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Device for Precision Cold Shearing Using Bar Torsion

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Abstract
The precision cold shearing is a production process used for intermediary parts or even final parts manufacture, from round metal bars or other laminated profiles, obtaining a high dimensional and geometric precision, and higher surface quality in comparison with conventional metal shearing processes. There are well-known two methods of precision cold shearing, by conventional shearing or by material torsion. The precision cold shearing by material torsion is suitable for parts manufactured from metal bars which do not have a round transversal section, or various laminated profiles, where the conventional shearing process is difficult to be implemented and to obtain similar results. In the literature, there is presented a special machine tool for metal bar shearing by material torsion. The disadvantage of this machine tool is that the manufacturing costs for such a machine tool are at a very high level. The paper presents a simple device for metal bar precision cold shearing by material torsion which can be easily implemented using a conventional simple action mechanical or hydraulic press. The device uses the principle of spatial material compression, before the proper shear, using a simple lever system, and it is recommended for precision cold shearing of hard and medium-hard materials.

Keywords
precision cold shearing, material torsion, spatial material compression, hard and medium-hard metals

1. Introduction

Throughout the manufacturing industry, obtaining a final metal product supposes, most often, that the production starts from a raw material, except the casted/moulded parts or the 3D printed parts. For products manufactured from metal bars, usually the first operation is cutting or shearing of the metal bar into smaller pieces that become raw materials for other parts, further processed using cutting technologies, hot or cold pressing technologies, unconventional technologies or other manufacturing methods. There are many technologies used for metal bar cutting as follows: cold shearing, cutting using band saws or circular saws, cutting using turning operations or unconventional techniques as abrasive water jet cutting, laser cutting, plasma cutting or other modern techniques [1]. Two of the most used technologies are the cold shearing and the band saw cutting, each with its advantages and disadvantages. The band saw cutting is most often used for small volume production, in small manufacturing shops or in industrial companies, but also for mass production when the raw materials with large dimensions are difficult or impossible to be sheared. The band saw cutting has the advantage of obtaining a clean cutting surface with a square end edge, but its major disadvantage is the cutting cycle time which is much longer in comparison with a shearing process. The cold shearing process is suitable to be implemented for large volume production due to its short cycle time, but it has many restrictions. The metal bar dimension that can be sheared are relative small and a poor quality of the resulted end edge and surface is obtained. Another restriction of cold shearing is that it cannot be used for tube or hallow profiles shearing because the resulted profile will be flattened [2]. Multiple topics from the literature review have been addressed on theoretical and experimental research upon the shearing process of metal bars [3, 4], wire profiles [5] or sheet metal raw materials [6], including high speed shearing solutions and process finite element analysis [7, 8].

In industrial manufacturing domain there are multiple situations when different parts are processed starting from metal bars or other laminated profiles, requiring a high geometric and dimensional precision and higher surface quality. These parts can be manufactured using various metal cutting technologies as turning, milling or using the precision cold shearing process. The precision cold shearing is a high productivity process being very efficient especially for large volume productions. This process eliminates the disadvantage of the poor surface quality and accuracy obtained using conventional cold shearing process.

2. Precision cold shearing working principle

The precision cold shearing working principle is based on the T. Karman's theory [9] according to which the process starts with the material spatial compression in the shearing area. Further, taking into consideration the absence of the clearance between the two cutter tools, the process met the right conditions for material cutting by quasi-pure shearing.

There are two methods used for precision cold shearing implementation:

- using conventional precision cold shearing – for this process, the punch cutting blades execute a simple linear translation in the shearing direction;
- using the precision cold shearing by material torsion – this process is different in comparison with the conventional precision cold shearing because the effective shear is done by material torsion. For this process a special device is needed and the cutter tools will execute a rotational motion during the process.

For products manufacture there are used various methods for precision cold shearing through material torsion. In figure 1 is presented the working principle of a device used for precision cold shearing of round bars [9]. The material shear is executed by a combined motion of the cutter tools, using shear and torsion at the same time. The bar is clamped between the two sets of cutting tool using a force F. A set of cutting tools is fixed on the device, and the other set of cutting tools execute a rotational motion around the device axis, causing, in a simultaneous way, a shearing and a small torsion movement of the material bar. In this way the round metal bar is sheared.

