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A Review on Recycling Aluminum Chips by Hot Extrusion Process

S.N. Ab Rahim[1], M.A. Lajis[1], S. Ariffin[2]

[1]Advanced Manufacturing and Materials Center (AMMC),
[2]Faculty of Mechanical & Manufacturing Engineering,
University Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, Malaysia

* Corresponding author. Tel.: +6013-2805549; *E-mail address:* Syaiful5599@gmail.com

Abstract

At present of the manufacturing sector, which is at the economic level, must be made to sustain societies in the high living by industrial societies and able to increase productivities so that they are able to achieve the same standard of living equally. It will be a big issue because recycled materials have become very important to environmental. This paper presents an overview of the trends and the concept of emerging to identify the recyclability contents of the product for recycling aluminum chips by the hot extrusion process. It shows that even though to achieve the sustainability, it needs the holistic optimization of the entire environment. Extrusion technology research is continuously improving which mainly focused to attain of the optimum mechanical and physical properties and also modeling and optimization of the extrusion parameters.

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Keywords: Aluminum chip; Recycling; sustainability, Hot Extrusion

1. Introduction

Aluminum is everywhere. We see it in the packaging, soft drink cans, food plates, foil, siding, gutters, automotive part and more. What most people don't realize is that aluminum is practically the perfect recyclable material. Out of the most common recyclable materials that clutter up our landfills; glass, paper, metals, cardboard, plastics, aluminum is the only material that's endlessly recyclable, 100% recyclable, and that pays for itself. Air pollution is associated with synthetic materials and other harmful impurities that diffuse and become part of the air. These materials are mostly industrial wastes, vehicle exhaust fumes, action logging and so the issue of solid particles and gases that escape into the air. There are many adverse effects that would befall mankind if control measures are not taken immediately to address the contamination. Even for recycling culture among the country's government intensify campaign 3R (Reuse, Reduce, Recycle) to provide bins garbage variety of colors so that litter easily separated by categories such as plastic, glass and paper. Figure 1 shows the evolution of different manufacturing concepts and their contributions to stakeholder value, and the proposed closed-loop system involving 6Rs.

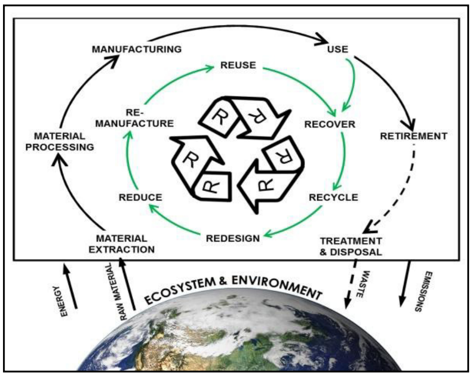

Fig. 1. Close-loop product life-cycle system in 6R approach [2]

Metals have always been the most recycled material in the world. The recycling of waste metallic material and use of scrap is important for economic production of steelworks,

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Matjaz Torkar [1]. In fact, the making of steel requires recycled steel in the production of the raw material. Recycling metals saves energy and helps prevent the depletion of natural resources. An entire industry has grown up around recycling metal. This is because everything that contains metal is intrinsically valuable. In subsequent decades, the transportation and construction sectors have always been the principal benefactors of aluminum extrusion products. Even in present times, the bulk of extrusion usage is in manufacturing doors and windows, followed by passenger vehicles. The short history of aluminum extrusion, in comparison to other metals, has seen extensive development and growth, revolutionizing the way we live. As new purposes are discovered in space exploration and here at home, aluminum extrusion will continue to be an important part of the future.

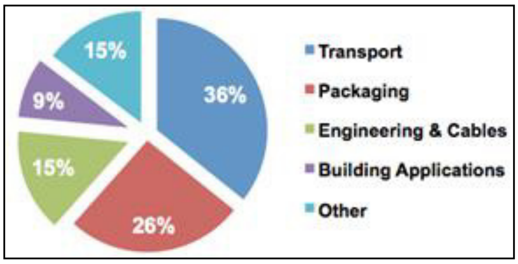

Fig. 2. Global Old Scrap Recycled by Market (IAI report 2012)

Figure 2 above shown, based on data from the International Aluminum Institute, the current global aluminum old scrap market primarily consists of scrap from automotive and packaging. These factors will make recycling more competitive, and over time the relative importance of secondary aluminum production to society will grow.

