THE ANALYSIS OF LIFE CYCLE ASSESSMENT AND LIFE CYCLE COSTING IN DIRECT RECYCLING HOT PRESS FORGING OF ALUMINIUM AA7075

NASHA EMIEZA BINTI RUHAIZAT

A thesis submitted in
fulfillment of the requirement for the award of the
Doctor of Philosophy

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

FEBRUARY 2023

For my beloved family and dearly friends,

So verily, with the hardship, there is relief.
Indeed in the hardship, there is relief.
So when you have finished, then stand up for Allah worship.
And to your Lord turn all your incovation.
(Al-Inshirah: 5-8)

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis. Special appreciation goes to my supervisor, Ts. Dr. Nur Kamilah binti Yusuf and my co-supervisor, Professor Dr. Mohd Amri Lajis for their supervision and constant support. His/her pursuit and passion for doing research are unstoppable and inspired me in implementing this project.

Heartfelt acknowledgement was expressed to my late father, Ruhaizat bin Ismail and my mother, Norasiah binti Awang, and my siblings, Mrs Nasha Amira binti Ruhaizat and Ms Nasha Nadia binti Ruhaizat. Without their support, encouragement, guidance and advice, I may never have made it through this arduous journey in my studies. When I felt down, their love gave me the fortitude to confront all the issues and obstacles that occurred.

I would like to express my sincere thanks and gratitude to my fellow friends in the post-graduate room for their friendly cooperation and moral support. In this regard, I am especially thankful to Ms Siti Nur Shuhada binti Jamal and Mr. Ikhwan Shah Tisadi bin Tukiat. Hopefully, they will succeed in their studies and career. I gratefully acknowledge the main financial support of the Ministry of Higher Education (MOHE), Malaysia for funding this project through the Fundamental Research Grant Schemes (FRGS/1/2019/TK09/UTHM/03/1).

There are countless people without whom the investigation would be difficult to conduct, both directly and indirectly. I would like to acknowledge all the Sustainable Manufacturing and Recycling Technology, Advanced Manufacturing and Materials Center (SMART-AMMC) members. May Allah bless all of us with guidance and grace in this life and hereafter. Amin.

ABSTRACT

Aluminium is the second largest used metal after iron which contributes a large impact on the environment. Recycling is a well-known method for mitigating the environmental impacts of aluminium production. However, the conventional recycling approach requires high energy consumption for remelting scrap and involves many operations which can increase the cost. Therefore, solid state direct recycling has been implemented to reduce energy and material consumption. It is essential to produce an aluminium billet that possesses superior functional performance as well as minimizes the environmental impact and economic cost. For this purpose, this study investigated the effect of the hot press forging (HPF) process parameter on the functional performance of recycled AA7075 billet. In addition, the analysis of life cycle assessment (LCA) and life cycle costing (LCC) approach were used to compare the environmental impact and economic cost of aluminium recycling routes between remelting and HPF process. The response surface methodology (RSM) and the desirability function were implemented in this study to optimise the aluminium recycling condition of AA7075 aluminium alloys. The study of DR-HPF shows that the optimum parameter for AA7075 aluminium alloy based on statistical optimization by RSM is 480°C forging temperature and 85.56 minutes holding time with 0.780 desirabilities. The maximum process parameter of recycled specimens is comparable to the theoretical ASM AA7075. Compared to the remelting process, the HPF method significantly reduces GWP and manufacturing costs by up to 85.26 % and 82.46 %, respectively. The potential of the HPF process as an alternative approach in terms of environmental impact reduction and functional performance offered for recycling AA7075 aluminium scrap has been demonstrated.

ABSTRAK

Aluminium adalah logam terpakai kedua terbesar selepas besi yang menyumbang impak besar kepada alam sekitar. Kitar semula ialah kaedah yang terkenal untuk mengurangkan kesan alam sekitar pengeluaran aluminium. Walau bagaimanapun, pendekatan kitar semula konvensional memerlukan penggunaan tenaga yang tinggi untuk mencairkan semula sekerap dan melibatkan banyak operasi yang boleh meningkatkan kos. Oleh itu, kitar semula langsung keadaan pepejal telah dilaksanakan untuk mengurangkan penggunaan tenaga dan bahan. Ianya penting untuk menghasilkan bilet aluminium yang mempunyai prestasi fungsian yang unggul serta meminimumkan kesan alam sekitar dan kos ekonomi. Untuk tujuan ini, kajian ini menyiasat kesan parameter proses penempaan tekan panas (HPF) ke atas prestasi fungsi kitar semula AA7075 bilet. Di samping itu, pendekatan penilaian kitaran hayat bersepadu (LCA) dan kos kitaran hayat (LCC) telah digunakan untuk membandingkan kesan alam sekitar dan kos ekonomi antara proses pencairan semula dan HPF. Metodologi permukaan tindak balas (RSM) dan fungsi keinginan telah dilaksanakan dalam kajian ini untuk mengoptimumkan keadaan kitar semula aluminium aloi AA7075. Kajian DR-HPF menunjukkan bahawa parameter optimum untuk aloi aluminium AA7075 berdasarkan pengoptimuman statistik oleh RSM ialah suhu penempaan 480°C dan masa penahanan 85.56 minit dengan 0.780 kemahuan. Maksimum parameter untuk kitar semula spesimen adalah setanding dengan teori ASM AA7075-O. Jika dibandingkan dengan proses pencairan semula, kaedah HPF memberikan pengurangan ketara dalam GWP dan kos pembuatan masing-masing sehingga 85.26% dan 82.46%. Potensi proses HPF sebagai pendekatan alternatif dari segi pengurangan kesan alam sekitar dan prestasi fungsi yang ditawarkan untuk mengitar semula sekerap aluminium AA7075 dapat ditunjukkan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ABD	-	Aluminium Black Dross
AC	-	Acidification
ADP	-	Abiotic Depletion Potential
AHP	-	Analytical Hierarchy Process
AMMC	-	Advanced Material and Manufacturing Center
ANOVA	-	Analysis of Variance
C_2F_6	-	Hexafluoroethane
CaF_2	-	Calcium Fluoride
CF_4	-	Carbon tetrafluoride
CCD	-	Central Composite Design
CH_4	-	Methane
CO_2	-	Carbon Dioxide
CTP	-	Compressive Torsion Process
$CuAl_2$	-	Copper Aluminide
CR	-	Conventional Recycling
DF	-	Desirability Function
DR	-	Direct Recycling
EAA	-	European Aluminium Association
ECAP	-	Equal Channel Angular Pressing Angular Process
EDX	-	Energy Dispersive X-ray
ELCC	-	Environmental Life Cycle Costing
EWC	-	European Waste Catalogue
FESEM	-	Field Emission Scanning Electron Microscope
FSC	-	Friction Stir Consolidation
f.u	-	Functional unit
GHGs	-	Greenhouse Gasses
g/cm^3	-	Gram per cubic centimetre

GWP	-	Global Warming Potential
HPF	-	Hot Press Forging
HPT	-	High-pressure Torsion
HFCs	-	Hydrofluorocarbons
HH	-	Human Health
H_2	-	Hydrogen
H_2S	-	Hydrogen Sulfide
IAI	-	International Aluminium Institute
JAS	-	Jabatan Alam Sekitar
ISO	-	International Organization for Standardization
KCl	-	Potassium Chloride
kWh	-	Kilowatt-hour
LCA	-	Life Cycle Assessment
LCC	-	Life Cycle Cost
$LCCO_2$	-	Life Cycle Carbon Dioxide
LCE	-	Life Cycle Engineering
LCEA	-	Life Cycle Energy Analysis
LCI	-	Life Cycle Inventory
LCIA	-	Life Cycle Impact Assessment
LCM	-	Life Cycle Management
LCSA	-	Life Cycle Sustainability Assessment
LOM	-	Light Optical Microscope
MADM	-	Multi-attribute Decision Making
MAETP	-	Marine Aquatic Ecotoxicity Potential
MCDA	-	Multi-criteria Decision Analysis
Mg_2Si	-	Magnesium Silicide
Mpa	-	Megapascal
Mt	-	Metric tons
MYR	-	Malaysian Ringgit
Na_3AlF_6	-	Cryolite
NaCl	-	Sodium Chloride
NH_3	-	Ammonia
NMP	-	Non-metallic Product

N_2O	-	Nitrous Oxide
PFCs	-	Perfluorocarbons
PH_4	-	Phosphonium
PECS	-	Pulsed Electric Current Sintering
POCP	-	Photochemical Oxidant Creation Potential
POF	-	Photochemical ozone formation
REPA	-	Resource and Environmental Profile Analysis
RSM	-	Response Surface Methodology
SSR	-	Solid State Recycling
SDR	-	Semi Direct Recycling
SETAC	-	Society Environmental Toxicology and Chemistry
SHT	-	Solution Heat Treatment
SMART	-	Sustainable Manufacturing and Recycling Technology
SPS	-	Spark Plasma Sintering
TETP	-	Terrestrial Ecotoxicity Potential
T_m	-	Melting Point
TNB	-	Tenaga Malaysia Berhad
TGA	-	Thermo-gravimetric Analysis
TOPSIS	-	Technique for Order of Preference by Similarity to Ideal Solution
UTM	-	Universal Testing Machine
UTS	-	Ultimate Tensile Stress
UTHM	-	Universiti Tun Hussein Onn Malaysia
WSM	-	Weight-sum model
WBCSD	-	World Business Council for Sustainable Development
Wt%	-	Weight %
YS	-	Yield Strength
°C	-	Degree Celcius

CHAPTER 1

INTRODUCTION

The continuous growth of aluminium alloy demand has led to a rise in the quantity of aluminium scrap (Gancarczyk, Nowotnik, & Boczkal, 2021). The production of raw materials requires an enormous amount of energy and generates a substantial amount of carbon dioxide emissions annually (Ho et al., 2020; Baffari et al., 2019). Approximately 93 % of carbon dioxide can be reduced through the production of secondary aluminium (Yasinskiy et al., 2021). Recycling aluminium may conserve energy and resources, delaying the depletion of virgin resources (Söderholm & Ekvall, 2019).