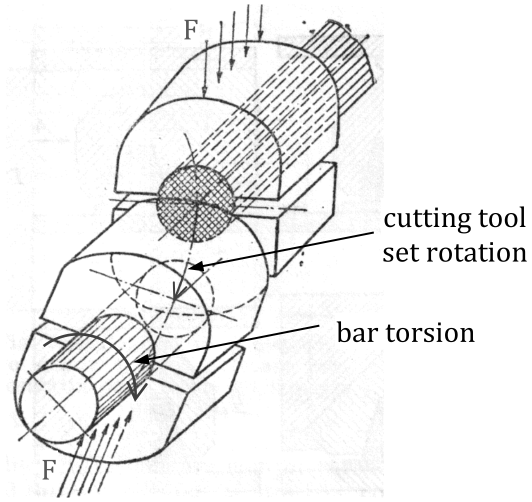

Fig. 1. Working principle of a device used for precision cold shearing [9]

In figure 2 is presented the sketch of a machine tool used for precision cold shearing by material torsion [10]. The machine tool is composed of two identical subassemblies, a fixed one, named A, which is not drawn in figure 1, and a rotating subassembly, named B. Both subassemblies are mounted in the machine tool main body 1. The rotating subassembly B is composed of a cylindrical body 2, inside of which there are mounted the fix cutter tool 3 and the mobile cutter tool 4. The machine has a linear hydraulic motor 8 which pushes up the lever 5 using the vertical lever 6 and the join 7. When the piston of the hydraulic motor goes down, the lever 5 acts upon the mobile cutter tool 4 which first clamps and tights the bar upon the fixed cutter tool 3. When the force named Q increases over the necessary tightening force, the rotating subassembly B starts to rotate around its centre axis causing the bar shearing by torsion. When the piston of the hydraulic motor goes up, in the reverse direction, the Q force stops pressing on the mobile cutter tool 4 and the entire subassembly B returns to its initial position. The metal bar piece is sheared and can be removed from the machine tool.

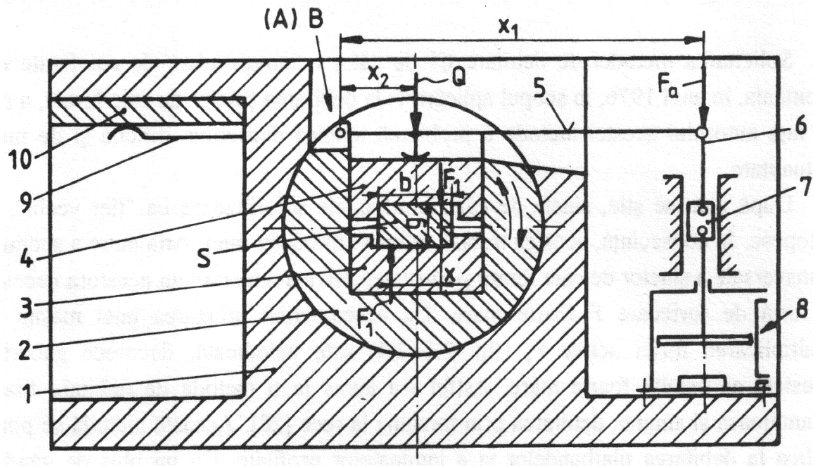

Fig. 2. Machine tool used for precision cold shearing by material torsion

In this paper, there are presented the design, the working principle and the kinematic scheme of a simple device used for metal bar shearing by material torsion. A great advantage of this device, in comparison with the machine presented in figure 2, is that it can be implemented using any conventional simple action press with mechanical or hydraulic system. It is recommended to use a mechanical press because it has the advantage of a great productivity in comparison with a hydraulic press.

3. The design of the metal bar shearing device

The device 3D model was designed in CATIA V5 software using two available workbenches, the “Part Design” workbench for components design and the “Assembly Design” workbench for device assembly. In figure 3 is presented a device isometric view where the device symmetry plane and the rotation axis for material torsion can be noticed.

