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Several aspects regarding the machinery and equipment used in the drawing of sheets

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Abstract. For the drawing of small-sized parts, open-type presses with double action are preferred, as the processing is carried out under better conditions than on those with single action. This paper presents the eccentric mechanical press that was used for drawing small cylindrical parts made of A3K strip. For the smooth progress of the deformation process, it was necessary to know the magnitude and variation of force during the working stroke. The press was equipped with the drawing die onto which a dynamometric sensor was mounted, allowing both the measurement of the force required for deformation and the retention pressure of the flange. An inductive displacement transducer was mounted on the ram of the press. The signals collected from the transducer and sensor were amplified by an electronic strain gauge and transmitted to an oscillograph for visualization. The parts were produced using active elements of different sizes while maintaining the same clearance value between them.

1. Introduction

The processing by drawing of small parts is preferably done using dies mounted on double-action open type presses. A variant of the kinematic scheme of such a press is presented in Fig.1 [4]. The main drive shaft rotation 10 is achieved through a two-stage reduction gear. One stage is provided by the gear drive 6-9, and the other by the belt gearing 2, from motor 1 to flywheel 3. On the flywheel shaft 3 and drive gear 6, coupling 4 and brake 5 are mounted. On crankshaft 10, cams 8 are mounted, which through rollers 7 transmit motion to connecting rods 12. These set in motion the outer slide of press 14, which moves on the guides made on the press bed 15. The inner slide 13 moves on special guides made on the outer slide and is driven by connecting rod 11, which receives motion from crankshaft 10.

2. The experimental stand used in drawing

The parts referenced in this paper were drawn from A3k steel strip with a thickness of 0.4mm. They have a flat bottom that connects to the vertical wall with a radius of 2mm. For their production, a dynamometric die with rapidly interchangeable active elements [2] was used, which was mounted on the PAI 16 eccentric mechanical press.

The dynamometric die consists of the base plate 1, onto which the guide columns 2 are mounted, equipped with retaining rings 3, and the head plate 10 in which the guide bushes 11 and the clamping head 16 are installed, secured with screws 15. The active plate 4 is designed as a pad plate for the positioning and centering of the active ring elements 22 (with a minimal zero clearance fit), thus ensuring their rapid replacement. Punches 19, of various diameters, are mounted in the head plate 10 with a minimal zero clearance fit and are supported with the front part on the flange of the clamping head.

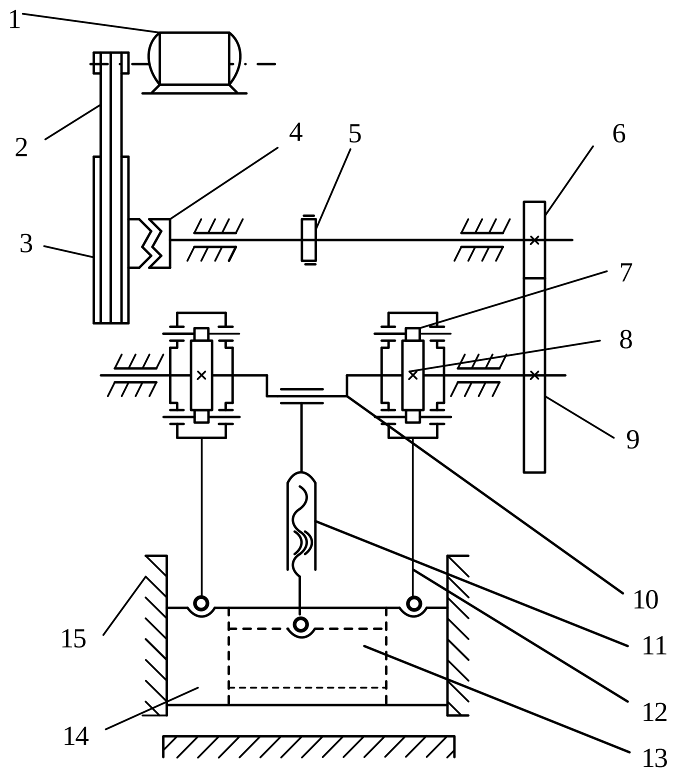

Fig. 1 Kinematic scheme of an open type press with double action [4]