Current practices in metal recycling plants involve turning aluminium scraps into a molten state known as conventional recycling (CR) (Paraskevas et al., 2012). However, the CR process is inefficient in terms of energy consumption, produces toxic gases and causes permanent metal loss during remelting (Wagiman et al., 2020; Baffari et al., 2019; Wan et al., 2017). Thus, solid state by direct recycling hot press forging (DR-HPF) has been selected in this study. HPF has fewer steps since the intermediary processes of ball-milling and cold-compacting are eliminated, as well as lower cost and energy consumption because the process occurs above the recrystallization temperature (Ahmad et al., 2016; Ahmad, Lajis, & Yusuf, 2017; Khamis, Lajis, & Albert, 2015).

Aside from environmental concerns, economic concerns have also been raised about sustainability. This issue is frequently manifested by an increase in raw material, electricity and gas. Therefore, it is crucial to focus on developing a sustainable strategy for aluminium shaping industries that emphasises promoting cost, energy and resource efficiency by utilizing life cycle assessment (LCA) and life cycle cost (LCC).

1.1 Background of Study

Over the last 20 years, there has been a surge in sustainability publications. The three-pillar concept of sustainability consists of environmental, economic and social, commonly depicted by three intersections circles with overall sustainability at the centre (Purvis, 2019). In addition, the public has been paying attention to how industries affect the environment, and discussions about sustainable behaviour and climate change are on the international agenda (Luthin, Backes, & Traverso, 2021). For decades, European Union policy has aimed at minimising waste, lowering the emission of hazardous toxic to the environment and limiting the environmental impact (Hughes, 2017). As a result, the demand for sustainable raw materials and finished goods has intensified throughout the supply chain.

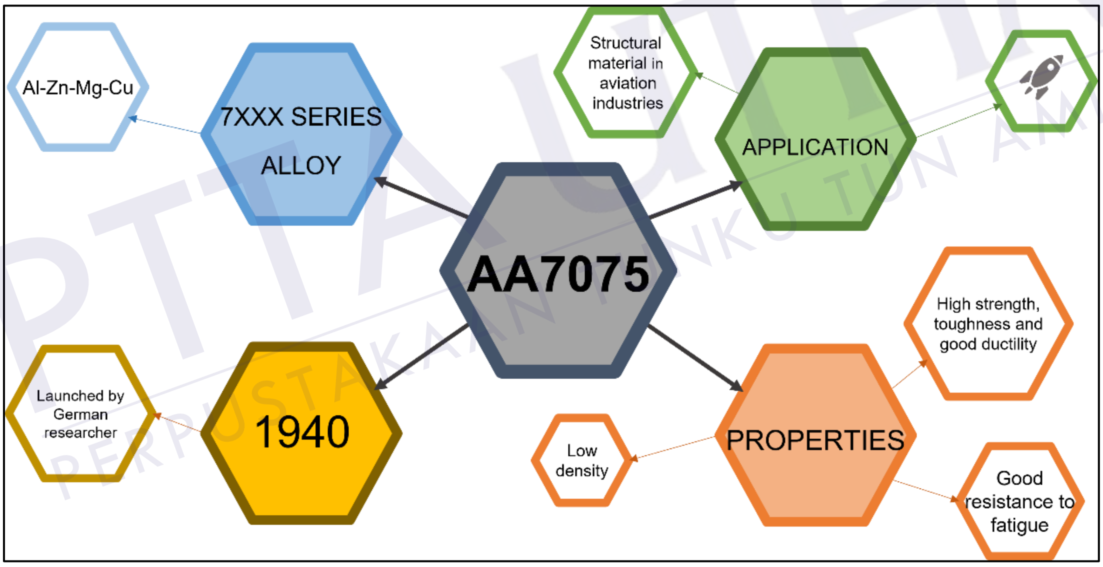

Figure 1.1: Infographic of AA7075 aluminium alloy

Figure 1.1 illustrates the infographic of AA7075 aluminium alloy. There are various types of aluminium alloys. Al-Zn-Mg-Cu alloys, categorized as 7XXX series aluminium alloys, have been widely used as structural materials in aeronautical industries (Aziz, 2018). German researchers commercially launched them in 1940 (Kiliç et al.2020). Aluminium alloy AA7075 is widely used in the aerospace industry due to their attractive properties such as high strength, ductility, low density, toughness and resistance to fatigue, and their favourable strength-to-weight ratio and corrosion resistance compared to conventional stainless steels (Aziz, 2018).

Aluminium is the third most abundant element on earth which does not exist in nature as a free element (Abdulkadir, Ajayi, & Hassan, 2015). Nonetheless, aluminium is the second-largest used metal after iron (Mahinroosta & Allahverdi, 2018). According to the statistic forecasting aluminium consumption from 2021 to 2029, with a compound annual growth rate of 2.6 %, global aluminium consumption is projected to reach approximately 64.2 million metric tonnes in 2021 (Statista, 2022b). China is by far the world's largest producer of aluminium, with a record 37.08 million tonnes produced in 2020 (Staff, 2021). However, its government intends to limit yearly smelting capacity to 45 million tonnes, and companies are aiming to recycle more scrap metal instead, under pressure to reduce emissions.

Table 1.1 shows the details of the aluminium production for Southeast Asian nations. From the data, Malaysia, Indonesia and Singapore produce approximately 908, 220.6,51.1 thousand metric tonnes respectively. Thailand does not produce primary aluminium while used secondary approximately 22.6 thousand metric tonnes of secondary aluminium

.

Table 1.1: The details of aluminium production for Southeast Asian nations

Country	**Details of aluminium production**	**Year**	**Source**
Malaysia	Approximately 908 thousand metric tonnes	2021	(Müller, 2022)
Indonesia	Approximately 220.6 thousand metric tonnes	2021	(Statista, 2022c)
Singapore	Approximately 51.1 thousand metric tonnes	2021	(Statista, 2022a)
Thailand	Thailand does not directly produce aluminium from upstream sources. Instead, aluminium scrap is recycled. Approximately 22.6 thousand metric tonnes of secondary aluminium	2020	(Manakitsomboon, 2021; Thaimetal aluminium, 2022)

It is found that aluminium production is an energy-intensive process. It produces a lot of black dross during remelting or refining of aluminium and creates hazardous waste that poses a major threat and challenge to the aluminium industry (Abdulkadir et al., 2015). Table 1.2 shows the distribution of waste produced by the aluminium industry according to the European Waste Catalogue (EWC). Table 1.2 shows hazardous waste produced by the aluminium industry coded 100304, 100308, 100309, 100315, 100317, 100319, 100321, 100323, 100325, 100327 and 100329. By referring to Table 1.2, the hazardous waste type with code numbers 100304, 100308, 100309 and 100321 has contributed a significant amount of hazardous waste to the aluminium industry.

Table 1.2: The hazardous wastes type from the aluminium industry according to the European Waste Catalogue (Mahinroosta & Allahverdi, 2018)

Hazardous waste type	**Code**
Slag from primary production	100304
Salt slag from secondary production	100308
Black dross from secondary production	100309
Dross that emits flammable gases in dangerous quantities in contact with water	100315
Tar-containing waste from anode production	100317
Flue gas dust containing hazardous materials	100319
Dust and other particulates comprising hazardous materials	100321
Solid wastes from processing the gas comprising hazardous materials	100323
Filter sludge and cake from processing gas containing hazardous materials	100325
The waste from cooling water treatment containing oil	100327
Hazardous waste from salt slag/black dross processing	100329

Aluminium recycling practices have been debated for many years back, since the 1900s. Aluminium recycling emits only 5% of greenhouse gas and utilizes 95% less energy than primary aluminium production (Wagiman et al., 2020). Primary aluminium manufacturing uses between 174 to 186 Megajoules per kilogram, whereas secondary production uses between 10 to 20 Megajoules per kilogram (Green, 2007). Secondary aluminium production requires less energy due to its raw materials consisting of aluminium scrap and primary metallic aluminium scrap. (Tsakiridis & Oustadakis, 2013). Therefore, aluminium is manufactured through two different pathways in which primary aluminium production by alumina is extracted from bauxite ore and secondary aluminium production by aluminium scrap (Tsakiridis & Oustadakis, 2013).