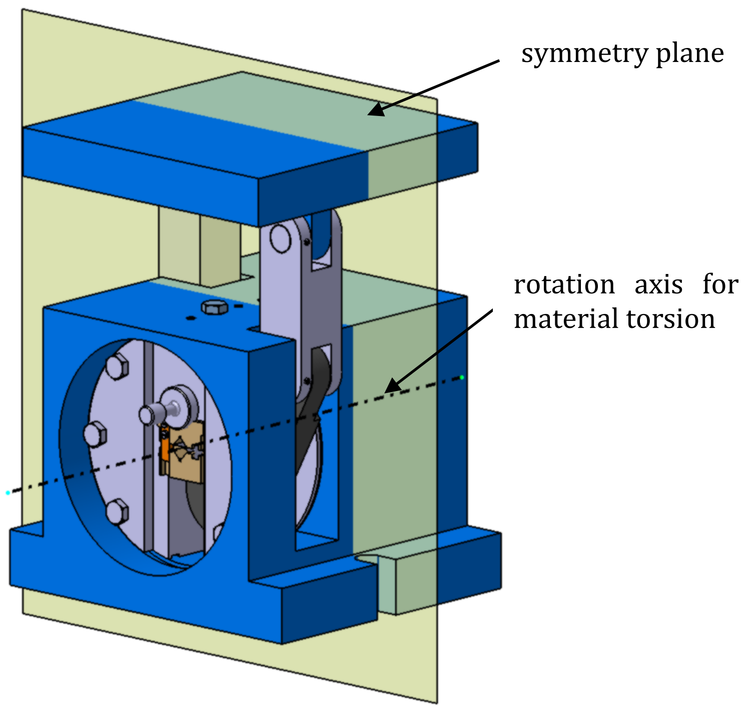

Fig. 3. Isometric view of the device for metal bar precision shearing by material torsion

Considering the device symmetry, in figure 4 is presented an exploded view for only one half of the device components. In this figure, the main components and its names are highlighted.

