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DEVICE FOR GRIPPING AND GUIDING THE FRONT OF HOT EXTRUDED AQLUMINIUM PROFILES: DESIGN – MANUFACTURE – OPERATING TRIALS

In the work, an original device for gripping and guiding the front of hot extruded aluminium profile (s) was proposed. It replaces manual gripping operation of aluminium extrudates with an automated one without the involvement of the press operator with a translation into enhanced workplace safety, improved geometric stability of the guided profiles on the press run out table and increased productivity of the production process. The idea and design of a laboratory device was presented and the results of laboratory test were shown. It was revealed that for a 2500 T press, in order to achieve a 50% time reduction in automated gripping compared to manual gripping, the automated gripping must be carried out at a metal exit speed of at least 3.3 m/min. The assumptions of applying the proposed device in industrial practice were discussed.

Keywords: Extrusion; productivity; aluminium alloys; gripping and guiding device; staff safty

1. Introduction

Hot extrusion of a variety of aluminium alloy profiles is one of the most common ways of manufacturing long products with complex cross-sectional shapes. There are many companies in the world that produce aluminium alloy profiles, using original production lines equipped with extrusion presses of different pressures. In today's hot extrusion lines for aluminium alloy profiles, the metal exiting the die opening is manually fed by the press operator into a puller-type device whose task is to guide the extruded profile along the press path run during the extrusion cycle. The disadvantage of manually feeding the extruded profile into the press puller is that it is a cumbersome and dangerous operation for the press operator, and in practice it takes approximately 60 to 90 seconds, which reduces the efficiency of the production process. The press operator who feeds the extruded bar into the puller is exposed to the risk of being hit by the puller, which, returning to its starting position, moves automatically, very quickly and almost silently.

The vast majority of research related to the initial phase of aluminium profile extrusion concerns solutions for the operation and design of the device used to pull, tension and guide the product along the press run. Of course, the best known are the so-called single pullers, which were the first to appear, while double or even triple pullers are now in technological practice. Hollis [1] presented in his paper double pullers that work in conjunction with a movable cutting device and produce an extruded length, which contains a die stop mark. He demonstrated that the use of two pullers with a modern press having a short dead cycle time, will improve productivity in any situation. Gramaticopolo [2] proposed a flying cut double puller that consists of two overhead puller carriages and one flying cut saw that is installed on the opposite side of the run-out from the operator. In this way, the hand off and the necessary synchronization of the two pullers from traditional puller systems are avoided. Flying saw in connection with the double puller it is possible to substantially reduce the waste rate and increase at the same time the productivity. The saw position is controlled in such a way, that the “flying“ separation operation occurs in the welding mark. This enables a noticeable reduction in waste. Other advantages are simplicity, reliability and flexibility. Spizzo [3] proposed the three-puller system with a fast quench permit runway-to-stretcher direct transfer fixed translation system (FTS). This FTS picks up the extruded bars and deposits them directly in the stretcher jaws having quenched the profiles at a very fast rate in an air/water tunnel, immediately after their exit from the press. Salahat [4] revealed that implementation of AC drive with direct torque control led to savings in electrical energy consumption, reduction in breakdown and maintenance intervals and improvement of product quality. Bertoli [5] discussed design challenges when

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converting from a hydraulic puller system to an electric puller (ePuller). This greatly improves maintenance reliability, and enhances puller performance by making the overall system lighter and more responsive. Kumar et al. [6] proved that the design of a portable mechanism is carried out i.e. hydraulic puller so that it can be carried to the place where there is drive axle assembly. This is a quicker process and involves less man power.

Patent US4307597A [7] describes a puller for extruded profiles, comprising a carriage that is movable on rails along an output conveyor for extruded profiles and in which a puller head with a fixed and a movable clamping jaw is arranged to rotate about a vertical axis so that the puller head can be pivoted laterally away from the output conveyor. The two clamping jaws extend approximately the full width of the exit conveyor, and the movable clamping jaw includes a plurality of clamping segments that are supported on the winch head for free swinging movement about the horizontal axis and adjusted to rotate in the opening direction by the driving means.

Patent EP1236523A1 [8] presents a new concept for a tensioning device includes tensioning units consisting of a tensioning element and a pressure pad, which tilts relative to the tensioning element. Preferred features: The pressure pad has a transport area for the profile and tilts in a plane that is parallel to the transport plane of the transport unit. The pad tilts at an angle of approximately 90 degrees.

Patent EP1371428A2 [9] shows an antiparallel crank mechanism which has a mechanical connection between the puller carriage and the device itself formed by the main arm and coupling. The main arm and the coupling are placed on the trolley on one side and on the puller device on the other side so that the main arm and the coupling are placed in an antiparallel position with respect to each other.

The present invention EP0471339A1 [10] relates to an extracting device for use with a metal extrusion press adapted to extract extruded metal, two carriers are movable on one side of the run-out table , one of the carriers in its working position does not interfere with the other carrier in its retracted position when they pass each other, the two carriers are alternately used to extract the extruded metal to increase the efficiency of its production, space is available above the run-out table to accommodate a cooling system to effectively cool the extruded metal.

The manual gripping takes place in the space "*b*" where the press operator aligns the bent profile(s) with the press axis and directs them to be gripped by the puller (Fig. 1).

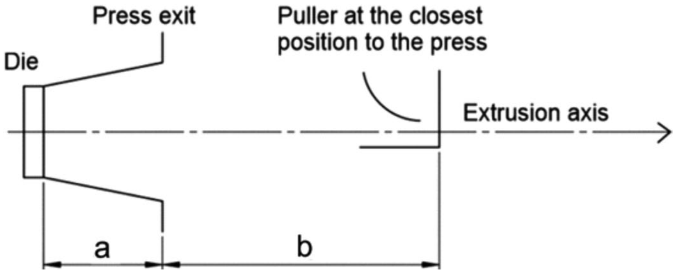


Fig. 1. Simplified (illustrative) diagram of the exit on the discharge table of a horizontal extrusion press for metals and alloys, including the puller

The time required for the actual "grip" by the press operator (t_r) is as follows:

$$t_r = \frac{b}{V_{wk}} \tag{1}$$

where: b – distance between press exit and a puller at the closest position to the press; V_{wk} – metal exit speed during the grip.

During manual gripping, the press operator does not have access to the extruded profile located in the space "*a*", so that to perform manual gripping a time longer than "t_r" is required to include the time needed to move the profile through the space "*a*".

A general formula for the total manual handling time t_c takes the form:

$$t_c = \frac{a+b}{V_{wk}} \tag{2}$$

At the start of extrusion, the press operator applies the lowest possible extrusion speed so that the beginning of the extruded bar can be manually inserted into the puller jaws. The discharge speed is very low and the time for this operation is inefficient and can even be more than 1 minute which means a significant loss in process efficiency. The higher the extrusion speed, i.e. the shorter the operating time, the more economically detrimental is the slowing down of the process speed.