Currently, two major non-ferrous metal recycling techniques have been proposed; conventional recycling (CR) and solid-state recycling (SSR). The CR technique involves remelting the scrap and casting it into new products. As for CR techniques, several remarkable problems are listed as follows (Wan et al., 2017):

i. High metal loss due to the high chemical reactivity and large specific metal surface area.
ii. Toxic gases are produced by the combustion of the oil emulsion adhering to the chips.
iii. High energy consumption and processing costs.

REFERENCES

Abdulkadir, A., Ajayi, A., & Hassan, M. I. (2015). Evaluating the Chemical Composition and the Molar Heat Capacities of a white Aluminum Dross. *Energy Procedia*, *75*, 2099–2105. https://doi.org/10.1016/j.egypro.2015.07.326

Abdullah, W., Mohammad Sukri, M., Mohd Amri, L., Shazarel, S., Mohd Idrus, M. M., & Mohammed, H. R. (2020). Direct recycling of aluminium chips into composite reinforced with in situ alumina enrichment. *Materials Science Forum*, *975 MSF*, 165–170. https://doi.org/10.4028/www.scientific.net/MSF.975.165

Achillas, C., & Vlachokostas, C. (2020). Life cycle thinking : towards the sustainable management of resources in aluminium production. *Euro-Mediterranean Journal for Environmental Integration*, *3*. https://doi.org/10.1007/s41207-020-00153-3

Ahmad, A., Lajis, M. A., Yusuf, N. K., Shamsudin, S., & Zhong, Z. W. (2017). Parametric optimisation of heat treated recycling aluminium (AA6061) by response surface methodology. *AIP Conference Proceedings*, *1885*(Egm), 1–7. https://doi.org/10.1063/1.5002240

Ahmad, A., Lajis, M. A., Yusuf, N. K., & Wagiman, A. (2016). Hot press forging as the direct recycling technique of aluminium- A review. *ARPN Journal of Engineering and Applied Sciences*, *11*(4), 2258–2265.

Ahmad, Azlan, Lajis, M. A., Shamsudin, S., & Yusuf, N. K. (2018). Conjectured the behaviour of a recycled metal matrix composite (MMC-AlR) developed through hot press forging by means of 3D FEM simulation. *Materials*, *11*(6). https://doi.org/10.3390/ma11060958

Ahmad, Azlan, Lajis, M. A., & Yusuf, N. K. (2017). On the role of processing parameters in Producing recycled aluminum AA6061 based metal matrix composite (MMC-AlR) prepared using hot press forging (HPF) process. *Materials*, *10*(9). https://doi.org/10.3390/ma10091098

Ahmad, Azlan, Lajis, M. A., Yusuf, N. K., & Ab Rahim, S. N. (2020). Statistical optimization by the response surface methodology of direct recycled aluminum-alumina metal matrix composite (MMC-AlR) employing the metal forming process. *Processes*, *8*(7). https://doi.org/10.3390/pr8070805

Al-alimi, S., Amri, M., Shamsudin, S., & Kamilah, N. (2021). Development of Hot Equal Channel Angular Processing (ECAP) Consolidation Technique in the Production of Boron Carbide (B4C) -Reinforced Aluminium Development of Hot Equal Channel Angular Processing (ECAP) Consolidation Technique in the Production of Boron. *Int. Journal of Renewable Energy Development*, (August). https://doi.org/10.14710/ijred.2021.33942

Al-Alimi, S., Lajis, M. A., Shamsudin, S., Chan, B. L., Mohammed, Y., Ismail, A. E., & Sultan, N. M. (2020). Development of metal matrix composites and related forming techniques by direct recycling of light metals: A review. *International Journal of Integrated Engineering*, *12*(1), 144–171.

Al-alimi, S., Lajis, M. A., Shamsudin, S., Yusuf, N. K., Chan, B. L., Hissein, D. D., … Sabbar, H. M. (2021). Hot extrusion followed by a hot ecap consolidation combined technique in the production of boron carbide *(B4C)* reinforced with aluminium chips (AA6061) composite. *55*(3), 347–354. https://doi.org/10.17222/mit.2020.177

Al-Alimi, S., Mohd Amri Lajis, Shamsudin, S., Yusuf, N. K., Altharan, Y., Didane, D. H., … Msebawi, M. S. (2022). Effects of Preheating Temperature on Deformed AA6061 Aluminium Properties of Hot Equal Channel Angular Pressing (ECAP) by Using Deform-3D Software. *Arabian Journal for Science and Engineering*. https://doi.org/10.1007/s13369-022-07149-x

Albuquerque, T. L. M., Mattos, C. A., Scur, G., & Kissimoto, K. (2019). Life cycle costing and externalities to analyze circular economy strategy : Comparison between aluminum packaging and tinplate. *Journal of Cleaner Production*, *234*, 477–486. https://doi.org/10.1016/j.jclepro.2019.06.091

Alimi, S. Al, Shamsudin, S., Yusuf, N. K., Lajis, M. A., Zhou, W., Didane, D. H., … Harun, Z. (2022). Recycling Aluminium AA6061 Chips with Reinforced Boron Carbide (B4C) and Zirconia (ZrO2) Particles via Hot Extrusion. *Metals*.

Altan, T., & Ngaile, G. (2005). Cold and Hot Forging. In *ASM International*.

American Society for Testing and Materials E384. (2017). Standard Test Method for Microindentation Hardness of Materials. *An American National Standard*. https://doi.org/10.1520/E0384-17

American Society for Testing and Materials E8/E8M. (2016). *Standard Test Methods for Tension Testing of Metallic Materials*. 0–30. https://doi.org/10.1520/E0008

Amienyo, D., & Azapagic, A. (2016). Life cycle environmental impacts and costs of beer production and consumption in the UK. *Int J Life Cycle Assess*, *21*, 492–509. https://doi.org/10.1007/s11367-016-1028-6

Amini Mashhadi, H., Moloodi, A., Golestanipour, M., & Karimi, E. Z. V. (2009). Recycling of aluminium alloy turning scrap via cold pressing and melting with salt flux. *Journal of Materials Processing Technology*, *209*(7), 3138–3142. https://doi.org/10.1016/j.jmatprotec.2008.07.020

Ardika, R. D., Triyono, T., Muhayat, N., Ardika, R. D., Triyono, T., & Muhayat, N. (2021). A review porosity in aluminum welding. *Procedia Structural Integrity*, *33*(2019), 171–180. https://doi.org/10.1016/j.prostr.2021.10.021

ASM International Handbook Committee. (2005). *Forging of Aluminum Alloys* (Vol. 14A). https://doi.org/10.1016/0025-5416(79)90198-8

ASM International Handbook Committee. (2006a). *Forming and Forging* (Vol. 14).

ASM International Handbook Committee. (2006b). *Volume 14* (Vol. 14). ASM international.

ASM International Handbook Committee volume 4. (1991). *Heat Treating of Aluminum Alloys* (Vol. 4). https://doi.org/10.1361/asmhba000

ASM Material Data Sheet. (n.d.-a). ASM Aerospace Specification Metals.

ASM Material Data Sheet. (n.d.-b). ASM Aerospace Specification Metals Inc. Retrieved September 5, 2022, from Matweb website: https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA7075O

ASM Material Data Sheet. (n.d.-c). Retrieved February 20, 2023, from https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA7075O

ASTM E3. (1995). Standard Practice for Preparation of Metallographic Specimens. *An American National Standard*, *03*(March).

ASTM E340. (1995). Standard Test Method for Macroetching Metals and Alloys. *American Society for Testing and Materials*.

ASTM E8M. (2004). *Standard Test Methods for Tension Testing of Metallic Materials [Metric]*.

Atadashi, I. M., Aroua, M. K., Abdul Aziz, A. R., & Sulaiman, N. M. N. (2012). High quality biodiesel obtained through membrane technology. *Journal of Membrane Science*, *421–422*, 154–164. https://doi.org/10.1016/j.memsci.2012.07.006

Aziz, S. J. (2018). *Study the Effects of Microwave Furnace Heat on The Mechanical Properties and Estimated Fatigue life of AA 7075-T73 with Oil and salt solution Treatments*. (1).

Badarulzaman, N. A., Karim, S. R., & Lajis, M. A. (2014). Fabrication of Al-Sn composites from direct recycling aluminium alloy 6061. *Applied Mechanics and Materials*, *465–466*, 1003–1007. https://doi.org/10.4028/www.scientific.net/AMM.465-466.1003

Baffari, D., Reynolds, A. P., Masnata, A., Fratini, L., & Ingarao, G. (2019). Friction stir extrusion to recycle aluminum alloys scraps : Energy efficiency characterization. *Journal of Manufacturing Processes*, (February). https://doi.org/10.1016/j.jmapro.2019.03.049

Bertram, M., Martchek, K. J., & Rombach, G. (2009). Material Flow Analysis in the Aluminum Industry. *Industrial Ecology*, *13*(5), 650–654. https://doi.org/10.1111/j.1530-9290.2009.00158.x

Boin, U. M. J., & Bertram, M. (2005). Melting Standardized Aluminum Scrap : A Mass Balance Model for Europe. *Minerals, Metals and Materials Society*, *57*(8), 26–33.