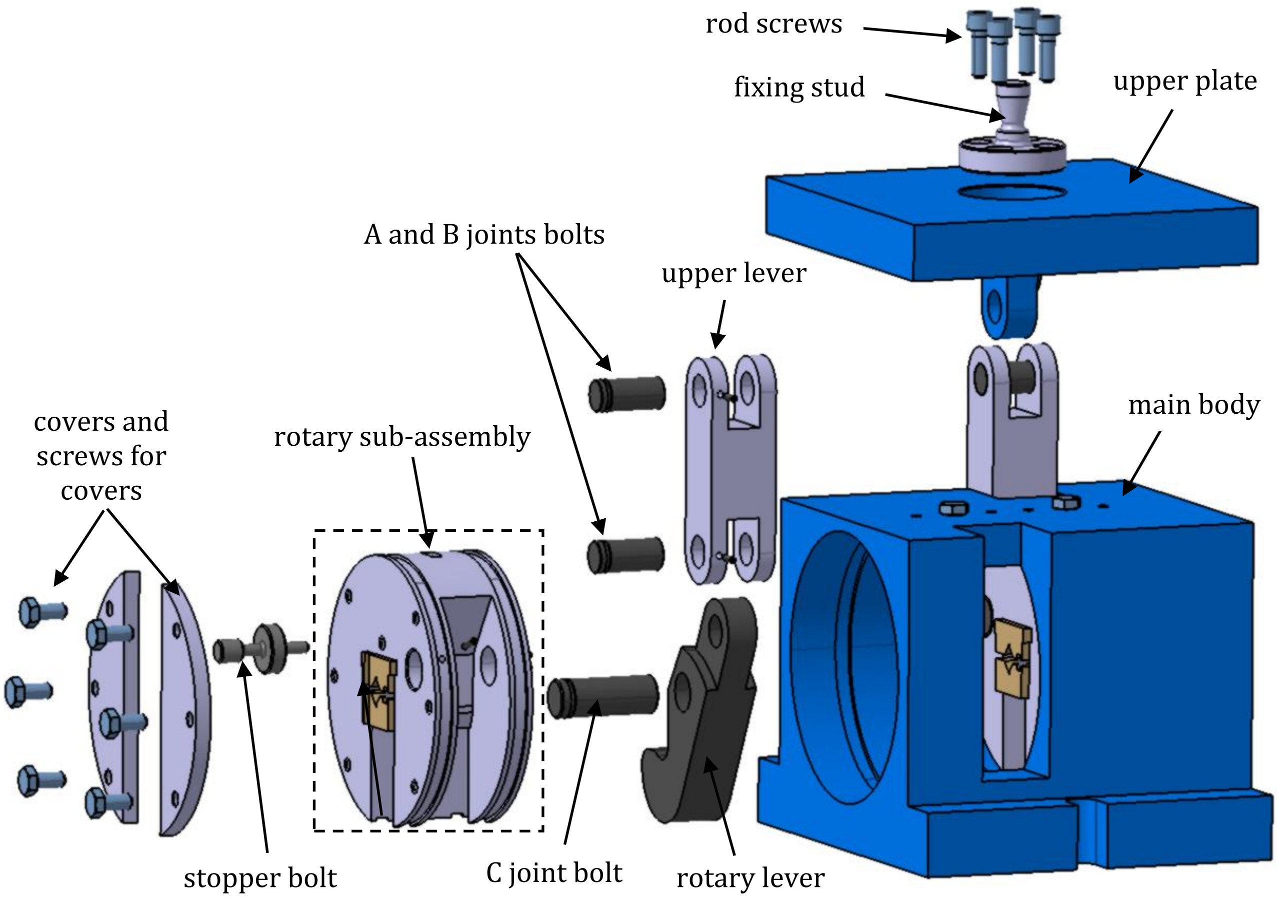

Fig. 4. Exploded view of the device components

Figure 5 presents a detailed view of one of the rotary sub-assembly which is composed of a cutting tool set and a cylindrical drum. The cutting tool set include two cutters. The upper cutter is guided in the clearance from the cylindrical drum and is fixed by the stopper bolt from figure 4. The other cutter is mobile in vertical direction in the cylindrical drum pocket, and it ensures the cutting tool set opening using two springs guided by two pins. The guiding rod ensures the relative position between the mobile cutter and the fixed cutter.

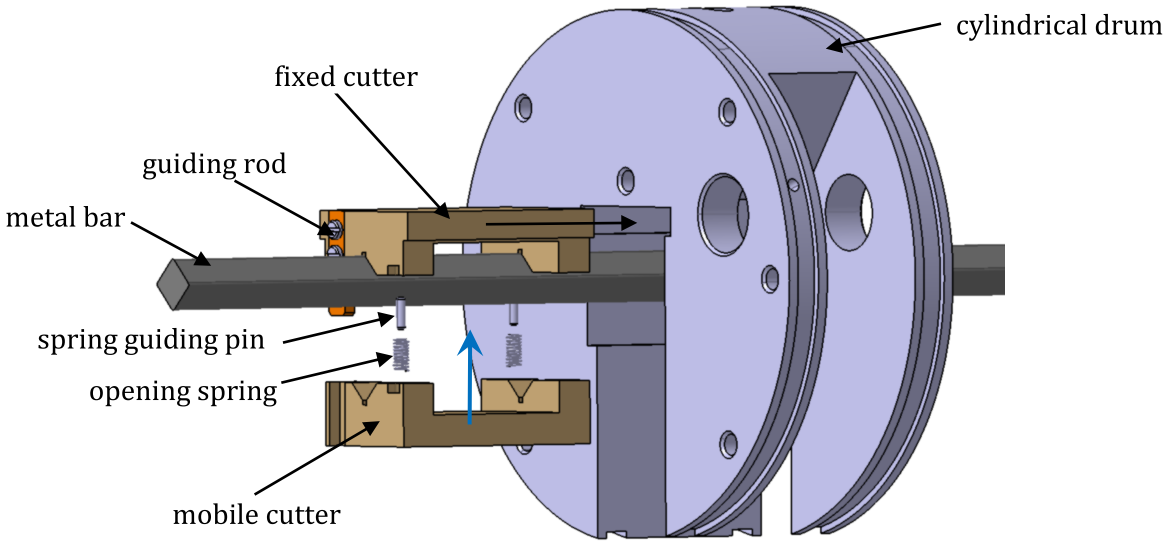

Fig. 6. The rotary sub-assembly

Both cutting tools have a V shape curving on the active surfaces, necessary to clamp the square profile of the metal bar. Both cutters are active tools, the mobile cutter being the one which ensures clamping and releasing the metal bar, and also the material compression necessary for precision cold shearing.

