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Study of the Direct Extrusion Behavior of Aluminum and Aluminum Alloy-2014 Using Conical Dies

Dr. Ahmed A. Akbar
Production Engineering and Metallurgy Department, University of Technology /Baghdad.
Email: Akbarthree @yahoo.com
Dr. Rabiha S. Yaseen
Production Engineering and Metallurgy Department, University of Technology /Baghdad
Email:rabihazw@yahoo.com

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ABSTRACT

The present work concerns with study of extrusion behavior of aluminum alloy-Al2014 comparing with pure aluminum-Al1050, using different die angles (α=15, 30 and 75°) and different billet lengths (20, 28, 40 and 52mm). Results showed that the extrusion load increase when billet length increases for aluminum alloy (Al-2014) and pure aluminum (Al-1050). The results also showed that small die angles required higher extrusion load than large die angles. The Brinell hardness values showed that aluminum alloy (Al-2014) undergoes higher work hardening due to the presence of copper compared with the pure aluminum (Al-1050), in addition to formation of dead metal zone which resists the metal flow through the die opening.

Keywords: Aluminum alloy (Al-2014), pure aluminum (Al-1050), extrusion behavior, dies angles, billet lengths, and Brinell hardness (HB).

دراسة سلوك البثق المباشر للألمنيوم وسبيكة الألمنيوم-2014 بإستخدام قوالب مخروطية

الخلاصة

يقدم البحث دراسة سلوك البثق للألمونيوم السبائكى Al-2014 ومقارنته مع الألمونيوم النقي Al-1050 وباستخدام قوالب مختلفة الزوايا (α=15, 30 & 75°) وكذلك باستخدام أطوال مختلفة للعينات (20، 28، 40& 52) ملم حيث بينت النتائج أن قوة البثق تزداد بزيادة طول المعدن المبثوق للمعدن النقي والسبائكى ولكن السبائكى يحتاج إلى قوة بثق أكبر من المعدن النقي بسبب تعرض الألمونيوم السبائكي للتصليد الانفعالي. وبينت النتائج أيضا أن استخدام زاوية قالب صغيرة يحتاج إلي قوة بثق عالية بسبب تعرض المعدن إلى التصليد بشكل كبير. وأكدت نتائج قياس الصلادة في مواضع مختلفة أن الألمونيوم السبائكي(2014) المبثوق يتعرض للتصليد الانفعالي بسبب وجود النحاس في السبيكة مقارنة مع الالمنيوم النقي الخالي من العناصر السبائكية ونشوء المنطقة الميتة التي تعيق تدفق المعدن من فتحة القالب.

INTRODUCTION

The properties of aluminum, in comparison with other metals, make it the most popular choice for large-scale manufacturing of consumer goods; in the manufacturing of the transportation machinery and electronics; and for products widely used in building and construction [1, 2]. Some more examples of aluminum extrusion applications are aerospace products, architectural framing, copier components, circuit board, modem housing, medical equipment, vending machines and cable management products [3,4]. Plasticity analysis of pure aluminum -1100 extruded with palm olein as a lubricant was studied [5].The experimental results focused on the extrusion force , surface roughness of both the deformation area and the product surface and the sliding velocity using taper extrusion dies with45-degree half die angle . Results were compared with experiments carried out using paraffin .Better plastic behavior were obtained with palm olein lubricant .Also sequence effects of twist extrusion and rolling on microstructure and mechanical properties of aluminum alloy 8112 was also studied [6]. Twist extrusion process of Al 8112 samples was carried out using a twisted die with 60º die angle and the samples were processed through rolling subsequently. The results demonstrated that implementation of rolling not only reduced heterogeneity but also decreased the grain size and, consequently enhanced the bulk strength.