Brogaard, L. K., Damgaard, A., Jensen, M. B., Barlaz, M., & Christensen, T. H. (2014). Resources , Conservation and Recycling Evaluation of life cycle inventory data for recycling systems. *"Resources, Conservation & Recycling," 87*, 30–45. https://doi.org/10.1016/j.resconrec.2014.03.011

Brough, D., & Jouhara, H. (2020). The aluminium industry : A review on state-of-the-art technologies , environmental impacts and possibilities for waste heat recovery. *International Journal of Thermofluids*, *2*. https://doi.org/10.1016/j.ijft.2019.100007

Buffa, G., Baffari, D., Ingarao, G., & Fratini, L. (2020). Uncovering Technological and Environmental Potentials of Aluminum Alloy Scraps Recycling Through Friction Stir Consolidation. *International Journal of Precision Engineering and Manufacturing - Green Technology*, (0123456789). https://doi.org/10.1007/s40684-019-00159-5

Calder, G. V., & Stark, T. D. (2010). *Aluminum Reactions and Problems in Municipal Solid Waste Landfills*. (October), 258–265.

Castro, M. B. G., Remmerswaal, J. A. M., Reuter, M. A., & Boin, U. J. M. (2004). A thermodynamic approach to the compatibility of materials combinations for recycling. *Resources, Conservation & Recycling*, *43*, 1–19. https://doi.org/10.1016/j.resconrec.2004.04.011

Chan, B. L., & Lajis, M. A. (2015). Direct recycling of aluminium 6061 chipThrough cold compression. *International Journal of Engineering and Technology*, *15*(4), 43–47.

Chang, L., Yuan, S., Huang, X., & Cai, Z. (2023). Determination of Johnson-Cook damage model for 7xxx laminated aluminum alloy and simulation application. *Materials Today Communications*, *34*, 105224. https://doi.org/10.1016/J.MTCOMM.2022.105224

Chiba, R., Nakamura, T., & Kuroda, M. (2011). Solid-state recycling of aluminium alloy swarf through cold profile extrusion and cold rolling. *Journal of Materials Processing Technology*, *211*(11), 1878–1887. https://doi.org/10.1016/j.jmatprotec.2011.06.010

Choi, S. K., Chun, M. S., Tyne, C. J. Van, & Moon, Y. H. (2006). *Optimization of open die forging of round shapes using FEM analysis*. *172*, 88–95. https://doi.org/10.1016/j.jmatprotec.2005.09.010

Ciroth, A., Franze, J., & Berlin, G. (2009). *Life Cycle Costing in SimaPro*. (August), 1–10.

Ciroth, A., Huppes, G., Klöpffer, W., Rüdenauer, I., Steen, B., & Thomas Swarr. (2008). *Environmental Life Cycle Costing* (and G. R. David Hunkeler, Kerstin Lichtenvort, Ed.). Webster, New York, USA Boca: SETAC Publications.

Cislo, C. N., Kronthaler, B., Buchmayr, B., & Weiß, C. (2020). Solid state recycling of aluminum alloy chips via pulsed electric current sintering. *Journal of Manufacturing and Materials Processing*, *4*(1). https://doi.org/10.3390/jmmp4010023

Crowley, D., Staines, A., Collins, C., Bracken, J., Bruen, M., Fry, J., … This. (2003). Health and Environmental Effects of Landfilling and Incineration of Waste - A Literature Review. In *health research board*.

Daneshpayeh, S., Ashenai Ghasemi, F., Ghasemi, I., & Ayaz, M. (2016). Predicting of mechanical properties of PP/LLDPE/TiO2 nano-composites by response surface methodology. *Composites Part B: Engineering*, *84*, 109–120. https://doi.org/10.1016/j.compositesb.2015.08.075

David, E., & Kopac, J. (2013). Aluminum recovery as a product with high added value using aluminum hazardous waste. *Journal of Hazardous Materials*, *261*, 316–

324. https://doi.org/10.1016/j.jhazmat.2013.07.042

Derringer, G., & Suich, R. (1980). Simultaneous Optimization of Several Response Variables. *Journal of Quality Technology*, *12*(4), 214–219. https://doi.org/10.1080/00224065.1980.11980968

Doege, E., & Bohnsack, R. (2000). *Closed die technologies for hot forging*. *98*, 165–170.

Duflou, J. R., Tekkaya, A. E., Haase, M., Welo, T., Vanmeensel, K., Kellens, K., … Paraskevas, D. (2015). Environmental assessment of solid state recycling routes for aluminium alloys : Can solid state processes significantly reduce the environmental impact of aluminium recycling ? *CIRP Annals - Manufacturing Technology*, 8–11. https://doi.org/10.1016/j.cirp.2015.04.051

Dzurˇnák, R., Augustín Varga, J. K., Jablonský, G., & Lukáˇ, L. (2019). Influence of Burner Nozzle Parameters Analysis on the Aluminium Melting Process. *Applied Sciences*, *9*(1614).

EAA. (2013). Environmental Profile Report for the European Aluminium Industry April 2013- Data for the year 2010 Life Cycle Inventory data for aluminium production and transformation processes in Europe. In *European Aluminium Association*. Retrieved from https://european-aluminium.eu/media/1329/environmental-profile-report-for-the-european-aluminium-industry.pdf

ecoinvent Database - ecoinvent. (n.d.). Retrieved February 20, 2023, from https://ecoinvent.org/the-ecoinvent-database/

European Aluminium Refiners and Remelters. (2012). *Aluminium Recycling in Europe: The Road to High Quality Products*.

Fogagnolo, J. B., Ruiz-Navas, E. M., Simón, M. A., & Martinez, M. A. (2003). Recycling of aluminium alloy and aluminium matrix composite chips by pressing and hot extrusion. *Journal of Materials Processing Technology*, *143–144*(1), 792–795. https://doi.org/10.1016/S0924-0136(03)00380-7

Franchetti, M. J., & Apul, D. (2013). *Carbon Footprint Analysis - Concepts, Methods, Implementation and Case Studies*.

Fuziana, Y. ., Warikh, A. R. ., Lajis, M. ., Azam, M. ., & Muhammad, N. . (2014). *Recycling aluminium (Al 6061) chip through powder metallurgy route*. *18*(Al 6061), 354–358.

Gancarczyk, K., Nowotnik, A., & Boczkal, G. (2021). Microstructure and Properties of As-Cast and Heat-Treated 2017A Aluminium Alloy Obtained from Scrap Recycling. *Materials*.

Gentil, E. C., Damgaard, A., Hauschild, M., Finnveden, G., Eriksson, O., Thorneloe, S., … Christensen, T. H. (2010). Models for waste life cycle assessment : Review of technical assumptions. *Waste Management*, *30*(12), 2636–2648. https://doi.org/10.1016/j.wasman.2010.06.004

GHG Protocol. (2016). Global Warming Potential Values. *Greenhouse Gas Protocol*, *2014*(1995), 1–4. Retrieved from https://www.ghgprotocol.org/site

Gielen, D., & Kram, T. (1998). *The Role of Non-CO 2 Greenhouse Gases in Meeting Kyoto Targets 1 Western European emissions*. 17–18.

Gobikannan, N., Senthilkumar, T., & Amizharasan, S. (2014). Application of Response Surface Methodology and Firefly Algorithm for Optimizing Multiple Responses in Turning AISI 1045 Steel. *Arab J Sci Eng*, 8015–8030. https://doi.org/10.1007/s13369-014-1320-3

Goedkoop, M., Heijungs, R., Huijbregts, M., Schryver, A. De, Struijs, J., & Zelm, R. van. (2009). *ReCiPe 2008- A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level*.

Green, J. (2007). *Aluminum recycling and processing for energy conservation and sustainability*. ASM international, Material Park, OH.

Gronostajski, J., & Matuszak, A. (1999). Recycling of metals by plastic deformation: an example of recycling of aluminium and its alloys chips. *Journal of Materials Processing Technology*, *92–93*, 35–41. https://doi.org/10.1016/S0924-0136(99)00166-1

Gronostajski, J. Z., Kaczmar, J. W., Marciniak, H., & Matuszak, A. (1997). Direct recycling of aluminium chips into extruded products. *Journal of Materials Processing Technology*, *64*(1–3), 149–156. https://doi.org/10.1016/S0924-0136(96)02563-0

Gronostajski, J. Z., Marciniak, H., & Matuszak, A. (1996). Production of composites on the base of AlCu4 alloy chips. *Journal of Materials Processing Technology*, *60*(1–4), 719–722. https://doi.org/10.1016/0924-0136(96)02410-7

Groover, M. P. (2013). Fundamentals of Modern Manufacturing:Materials, Processes, and Systems. In *Journal of Chemical Information and Modeling* (Vol. 53).