4. Metal bar shearing device working principle

For a better understanding of the device working principle, in figure 7 it is presented a front view of the assembled product, where the device main body and both cylindrical drums are set transparent for a better analysis of the interactions between components.

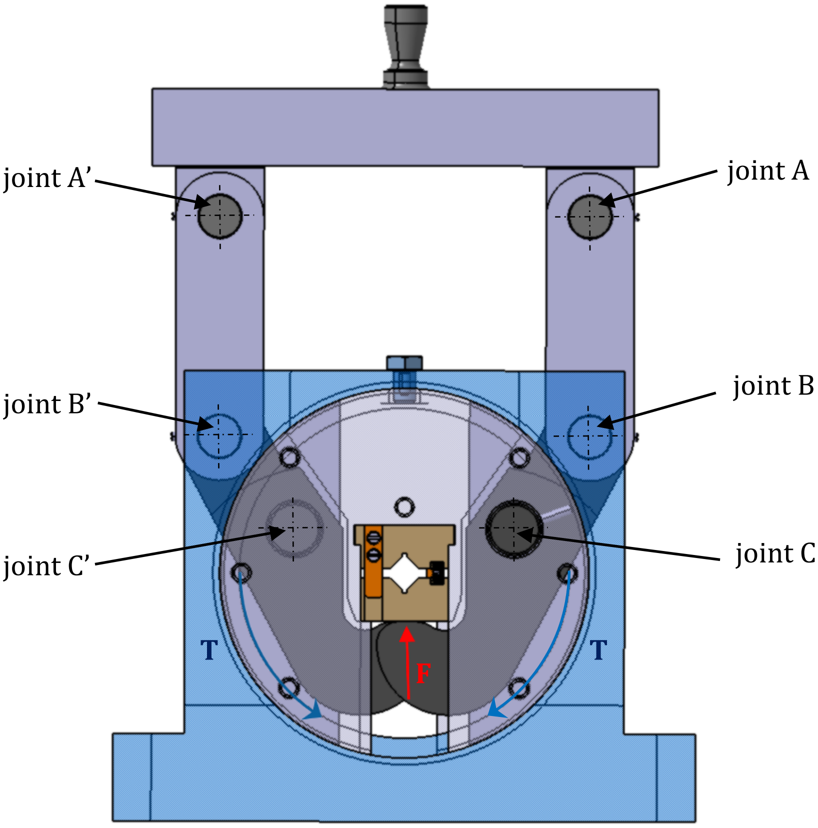

Fig. 7. Device front view

The device is composed of many components. The main body is the component inside of which are mounted most of the device components, and it will be fixed on the press machine table using two or more screws. The upper plate will be clamped in the press ram using a fixing stud. Both rotary subassemblies are symmetrically positioned inside the main body. The ram stoke is transmitted to the lower device sub-assembly by two upper levers using joints A/A' and B/B'. On the ram downward stroke, the upper plate and the upper levers transmit the vertical displacement to both rotary levers. These rotary levers are assembled in the cylindrical drums using two bolts which allows the levers rotation around their axis, namely C and C' joints. In a first phase, the rotary lever pushes up the mobile cutter which clamps and presses the metal bar, applying upon the material the compression force F. Further, when the press ram continues its downward stroke, the rotary lever will twist the entire rotary sub-assembly around the device axis with the torsion torque T. At the same time, the other symmetrical rotary sub-assembly will be twisted, using the same mechanism, but in an opposite direction. Twisting the metal bar in two opposite directions, the material is sheared in a precise manner by the cutting tool sets, in the device symmetry plane area. On the ram upward stroke, both rotary subassemblies return to their initial position, the rotary levers release the mobile cutters which are pulled down by two springs for each cutting tool set. Thus, the metal bar can be pushed forward together with the sheared piece, or can be removed from the device.