The effect of die geometry and extrusion speed on cold extrusion of aluminum and lead alloys were studied [7]. An experimental investigation was made on the effect of die reduction area. Loading rate on the quality of the extrusion product, extrusion pressure and flow pattern of the cold extruded aluminum and lead alloys. The radii of curvature of the extruded aluminum and lead alloys and the average hardness along the product were found to increase with increasing die reduction in area.[7]

The main objectives of the present work are: (1) to study the extrusion behavior of aluminum alloy (Al-2014) and comparing with pure aluminum (Al-1050), (2) to study the mechanical properties related of the extrusion parameters (die angles and billet lengths) by measuring the hardness at different positions, (3) to study the effect of surface contact length of extrusion load and (4) to study the effect of work hardening due to extrusion parameters.

EXPERIMENTAL WORK

To investigate the extrusion behavior of aluminum alloy (Al- 2014) under various extrusions die angle (α) and billet length then comparing with pure aluminum (Al-1050) a number of practical procedures are done. These procedures include the preparation and manufacture of complete die-punch set and the billets.

Materials: Commercial pure aluminum (Al-1050) and aluminum alloy (Al-2014) have been used. The chemical compositions of the chosen materials are given in Table (1).The specimens were prepared as billet with diameter of 25mm and lengths range (20, 28, 40, and 52 mm) [8,9].

Table(1). The chemical compositions of pure aluminum (Al-1050) and aluminum alloy (Al-2014).

Table(1). The chemical compositions of pure aluminum (Al-1050) and aluminum alloy (Al-2014).

Elements	**Al- 1050 (Wt %)**	**Al- 2014 (Wt %)**
AL	99.446	Reminder
Si	0.11	0.5-1.2
Mg	0.006	0.2-0.8
Cu	0.038	3.9-5
Ni	0.003	-
Sn	0.002	-
Mn	0.005	0.4-1.2
Fe	0.36	0.7
Zn	0.03	0.25
Cr	-	0.1
Ti	-	0.15
Other elements	-	0.2

THE EXTRUSION PROCESSES

The extrusion load with conical die angle was affected by many factors as follows:

1. Related lengths of the billets (20, 28, 40, and 52 mm).
2. Semi cone angles of the dies (α =15, 30, and 75°).

At room temperature, the extrusion process was carried out by using the hydraulic press with digital indicator rating 2000 KN capacity with speed 0.38 mm/min. This universal compression machine was used in pressing the extrusion ram. Punch travel was recorded using a dial gauge with a magnetic stand [7-12].

During extrusion process, extrusion load was recorded for each punch travel for all parameters. Extrusion load of Al-2014 for each punch travel through the process is shown in Fig 1, for the different billet lengths (20, 28, 40, and 52 mm) and at a die angle α= 75^{o}.

Comparison between extrusion behaviors of Al- 2014 and Al-1050 is shown in Fig 2 (a, b). The effect of conical die angle (α =15, 30, and 75°) is also illustrated for Al- 2014 in Fig 3. The ultimate extrusion load including the effect of surface contact friction was also studied by representing the effect of length of contact between billet and container wall (20, 28, 40, and 52 mm) as shown in Fig 4.

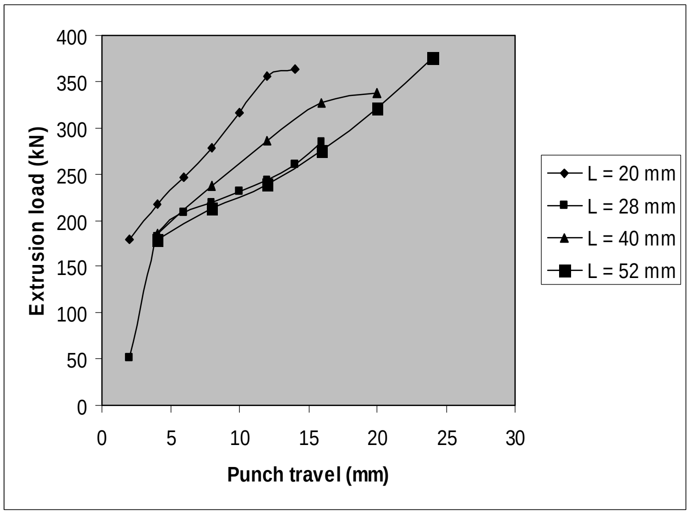

Figure (1) direct extrusion load vs. punch travel for aluminum alloy (Al-2014) at die angle α = 75°.