The extrusion cycle is shown in Fig. 2 using the example of concurrent extrusion in the form of an extrusion force – punch path relationship. As soon as the billet is loaded into the container, the punch is actuated, causing the billet to swell and, as the force reaches a maximum, the profile begins to flow out of the die opening. The process ends when the force begins to increase again. At this point the operating time ends and the so-called dead time begins [11].

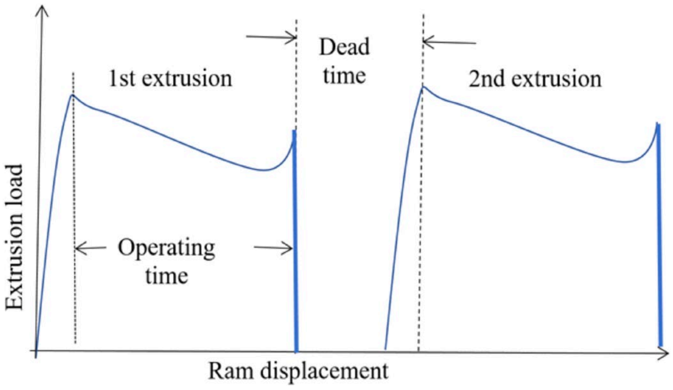


Fig. 2. Extrusion cycle in the concurrent extrusion of metals and alloys [11]

Dead time is therefore the period between the end of the extrusion of the previous billet and the start of the flow of the extruded bar from the next billet. For the 6xxx series alloys, the operating time is approximately 3 minutes, depending on the length of the billet. This is the period of time that most determines the efficiency of the extrusion process, and reducing this time will improve process efficiency. The aim should therefore be to maximise the extrusion speed, which determines the operating time. Dead time is also very important. During this time, the end of the profile is removed from the die, the so-called butt is removed from the container and the next billet is loaded, followed by its swelling which ends the dead time. This period usually takes about one minute, although, an advanced extruder can reduce this time to twenty seconds. According to Robbins [12], using the example of the extrusion of 6063 alloy, with an extrusion time of 163 seconds, the dead time is 21 seconds. However, such a short time may refer to the case of "billet-by-billet" extrusion, where the butt is not removed from the container before the next billet is loaded. Both the operating time and the dead time have an impact on the cost of the extrusion process. Data on this subject have been published by Brightstar Aluminum Machinery [13] and they show that when extruding 30 billets per hour, a saving of 10 seconds per billet results in a total of 7,200 seconds (2 hours) and this represents an 8% increase in process efficiency. G. Bessey, on the other hand, reports that a reduction in dead time of 1 second results in a 0.7 to 1.0% productivity gain, depending on the manufacturer's technological advancement [14].

There are, of course, other ways to improve the efficiency of the extrusion process. One is to use containers with an appropriate temperature gradient. A container with a built-in stable thermal gradient (rather than a uniform temperature) provides the optimum extrusion condition, resulting in maximised metal exit speed [15].

Other authors show a simple way to monitor the time loss and the cycle time of a billet as a result of the ram speed [16]. The idea is to monitor and visualise online the actual situation of the extrusion press. The system looks at contact pressure;when there is an interruption in the dead cycle longer than expected, the system will highlight the buttons representing the "cause" of the problem from which the operator must choose.

Another option could be an innovative hybrid drive system for hydraulic aluminium extrusion presses. By combining innovative servomotor and hydraulic systems in hybrid aluminium extrusion systems, the advantages of both types of systems are exploited, leading to energy and efficiency savings in extrusion production [17].

In the paper [18], the authors present an application of the Single Minute Exchange of Dies (SMED) lean method. The results show that the implementation of SMED can lead to operating cost savings in the range of 5% to 15%, while increasing production capacity.

The authors of another paper [19] show the effect of process parameters on press productivity. In particular, 3D simulations were performed to determine the effect of billet geometry (i.e. primarily billet length and diameter) on press load, extrusion temperature and the mode of deformation in the billet. Such simulations have proven invaluable to the extruder in optimising container dimensions, tooling and die design to maximise productivity.

In the paper [20], a novel continuous extrusion process was invented to provide a constant material flow at the die exit during the dead cycle time and to reduce scrap. The process is a combination of direct and indirect hot extrusion with a stationary valve. The challenge is to design the valve and associated parameters to ensure a constant profile speed. Model experiments of continuous extrusion show the unique distribution of material in the profile.

In the present work, an original device for gripping and guiding the front of hot extruded aluminium profile (s) was proposed. The idea and design of a laboratory device was presented and the results of laboratory test were shown. The aim of the research was to demonstrate the advantages of using the proposed tapping and guiding set for extruded aluminium profiles, i.e. shorter time spent gripping the product in the puller jaws and higher geometric stability of the extruded profiles already at the entry point before they are straightened on the straightening machines.

2. Idea of the gripping and guiding device

The proposed original gripping and guiding device, which is the subject of this study, aims to eliminate the inconveniences of the extrusion process and to automate the operation of feeding the extruded profile into the press puller without the involvement of the press operator. The main advantage of the proposed gripping and guiding device, apart from improving the safety conditions for the press operator and automating the process, is that it can be applied to any press used for the hot extrusion of aluminium alloy profiles. The benefits of the new device can be determined by following the extrusion cycle on the press.

The use of a new device in the extrusion press line will eliminate the time associated with manually inserting the end of the extruded bar into the puller jaw. The device is located between the press exit and the puller start position. In most presses, this distance is approximately 1-1.5 m and the designed gripping and guiding device will be adapted to this distance. It is assumed that the actual automated gripping (t_{rz}) will take place in the space "*a*", while the space "*b*" will be the space in which the "aligned" profile will be guided for gripping by the puller.

The time required for the actual automated "grip" (t_{rz}) is as follows:

$$t_{rz} = \frac{a}{V_{wk}} \tag{3}$$

In order to carry out the automated grip at the time t_{rz}, we must add the time needed to move the profile through the space "*b*". The general formula for the total time for automated grip t_{zc} is therefore as follows:

$$t_{zc} = \frac{a}{V_{wka}} + \frac{b}{V_{wkb}} \tag{4}$$

where: V_{wka} – speed of the discharge of the profile in the space "*a*"; V_{wkb} – speed of the discharge of the profile in the space "*b*".

The minimum time required for a manual grip is as follows:

$$t_{c\,\min} = \frac{a+b}{V_{wk\,\max}} \tag{5}$$

where: $V_{wk\,\max}$ – maximum speed of discharge of the profile at which the press operator can bring the profile into line with the press and place it in the puller jaws.