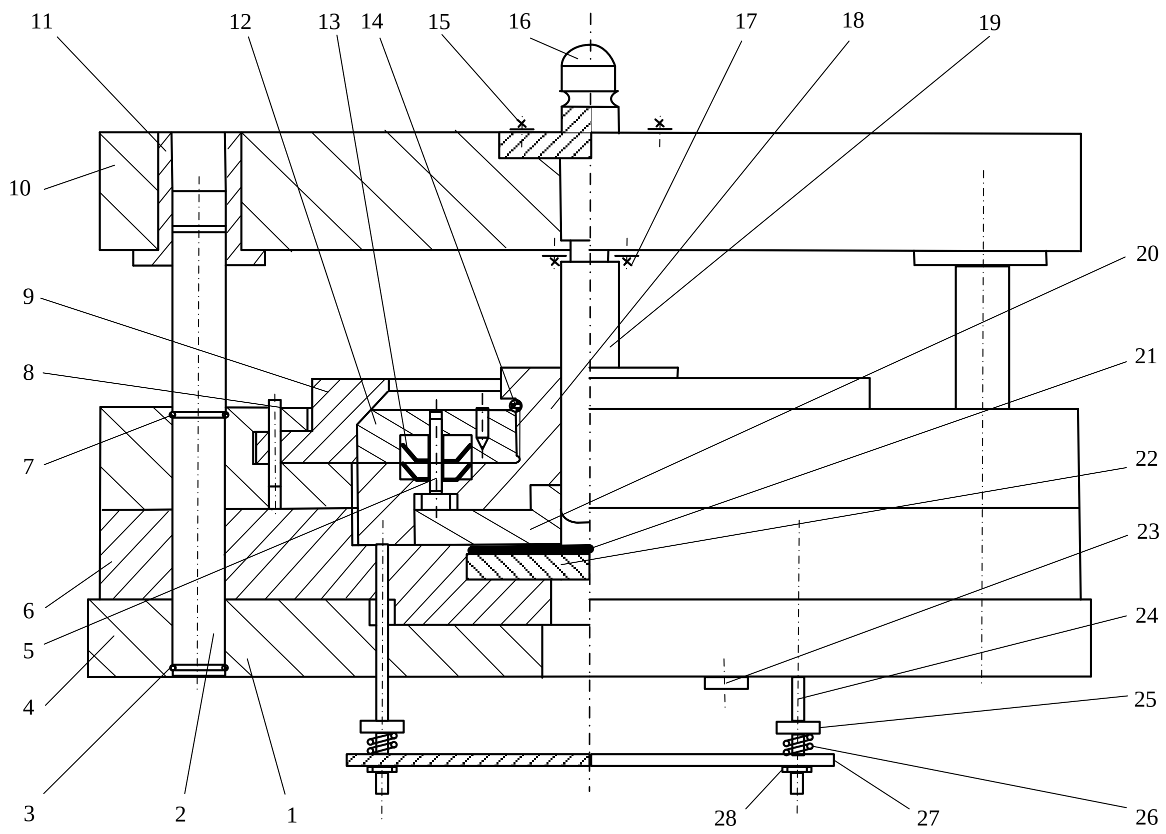

Fig.2 Dynamometric die with rapidly interchangeable active elements

To prevent the punch from being pulled out when removing the formed part, a ring channel has been made on the pintle of the active element, into which the split washers enter and are retained by the ends of the hexagonal socket screws 17. Plate 6 contains the quick-removable subassembly that ensures the retaining pressure of the blank flange 21. The elastic ring 7 prevents the plate 6 from moving on the guide columns. The quick-removable subassembly consists of: pressing element 20, locking ring 9 which moves by rotation until it reaches the safety stop 8, threaded ring 12, disc springs 13, centering pins 5, support for the pressing and retaining element 18, safety ring 14. The possibility of quick assembly and disassembly of the subassembly is provided by the segmented flange of the lock ring 9, which enters the corresponding segmented channel in plate 6 and rotates counterclockwise until the flange segment shoulder contacts th safetye stop 8. The pressing and retaining force is ensured by screwing the threaded ring 12 using a pin wrench (one of the key entry holes being shown in the section of element 12) which transmits the force to the disc springs 13, providing elastic pressure. By rotating the locking ring 9 counterclockwise, the subassembly will be easily removed by rods 24. These are equipped with washers 25 on which helical springs 26 act. The springs also rest on ring 27, which is attached to the base plate 1 by screws 28. The active plate 4 is supported on the base plate 1 through four elastic elements shaped like bushes, which are compressed. Two strain gauges are paste on to each of these bushes, parallel and perpendicular to the axis. This system allows the measurement of the forming force and the pressing and retaining force. Plates 1 and 4 are secured using instrument headed hexagonal screws 23, which also serve to position the elastic bushes. These are preloaded by using spacer bushes.

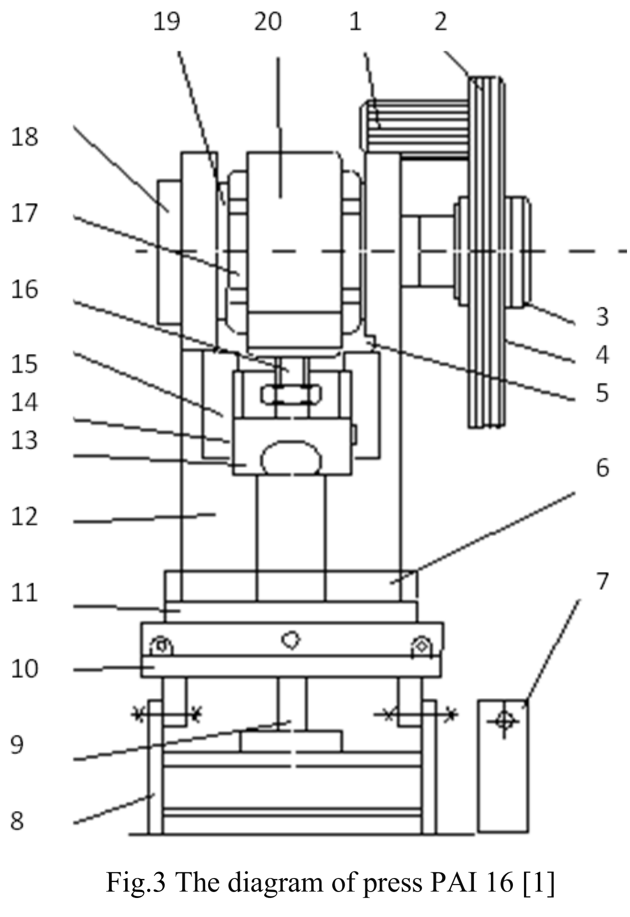

Fig.3 The diagram of press PAI 16 [1]