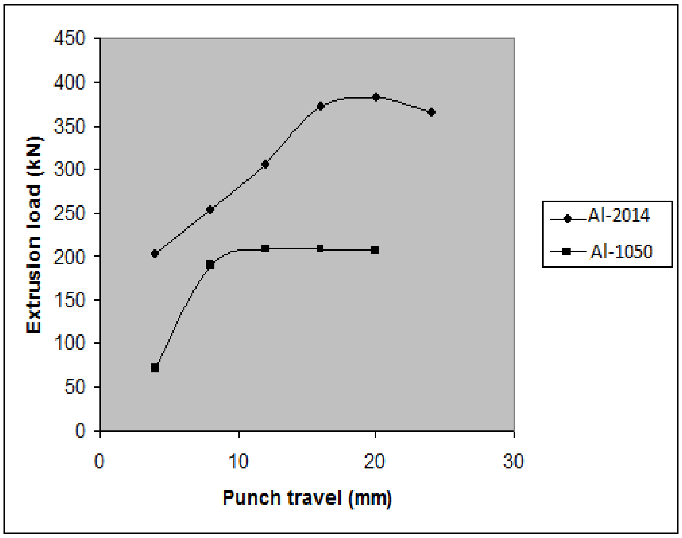

Figure (2a) Direct extrusion load vs. punch travel for pure aluminum (Al-1050) and aluminum alloy(Al-2014) at billet length 52 mm and die angle α = 15°.

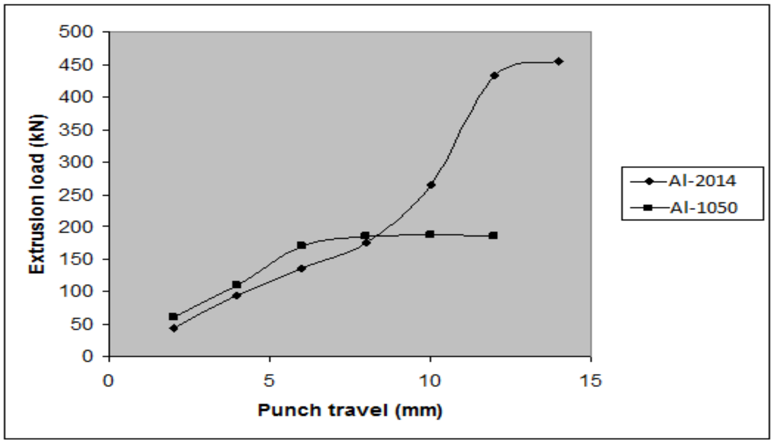

Figure (2b) Direct extrusion load vs. punch travel for pure aluminum (Al-1050) and aluminum alloy (Al-2014) at billet length 28 mm and die angle α = 15°.

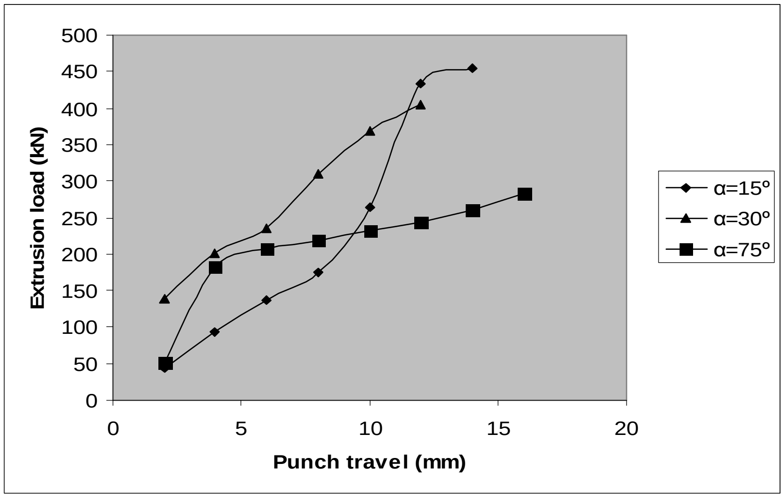

Figure (3) The effect of die cone angle (α) on extrusion load for aluminum alloy (Al-2014).