Güley, V., Güzel, A., Jäger, A., Ben Khalifa, N., Tekkaya, A. E., & Misiolek, W. Z. (2013). Effect of die design on the welding quality during solid state recycling of AA6060 chips by hot extrusion. *Materials Science and Engineering A*, *574*, 163–175. https://doi.org/10.1016/j.msea.2013.03.010

Haase, M., Ben Khalifa, N., Tekkaya, A. E., & Misiolek, W. Z. (2012). Improving mechanical properties of chip-based aluminum extrudates by integrated extrusion and equal channel angular pressing (iECAP). *Materials Science and Engineering A*, *539*, 194–204. https://doi.org/10.1016/j.msea.2012.01.081

Han, Y. L., Gao, J., Yin, Y. Y., Jin, Z. Y., Xu, X. M., & Chen, H. Q. (2016). Extraction optimization by response surface methodology of mucilage polysaccharide from the peel of Opuntia dillenii haw. fruits and their physicochemical properties. *Carbohydrate Polymers*, *151*, 381–391. https://doi.org/10.1016/j.carbpol.2016.05.085

Hatayama, H., Daigo, I., Matsuno, Y., & Adachi, Y. (2012). Evolution of aluminum recycling initiated by the introduction of next-generation vehicles and scrap sorting technology. *Resources, Conservation and Recycling*, *66*, 8–14. https://doi.org/10.1016/j.resconrec.2012.06.006

Hauschild, M. Z., Goedkoop, M., Guinée, J., Heijungs, R., Huijbregts, M., Jolliet, O., … Sala, S. (2013). *Identifying best existing practice for characterization* *modeling in life cycle impact assessment*. 683–697. https://doi.org/10.1007/s11367-012-0489-5

Ho, C. S., Mohd Nor, M. K., Ma'at, N., Alaric Sim, K. Y., Ibrahim, M. N., Jamian, S., … Yusuf, N. K. (2020). Damage Initiation and Evolution Analysis of Hot Extruded Recycled Aluminium Alloys (AA6061). *Materials Science and Engineering*, *824*. https://doi.org/10.1088/1757-899X/824/1/012017

Ho, Choon Sin, & Mohd Nor, M. K. (2020). Characterization of deformation behaviour and fracture mode of recycled aluminium alloys (AA6061) subjected to high-velocity impact. *Journal of Mechanical Engineering and Sciences*, *14*(3), 7222–7234. https://doi.org/10.15282/jmes.14.3.2020.22.0567

Hughes, R. (2017). The EU Circular Economy package – life cycle thinking to life cycle law? *Procedia CIRP*, *61*, 10–16. https://doi.org/10.1016/j.procir.2016.12.006

Huijbregts, M. A. J., Steinmann, Z. J. N., Elshout, P. M. F., Stam, G., & Zelm, R. Van. (2017). ReCiPe2016 : a harmonised life cycle impact assessment method at midpoint and endpoint level. *The International Journal of Life Cycle Assessment*, 138–147. https://doi.org/10.1007/s11367-016-1246-y

Huijbregts MAJ, Steinmann ZJN, Elshout PMF, Stam G, V. F., & Vieira MDM, V. Z. R. (2016). ReCiPe 2016- A harmonized life cycle impact assessment method at midpoint and endpoint level Report I: Characterization. In *National Institute for Public Health and the Environment*.

Huo, W., Guo, M., Hou, L., Cui, H., Sun, T., Zhuang, L., & Zhang, J. (2014). Recrystallization behavior of high-strength AA 7075 alloy processed by new short-cycled thermo-mechanical processing. *Materials Science Forum*, *794–796*, 1269–1274. https://doi.org/10.4028/www.scientific.net/MSF.794-796.1269

Ingarao, G. (2017). Manufacturing strategies for efficiency in energy and resources use: The role of metal shaping processes. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.10.182

Ingarao, G., Baffari, D., Bracquene, E., Fratini, L., & Duflou, J. (2019). Energy demand reduction of aluminum alloys recycling through friction stir extrusion processes implementation. *Procedia Manufacturing*, *33*, 632–638. https://doi.org/10.1016/j.promfg.2019.04.079

Ingarao, G., Priarone, P. C., Deng, Y., & Paraskevas, D. (2018). Environmental modelling of aluminium based components manufacturing routes : Additive manufacturing versus machining versus forming. *Journal of Cleaner Production*, *176*, 261–275. https://doi.org/10.1016/j.jclepro.2017.12.115

Islam, H., Jollands, M., Setunge, S., & Ahmed, I. (2014). Life cycle assessment and life cycle cost implications of wall assemblages designs. *Energy & Buildings*, *84*, 33–45. https://doi.org/10.1016/j.enbuild.2014.07.041

Islam, M. A., Alam, M. R., & Hannan, M. O. (2012). Multiresponse optimization based on statistical response surface methodology and desirability function for the production of particleboard. *Composites Part B: Engineering*, *43*(3), 861–868. https://doi.org/10.1016/j.compositesb.2011.11.033

ISO 14040. (2006). *Environmental management - Life Cycle Assessment - Principles and framework. International Organization for Standardisation (ISO)*. Geneva, Switzerland.

ISO 14044. (2006). *Environmental Management - Life Cycle Assessment — Requirements and Guidelines. International Organization for Standardisation (ISO)*. Geneva, Switzerland.

Jamekhorshid, A., Sadrameli, S. M., & Bahramian, A. R. (2014). Process optimization and modeling of microencapsulated phase change material using response surface methodology. *Applied Thermal Engineering*, *70*(1), 183–189. https://doi.org/10.1016/j.applthermaleng.2014.05.011

Joshi, T. C., Prakash, U., & Dabhade, V. V. (2015). Microstructural development during hot forging of Al 7075 powder. *Journal of Alloys and Compounds*, *639*, 123–130. https://doi.org/10.1016/j.jallcom.2015.03.099

Kadir, M. I. A., Mustapa, M. S., Mahdi, A. S., Kuddus, S., & Samsi, M. A. (2017). Evaluation of hardness strength and microstructures of recycled Al chip and powder AA6061 fabricated by cold compaction method. *IOP Conference Series: Materials Science and Engineering*, *166*(1). https://doi.org/10.1088/1757-899X/165/1/012012

Kanetake, N., Kume, Y., Ota, S., & Morimoto, R. (2014). Upgrading in mechanical properties of high performance aluminum alloys by compressive torsion process. *Procedia CIRP*, *18*, 57–61. https://doi.org/10.1016/j.procir.2014.06.107

Khajouei-Nezhad, M., Paydar, M. H., Mokarizadeh Haghighi Shirazi, M., & Gubicza, J. (2019). Microstructure and Tensile Behavior of Al7075/Al Composites Consolidated from Machining Chips Using HPT: A Way of Solid-State Recycling. *Metals and Materials International*, (0123456789). https://doi.org/10.1007/s12540-019-00428-7

Khamis, S. S., Lajis, M. A., & Albert, R. A. O. (2015). A sustainable direct recycling of aluminum chip (AA6061) in hot press forging employing Response surface methodology. *Procedia CIRP*, *26*, 477–481. https://doi.org/10.1016/j.procir.2014.07.023

Kiliç, S., Kacar, İ., Şahin, M., Öztürk, F., & Erdem, O. (2020). Investigation of Effect on the Mechanical Properties of Quenching Temperature in Aa7075. *Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, *9*(1), 528–537. https://doi.org/10.28948/ngumuh.681273

Kilickap, E., Huseyinoglu, M., & Yardimeden, A. (2011). *Optimization of drilling parameters on surface roughness in drilling of AISI 1045 using response surface methodology and genetic algorithm*. 79–88. https://doi.org/10.1007/s00170-010-2710-7

Kim, Y. H., Ryou, T. K., Choi, H. J., & Hwang, B. B. (2002). An analysis of the forging processes for 6061 aluminum-alloy wheels. *Journal of Materials Processing Technology*, *123*(2), 270–276. https://doi.org/10.1016/S0924-0136(02)00087-0

Koch, A., Bonhage, M., Teschke, M., Luecker, L., Behrens, B., & Walther, F. (2020). Electrical resistance-based fatigue assessment and capability prediction of extrudates from recycled field-assisted sintered EN AW-6082 aluminium chips. *Materials Characterization*, *169*(September), 110644. https://doi.org/10.1016/j.matchar.2020.110644

Kore, A. S., Nayak, K. C., & Date, P. P. (2017). Formability of aluminium sheets manufactured by solid state recycling. *Journal of Physics: Conference Series*, *896*(1). https://doi.org/10.1088/1742-6596/896/1/012007

Krolo, J., Lela, B., & Dumanić, I. (2019). Statistical analysis of the combined ecap and heat treatment for recycling aluminum chips without remelting. *Metals*, *9*(6). https://doi.org/10.3390/met9060660

Kuddus, S., Mustapa, M. S., Ibrahim, M. R., Shamsudin, S., Kadir, M. I. A., & Lajis, M. A. (2017). Microstructures and tensile characteristics on Direct Recycled Aluminium Chips AA6061/Al powder by hot pressing method. *Materials Science Forum*, *909 MSF*, 9–14. https://doi.org/10.4028/www.scientific.net/MSF.909.9

Kumar, M., Kumar, A., Ji, H., Song, Q., Liu, Z., Cai, W., … Khanna, N. (2020). Impact of layer rotation on micro-structure , grain size , surface integrity and mechanical behaviour of SLM Al-Si-10Mg alloy. *Integrative Medicine Research*, *9*(5), 9506–9522. https://doi.org/10.1016/j.jmrt.2020.06.090

Kumar, T., Mohsin, R., Majid, Z. A., Ghafir, M. F. A., Yusuf, N. K., Kim, J. Y., … Sahri, D. M. (2019). Response surface methodology application in optimization of performance and exhaust emissions of RON 98, aviation gasoline 100LL and the blends in Lycoming O-320 engine. *Fuel*, *256*(July), 115909. https://doi.org/10.1016/j.fuel.2019.115909

Kume, Y., Ota, S., Kobashi, M., & Kanetake, N. (2014). Upgrading property of the Al-Fe alloys through microstructure refinement by compressive torsion processing. *Materials Science Forum*, *794–796*, 802–806. https://doi.org/10.4028/www.scientific.net/MSF.794-796.802

Kuntoˇglu, M., Aslan, A., Pimenov, D. Y., Giasin, K., Mikolajczyk, T., & Sharma, S. (2020). Modeling of Cutting Parameters and Tool Geometry for Multi-Criteria Optimization of Surface Roughness and Vibration via Response Surface Methodology in. *Materials*.

