WARM EXTRUSION OF AA7075 ALUMINUM ALLOY

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ABSTRACT

The aim of this paper is to present the warm extrusion process of AA7075 aluminum alloy, which was produced in Vietnam. The forward extrusion method and backward extrusion method were used. The process parameters considered include the different deformation temperatures, T_w (200⁰C, 220⁰C, 240⁰C, 260⁰C, 280⁰C, and 300⁰C) and machining speed, v_s (30mm/s) and coefficient of friction, μ (0.3). The responses measured were extrusion force (F) and hardness of products (HV). The results show that the forming ability of AA7075 can be significantly improved when the forming process is carried out in the temperature range from 200⁰C to 260⁰C. At forming temperature over 260⁰C, the forming ability is still guaranteed, but the surface quality of the product is low and the hardness of the product is reduced due to the influence of high temperature. This is the basis for the selection of technological parameters to implement the extrusion process of high strength aluminum alloys for industrial applications.

Keywords: *Aluminum alloy AA7075; Warm extrusion; Process parameters; Forming ability.*

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NOMENCLATURE

T_w: Deformation temperature (⁰C)
v_s: Machining speed (mm/s)
μ: Coefficient of friction
F: Extrusion forces (Ton)
HV: Hardness of product.

1. INTRODUCTION

In the automotive and aerospace industries, weight reduction of structural components is an important requirement in design and manufacturing technology. The replacement of steel structures with lightweight materials such as aluminum and magnesium alloys are among the methods being applied [1, 2]. Aluminum alloys are widely used in automotive structures such as the vehicle body and powertrain and some body panels to reduce mass. Aluminum alloy has also been the predominant material of choice since the introduction of the Boeing for certain applications [3, 4, 5]. In which, the AA7075 high strength aluminum alloy is used to replace high strength steel [6]. However, the AA7075 alloy has very limited deform ability at room temperature. The elongation to fracture for tensile tests of this alloy was achieved 8% at 20⁰C. Therefore, the applicability of aluminum alloy AA7075 in industries is limited.

To improve the deform ability of AA7075 aluminum alloy to increase the scope of their application, several new forming methods have been used to replace cold forming. The methods are widely used include hot forming and superplastic forming. In both these methods, the workpiece is deformed in the high temperature state, the forming ability is greatly increased. However, the surface quality of the product achieved is a not high due to the influence of temperature and abrasion of the tools. Besides, the hot forming will cause complexity for the technological process and increase production cost [7].

Recently, warm forming method has been studied and applied. With this method, forming is performed at temperatures just above room temperature but below the recrystallization temperature. The working temperature is taken to be $0.3T_m$ where T_m is the melting point of the workpiece [8]. The warm forming method can enhance plastic deformation properties, reduce the forming force, and reduce the heat treatment steps. The formed product has relatively good surface quality and meets the requirements for mechanical properties. The formed product has a relatively good surface quality and meets the requirements for mechanical properties compared to the hot forming process [9].

This paper presents the results of the warm extrusion process of 7075 aluminum alloy. The forward extrusion method and backward extrusion method were used. The process parameters considered include the different deformation temperature, T_w (200⁰C, 220⁰C, 240⁰C, 260⁰C, 280⁰C, and 300⁰C) and machining speed, v_s (30 mm/s) and coefficient of friction, μ (0.3). The responses measured were extrusion force (F) and hardness of products (HV). This is the basis for the selection of technological parameters to implement the extrusion process of high strength aluminum alloys for industrial applications.

2. RESEARCH METHODOLOGY

The material used in this study was an AA7075 aluminum alloy. This alloy was produced in Vietnam. Composition specification of AA7075 is shown in Table 1.