The minimum time needed for an automated grip is:

$$t_{c\ \min} = \frac{a}{V_{wka\ \max}} + \frac{b}{V_{wkb\ \max}} \tag{6}$$

where: $V_{wka\,\max}$ – maximum profile discharge speed at which the automated gripping system "aligns" the profile in the space "a"; $V_{wkb\,\max}$ – maximum profile discharge speed at which it is possible to feed the profile into the puller.

In the case of the manual grip, there is a concept of minimum grip time as a basis to which we can relate the reduction in grip time when using automated gripping. The effectiveness of the automated grip compared to the manual grip depends on the time efficiency of the elements of the automated grip. In practice, it is possible to reduce the automated gripping time in relation to the manual gripping time by at least 50%.

The idea for an innovative kit for gripping and guiding extruded aluminium profiles (in a laboratory set-up) includes 3 areas related to gripping the profile, and guiding and feeding the pre-straightened profile into the puller jaw (Fig. 3). In the area "I", we have the gripping funnel, which is used to catch the profile after it comes out of the die (in the laboratory setup, a die "bending system" must be used), and then its task is to feed the profile into the bending alignment area "II" by means of gripping troughs to the roller straightening system "III".

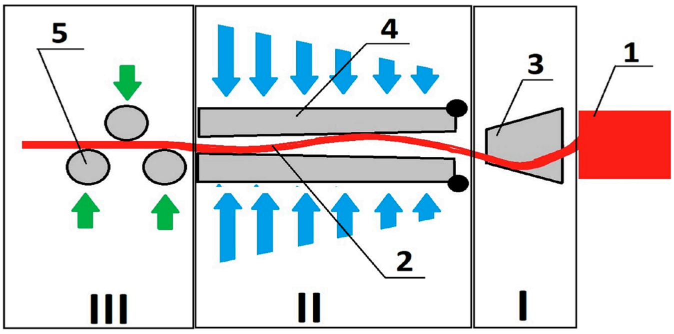
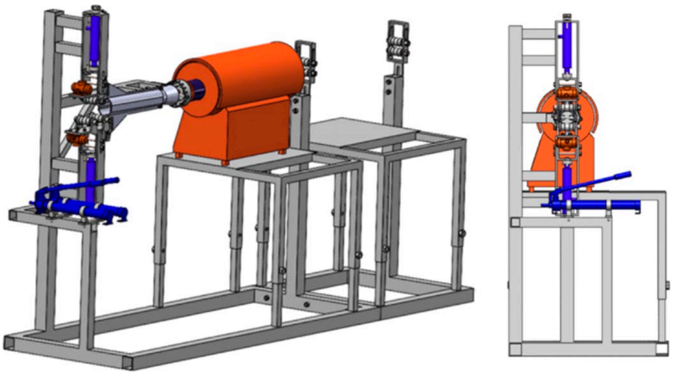


Fig. 3. Idea of a 3-stage gripping and guiding system, where: 1 – die exit area, 2 – extruded aluminium profile, 3 – catching funnel, 4 – gripping troughs, 5 – roller straightening system

3. Design of a laboratory device for the gripping and guiding of aluminium extruded products

Once the idea was developed, a laboratory kit for gripping and guiding aluminium profiles was designed. It is based on a modular steel construction with the possibility of expanding it with additional functional blocks. The kit consists of an adjustable base for a system to insert the profile into the heating area, an adjustable base for the heating system and the gripping and guiding set itself. Fig. 4 below shows the 3D assembly of the kit. The device consists of 3 main parts: the furnace area where we heat the profile to a temperature imitating the hot extrusion process, the decalibration system where we intentionally curve the profile and the profile grip and guide system where we catch the profile, guide it to the rollers and initially straighten it. After heating the profiles in the furnace to the assumed temperature, it goes to a roller or pin decalibrator which curves it in a specific direction. After the profile is curved, it is not straight and its trajectory significantly deviates from the axis. First, the profile goes to the cone which catches it and sets it in the area of a circle with a diameter of 110 mm, then 2 movable rails guide it to the intercepting rollers where we additionally narrow the area in which the profile is fed. After passing through a package of 3 roller systems (one at the top and two at the bottom), the profile is initially set in the axis and straightened. Electric vibrators are mounted on the roller systems which reduce the friction of the profile on the rail walls and roller flanges.



a) b)

Fig. 4. Laboratory kit for gripping and guiding aluminium profiles: a) side view, b) view from the profile exit side

Fig. 5 shows a cross-section of the 3-area gripping and guiding system, where the key areas are the catching funnel responsible for picking up the profile at the exit of the die area, the gripping troughs that hydraulically clamp the profile(s) into the narrowed straightening area, and the roller straightening system hydraulically adapted to the profile cross-section responsible for straightening it. The arms of the straightening system are fitted with electro-vibrators that induce high-frequency forced vibrations in the system, thus reducing the frictional resistance at the point of contact between the material and the tool.

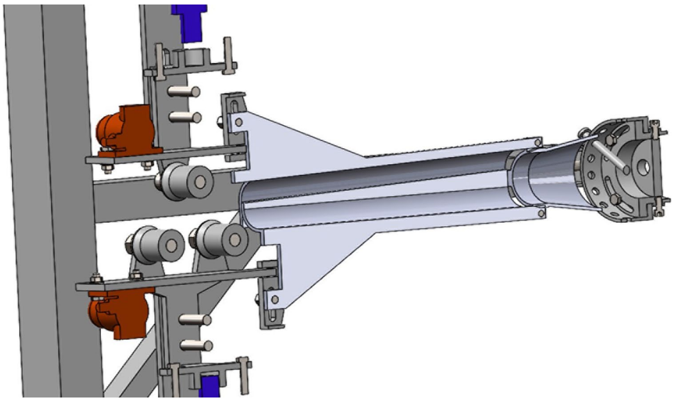


Fig. 5. Cross-section of the gripping and guiding system

The design uses two types of "dies" with a bending system responsible for applying the bending moment to the profile(s) and thus changing the profile path from linear to non-linear which is the equivalent to a real transition in the profile discharge phase during extrusion. Fig. 6a shows a "die" with a bending bar. The angle of the bar determines the deflection of the profile as it exits the die. Fig. 6b shows a roller version of the "die", where we have 3 rollers on a rotating base with rollers dedicated to the profile. This arrangement provides a similar bending effect to the single bar die, but reduces contact friction, resulting in less force required to move the profile in the set. Both arrangements can be used interchangeably, depending on the assumptions which have been made.