2. Recycling Aluminum

Aluminum recycling is one of the process by which scrap aluminum can be reused in products after its initial production. The process involves simply re-melting the metal, which is far less expensive and energy intensive than creating new aluminum through the electrolysis of aluminum oxide (Al_2O_3), which must first be mined from bauxite ore and then refined. The processes used for recycling aluminum scrap follows very different from that used to produce primary metal, but in many ways the same general sequence [4]. The industrial scale production and use of aluminum metal are barely a century old, yet in the time, the industry has grown until it is second only to the iron and steel industry among metal producers (figure 3). The influence of automotive aluminum use of recycling pattern is significant, since most recycled aluminum is used in this sector. According to study by Jirang Cui, et al [8] show with the climate change of concern, usage of aluminum in automotive application with the concept of light weight is predicted to be increased steadily. And that researcher also show by using recycled aluminum in place of primary aluminum metal results in significant energy and greenhouse gas emissions was saved. The current predominance of cast alloys makes this easier, since cast alloys have a higher tolerance for impurities and can absorb a wider variety of scrap. Metal are important, reusable resources. Although metals, in contrast to resources such as

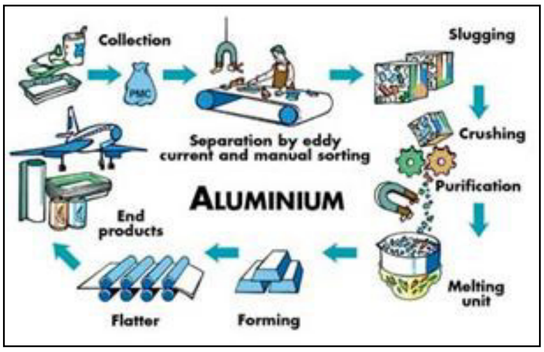

Fig. 3. Conventional aluminium recycling process (FPO, Belgium)

lumber, are not renewable and therefore exist in finite supply. Sustainability energy savings are associated with producing aluminum from recycled aluminum scrap instead of original aluminum. A new technique of aluminum recycling published by Samuel [6], presented the work of the direct conversion technique introduced characterized by low energy consumption, large metal savings and very low air pollution emission as compared with conventional methods. Recycled aluminum uses 5% of the energy that would be needed to create a comparable amount from raw materials. The benefit with respect to emissions of carbon dioxide depends on the type of energy used.

3. Hot Extrusion Process

The aluminum extrusion process starts with the die being loaded into the press. The die has openings that will create the profile when the aluminum is pushed through. That dies was preheated to prevent the aluminum from sticking in these openings. Next, the wrought alloy is brought to the press in the form of a billet. The billet as a solid so lent oracle length of a lawyer there can be up to seventy two inches long abilities and placed in a heating furnace and he did to 900°F. This temperature allows the billet to become soft yet still maintain its shape in a solid form. Note that the aluminum has not changed color. Even as a basis for heating furnace at 900 degrees. The heat has made billet it is now loaded into the press. As pressure is first applied the billet is crushed against the dye. Them as the pressure increases the soft but still solid aluminum has no place else to go and begins to squeeze out through the opening of the die to emerge on the other side as a fully formed profile. The extrusion has cooled after emerging from the dye either naturally or through the use of air or water quenchers. This is a critical step to ensure sufficient metallurgical properties after aging. The extrusion is then transferred to a cooling table. A stretcher is used after the profile has been cool to straighten the extrusion incorrect any twisting that may have occurred after the extrusion. A finish cuts off is used to cut the profile to the specified commercial life. Extrusions are then placed on rafts as they are prepared for the aging process. Extrusion alloys reach their optimal strength through the process of aging. Sometimes known as age hardening natural dating occurs at room temperature. Artificial aging takes place through controlled heating in an aging often. The aging of and further strengthens or hardens the profile through controlled thermal treatments that affect the metallurgical structure of the alloys. Yielding maximum strength hardness has elasticity for the profile. Once the extrusion process is complete the die is removed from the press and cleaned of any residual aluminum. After cleaning the die is inspected and prepared for the next time it will be used to extrude this profile.