5. Device kinematic scheme

The device kinematic scheme is presented in figure 8. In this scheme, the blue colour represents the kinematic mechanism when the press machine is in resting state, the press ram is in its upper position and the rotary lever has no contact with the mobile cutter. In orange is symbolised the first stage of the shearing process, when the press ram downward stroke has already started, down to the H_{FC} value, and the rotary lever has come in contact with the mobile cutter applying force upon the metal bar, compressing the material between the two cutters. The final stage of the mechanism was sketched sing a green colour. In this stage the press ram continues the downward stroke until its lower position (H_T stroke), and the rotary lever twist both rotary subassemblies with an angle called θ. The material total torsion angle will be 2θ because the rotary subassemblies are twisted in two opposite directions.

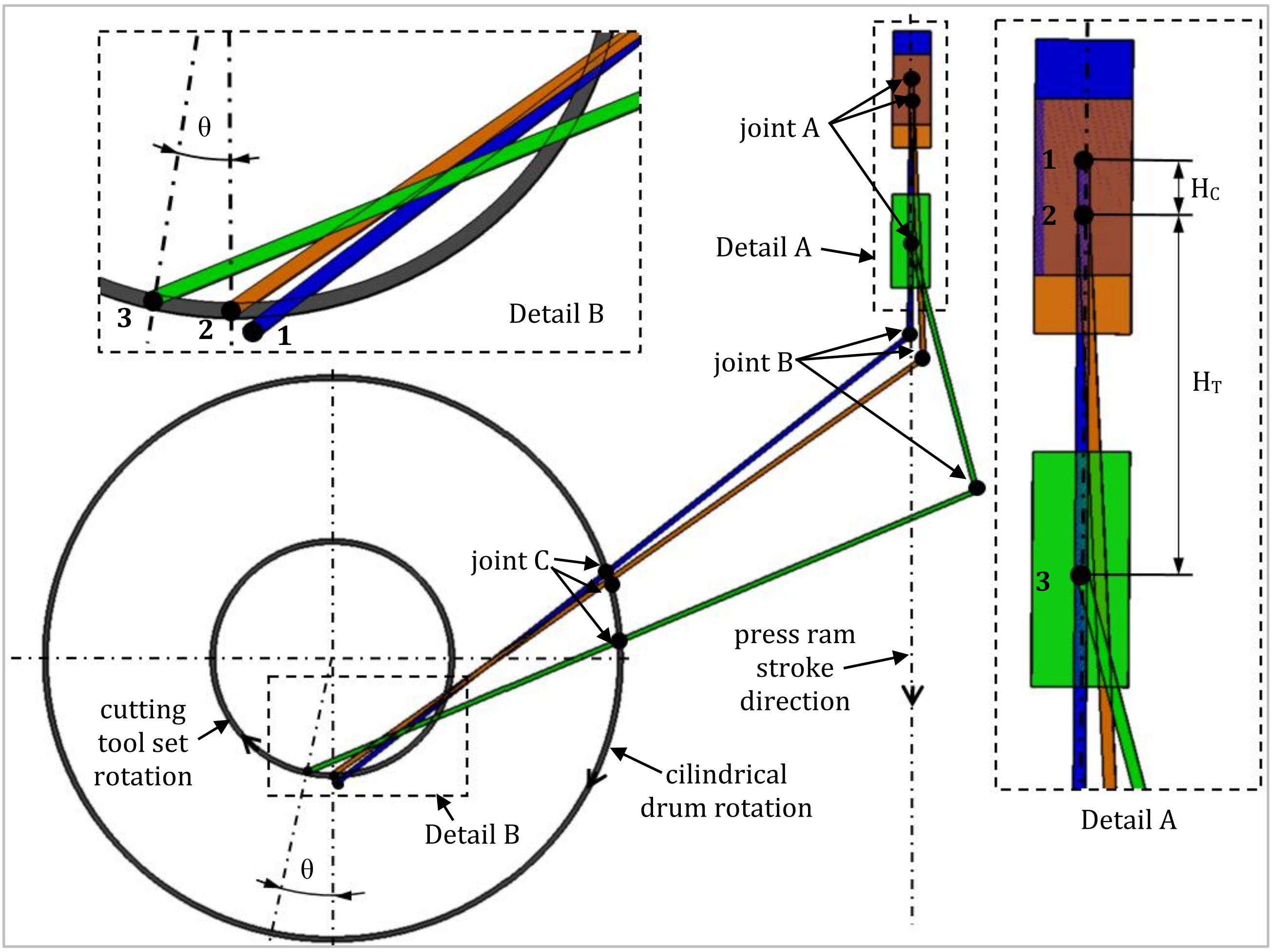

Fig. 8. Device kinematic scheme

According to figure 8, detail A and B, in the device mechanism there are three main working phases:

1 – Resting stage. At this stage, the press ram is in its upper position and the rotary levers has no contact with the mobile cutter, thus the metal bar is unclamped and can be handled or released;

2 – Clamping and compressing stage. At this stage, the press ram downward stroke has the H_C value, the rotary levers has come into contact with the mobile cutter clamping and compressing the metal bar;

3 – Torsion stage. At this stage, the press ram continue its downward stroke with H_T value, twisting both rotary subassemblies in opposite directions with θ angle. Thus, the metal bar is twisted with double of θ angle and it will be sheared by material torsion using both cutting tool sets.

A kinematic analysis was done in CATIA V5 in order to measure the rotation angle (θ) and the total torsion angle (2θ) for several values of the press ram downward stroke. Both, the rotary sub-assembly rotation angle and the total torsion angle values are centralised in table 1.

Table 1. The values obtained for θ and 2θ using kinematic analysis in CATIA

Press ram downward stroke – H_T [mm]	One rotary sub-assembly rotation angle - θ [°]	Total torsion angle - 2θ [°]
5	3.3	6.6
10	6.42	12.84
15	9.41	18.82
20	12.31	24.62
25	15.13	30.26
30	17.9	35.8
35	20.65	41.3
40	23.36	46.72
45	26.06	52.12
50	28.75	57.5

The values for total torsion angle are introduces in a graphical representation, function of the press ram downward stroke H_T. Figure 9 presents the proportionality between this two parameters.

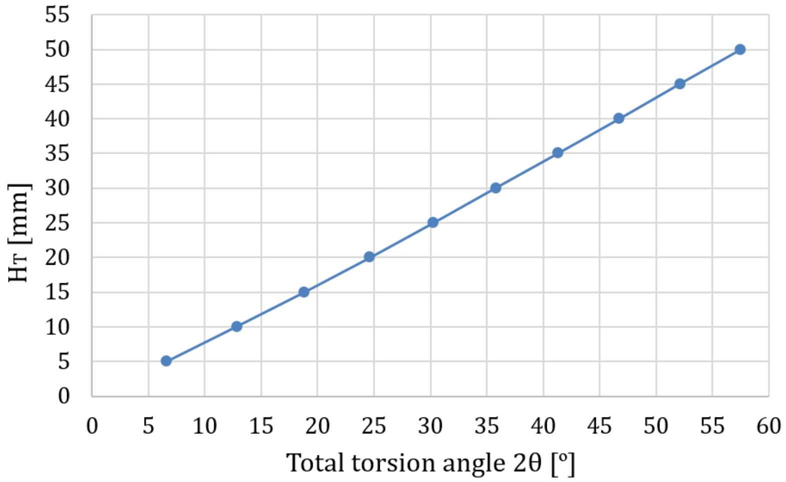

Fig. 9. Proportionality between total torsion angle (2θ) and ram stroke (H_T)

The graph from figure 9 can be used, as a calibration curve, to establish the press ram downward stroke necessary to obtain a certain torsion angle which ensure the metal bar shearing.

6. Conclusions

The raw material bars are often used in the manufacturing industry to obtain finished products using various manufacturing processes. Usually, the raw material bar are splitted in multiple smaller pieces that serve as raw materials for the final products. The most used method for metal bar cutting, especially for mass production, is the cold shearing process. In addition to the conventional cold shearing method, a machine tool used for precision cold shearing by material torsion was presented. A great disadvantage is that the design and manufacturing of such machine tool is very expensive.

A new device for precision cold shearing by material torsion was designed in CATIA V5 and was presented in the current paper. The device advantage it is that its design is very simple and its manufacturing is less expensive in comparison to the machine tool. At the same time, it can be implemented on any mechanical or hydraulic press without special requirements. All the device components and its working principle were presented in detail.

Future work suppose the device manufacturing and implementation. Experimental research will be done using various materials. The products quality will be compared with the quality obtained using other shearing methods.

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