Because the semi-finished product has the retaining force applied when it is fixed on the die, the parts could be drawn on the PAI 16 mechanical press, which has the shaft parallel to the press table [1]. Column 12 has the shape of the letter C, is solid with the table 11 and is mounted on the frame 8. The press column can be tilted with the help of the screw mechanism to facilitate the evacuation of the parts. The headwork 13 slides on the removable guides existing on the column. On the eccentric shaft 19, the eccentric bushing 17 is mounted on which the connecting rod 20 is mounted. This transmits the movement from the eccentric to the headwork. The spherical-headed screw, part of the connecting rod, is articulated with the headwork through a pressure plate and a nut. In the ram, under the spherical joint, a safety device for overloads is mounted. On the headwork, a ball stroke limiter is mounted, which has the role of stopping the electric motor in the event of breaking the safety plate. Also on this, the support for the stroke counter is mounted. At its lower part, the headwork has a place for fixing the upper package of the die, of Φ25mm x 60mm. The electric motor 1 sends the movement to the flywheel 2 and through the rotating feather 3 it reaches the eccentric shaft. Between the flywheel and the frame, a cam is mounted on the eccentric shaft that triggers the mechanism in case of stroke by stroke work. The wheel brake with shoes 18 mounted on the eccentric shaft has the role of canceling the kinetic energy of the shaft after disconnecting the flywheel from the stroke by stroke work. For the shaft to stop in the desired position, it is necessary to adjust the pressure of the shoe with the help of a screw with a nut. When working with continuous strokes, to avoid unnecessary wear of the ferrodo, it is recommended to press the shoe on the braking washer. On the general electric panel 7, there are the selector for the working regimes and the command selector. The strokes are commanded from the buttons of the control panel 10. The press is equipped with an additional plate because the press mass is not adjustable. The electromagnetic-type relay 5 and the actuating lever system 4 serve for the stroke command. The headwork 13 is provided with a recess in which the command bar of the ejector pin 14 works, actuated by the removable pads 15. A kinematic scheme of such a press is presented in fig. 4 [4], in which were noted: 1 - electric motor, 2 - transmission belt, 3 - flywheel, 4 - coupling, 5 - crankshaft, 6 - brake, 7 - eccentric bushing, 8 - connecting rod, 9 - slider.