Extrusion is defined as the process of shaping material, such as aluminum, by forcing it to flow through a shaped opening in a die. Aluminum extrusion is a technique used to transform aluminum alloy into objects with a definitive cross-sectional profile for a wide range of uses, as illustrated in Fig. 4. The extrusion process makes the most of aluminum's unique combination of physical characteristics. Its malleability allows it to be easily machined and cast, and yet aluminum is one third the density and stiffness of steel so the resulting products offer strength and stability, particularly when alloyed with other metals. Extrusion is done by squeezing the metal in a closed cavity through a tool, known as an die using either a mechanical or hydraulic press. Extrusion performance can be affected by three major factors, mainly, the number of billets used scrap, the die life and the extrusion speed [24]. Extrusion produces compressive and shear forces in the stock. No tensile is produced, which makes high deformation possible without tearing the metal. The cavity in which the raw material is contained is lined with a wear resistant material. This can withstand the high radial loads that are created when the material is pushed the die. According to Tekkaya [9], that due to the occurring strains, pressure and temperature at high quality longitudinal seam weld within the profile was assumed during conventional extrusion.

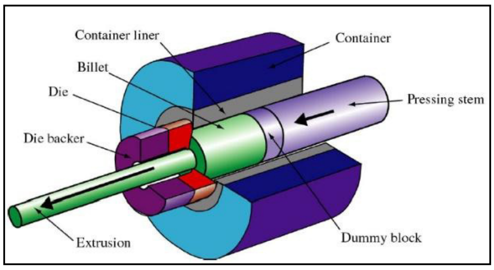

Fig. 4. Illustration of extrusion process by Kalpakjian, S.

In an extrusion press, pressure is applied to the billet by the ram where the dummy block is attached to the end of the ram stem. The most important factor in the extrusion process is temperature. Temperature is most critical because it gives aluminum desired characteristics such as hardness and finish. The alloyed press bars that are cut into smaller pieces, are heated in an induction furnace to around 450°C to 500°C. Right after the completion of pressing operation, air or water is used to cool the profile. Just after cooling, the profile is straightened and all the internal stresses are released by the process of stretching, which is done on a pulling machine. The resultant profile is then cut into the desired lengths. Finally, the process of ageing provides the material the required strength. The ageing process can be done naturally at normal temperature or artificially at an elevated temperature in the range of 170°C to185°C. To reduce possible deviations, an accurate control of the material flow and its influencing parameters such as temperature field or die geometry is necessary [25].

4. Mechanical Properties

The solid bonded material has similar mechanical performance of reference as-cast material, with only a small reduction in ultimate tensile strength and ductility. Energy data were recorded throughout the compaction and extrusion processes, solid bonding saving 96% of the energy associated with melting. Approximately 30% of all aluminum is extruded to produce finished or semi-finished products. Hence, the solid bonding process presents a major carbon abatement strategy for the aluminum industry. The microstructure of extruded chip-based billets differs from the microstructure of extruded cast billets in term of shape and size of the grains [7]. Zhang et.al [10], yield strength and ultimate tensile strength of as-extruded is improved with rising extrusion ratio, which can be attributed to the refinement of the grain size. Chip based billets extruded through the flat-face die have a smaller grain size compared to cast billets extruded through the same die. Chips moisture reduction, induction melting under protective atmosphere and a specially developed degassing technique were found the most important factors influencing the recycling process by Puga [11]. The recycled aluminum alloy presents a chemical composition according to the expected standards and similar to that obtained using exclusively commercially ingot as melting stock and the generated dross is free from salts and fluxes. The experimental material showed a good combination of strength and plasticity by Mu Hao-Liang [12]. The positive effect of the use of the extrusion porthole die can be observed in the increased ductility of the profiles manufactured from machining chips. First the oxide layers must be broken down to allow virgin metal-to-metal contact and second the cumulative value of the ratio of the mean streets of the flow stress must be greater than a constant value [3].