Table 1. Chemical composition of AA7075 (weight percent, %wt)

Zn	Mg	Cu	Fe	Cr	Ti	Zr	Mn	Si	Al
5.35	2.34	1.32	0.30	0.22	0.04	0.0027	0.024	0.05	Balance

The initial workpiece is machined with a diameter of 30mm and a height of 20mm. The Initial workpiece, semi-products after backward extrusion and forward extrusion are presented in Fig. 1. The extrusion process was performed by a 100-ton hydraulic press (YH32-100T). The YH32 hydraulic press has two motion modes of the upper slide including 5mm/s and 30mm/s. Because the extrusion process is carried out at warm temperatures, a larger speed of the upper slide is chosen. When warm or hot forming, the strain rate significantly affects the deformability of the materials [3, 8]. The containers with the specimens were heated to the deformation temperature in a Nabertherm chamber furnace LH120/13, and the specimens were then placed into the working chamber of extrusion dies (Fig. 2). The stroke of the press is limited by the stroke control unit (Fig. 3). The delay before beginning the extrusion was 20 ÷ 30s. The heating process for the dies was done on a furnace capable of heating up to 800°C, with a set temperature of ±3°C. Thermocouple is used to ensure the accuracy of die heating temperature (Fig. 4).

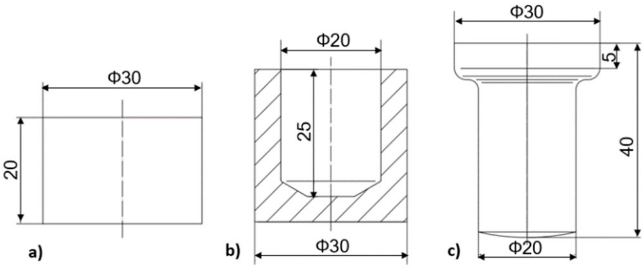
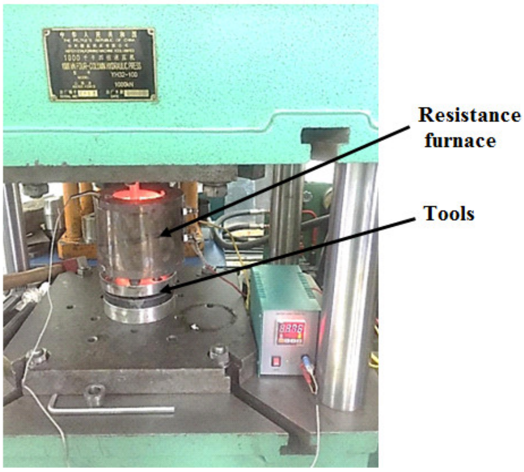


Fig. 1. Initial workpiece (a), semi-products after backward extrusion (b) and forward extrusion (c)

(a) The 100-ton hydraulic press



(b) Scheme of the extrusion set-up and tools

Fig. 2. Warm extrusion test equipment used in experiment

The extrusion force is calculated based on the pressure value of the main cylinder of the hydraulic press YH32. The hardness of products after warm extrusions were examined using a HV-1000 micro Vickers hardness tester. Experimental tools are forward extrusion and backward extrusion dies. The punch and die are made of SKD61 steel, which are treated to a hardness of 58 ÷ 62HRC. Tools of the extrusion process are subjected to great pressure caused by the deformation process. Therefore, ensuring the durability and rigidity of the forming tool is extremely necessary. All mounting surfaces are cleaned.

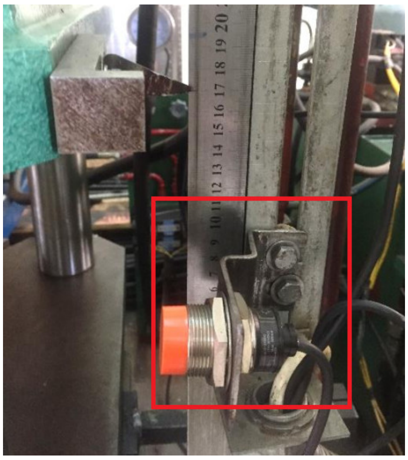


Fig. 3. The stroke control unit of hydraulic press

(a) Resistance furnace

(b) Control box

(c) Thermocouple

Fig. 4. The resistance furnace for die heating

The cylindrical specimens with a diameter of 30 mm and a height of 30 mm were used for the experiments. Specimens were placed inside resistance furnace and make sure a predetermined temperature before the extrusion processes were started. The experiments were completed at eight different temperatures of 20°C, 200°C, 220°C, 240°C, 260°C, 280°C, 300°C, and 500°C with a constant machining speed of 30 mm/s and coefficient of friction of 0.3 (Corresponding to high temperature deformation process using lubricants). The products after extrusion are cooled in air.