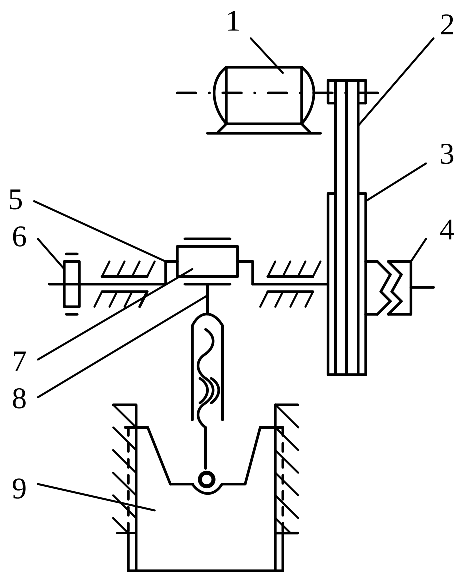

Fig. 4 Kinematic scheme of a mechanical press [4]

The measurement of the force necessary for deformation is carried out with the help of the dynamometric sensor [2]. The body of this 9 has the shape of a cylinder provided with a flange, which is mounted in the hole in the press table, so that the shaft collar rests on that recess. The tubular rod 4 is coaxial with the body 9 and solid with the plate 8. The reference 8 rests on the body 9 through four elastic bushings 7, which are subjected to compression stress by the pressing forces. These elastic elements are kept in position and are subjected to preloading with the help of spacer bushings 6 and screws 5. The die described above is placed on the plate 2 and is fixed with the help of fixing strap and screws for T channels. On the outside of each active element, the active transducers 2 are glued, arranged parallel to the axis of the bushing and the transducers 3 which have the role of compensating the effect of temperature variation and which are applied perpendicular to the axis of the bushing. On the intermediate contacts, the connection wires of the transducers were glued. The transducers are mounted in half-bridge [6], so that the signals given by the two types of transducers are summed up. The sensing device is powered at 4V and its nominal load is 160kN.