5. Physical Properties

Hot extrusion is done at fairly high temperatures, approximately 50 to 75 % of the melting point of the metal. In addition, Gronostajski et. al. [5] estimated a reduction in energy use of about 70% is possible compared to the existing melting method. Typical parts produced by extrusions are trim parts used in automotive and construction applications, window frame members, railings, aircraft structural parts. Based on these advantages, combination of machining and extrusion can lead to a reduction of energy needed for recycling from 16–19 GJ/T to 5–6 GJ/T faced by Gronostajski et al. [5]. The extrusion of aluminum scrap based on chips produced by turning or machining principally works when the same kind of alloys such as AA-6060 is used. The influence of the pre compacting process is negligible when a high pressure, temperature, and strain level inside the die is guaranteed. Using the new approach instead of re-melting, the aluminum scrap in a form of machining chips is directly extruded into aluminum profiles utilizing remarkably lower energy compared to conventional recycling by re-melting. The positive effect of the use of the extrusion porthole die can be observed in the increased ductility of the profiles manufactured from machining chips. A fracture strain of 26% corresponds to more than 80% higher ductility while compared to the aluminum profiles extruded through the flat-face die. In order to ensure the wedding of the ship's two criteria must be fulfilled. First the oxide layers must be broken down to allow virgin metal-to-metal contact and second the cumulative value of the ratio of the mean streets of the flow stress must be greater than a constant value. When these two conditions are fulfilled it can be assumed that chips are welded together. Guley et. al, [3] have investigated the pre-condition for the solid state welding of chips is that the brittle and continuous oxide layers must be broken down by imposing substantial sheared formation on the chips. With the increasing stem speed, the temperature of the extrudate and required extrusion force increased, and the welding quality of extruded would be improved [26]. According to research by Samuel [6] , the direct technique for recycled aluminum provides high productivity and about 80% green density (before sintering), in addition the new technique provides very low air pollution emission and high metal saving as compared with conventional methods.

6. Modeling and Optimization

Process parameter had a major factors influence on the quality of product. The maximum shear stress level reaches the shear strength of the material at the extrusion temperature and ram speeds [3]. The parameter in Table 1 shows influence quality of aluminium product. The major extrusion parameters include the die design representing redundant work (additional material shearing) and friction forces within the die, the extrusion ratio R, ram speed and extrusion temperature. Promising results in terms of energy savings and production of the highest quality engineered aluminium profiles [15]. By using the difference temperature, Hu Moa-Liang [14] shown that recrystallization grain size is smaller than that of the original grains when the deformation degree is lower. The mechanisms of dynamic recrystallization depend on the plastic deformation process and change with the deformation temperature. Previous researchers are using temperature process at 400°C for magnesium material chips. According to Mu Hao-Liang [12], extrusion ratio of 40:1 showed higher ultimate tensile strength and higher elongation to failure. Beside that the oxidation layers were completely broken into pieces by high compressive and shear force. The main strengthening mechanism was grain refinement strengthening and homogeneous distribution of oxide precipitate. DEFORM-3D is a finite element method (FEM) software based on process simulation, specifically designed to analyze three-dimensional (3D) metal flows in the metal deforming process, to provide valuable process analysis data, and to analyze materials flow and temperature distribution related in the forming process. The extrusion through the porthole die resulting in a much better welding of the chips and revealed more than 80% higher ductility compared to the profiles extruded through a flat-face die.

Although the studies mentioned, white dross from primary aluminum production and from secondary recycling operations still contains useful quantities of aluminum which can be extracted industrially. Yasumasa Chino [19-20] defined the repeatedly recycled specimen would be severe deformation with a high density of dislocations by repeated machining process and dispersed oxide contaminations which inhibit the grain growth during hot extrusion. The oxide contamination level exceeds the permissible contamination concentration for a high formability. The recycled specimen exhibited superplastic behavior, but not to the as-received specimens. The recycled specimen showed diffusional necking, not premature fracture. However, the as-received specimen exhibited premature fracture. In recent years, related studies [21] making the chip more suitable for hot extrusion by increasing the density by cold press. High extrusion temperature makes the plastic flow of an extremely plastic matrix into pores and voids possible. For further study a robust design method will develop for reducing cost and improving quality in aluminum recycling. According to previous studies, a robust design is presented for improving productivity during an aluminum recycling process so that high-quality products can be produced at low cost. Then, with time consideration, as complexity in dynamics of hot extrusion processes, increased substantially, researchers and practitioners have focused on mathematical modeling techniques to determine optimal or near-optimal process condition(s) with respect to various objectives and responses criteria. Therefore, modeling and optimization technique called response surface methodology (RSM) for example, could be used to provide optimal or near-optimal solutions to the overall optimization problem formulated, and subsequently implemented in actual hot extrusion process. The billet temperature, ram speed and time preheat are the primary process variable that determine the quality of the extrude aluminum profile and the productivity of the extrusion process. The optimization of the extrusion process concerns the interplay between these three variables in the relation to the extrudate temperature and the constant extrusion pressure. From the summary as shown in Table 1, it shows that among the best parameters chosen in the hot extrusion process include preheat time, preheat temperature and ram speed.