After leaving the furnace and before entering the die bending system, the profile(s) pass(es) through a positioning die (Fig. 7b) to allow the profile to be stabilised on a given line, which translates into the correct degree of bend (angle of deflection) from the centre point. Once bent, the profile(s) go(es) straight to the catching funnel (Fig. 7a), which directs them to the gripping troughs. The funnel reduces the maximum possible deviation of the circular spread of the profiles from 120 mm diameter to 80 mm diameter and feeds the profile(s) directly into the gripping troughs.

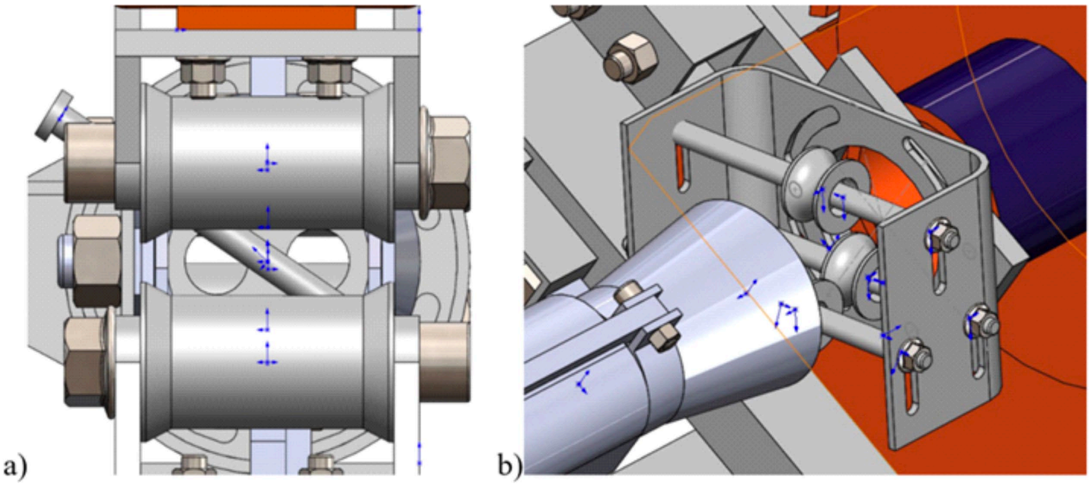


Fig. 6. Bending system of the profile(s) after leaving the area of the "die": a) "die" with a bending bar, b) "die" in the version with rollers

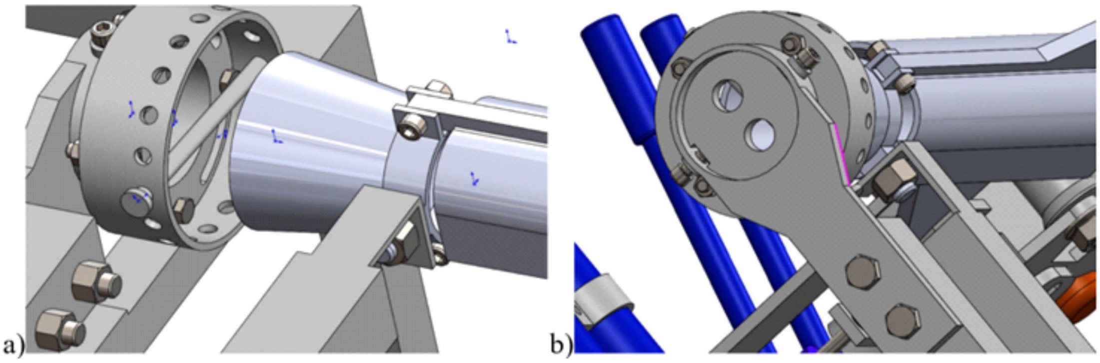


Fig. 7. Elements of the gripping and guiding system: a) catching funnel, b) positioning die

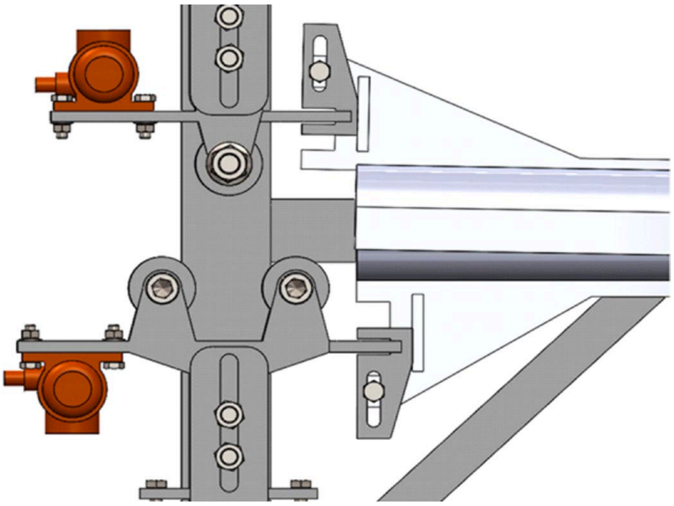


Fig. 8. Roller straightening system for profiles after the catching process

The profile(s), after leaving the adjustable system of gripping troughs, go(es) to the (3-point) roller straightening system (Fig. 8). This system pre-straightens the profiles in order to prepare them to receive the tension (puller) system. In an industrial environment, after pre-straightening, the profiles would go to the jaws of the puller. The system of gripping troughs is connected by a height-adjustable lock to the straightening system, so that they calibrate each other when changing the height of the lower or upper mounting point of the rollers. The system of gripping troughs and the pre-straightening system are hydraulically adjustable for the given test set-up, with a feed rate of 10 to 100 mm per minute and a stroke tolerance of up to 0.5 mm. Once the profile(s) has/have been caught by the tension (puller) jaw, the set can be opened, i.e. both the straightening system and the of gripping trough system move away from the profile so as not to disturb the further transition. Only the guiding funnel remains, since in industrial conditions it is located in the press opening directly at the exit of the die.

4. Laboratory trials

Fig. 9 shows a ready-to-run laboratory test stand for carrying out test and commissioning trials on aluminium profiles flowing out of the "die" opening. The roller system that pushes the profiles into the furnace is shown in Fig. 10. The next figure, Fig. 11, shows the "die" with the bending bar (Fig. 11a) and the bending roller die (Fig. 11b).

Once the profile has been heated to a temperature of e.g. 550°C, we start to move the profile at a speed V of e.g. 2 m/min. using the push-in system, recording the position of the beginning of the bent profile in the "die – puller" space with a photo /video camera positioned in the "press" axis. When the length L (i.e. the hot part) of the profile is covered, the filming is stopped and the bent profile is cut off at the die.

The next measurement is carried out after heating the profile to the preset temperature of e.g. 500°C, moving it at a speed of e.g. 2 m/min and recording, as before, the position of the beginning of the bent profile in the "die – puller" space with a photo/video camera positioned in the "press" axis. The test is carried out until the section of the profile to be tested is completely covered (e.g. 6 m). For subsequent tests, we change the process parameters in order to complete the pre-set programme of temperature and extrusion speed changes for the assumed profile cross-section shape.