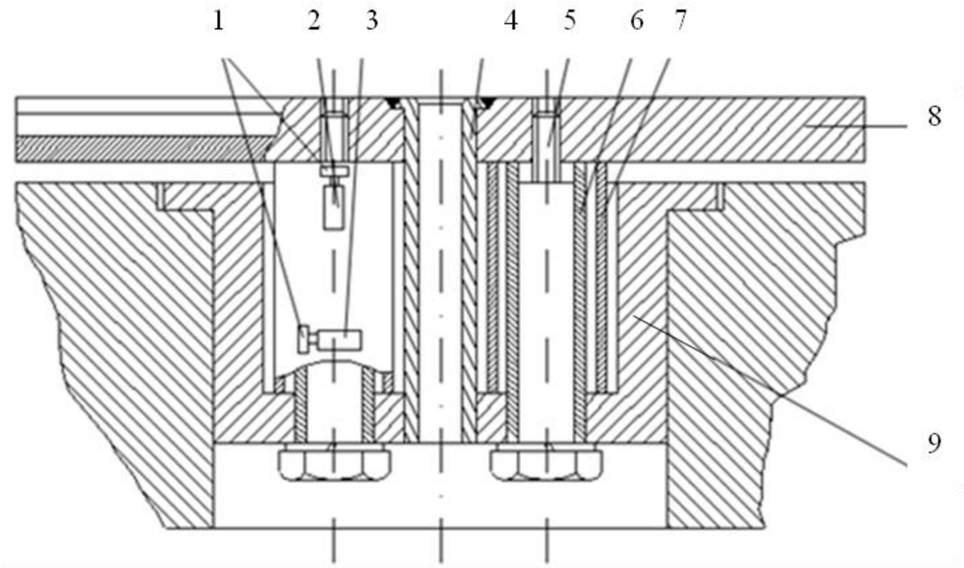

Fig. 5 Dynamometric sensing [2]

In principle, it is envisaged to measure the variation of the resistance of an insulated electric conductor that has been fixed on an elastic metal piece and on which a force is applied, which generates elastic deformations of both, the piece and the conductor. In the end, a relationship will be established between the force applied from the outside and the variation of the voltage/current intensity that passes through the conductor, values that can be easily measured using electrical devices. The correct measurement of the drawing forces and those of pressing and retention, which are applied to the flange of the semi-finished product, impose the calibration operation of the dynamometric sensor of the die. This consists in applying different loads and establishing a relationship between this load F[daN] and the specific deformation ε[μm/m], which will be read at the electronic tensometer. The calibration equation for forces under 1000daN has been established, which predicts the measured force with errors under 2%:

$$F = 77{,}647 + 104{,}1226 \cdot \varepsilon - 3{,}052 \cdot \varepsilon^2 \quad [daN] \tag{1}$$

The measuring stand contains the half-bridge of the transducers that collect signals from the dynamometric sensing, respectively the inductive displacement transducer, which are transmitted to an electronic tensometer with two channels N-2321 and which amplifies them and transmits them to the oscilloscope S8-13 for amplification and visualization. On the oscilloscope screen, the variation diagram of the drawing force along the working stroke F-h will be described. This represents the result of the composition of the spot deviation horizontally, due to the displacement of the headwork with the deviation of the spot vertically, due to the variation of the deformation force.

3. Experimental results

The semi-finished product used for the drawing of small cylindrical parts with a flat bottom was a 22mm wide band of aluminum-calmed steel A3k-Galfinband, which was subjected an annealing treatment to improve plasticity [5]. To further assist the material pulling in the clearance between the active plate and the punch, the notching operations were performed on the band at the diameter D.

The dimensions of the punch d_p, the die d_m, and the value of the clearance j are presented in Tab. 1. Also noted were A_q - the retaining surface [mm^2], Q - the retaining force [daN], F - the drawing force [daN], h - the height of the piece [mm], m - the drawing coefficient.
To determine the retaining force, the oscilloscope with memory and the electronic tensometer were calibrated, and it resulted that a specific deformation of 10μm/m corresponds to a voltage of 20V. Therefore, the specific deformation was determined with the relation:

$$\varepsilon = 0{,}5 \cdot U. \quad (2)$$

The equations of the calibration curves were:

$$F = 77{,}647 + 52{,}0613 \cdot U - 0{,}763 \cdot U^2. \quad (3)$$

$$Q = 77{,}647 + 104{,}1226 \cdot \varepsilon - 3{,}052 \cdot \varepsilon^2 . \quad (4)$$

The retaining pressure was calculated with the relation [3]:

$$Q = q \cdot \pi/4 \cdot [D^2-(d_m + r_m)^2], \quad (5)$$

where q - specific retaining pressure (for steel 0,3daN/mm^2), r_m = 2,5mm. After solving equation (4), the positive square root for ε will be chosen. The parameters A_q, h, m are calculated using the relations from the specialized literature used in the design of the drawing process [3].