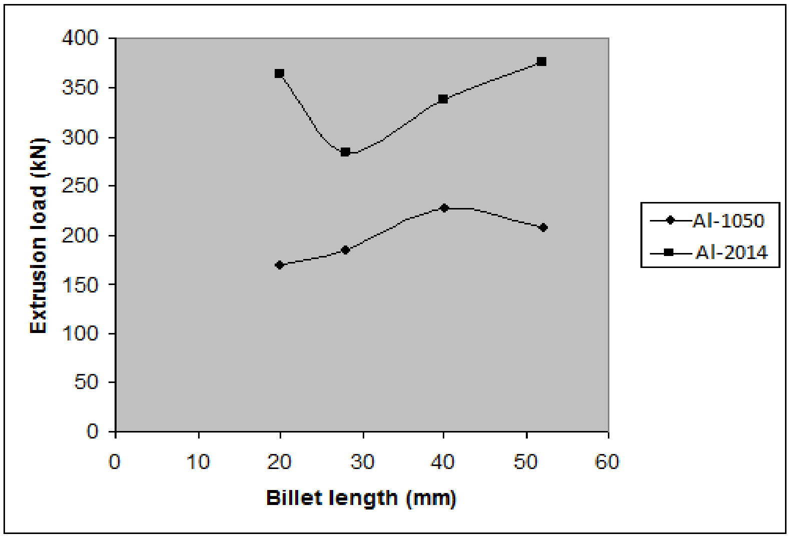

Figure (4) Effect of billet length on ultimate extrusion load of pure aluminum(Al-1050) and aluminum alloy (Al-2014) at die angle α = 15°.

MECHANICAL BEHAVIOR OF THE EXTRUDATE

To study the mechanical properties changes during extrusion of Al- 2014 which is a heat treatable alloy, the hardness variation along the extrudate axis before and after flowing out through the die opening was measured and the hardness variation from the center line towards the outer diameter before and after extrusion was studied.

Different extrudates were machined to half sections then mounted to grind and polish for hardness measurement. Hardness measuring values obtained for the different samples are given in Table 2. The brinell hardness values were recorded in three locations; one set of readings was along the extrusion axis (X) and second was across the billet section from center to surface before entering the die (Y_1) and the third after extruding (Y_2), as shown in Fig 5. Considering these values using the billet hardness which was measured to be equal to (88 HB) before extrusion will help to discuss the work hardening effect.

DISCUSSION

A number of experiments were done in this work. A group of tests were performed to study the effect of billet length on extrusion load of aluminum alloy (Al-2014) and comparing the results with that of pure aluminum (Al-1050).

Many experiments have been done to study the effect of friction between billet and container wall beside the ability of the material to work-harden using different die angle (α= 15, 30 and 75°).

To study the formability and flow of Al-2014 through the die opening, and the effect of die angle of the formation of dead-metal zone, which increase extrusion load have been considered.

Hardness testing results of the extruded metal also supported the results of the effect of billet length and die angle and explained the extent of hardenability.

Table (2) Brinell hardness values along and across billet axis.

