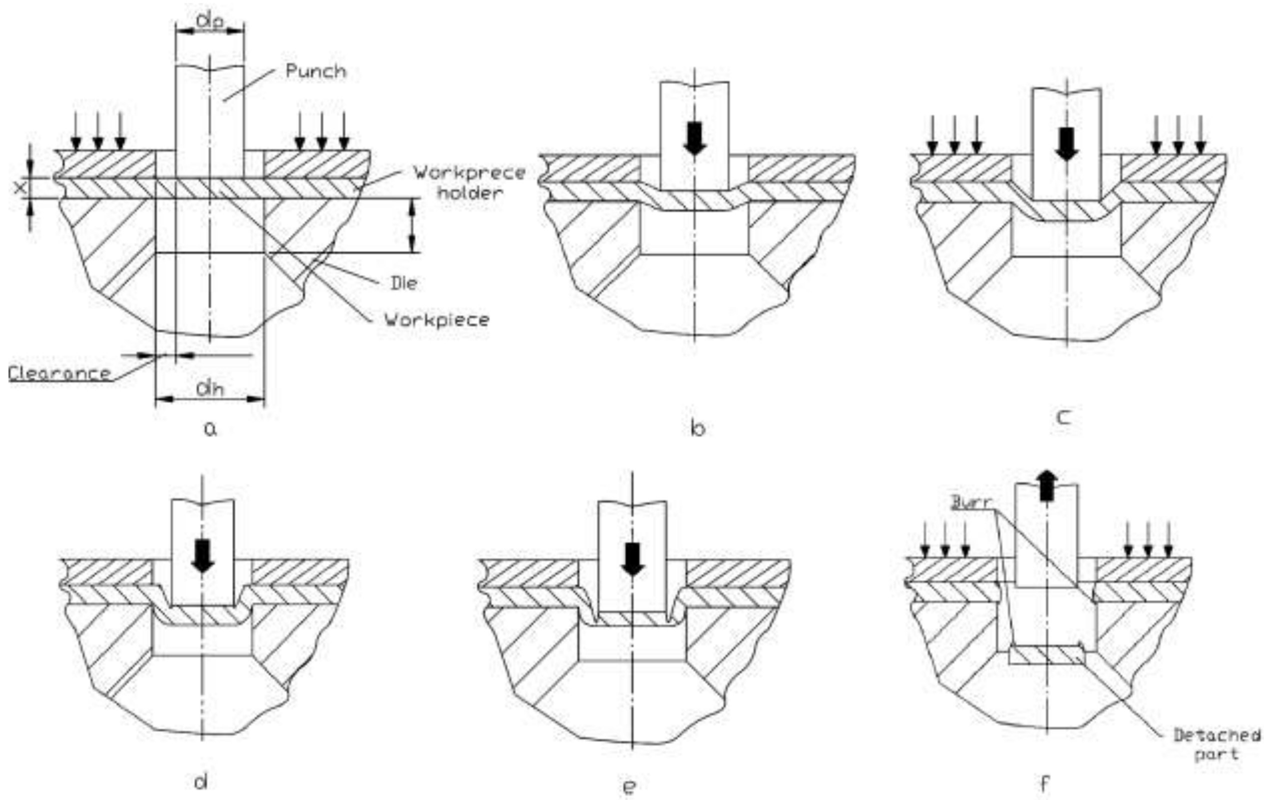

Figure 1: *Phases of the perforation process: a - contact of the punch with the workpiece; b - elastic deformation of the workpiece material; c - initiation of a plastic deformation process; d - the appearance of the first cracks; d - crack propagation; f - detachment of a part of the workpiece.*

It can thus be seen that the device which could help to meet the requirements under consideration could include as an essential element a punch 1, consisting of a T-shaped plate, attached to the punch plate 2 and having the same thickness as the plate corresponding to the punch 1.

Punch 1 moves along a direction perpendicular to the upper surface of a strip-type workpiece 3. The workpiece 3 also has a width equal to the thickness of punch 1 and is clamped on two plates 4 and 5, which provide conditions for the materialization of an active plate of a die. Plates 4 and 5 are secured to the base plate 6 of the device by welding or using screws.

The clamping of the workpiece 3 on plates 4 and 5 materializing the active plate of the die is made using two screws 7 and 8 and two parts 9 and 10, acting as washers for applying on a larger surface the clamping force of the workpiece 3.

The movement of the punch plate 2 to the active plate of the die materialized by plates 4 and 5 is guided by two columns 11 and 12.

Above punch plate 2 there is an elastic deformable part 13, which fulfills the role of a dynamometric ring. At the top of part 13, another plate 14 acts. It has a thickness equal to the thickness of the plate materializing punch 1 and a thickness equal to plates 4 and 5. Plate 14 materializes the active plate of a die. Punch 1 acts on the workpiece 3. A dial gauge A fixed in plate 14 will be used to highlight the deformation of part 13 and the force's size. In this way, the indications of the dial gauge A provide information on the force exerted by punch 1 on the workpiece 3.

The device can be placed on the table of a vertical column drilling machine or a milling machine table. When the table is manually or mechanically raised, the punch gradually penetrates workpiece 3, until part of this workpiece is separated.

When gradually entering workpiece 3, a second dial gauge B will be used. This dial gauge is clamped in the punch holder plate 2, and it facilitates highlighting the distance traveled by the front surface of punch 1. Probe 16 of the dial gauge B will contact plate 5, which contributes to the materialization of the die active plate.

The plate 14 will come into contact with the front surface of the main shaft of the vertical drilling machine or with the main shaft of a milling machine.

The area of the workpiece 3 which is affected by the action of the active edges of the punch 1 and the plates 4 and 5, which materialize the active plate of the die, can be observed directly, or photographed or filmed.

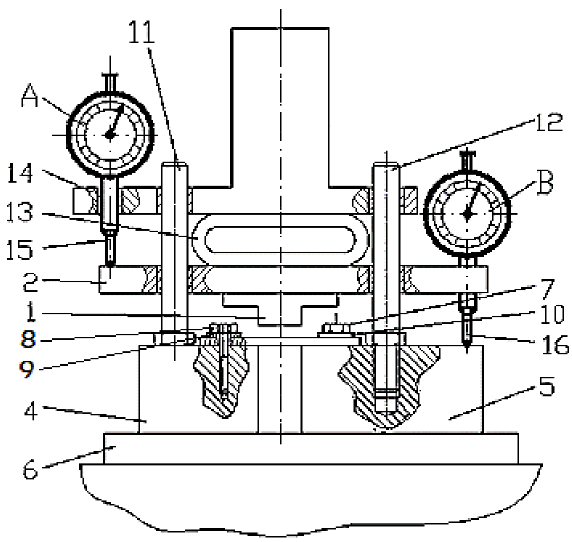

Figure 1: *Schematic representation of the device for the study of the drilling shear process.*

5. Conclusions

Punching is considered as aa cold plastic deformation processing of a sheet or strip type workpiece, and it is used to obtain perforated holes with simpler or more complicated contours. More in-depth knowledge of the processes in the workpiece during punching could facilitate the identification of conditions that could ensure optimal punching. The purpose of the paper was to present how a constructive solution was outlined for a device intended to track or record how a part of a strip-type workpiece is separated. Attention was paid to simulating, as far as possible, the specific conditions of a real punching process. The device was designed based on the functional requirements of identification of the punching tool components using the first axiom of the axiomatic design. In the future, it is intended to manufacture the device and to carry out experimental research by using this device. In this way, a deepening of the knowledge about the processes in the workpiece material during the punching process will become possible.

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