Table 1 : Summary of Extrusion Process Parameter (Preheat Time vs Preheat Temperature vs Ram Speed) for Improving Extrusion Quality

No	Parameter	Author	V.Guley (2013)	M.Haase (2012)	Cunsheng Z (2012)	Hu Moa-liang (2012)	Wojciech Z. (2012)	Tielei Zhang (2011)	Hu Moa-liang (2010)	A.E. Tekkaya (2009)	Shuyan Wu (2009)	M. Schikorra (2008)	Hu Moa-liang (2008)	Yasumasa C. (2006)	Yasumasa C. (2005)	Yasumasa C. (2004)	J.B. Fogagnolo (2003)	J.Z.Gronostajski (1997)	Mamoru M. (1995)	Parameter Summary	Conclusion/ Remark
		Material	AA6060	AA6060	AA6063	Mag. All AZ91D	AA6060	Mag. All AZ31B	Mag. All AZ91D	AA6060	Mag. All AZ31B	AlMgSi0	Mg-Alll AZ31	Mg-Alll AZ31	Mg-Al-Ca Alloy	AA5083	AA6061	Aluminm Alloy	Mag. All AZ91	AA 6061	
1.	Preheat Temp. (°C)	300																			
		350																			
		400											√								
		450					√	√	√											√	Temperature Frequently/ Increase UTS
		500	√							√											
		550		√								√									
2.	Process Temp. (°C)	300				√									√				√		
		350				√					√										
		400				√					√			√	√				√		
		450		√	√	√					√	√				√				√	Temperature Frequently/ Increase UTS
		500															√	√	√		
		550		√																	
3.	Preheat Time (min@ hour)	20 min							√		√		√							√	Common Preheat Time
		50 min															√				
		1 hour																			
		2 hours	√																		
		3 hours																			
		6 hours		√																	
4.	Ram Speed (mm/s)	0.1						√													
		0.15			√				√												
		1	√	√	√		√			√		√						√	√	√	Common Speed/ Good surface
		1.2			√	√															
		2																			
		3										√									

The common extrusion parameters used by many researchers are highlighted in the column of parameter summary. When the billet temperature is low, the initial temperature rise is affected by the ram speed. The common preheat temperature is used by previous researcher is 450°C. For frequently temperature process conditions commonly used are 450°C controlling in the extrusion container area. Another essential point is common preheat time was used 20 minutes, but some researcher investigates preheat time by 2 hours and 6 hours depend on the material. Commonly, many researchers used ram speed of 1 mm/s on hot extrusion process. By the maximum extrusion speed, is one the most significant factors influencing the cost and efficiency of the extrusion process. Recently, researchers found that several subjects need further investigation for instance aluminum extrusion dies, including die technology, computer design, finite element analysis (FEA), die bearings and metal flow, die bearing surfaces, design systems and treatments, hollow dies and special die design factor.

7. Conclusion

In this paper, summarizing the literatures published in the academic journals, the recyclability requirements are;

a) Previously finding shows that even though many researchers used process temperature at 450°C for extrusion process, but still there is a gap for improving the whole process by selecting other temperature.
b) For Aluminum Alloy, higher ram speed or extrusion ratio for the ECAP die led to a slight decrease of strength and ductility for the extrusion due to higher deformation temperature.
c) Extrusion process technology research is continuously improving in many areas including increasing extrusion speed, extrusion with constant mechanical properties, improving productivity and quality, and the extrusion of new alloys with improved strength-to-weight ratio, especially in the aircraft industry.
d) The extrusion process is also affected by the strength of

the material, with are a combination of optimum ram speed, preheat temperature and preheat time.

e) The principle of processing wrought alloys is temperature and ram speed. The workability at elevated temperature, extrusion ratio and grain size on mechanical properties were investigated and they were the dependent variables.

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