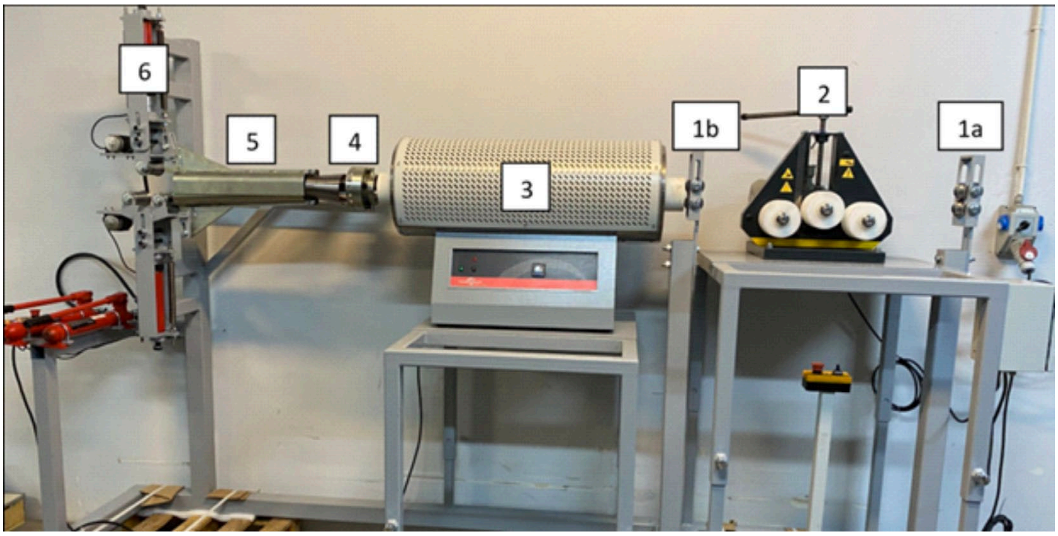


Fig. 9. Test stand with a gripping system, where: 1a/1b – guide rollers, 2 – drive rollers, 3 – heating furnace, 4 – die with bending system, 5 – funnel with gripping troughs, 6 – roller and guide system

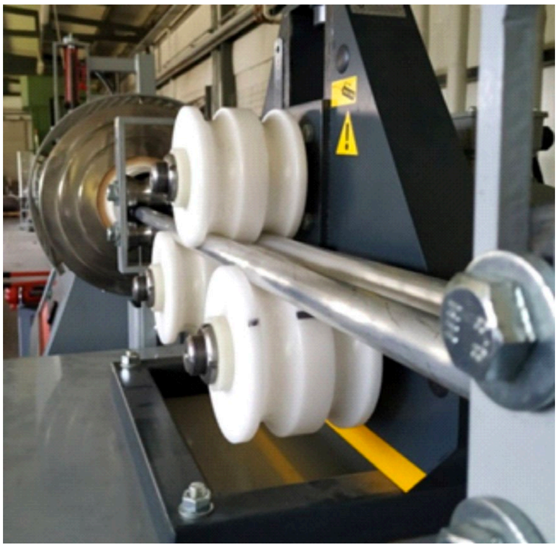


Fig. 10. Drive rollers to create profile movement through the furnace and the die opening

5. Results

The "extrusion" of Ø25×3 mm tubes through single-hole dies and Ø25×3 mm pipes through double-hole dies was investigated in the implementation trials. The implementation tests were carried out at a temperature of 450°C and 550°C, with an output speed ranging from 2 m/min to 15 m/min. Fig. 12 shows the extrusion of a circular tube without a gripping system, while Fig. 13 presents the extrusion of a circular tube with a gripping system.

The commissioning and implementation tests provided data describing the geometric stability of the extruded profiles in the "die" – puller area in the absence of a gripping device and when a gripping and guiding device is used. With the results

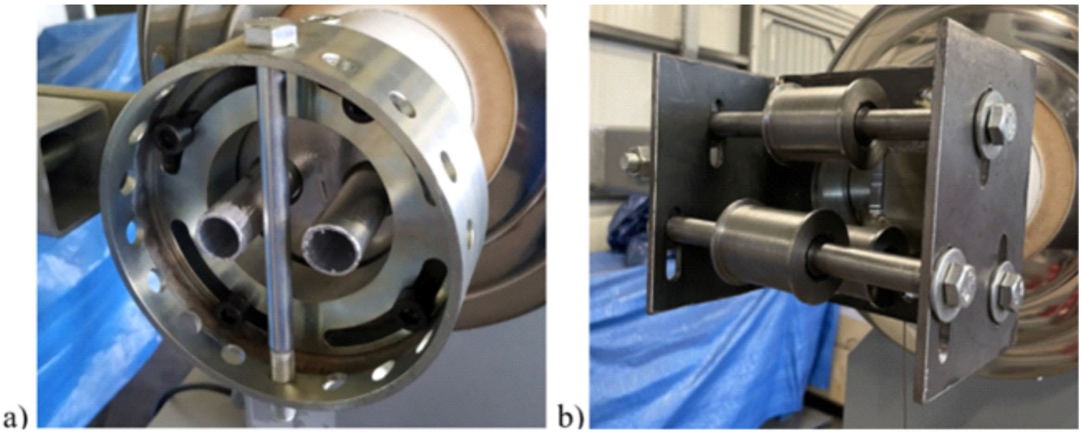


Fig. 11. Elements of the gripping and guiding system, where: a) ”die” with bending bar, b) roller bending “die”

Fig. 12. Examination of a Ø25×3 mm tube without a gripping system. Shots before and during the examination

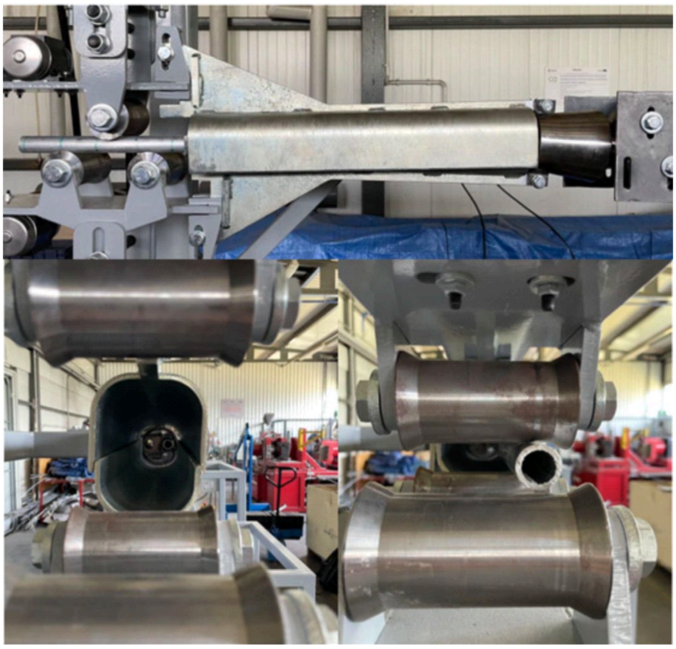


Fig. 13. Examination of a Ø25×3 mm tube with a gripping system. Shots before and during the examination

in TABLES 1-2, the following figures (Figs. 14 to 15) show the coordinates of the start of the extruded profiles.