3. RESULTS AND DISCUSSION

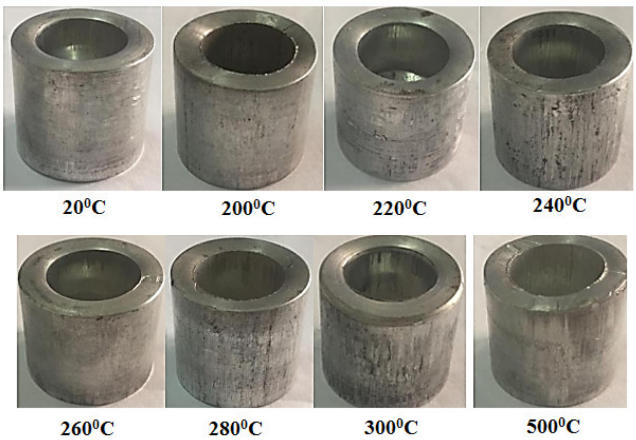


Fig. 5. The products after forward extrusion process

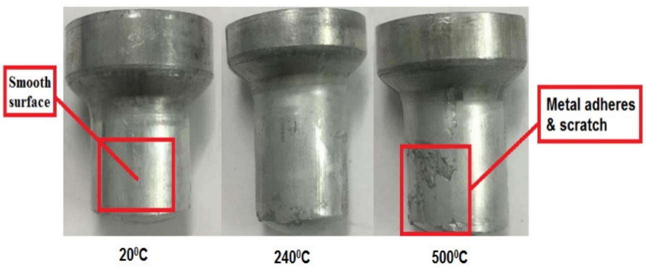


Fig. 6. The product surface quality when forward extrusion at different temperatures

The products after backward extrusion processes at different temperatures are shown in Fig. 5. These products achieve the required geometric dimensions. It was found that the product surface quality is best achieved when cold backward extrusion (20°C). In the case of hot backward extrusion (500°C), the product surface is scratched and metal adheres due to the high deformation temperature. In the case of warm extrusion, the surface is relatively smooth. However, at forming temperature over 260°C, the surface begins to appear scratches along the length of the product. Similar results are obtained in the case of forward extrusion. The surface quality of the product when forward extrusion with different temperatures is illustrated in Fig. 6.

The extrusion forces at different temperatures are determined and shown in Table 2 and Fig. 7. The maximum extrusion force is obtained at temperature 20°C (cold extrusion) in both forward extrusion and backward extrusion processes. The minimum extrusion force is obtained at temperature 500°C (hot extrusion). The force of warm extrusion is significantly reduced compared to that of cold extrusion. This phenomenon can be explained as follows. Increased forming temperature results in diminish of the strength which causes material plasticity increase [10, 11].

Table 2. The extrusion forces at different temperatures

Temperatures, °C	20	200	220	240	260	280	300	500
Backward extrusion forces, Tons	11.5	7.0	6.0	5.5	5.3	5.0	4.7	3.5
Forward extrusion forces, Tons	16.5	8.0	7.8	7.5	7.0	5.0	4.8	3.6