Kuzman, K., Kacmarcik, L., Pepelnjak, T., Plancak, m., Vilotic, D. (2012). Experimental consolidation of aluminium chips by cold compression. *Journal of Production Engineering*, *15*(2), 79–82. Retrieved from http://www.jpe.ftn.uns.ac.rs/papers/2012/no2/17-Kuzman-JPE.pdf

Lajis, M. A., Khamis, S. S., & Yusuf, N. K. (2014). Optimization of hot press forging parameters in direct recycling of aluminium chip (AA 6061). *Key Engineering Materials*, *622–623*, 223–230. https://doi.org/10.4028/www.scientific.net/KEM.622-623.223

Lajis, Mohd Amri, Yusuf, N. K., & Ahmad, A. (2018). Life cycle assessment on the effects of parameter setting in direct recycling hot press forging of aluminum. *Materials Science Forum*, *923 MSF*, 143–148. https://doi.org/10.4028/www.scientific.net/MSF.923.143

Latif, A., Ingarao, G., & Fratini, L. (2022). Multi-material based functionally graded billets manufacturing through friction stir consolidation of aluminium alloys chips CIRP Annals - Manufacturing Technology friction stir consolidation of aluminium alloys chips. *CIRP Annals - Manufacturing Technology*, *71*(1), 261–264. https://doi.org/10.1016/j.cirp.2022.03.035

Laurent, A., Bakas, I., Clavreul, J., Bernstad, A., Niero, M., Gentil, E., … Christensen, T. H. (2014). Review of LCA studies of solid waste management systems - Part I: Lessons learned and perspectives. *Waste Management*, *34*(3), 573–588. https://doi.org/10.1016/j.wasman.2013.10.045

Laurent, A., Clavreul, J., Bernstad, A., Bakas, I., Niero, M., Gentil, E., … Hauschild, M. Z. (2014). Review of LCA studies of solid waste management systems - Part II: Methodological guidance for a better practice. *Waste Management*, *34*(3), 589–606. https://doi.org/10.1016/j.wasman.2013.12.004

Lazzaro, G., Eltrudis, M., & Pranovi, F. (1994). Recycling of aluminium dross in electrolytic pots. *Resources, Conservation and Recycling*, *10*(1–2), 153–159. https://doi.org/10.1016/0921-3449(94)90048-5

Leroy, C. (2009). Provision of LCI data in the European aluminium industry Methods and examples. In *International Journal of Life Cycle Assessment* (Vol. 14). https://doi.org/10.1007/s11367-009-0068-6

Li, X. (2017). *Friction stir consolidation of aluminum machining chips*. (Diid). https://doi.org/10.1007/s00170-017-1016-4

Lin, R., Liu, B., Zhang, J., & Zhang, S. (2022). Microstructure evolution and properties of 7075 aluminum alloy recycled from scrap aircraft aluminum alloys. *Journal of Materials Research and Technology*, *19*, 354–367. https://doi.org/10.1016/j.jmrt.2022.05.011

Liu, G., Bangs, C. E., & Daniel, B. M. (2011). Unearthing Potentials for Decarbonizing the U . S . Aluminum Cycle. *Environmental Science & Technology*, *45*(22), 9515–9522.

Liu, G., & Müller, D. B. (2012). Addressing sustainability in the aluminum industry: A critical review of life cycle assessments. *Journal of Cleaner Production*, *35*, 108–117. https://doi.org/10.1016/j.jclepro.2012.05.030

Loong, C. B., Lajis, M. A., Shamsudin, S., & Zainodin, N. E. (2022). Impact of Chromium Addition on the UTS and ETF of Aluminium Alloy AA6061 Chips Based Composite. *Journal of Basic and Applied Sciences*, 26–32.

Luthin, A., Backes, J. G., & Traverso, M. (2021). A framework to identify environmental-economic trade-offs by combining life cycle assessment and life cycle costing – A case study of aluminium production. *Journal of Cleaner Production*, *321*(December 2020), 128902. https://doi.org/10.1016/j.jclepro.2021.128902

Macintosh, W. H. (1983). Induction furnaces for melting secondary aluminium. *Conservation and Recycling*, *6*(1–2), 41–48. https://doi.org/10.1016/0361-3658(83)90015-2

Mahinroosta, M., & Allahverdi, A. (2018). Hazardous aluminum dross characterization and recycling strategies: A critical review. *Journal of Environmental Management*, *223*(February), 452–468.

https://doi.org/10.1016/j.jenvman.2018.06.068

Manakitsomboon, H. (2021). Annual production volume of secondary aluminum in Thailand from 2011 to 2020. Retrieved September 3, 2022, from Statista website: https://www.statista.com/statistics/1129559/thailand-aluminum-production-volume/

Manfredi, S., Tonini, D., & Christensen, T. H. (2011). Environmental assessment of different management options for individual waste fractions by means of life-cycle assessment modelling. *Resources, Conservation and Recycling*, *55*(11), 995–1004. https://doi.org/10.1016/j.resconrec.2011.05.009

Mao-liang, H., Ze-sheng, J., Xiao-yu, C., Qu-dong, W., & Wen-jiang, D. (2012). Solid-state recycling of AZ91D magnesium alloy chips. *Transactions of Nonferrous Metals Society of China*, *22*, s68–s73. https://doi.org/10.1016/S1003-6326(12)61685-9

Mei, C., Fujiwara, T., & Siong, C. (2018). Life cycle assessment and life cycle costing toward eco-ef fi ciency concrete waste management in Malaysia. *Journal of Cleaner Production*, *172*, 3415–3427. https://doi.org/10.1016/j.jclepro.2017.11.200

Meng, C. (2010). *Effect of Preheating Condition on Strength of AA6060 Aluminium Alloy for Extrusion*. Auckland University of Technology.

Meng, Y., Zhang, H., Li, X., Zhou, X., Mo, H., Wang, L., & Fan, J. (2022). *Tensile Fracture Behavior of 2A14 Aluminum Alloy Produced by Extrusion Process*. 1–13.

Merrild, H., Larsen, A. W., & Christensen, T. H. (2012). Assessing recycling versus incineration of key materials in municipal waste : The importance of efficient energy recovery and transport distances. *Waste Management*, *32*(5), 1009–1018. https://doi.org/10.1016/j.wasman.2011.12.025

Miah, J. H., Koh, S. C. L., & Stone, D. (2017). A hybridised framework combining integrated methods for environmental Life Cycle Assessment and Life Cycle Costing Internal Rate of Return. *Journal of Cleaner Production*, *168*, 846–866. https://doi.org/10.1016/j.jclepro.2017.08.187

Mohammed Iqbal, U., Senthil Kumar, V. S., & Gopalakannan, S. (2016). Application of Response Surface Methodology in optimizing the process parameters of Twist Extrusion process for AA6061-T6 aluminum alloy. *Measurement: Journal of the International Measurement Confederation*, *94*, 126–138. https://doi.org/10.1016/j.measurement.2016.07.085

Monteiro, V. M. (2014). Microstructural and Mechanical Study of Aluminium Alloys Submitted To Distinct Soaking Times During Solution Heat Treatment. 332–339.

Morris, J. (1996). Recycling versus incineration : an energy conservation analysis. *Hazardous Material*, *47*, 277–293.

Morris, J. (2005). Alternatives Comparative LCAs for Curbside Recycling Versus Either Landfilling or Incineration with Energy Recovery. *InLCA : Case Studies – Using LCA to Compare*, *10*(4), 273–284.

Moustafa, S., Daoush, W., Ibrahim, A., & Neubaur, E. (2011). Hot Forging and Hot

Pressing of AlSi Powder Compared to Conventional Powder Metallurgy Route. *Materials Sciences and Applications*, *02*(08), 1127–1133. https://doi.org/10.4236/msa.2011.28152

Müller, J. (2022). Production of aluminum in Malaysia from 2012 to 2021. Retrieved September 3, 2022, from Statista Research Department website: https://www.statista.com/statistics/1131257/malaysia-aluminum-production/#:~:text=According to the World Bureau,60 thousand tons of aluminum.

Nakamura, S., & Kondo, Y. (2006). A waste input – output life-cycle cost analysis of the recycling of end-of-life electrical home appliances. *Ecological Economics*, *57*, 494–506. https://doi.org/10.1016/j.ecolecon.2005.05.002

Noordin, M. Y., Venkatesh, V. C., Sharif, S., Elting, S., & Abdullah, A. (2004). *Application of response surface methodology in describing the performance of coated carbide tools when turning AISI 1045 steel*. *145*, 46–58. https://doi.org/10.1016/S0924-0136(03)00861-6

Norris, G. A. (2001). Integrating life cycle cost analysis and LCA. *International Journal of Life Cycle Assessment*, *6*(2), 118–120. https://doi.org/10.1007/bf02977849

Oliveira, F. B. (2012). *Life Cycle Assessment of a High-Density Datacenter Cooling System : TeliaSonera ' s ' Green Room ' Concept*. Stockholm.