TABLES 1 and 2 present the results of measurements of the change in the location of extrudates relative to the initial position. Numerical values defining the deviation of the profile in the X/Y axis over a length of 0.8 m in relation to the reference value of the position X = 0 and Y = 0 which corresponds to the location of the die hole. The table compares the results of the deviation of the profiles in different conditions of the process (speed and temperature) in the variant without guidance and in the variant with the gripping system. The visualization of the results is presented in the form of a shooting target in the diagrams – Fig. 14-15. TABLE 1 presents the measurement results for the 1-cavity die, while TABLE 2 presents the results for the 2-cavities die. In each case, two extrudate movement speeds were tested (v_1 = 2 m/min and v_2 = 15 m/min) and two different extrudate temperatures (T_1 = 450°C and T_2 = 500°C). In the case of the 1-cavity die, it is stated that for the variants where the gripping system was used, the influence of the extrudate temperature was almost completely eliminated. The maximum deviation from the press axis for extrudates with a temperature of 450 and 500°C is 80 mm, while in the analogous case of the process without the use of the system, this value is even 225 mm. In each case, both for the variable temperature and extrudate speed, the values of deviation from the press axis indicate a significantly higher stability of extrudate guidance using the gripping system. This is reflected in the graphical representation of the obtained results in Fig. 14, where a positive result is considered to be the smallest deviation from the centre of the circle – the coordinate system (0, 0). In the case of a much more complex one where gripping and controlled guiding of two profiles at the same time are necessary, the advantage of the new solution is even more proven. Almost all values of X and Y deviations for the tested variable parameters (speed and temperature) for both cavity no. 1 and 2 are lower in the range not exceeding 40 mm, while in the test without the use of the guiding system, the maximum deviation values are almost 6 times higher. This is perfectly presented by the graphic interpretation of the location of holes relative to the press axis, where the guiding system provided precise guiding of both profile no. 1 and no. 2, while without this system significant deviations are observed both vertically and horizontally.

TABLE 1

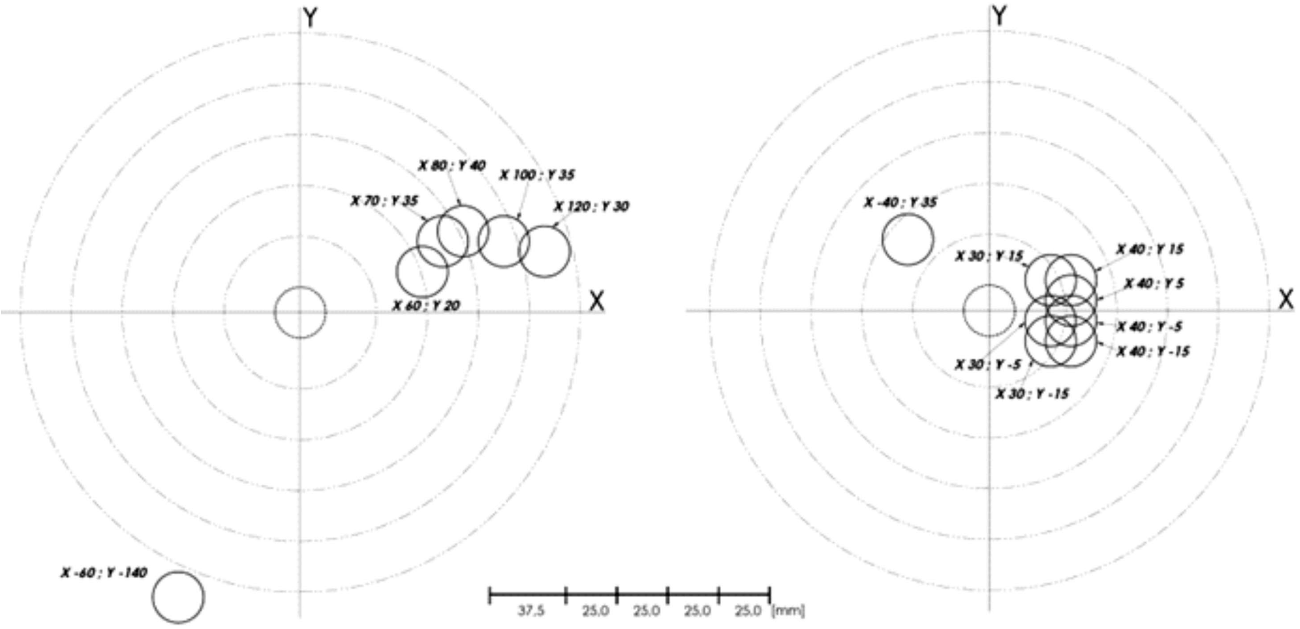
Tabular data of a Ø25 mm profile for a single-hole die in terms of displacement with respect to the press axis

Tube of Ø25 mm / single-hole die				
Exit speed / Temperature	**Extrudates displacement for variant without gripping system, [mm]**		**Extrudates displacement for variant with gripping system, [mm]**	
V_1 (2 m/min) / T_1 (450°C)	60	20	40	–15
V_1 (2 m/min) / T_1 (450°C)	70	35	40	5
V_2 (15 m/min)/ T_1 (450°C)	80	40	30	–15
V_2 (15 m/min)/ T_1 (450°C)	100	35	40	15
V_1 (2 m/min)/ T_2 (500°C)	120	30	–40	35
V_1 (2 m/min)/ T_2 (500°C)	–60	–140	40	–5
V_2 (15 m/min)/ T_2 (500°C)	180	35	30	15
V_2 (15 m/min)/ T_2 (500°C)	90	–190	30	–5