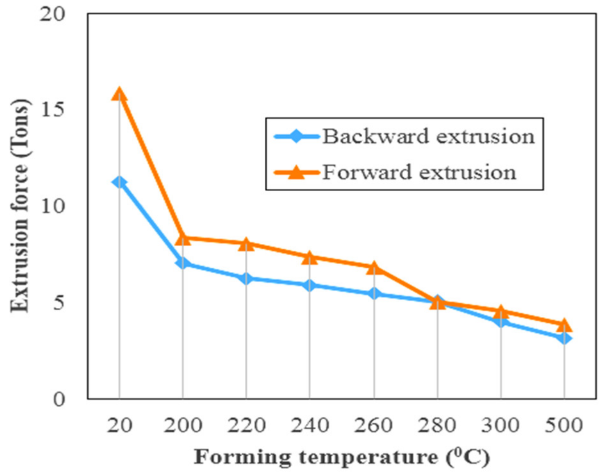


Fig. 7. Graph of extrusion forces at different temperatures

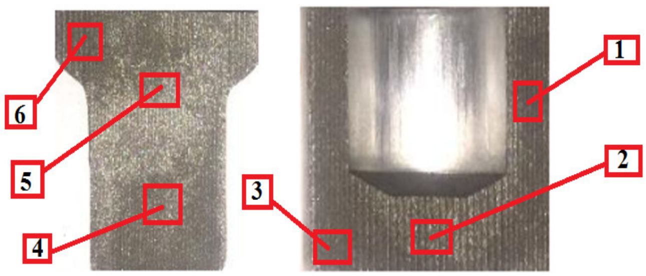


Fig. 8. The hardness measurement positions

Table 3. The microhardness of products at different temperatures

Extrusion methods	Temperature (^{0}C)	Average hardness (HV)	Surface quality
Backward extrusion	20	124	very good
	200	95	good
	220	90	good
	240	88	good
	260	85	good
	280	55	scratch
	300	54	scratch
	500	43	scratch
Forward extrusion	20	113	very good
	200	92	good
	220	87	good
	240	85	good
	260	82	good
	280	57	scratch
	300	55	scratch
	500	45	scratch

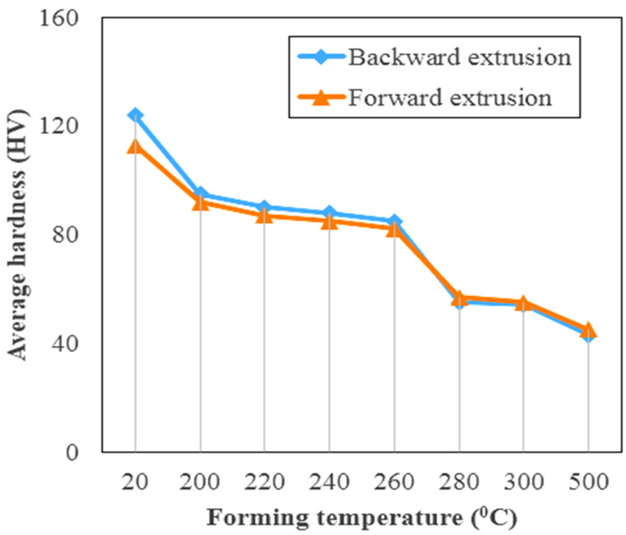


Fig. 9. Graph of product hardness at different temperatures after extrusion processes

The next stage of the research was to carry out microhardness tests. After the extrusion processes, the products are cut in half to prepare for microhardness testing. Microhardness was tested in three different positions on the cross-section. Hardness measurement positions are shown in Fig. 8. The average hardness is determined from the results of the measurements at three positions. The result of the test conducted according to extrusion processes is presented in Table 3 and Fig. 9.

Based on the results shown in Table 3 and Fig. 9, it is found that the hardness of the product after warm extrusion (forward extrusion and backward extrusion) is less than the hardness of the product after cold extrusion. The hardness of the product does not change significantly when the workpieces are heated to 200 ÷ 260°C. At forming temperature over 260^{0}C, the hardness of the products fell sharply due to the effect of the heating and forming processes on the material properties. Therefore, the products after hot extrusion have not high surface quality.

In addition, the hardness of the products after forward extrusion is smaller than that of backward extrusion. This phenomenon can be explained as follows. The specific pressure in backward extrusion is larger than in forward extrusion, so backward extrusion process usually occurs earlier and occurs more strongly than in the forward extrusion process when the pressure is increased on the workpiece. This shows that the die cavity is easier to fill [11].

4. CONCLUSIONS

The goal of the work was to study the warm extrusion process of AA7075 aluminum alloy. Microhardness of the products has been tested and extrusion force have been determined. These are preliminary results and will be further studied in future work. On the basis of the work done, the following conclusions were made:

1) Warm extrusion processes (temperature of the workpiece from 200°C to 260°C) allow to obtain correct products without any differences and defects (dimensions and surface quality).

2) Plastic deformation capacity of aluminum alloy AA7075 at temperatures over 260°C is sufficient to carry out extrusion process. However, the product is reduced in strength properties and surface quality. Surface of products appears scratches and metal adheres.

3) The warm extrusion force is smaller than cold extrusion process. This brings economic efficiency to the technological process and reduces the cost of the final product.

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