L= 52mm, α= 75°		
along-X	Across-Y_1	Across-Y_2
118 HB	115 HB	124 HB
115 HB	118 HB	128 HB
128 HB	121 HB	131 HB
131 HB	118 HB	131 HB
135 HB		
128 HB		
L= 28mm, α= 75°		
along-X	Across-Y_1	Across-Y_2
121	128	124
124	124	121
124	124	121
124	128	124
L= 28mm, α= 30°		
along-X	Across-Y1	Across-Y2
115	121	128
118	118	124
118	118	124
118	121	128

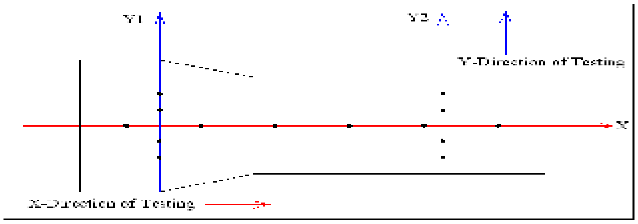

Figure (5) Brinell hardness in three locations along and across billet axis.

Figure (1) shows billet length for 20mm showed extrusion load is higher than for 28 and 40mm, due to the work hardening of the billet mass during extrusion process and the adhesion to the container wall. Moreover, long billets have the possibility of flow through the die opening (17.82mm) more than short one which is absolutely transformed to dead metal zone. For longer length (52mm), extrusion load is higher for all lengths due to the fact that friction force resists the extrusion process more severely.

Figure (2a), represents the effect of type of aluminum on the extrusion load. Aluminum alloy (Al-2014) with a length of 52mm showed higher extrusion load than pure aluminum (Al-1050) for die angle α=15° and die opening 17.82mm. This aluminum alloy undergoes work hardening due to the presence of copper which forms hard phases and so increase yield strength. This was also clear in hardness testing where an increase of hardness by 50% after extrusion; this resulted in an increase in the extrusion load required. Since the aluminum alloy is heat treatable so annealing of the billet may reduce the yield strength and lowers the effect of work hardening and dead metal formation.

In Figure (2b), the extrusion behaviors of Al-1050 and Al-2014 are represented for billet length of (28mm). both metals showed little difference of extrusion load up to (10mm) metal extruding but more than (10mm) showed a divergence between both behaviors, where the aluminum alloy required more extrusion load than pure one due to work hardening. While the length (52mm) showed a steady difference between aluminum alloy and the pure.

Figure (3), represents the extrusion load and punch travel for various die angles (α= 15, 30 and 75°), the die angle of 15° showed a behavior different than the expected, and after the travel of (12mm) the behavior was changed to the expected due to the fact that small die angle results in dead metal zone formation and process of adhesion with the die wall, so extrusion load became higher than large angle (75°) which results in easy metal flow and less work-hardening.

When representing ultimate extrusion load against billet length, an increase in the ultimate load was observed when billet length of more than (30mm) as shown in Fig 4. When mechanical properties of an extruded sample are studied; the variation of hardness along the extrusion axis before and after passing the die opening showed some changes.

brinell hardness measurement at positions before and after extrusion showed that for billet length of 52mm Brinell hardness range between 118 to 135 HB while it varies between 121 to 124 HB for billet length of 28mm and die angle of α=75°. Whereas for 28mm billet length and α=30° Brinell hardness (HB) varies between 124 to 128 HB due to work hardening effect.

CONCLUSIONS

From the previous results, a number of conclusions can be deduced, as follows:

1. Increase of billet length for pure aluminum (Al-1050) and aluminum alloy (Al-2014) caused an increase in extrusion load due to the increase in surface contact between the billet and container wall.
2. The aluminum alloy (Al-2014) showed higher extrusion load than pure aluminum (Al-1050) due to work hardening.
3. Extrusion load increased when die angle (α) was decreased, since small die angle causes dead metal zone, in addition to the effect of the presence of copper which forms hard phases.

4. Work hardening effect can be reduced by annealing the aluminum billet to reduce the work hardening and to reduce the friction effect.
5. The ultimate load required for extruding aluminum alloy (Al-2014) and pure aluminum (Al-1050) increases with the increase billet length due to an increase in friction effect.

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