TABLE 2

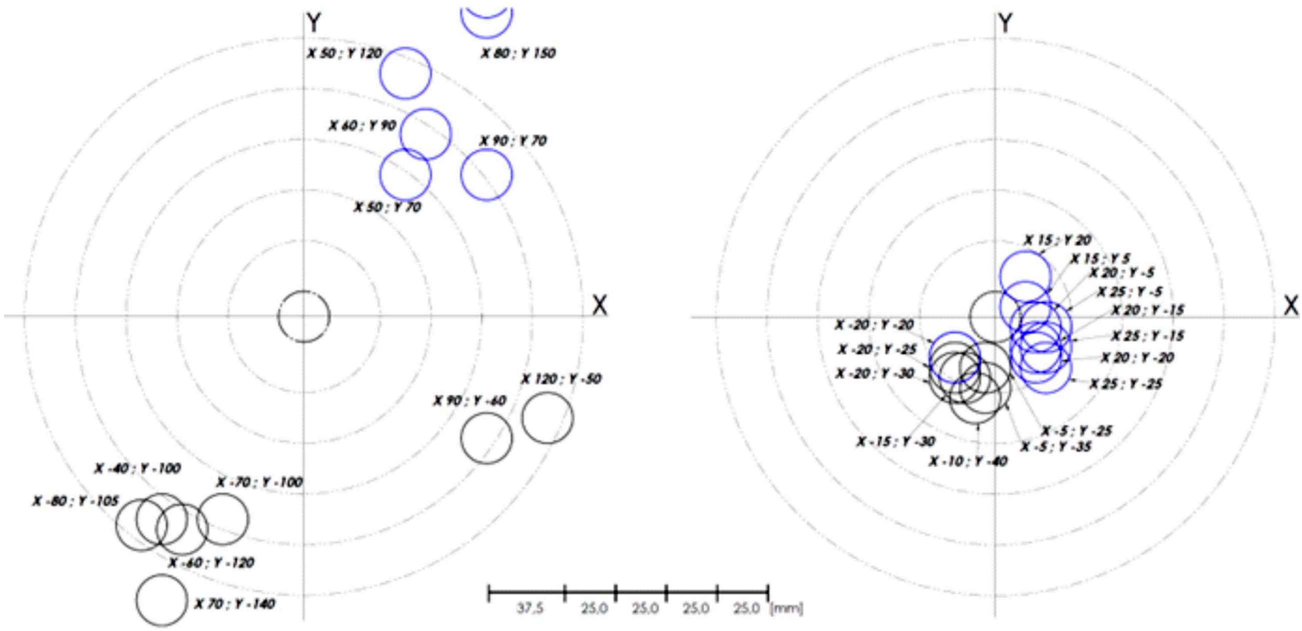
Tabular data of a Ø25 mm profile for a double-hole die in terms of displacement with respect to the press axis

Tube of Ø25 mm / double-hole die								
Exit speed / Temperature	**Extrudates displacement for variant without gripping system, [mm]**				**Extrudates displacement for variant with gripping system, [mm]**			
	Nr 1		**Nr 2**		**Nr 1**		**Nr 2**	
V_1 (2 m/min) / T_1 (450°C)	120	–50	50	70	–20	–20	20	–20
V_1 (2 m/min) / T_1 (450°C)	–70	–100	90	70	–5	–35	25	–5
V_2 (15 m/min)/ T_1 (450°C)	–40	–100	50	120	–20	–30	20	–15
V_2 (15 m/min)/ T_1 (450°C)	90	–60	60	90	–5	–25	20	–5
V_1 (2 m/min)/ T_2 (500°C)	–60	–120	90	160	–10	–40	25	–25
V_1 (2 m/min)/ T_2 (500°C)	–80	–105	80	150	–20	–20	15	5
V_2 (15 m/min)/ T_2 (500°C)	–65	–180	45	210	–20	–25	25	–15
V_2 (15 m/min)/ T_2 (500°C)	–70	–140	90	240	–15	–30	15	20



a) b)

Fig. 14. Position of a Ø25×3 mm profile after exiting the single-hole die in terms of X/Y coordinate map for: a) without a gripping system, b) with a gripping system



a) b)

Fig. 15. Position of a Ø25×3 mm profile after exiting the double-hole die in terms of X/Y coordinate map for: a) without a gripping system, b) with a gripping system

The effects of the gripping device are well illustrated by the examples of photographs of pipe sections after the extrusion process through the double-hole die: without a gripping device and with the application of a gripping device (Fig. 16).

According to the pre-set data ($a = 800$ mm and $b = 1300$ mm) the manual grip can in practice be carried out in the space between the exit of the profile from the press and the puller. Specifically, this is a distance of 1300 mm. In order for the puller to grip the profile, a distance of 2100 mm must be covered (including the space between the die and the press exit, which is dead for the press operator). In the case of automated grip, the grip is performed at a distance of 2100 mm, with the grip itself by the gripping troughs taking place at a distance of 800 mm and the remaining distance of 1300 mm being used to guide the profile to the puller through the profile guiding device.

The time for a manual grip on a 1300 mm section at a discharge speed of V_{wk} = 1.5 m/min is 52 seconds. The total grip time including the dead space of 800 mm between the die and the press exit plus manual grip at 1.5 m/min is 84 seconds. TABLE 3 shows the time required for manual gripping at different die exit speeds.

TABLE 3

Time of manual gripping of the profile from the die

V_{wyp} **[m/min]**	**Time for manual gripping [sek]**
1.5	52
2.0	40
4.0	20
8.0	10
16	5

From the data in TABLE 3, it can be seen that the maximum manual grip time for a skilled press operator can be around 40 seconds, corresponding to a maximum metal exit speed of 2 m/min. Manual gripping is practically impossible at metal exit speed speeds above 2 m/min. In order to achieve gripping at higher die exist speeds (above 2 m/min), it is necessary to auto-

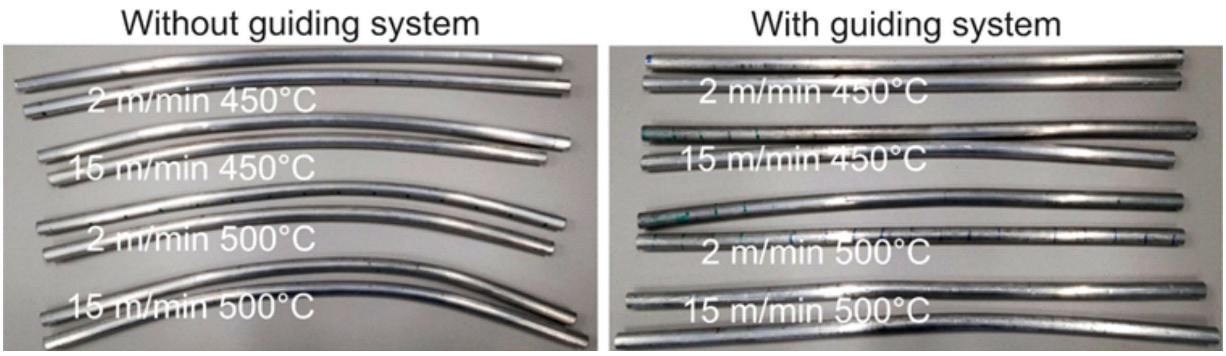


Fig. 16. Photographic documentation of cut-off sections of Ø25×3 mm profiles for the double-hole die (without a gripping system and with a gripping system) in relation to the individual temperature and speed parameters (two per variant)

mate the gripping process. This is the purpose of the gripping and guiding device that is being studied and tested. TABLE 4 shows the savings in gripping time with automated gripping compared to manual gripping for different metal exit speed speeds.