Tab. 1 Experimental conditions and results obtained in the deformation of the A3K strip

Nr exp	Punch	Die	j/2 [mm]	D [mm]	A_q [mm^2]	Q [daN]	ε [μm/m]	U [V]	F [daN]	h [mm]	m
	d_p [mm]	d_m [mm]									
1.	5.52	6	0.24	11	0	0	0.0	1.8	168.89	4	0.56
2.	8.02	8.5	0.24	17	83.8	25.15	34.6	3.4	245.84	4.1	0.57
3.	10.52	11	0.24	17	25.9	7.78	34.8	4.5	296.47	4.5	0.65

The realization of the experiments required the following steps:

- equipping the die with the active elements corresponding to each experiment;
- lubricating the semi-finished product and introducing it into the die;
- adjusting the position of the punch stroke to obtain the height of the piece;
- adjusting the electronic tensometer and oscilloscope for measurement;
- applying the force to ensure optimal retaining pressure;
- to compensate the electronic tensometer, triggering the punch stroke, and removing the drawn piece from the die;
- reading the value of the drawing force recorded on the oscillograph;
- measuring the effective height of the piece;

The pieces obtained experimentally are shown in fig.6. In fig. 7, 8 and 9 the diagrams of the drawing force - punch stroke are presented, which were determined during the processing of the three pieces.

Fig. 6 Drawn piece from A3k sheet

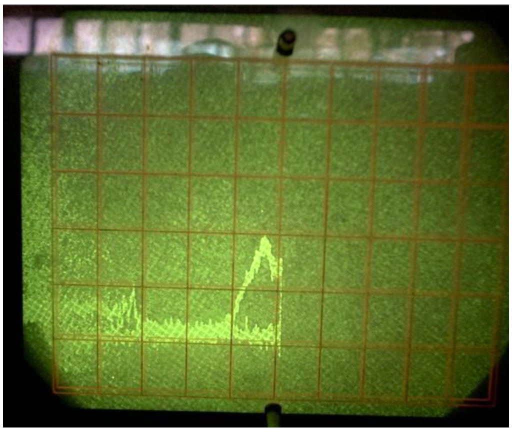

Fig. 7 F-h diagram for experiment 1

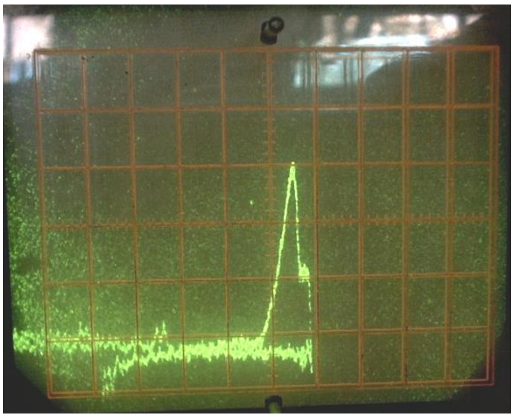

Fig.8 F-h diagram for experiment 2

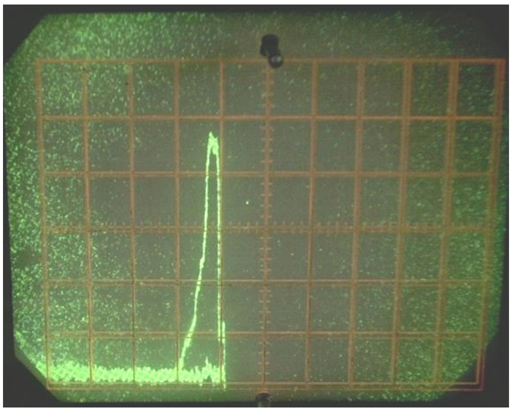

Fig. 9 F-h diagram for experiment 3

4. Conclusions

In this paper, the press, the die and the dynamometric sensing were described, along with the measuring stand, that allowed the study of the drawing process of small cylindrical pieces. The experiments were carried out on a semi-finished product made of steel strip, and the pieces met one of the quality criteria, namely that they maintained their integrity. In the future, it is planned to continue the study on other types of materials with the aim of appreciating their workability through drawing. Also, it is planned to create other sets of active elements that would lead to other clearance values and would allow the study of the influence of this factor on workability through drawing.

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