Özkan, A., Günkaya, Z., Tok, G., Karacasulu, L., & Metesoy, M. (2016). Life Cycle Assessment and Life Cycle Cost Analysis of Magnesia Spinel Brick Production. *Sustainability*, *8*, 1–13. https://doi.org/10.3390/su8070662

Pandey, A. K., Prajapati, N., Nayak, K. C., & Date, P. P. (2019). Sustainable manufacturing process for recycling of aluminum alloy waste into direct product by high-pressure torsion process. *Materials Today: Proceedings*, *18*, 3099–3108. https://doi.org/10.1016/j.matpr.2019.07.183

Paraskevas, D., Kellens, K., Dewulf, W., & Du, J. R. (2014). Environmental modelling of aluminium recycling : a Life Cycle Assessment tool for sustainable metal management. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2014.09.102

Paraskevas, D., Kellens, K., Dewulf, W., & Duflou, J. R. (2012). Resource Efficiency in Manufacturing : Identifying Low Impact Paths. *The 10th Global Conference on Sustainable Manufacturing*, 271–276.

Paraskevas, D., Kellens, K., Voorde, A. Van De, Dewulf, W., & Duflou, J. R. (2016). Environmental impact analysis of primary aluminium production at country level. *Procedia CIRP*, *40*, 209–213. https://doi.org/10.1016/j.procir.2016.01.104

Paraskevas, D., Vanmeensel, K., Vleugels, J., Dewulf, W., Deng, Y., & Duflou, J. R. (2014). Spark plasma sintering as a solid-state recycling technique: The case of aluminum alloy scrap consolidation. *Materials*, *7*(8), 5664–5687. https://doi.org/10.3390/ma7085664

Pasqualino, J., Meneses, M., & Castells, F. (2011). The carbon footprint and energy consumption of beverage packaging selection and disposal. *Journal of Food*

Engineering, *103*(4), 357–365. https://doi.org/10.1016/j.jfoodeng.2010.11.005

Pauer, E., Wohner, B., & Tacker, M. (2020). The Influence of Database Selection on Environmental Impact Results . Life Cycle Assessment of Packaging Using GaBi , Ecoinvent 3 . 6 , and the Environmental Footprint Database. *Sustainability*, (Lci).

Pedneault, J., Desjardins, V., Margni, M., Conciatori, D., Fafard, M., & Sorelli, L. (2021). Economic and environmental life cycle assessment of a short-span aluminium composite bridge deck in Canada. *Journal of Cleaner Production*, *310*(May), 127405. https://doi.org/10.1016/j.jclepro.2021.127405

Pepelnjak, T., Kuzman, K., Kačmarčik, I., & Plančak, M. (2012). Recycling of AIMgSi1 aluminium chips by cold compression. *Metalurgija*, *51*(4), 509–512.

Pezda, J. (2014). *The Effect of The T6 Heat Treatment on Hardness and Microstructure of The EN AC-AlSi12CuNiMg Alloy*. *53*(1), 63–66.

Poli, C. (2001). *Chapter 11 - Other Metal Shaping Processes BT - Design for Manufacturing*. https://doi.org/10.1016/B978-0-7506-7341-9.50015-X

Poulopoulos, S. G. (2016). Atmospheric Environment-Chapter 2. In *Environment and Development*. https://doi.org/10.1016/B978-0-444-62733-9.00002-2

Puga, H., Barbosa, J., Soares, D., Silva, F., & Ribeiro, S. (2009). Recycling of aluminium swarf by direct incorporation in aluminium melts. *Journal of Materials Processing Technology*, *209*(11), 5195–5203. https://doi.org/10.1016/j.jmatprotec.2009.03.007

Purvis, B. (2019). Three pillars of sustainability : in search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Rady, M. H., Mustapa, M. S., Wagiman, A., Shamsudin, S., Lajis, M. A., Alimi, S. Al, … Harimon, M. A. (2020). Effect of the heat treatment on mechanical and physical properties of direct recycled aluminium alloy (AA6061). *International Journal of Integrated Engineering*, *12*(3), 82–89. https://doi.org/10.30880/ijie.2020.12.03.011

Rahim, S. N. A., Lajis, M. A., & Ariffin, S. (2015). 12th Global Conference on Sustainable Manufacturing A Review on Recycling Aluminum Chips by Hot Extrusion Process. *Procedia CIRP*, *26*, 761–766. https://doi.org/10.1016/j.procir.2015.01.013

Ranjbari, M., Saidani, M., Shams, Z., Peng, W., Lam, S., Aghbashlo, M., … Tabatabaei, M. (2021). Two decades of research on waste management in the circular economy : Insights from bibliometric , text mining , and content analyses. *Journal of Cleaner Production*, *314*(May), 128009. https://doi.org/10.1016/j.jclepro.2021.128009

Rashid, M. (1997). *Mathematical Modeling and Optimization of Precipitation Hardening of Extrudable Aluminum Alloys*.

Rebitzer, G. (2002). Integrating Life Cycle Costing and Life Cycle Assessment for Managing Costs and Environmental Impacts in Supply Chains. *Cost Management in Supply Chains*, 127–146. https://doi.org/10.1007/978-3-662-11377-6_8

Ribeiro, I., Peças, P., & Henriques, E. (2013). Incorporating tool design into a comprehensive life cycle cost framework using the case of injection molding. *Journal of Cleaner Production*, *53*, 297–309. https://doi.org/10.1016/j.jclepro.2013.04.025

Roy, R. K., & Das, S. (2006). New combination of polishing and etching technique for revealing grain structure of an annealed aluminum (AA1235) alloy. *Journal of Materials Science*, *1*, 289–292. https://doi.org/10.1007/s10853-005-3304-x

Ruhaizat, N. E., Yusuf, N. K., Lajis, M. A., Al-alimi, S., & Shamsudin, S. (2022). Effect of Direct Recycling Hot Press Forging Parameters on Mechanical Properties and Surface Integrity of AA7075 Aluminum Alloys. *Metals*, *12*(10), 1555.

Ruhaizat, N., Yusuf, N., Lajis, M., Mazlan, A., Muktari, A., & Ahmad, A. (2021). *Effect of Hot Press Forging Parameter on Microstructural Analysis and Mechanical Properties in Direct Recycling of Aluminium Aircraft Alloy (AA7075)*. Recent Trends in Manufacturing and Materials Towards Industry 4.0.

Russel, A. M., & Lee, K. L. (2005). *Structure-property relations in nonferrous metals*.

Sajadifar, S. V., Moeini, G., Scharifi, E., Lauhoff, C., Böhm, S., & Niendorf, T. (2019). On the Effect of Quenching on Postweld Heat Treatment of Friction-Stir-Welded Aluminum 7075 Alloy. *Journal of Materials Engineering and Performance*, *28*(8), 5255–5265. https://doi.org/10.1007/s11665-019-04252-3

Salim, N., Hashim, R., Sulaiman, O., Ibrahim, M., Sato, M., & Hiziroglu, S. (2012). Optimum manufacturing parameters for compressed lumber from oil palm (Elaeis guineensis) trunks: Respond surface approach. *Composites Part B: Engineering*, *43*(3), 988–996. https://doi.org/10.1016/j.compositesb.2011.11.002

Samuel, M. (2003). A new technique for recycling aluminium scrap. *Journal of Materials Processing Technology*, *135*(1), 117–124. https://doi.org/10.1016/S0924-0136(02)01133-0

Schau, E. M., Traverso, M., Lehmannann, A., & Finkbeiner, M. (2011). Life cycle costing in sustainability assessment-A case study of remanufactured alternators. *Sustainability*, *3*(11), 2268–2288. https://doi.org/10.3390/su3112268

Schulze, P. C. (1999). Measures of Environmental Performance and Ecosystem Condition. In *Measures of Environmental Performance and Ecosystem Condition*. https://doi.org/10.17226/5147

Shamsudin, S., Lajis, M. A., & Zhong, Z. W. (2016). Evolutionary in Solid State Recycling Techniques of Aluminium : A review. *Procedia CIRP*, *40*, 256–261. https://doi.org/10.1016/j.procir.2016.01.117

Sherafat, Z., Paydar, M. H., & Ebrahimi, R. (2009). Fabrication of Al7075/Al, two phase material, by recycling Al7075 alloy chips using powder metallurgy route. *Journal of Alloys and Compounds*, *487*(1–2), 395–399. https://doi.org/10.1016/j.jallcom.2009.07.146

Sherif, Y. S., & Kolarik, W. J. (1981). Life cycle costing: Concept and practice. *Omega*, *9*(3), 287–296. https://doi.org/10.1016/0305-0483(81)90035-9

Shine, K. P., Fuglestvedt, J. S., Hailemariam, K., & Stuber, N. (2005). Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. *Climate Change*, (68), 281–302.