TABLE 4

Time savings due to the introduction of the profile grip after exiting the die. Designation: A – manual grip, B – automatic grip

	V_{wyp} [m/min]	Total time of gripping [s]	Time savings [s]
A	1.5	84	0
	1.5	84	0
	2.0	67	17
B	4.0	33	51
	8.0	16	68
	16.0	8	76

In order to reduce the time for gripping and transporting the profiles to the puller by min. 50% with respect to the standard feeding of the products to the puller by the press operator, Fig. 17 shows the relationship between the reduction of the gripping time as a function of the profile metal exit speed from the die opening.

From the analysis of the data in Fig. 17, it can be concluded that a reduction in the gripping time of 50% minimum can be achieved if the automated grip is performed in less than 42 seconds at a metal exit speed from the die opening of at least 3.3 m/min. In practice, it might be possible to reduce the gripping time further, but the speed inertia of the press might make this difficult. In the future, it may be possible to try to reduce the gripping time more effectively by using a method that involves gripping of, say, 3.3 m/min and then increasing the speed as the profile is fed into the puller. Once the profile has been gripped by the puller, the metal exit speed is increased to the target speed at which the extrusion cycle will be run.

6. Discussion

On the basis of an analysis of the initial phase of the hot extrusion process of aluminium alloy profiles, it was found that, in practice, the initial phase of the process, which includes the phase of metal flow from the die opening and gripping by the press puller, is carried out manually with the involvement of a press operator. In order to eliminate the manual feeding of the profile by the press operator into the puller which is a cumbersome dangerous operation for the operator and also reduces the efficiency of the extrusion process, it was decided to automate this stage of the process in order to improve the health and safety conditions and the efficiency of the extrusion process. To this end, a special laboratory device for gripping and guiding the profile in the die-puller space was designed and built, and a series of tests and trials were done to obtain the data needed to put this original device into practice. The laboratory device to grip the profile simulates the real operating conditions of an industrial press for extruding aluminium alloy profiles. Thanks to the use of "dies" with a bending bar or, alternatively, roller bending "dies", it was possible to induce a bend of the profile coming out of the die opening to mimic that which occurs in the actual extrusion process. The task of the proposed automated grip was to bend the profile coming out of the die opening towards the press axis, so that it could be gripped by the press puller. This operation replaces the manual bending of the profile by the press operator and feeding it into the puller. The commissioning tests of the gripping device confirmed the validity of the assumptions which had been made and provided the necessary information on the effectiveness of the grip over a wide range of parameters of metal exit speed (2-15 m/min.) and temperature in the range 450°C to 550°C. Thanks to the use of oscillating gripping troughs, it is possible to automatically bend the profile(s) coming out of the die opening and position them in the axis of the press in a circumscribed circle of no more than 100 mm, thus ensuring collision-free gripping by the press puller. In the course of the examinations, the position of the beginning of the profile in the die-puller space was analysed in order to assess the "work" that the gripping troughs had to do to align the outgoing profile on its way to the puller. It was found that the higher the extrusion temperature and the higher the exit speed of the profile from the die opening, the greater the deviation of the start of the profile in the die-puller space. An analysis of the efficiency of the extrusion process, comparing the times required for manual and automated gripping, has shown that it is practically possible to

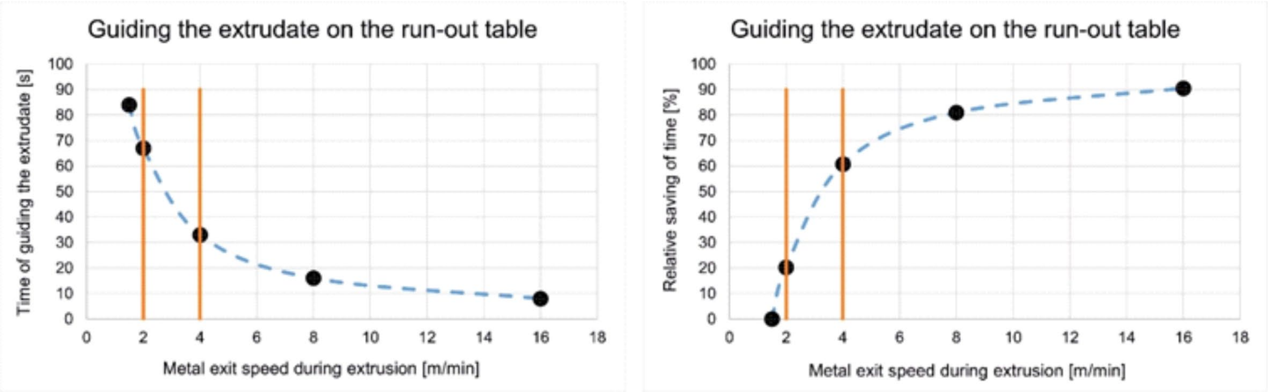


Fig. 17. Grip time as a function of the metal exit speed from the die opening

reduce gripping time by at least 50% using automated gripping compared to manual gripping performed by a highly skilled press operator.

7. Conclusions

The design, manufacture and testing of a laboratory-scale machine for the automated gripping of hot-extruded aluminium alloy profiles has demonstrated that it is possible to eliminate the manual gripping of the profiles exiting the die and their feeding into the puller by the press operator, which has been used in practice to date, and to replace this operation with an automated one without the involvement of the press operator.

The study has shown that:

- the maximum metal exit speed at which manual gripping is still possible for a skilled press operator is approximately 2 m/min and the space in which manual gripping is carried out is the distance between the metal exit from the press and the puller (1300 mm for a 2500T press),
- automated gripping of the profiles can be carried out at higher metal exit speeds than with manual gripping, and the space in which the automated gripping is carried out is the path between the exit of the profile from the die and the exit of the press (800 mm for a 2500 T press),
- in order to achieve a 50% time reduction in automated gripping compared to manual gripping, the automated gripping must be carried out at a metal exit speed of at least 3.3 m/min (the data refer to a 2500 T press),
- the key element of the automated gripping device are the gripping troughs, which oscillate during the gripping process, and which, in addition to aligning the profile to the press axis, reduce the friction at the trough-to-profile contact by oscillation,
- the proposed automated grip design can be applied in practice to any press designed for the hot extrusion of aluminium alloy profiles.

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