Shinzato, M. C., & Hypolito, R. (2005). Solid waste from aluminum recycling process: Characterization and reuse of its economically valuable constituents. *Waste Management*, *25*(1), 37–46. https://doi.org/10.1016/j.wasman.2004.08.005

Simonetto, E., Bertolini, R., Ghiotti, A., & Bruschi, S. (2020). Mechanical and microstructural behaviour of AA7075 aluminium alloy for sub-zero temperature sheet stamping process. *International Journal of Mechanical Sciences*, *187*, 105919. https://doi.org/10.1016/J.IJMECSCI.2020.105919

Sjölander, E., & Seifeddine, S. (2010). The heat treatment of Al-Si-Cu-Mg casting alloys. *Journal of Materials Processing Technology*, *210*(10), 1249–1259. https://doi.org/10.1016/j.jmatprotec.2010.03.020

Smith, A., Brown, K., Ogilvie, S., Rushton, K., & Bates, J. (2001). *Waste management options and climate change*.

Söderholm, P., & Ekvall, T. (2019). Metal markets and recycling policies : impacts and challenges. *Mineral Economics*.

Sources of Greenhouse Gas Emissions | US EPA. (n.d.). Retrieved February 18, 2023, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Staff, R. (2021). China’s primary aluminium output seen peaking in 2024. Retrieved September 3, 2022, from commodities news website: https://www.reuters.com/article/us-china-metals-carbon-aluminium-id

Statista. (2022a). Consumption of aluminum in Singapore from 2012 to 2021. Retrieved September 3, 2022, from Statista Research Department website: https://www.statista.com/statistics/1131266/singapore-aluminum-consumption/

Statista. (2022b). Global aluminum consumption projections from 2021 to 2029. Retrieved September 3, 2022, from Statista Research Department website: https://www.statista.com/statistics/863681/global-aluminum-consumption/

Statista. (2022c). Production of aluminum in Indonesia from 2012 to 2021. Retrieved September 3, 2022, from Statista Research Department website: https://www.statista.com/statistics/1131253/indonesia-aluminum-production/#:~:text=According to the World Bureau,246.3 thousand tons of aluminum.

Svoboda, S. (1995). Pollution Prevention in Corporate Strategy Note on Life Cycle Analysis. *National Pollution Prevention Center*. Retrieved from www.umich.edu/~nppcpub

Tahara, S., Kume, Y., Kobashi, M., & Kanetake, N. (2007). Influence of compressive torsion processing temperature on microstructure refinement and property of aluminum alloy. *Advanced Materials Research*, *24–25*, 133–136. https://doi.org/10.4028/www.scientific.net/amr.26-28.133

Tamburini, E., Costa, S., Summa, D., Battistella, L., Fano, E. A., & Castaldelli, G. (2021). Plastic (PET) vs bioplastic (PLA) or refillable aluminium bottles – What is the most sustainable choice for drinking water ? A life-cycle (LCA) analysis. *Environmental Research*, *196*(February), 110974.

https://doi.org/10.1016/j.envres.2021.110974

Tan, E., & Ogel, B. (2007). *Influence of Heat Treatment on the Mechanical Properties of AA6066 Alloy*. *31*, 53–60.

Tekkaya, A. E., Schikorra, M., Becker, D., Biermann, D., Hammer, N., & Pantke, K. (2009). Hot profile extrusion of AA-6060 aluminum chips. *Journal of Materials Processing Technology*, *209*(7), 3343–3350. https://doi.org/10.1016/j.jmatprotec.2008.07.047

Thaimetal aluminium. (2022). Aluminium production. Retrieved September 3, 2022, from https://www.thaimetal.co/en/materials/

The World Bank. (2022). Solid Waste Management. Retrieved September 4, 2022, from https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

Tsakiridis, P. E., & Oustadakis, P. (2013). Journal of Environmental Chemical Engineering Aluminium recovery during black dross hydrothermal treatment. *Biochemical Pharmacology*, *1*(1–2), 23–32. https://doi.org/10.1016/j.jece.2013.03.004

Velasco, E., & Nino, J. (2011). Recycling of aluminium scrap for secondary Al-Si alloys. *Waste Management and Research*, *29*(7), 686–693. https://doi.org/10.1177/0734242X10381413

Venkatesan, J., Lowe, B., Manivasagan, P., Kang, K. H., Chalisserry, E. P., Anil, S., … Kim, S. K. (2015). Isolation and characterization of nano-hydroxyapatite from salmon fish bone. *Materials*, *8*(8), 5426–5439. https://doi.org/10.3390/ma8085253

Wagiman, A., Mustapa, M. S., Asmawi, R., Shamsudin, S., Lajis, M. A., & Mutoh, Y. (2020). A review on direct hot extrusion technique in recycling of aluminium chips. *International Journal of Advanced Manufacturing Technology*, *106*(1–2), 641–653. https://doi.org/10.1007/s00170-019-04629-7

Wan, B., Chen, W., Lu, T., Liu, F., & Jiang, Z. (2017). Review of solid state recycling of aluminum chips. *Resources, Conservation & Recycling*, *125*(September 2016), 37–47. https://doi.org/10.1016/j.resconrec.2017.06.004

Wiedmann, T., Minx, J., Mont, O., Feng, H., Jha, M., Gassman, P. W., … Kouloumpis, V. (2007). *Ecological Economics Research Trends* (C. C. Pertsova, Ed.). Nova Science Publishers, Inc.

Wong, D. S., & Lavoie, P. (2019). Aluminum : Recycling and Environmental Footprint. *JOM*, *71*(9), 2926–2927. https://doi.org/10.1007/s11837-019-03656-9

World Aluminium. (2018). *Aluminium Carbon Footprint Technical Support Document*. Retrieved from http://ghgprotocol.org/feature/scope-3-calculation-guidance

Xiao, Y., & Reuter, M. A. (2002). Recycling of distributed aluminium turning scrap. *Minerals Engineering*, *15*(11 SUPPL. 1), 963–970. https://doi.org/10.1016/S0892-6875(02)00137-1

Xiao, Yanping, Reuter, M. A., & Boin, U. (2005). Aluminium recycling and environmental issues of salt slag treatment. *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering*, *40*(10), 1861–1875. https://doi.org/10.1080/10934520500183824

Yasinskiy, A., Padamata, S. K., Moiseenko, I., Stopic, S., Feldhaus, D., Friedrich, B., & Polyakov, P. (2021). Aluminium Recycling in Single- and Multiple-Capillary Laboratory Electrolysis Cells. *Metals*, *11*(1053).

Yusuf, N. K. (2017). *Effect of hot press forging parameter and life cycle assessment in direct recycling of AA6061 aluminium*. Universiti Tun Hussein Onn Malaysia.

Yusuf, N. K., Lajis, M. A., Daud, M. I., & Noh, M. Z. (2013). Effect of operating temperature on direct recycling aluminium chips (AA6061) in hot press forging process. *Applied Mechanics and Materials*, *315*, 728–732. https://doi.org/10.4028/www.scientific.net/AMM.315.728

Yusuf, N K, Lajis, M. A., & Ahmad, A. (2021). Life Cycle Assessment on the Direct Recycling Aluminium Alloy AA6061 Chips and Metal Matrix Composite (MMC- AlR). *The International Journal of Integrated Engineering*, *7*, 95–100.

Yusuf, N K, Medi, A. S., Lajis, M. A., Chan, B. L., & Shamsudin, S. (2021). Mechanical Properties of Direct Recycling Metal Matrix Composite (MMC-AlR) AA7075 Aircraft Aluminium Alloy. *The International Journal of Integrated Engineering*, *7*, 89–94.

Yusuf, Nur Kamilah, Lajis, M. A., & Ahmad, A. (2017). Hot press as a sustainable direct recycling technique of aluminium: Mechanical properties and surface integrity. *Materials*, *10*(8). https://doi.org/10.3390/ma10080902

Yusuf, Nur Kamilah, Lajis, M. A., & Ahmad, A. (2019). Multiresponse optimization and environmental analysis in direct recycling hot press forging of aluminum AA6061. *Materials*, *12*(12). https://doi.org/10.3390/ma12121918

Zhang, W., Guo, J., Gu, F., Gu, X., Guo, J., Gu, F., & Gu, X. (2018). Coupling life cycle assessment and life cycle costing as an evaluation tool for developing product service system of high energy-consuming equipment. *Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.02.146

Zhao, Z., Chen, Q., Yang, L., Shu, D., & Zhao, Z. (2011). Microstructure and mechanical properties of Mg-Zn-Y-Zr alloy prepared by solid state recycling. *Transactions of Nonferrous Metals Society of China*, *21*(2), 265–271. https://doi.org/10.1016/S1003-6326(11)60708-5

Zhou, B., Yang, Y., Reuter, M. A., & Boin, U. M. J. (2006). Modelling of aluminium scrap melting in a rotary furnace. *Minerals Engineering*, *19*(3 SPEC. ISS.), 299–308. https://doi.org/10.1016/j.mineng.2005.07.017

Zhu, S., Gao, C., Song, K., Chen, M., Wu, F., & Li, X. (2022). An assessment of environmental impacts and economic benefits of multiple aluminum production methods. *Journal of Cleaner Production*, *370*. https://doi.org/10.1016/J.JCLEPRO.2022.133523

Zhu, X., Jin, Q., & Ye, Z. (2020). Life cycle environmental and economic assessment of alumina recovery from secondary aluminum dross in China. *Journal of Cleaner Production*, 1–17. https://doi.org/10.1016/j.jclepro.2020.123291