International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
OPEN ACCESS
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST52310572

An Empirical Study of Hot-Extruded Recycled Aluminium Alloy Chips in 2014

Rupesh Kumar Gupta, Dr Mahendra Yadav, Suryakant
Department of Physics, Rama Bai Government women P. G. College, Akabarpur, Ambedkar Nagar
Uttar Pradesh, India

ARTICLEINFO

Article History:

Accepted: 30 Sep 2023
Published: 18 Oct 2023

Publication Issue
Volume 10, Issue 5
September-October-2023

Page Number
517-525

ABSTRACT

It has been discovered that the conventional method of recycling aluminum, which entails remelting the garbage, leads to several environmental problems, material inefficiencies, and energy resource depletion. The purpose of this research is to develop a way of recycling AA2014 aluminum that is both efficient and kind on the environment. Turning waste chips were collected, crushed into billets, and heated before being extruded. The design of the tests was carried out in accordance with the DOE methodology. Extrusion temperature and ratio were the distinguishing features of the recycling procedure. Researchers used tools like RA and ANOVA to develop mathematical models with solid statistical foundations. Both the ultimate tensile strength and the yield strength of the extruded aluminum are shown to be affected by the extrusion parameters using the equations used in this study. The investigation found that the tensile and yield strengths of the specimens were significantly affected by both the extrusion temperature and the extrusion ratio. To achieve the highest possible levels of the extrudates' aforementioned mechanical characteristics, an optimization procedure was carried out.

Keywords: AA2014, Regression analysis (RA), ANOVA

I. INTRODUCTION

Due to its superior combination of strength, low weight, and corrosion resistance, aluminum alloys have long been favored materials in a variety of industrial industries. Today, when environmental consciousness and resource conservation are at the forefront of public discourse, the efficient recycling of aluminum alloys has taken on new relevance. Aluminum alloy 2014 stands out above other alloys because of its high strength and remarkable mechanical features, making it ideal for applications in aerospace and structural design. Alloy 2014 in particular presents unique challenges during the recycling process of aluminum alloys. Traditional recycling methods typically include melting, which can reduce mechanical properties and necessitates significant energy use. One approach that has arisen as a potential solution to these problems is the use of solid-state recycling methods. Due to its capacity to preserve the material's structural integrity and boost sustainability, solid-state recycling is an attractive option for recycling aluminum alloy 2014. The purpose of this research is to examine the potential of solid-state recycling as a method for processing aluminum alloy 2014 chips, with a focus on hot extrusion. In hot extrusion, a material is subjected to high heat and intense pressure in order to cause deformation and consolidation, producing the required shape. This method has the dual benefit of preventing the alloy from melting and increasing its mechanical strength. However, a thorough statistical analysis is necessary to ascertain the viability and dependability of this recycling technique. The primary objective of this research is to assess hot extrusion's potential as a solid-state recycling method for aluminum alloy 2014 chips. Our goal is to employ statistical methods and techniques to objectively evaluate and analyze the key factors that have an effect on the recycled product's quality and consistency. For this purpose, it is necessary to examine a wide range of factors, such as temperature, pressure, and extrusion speed, in order to optimize the process and ensure that the final product meets all quality standards. In addition, it is expected that this study's findings will have wider implications for the recycling of further high-strength aluminum alloys, so contributing usefully to the sustainable exploitation of scarce resources. As the need for lightweight and high-performance materials grows worldwide, so does the importance of finding efficient ways to recycle aluminum alloys like 2014.

Gronostajski et al. (1996) utilized the hot extrusion method to manufacture composites consisting of aluminum (Al) and AlCu4 alloy chips, in conjunction with tungsten powder. The bonding between individual chips and the presence of porosities significantly impact the mechanical properties of chip extruded samples.

Fogagnolo et al (2003) conducted a study to investigate the feasibility of recycling AA-6061 chips with the application of cold or hot compaction, followed by hot extrusion.

The objective of the study undertaken by Schikorra et al (2008) was to evaluate the feasibility of recycling aluminium chips of AA-6060, AA-6082, and AA-7075 by the hot extrusion method.

Tekkaya et al. (2009) conducted a study to assess the feasibility of solid-state recycling of aluminum AA-6060 chips, as well as the incorporation of silicon carbide (SiC) particles into these chips, using a two-step method including cold compaction and subsequent hot extrusion.

In their work, Tang and Reynold (2010) investigated the process of wire manufacture using friction extrusion. In a similar vein, the exploitation of the hot forging method for this objective was examined by Yusuf et al. (2013). In a separate investigation, Misiolek et al. (2012) introduced the notion of Equal Channel Angular Pressing (ECAP) as a technique for wire manufacturing. In conclusion, the study conducted by Peng et al. (2009) investigated the utilization of the cyclic extrusion compression (CEC) technique within this particular domain.

Ab Rahim et al. (2015) did a detailed investigation on the recycling of chips using hot extrusion, providing a thorough analysis of the process. The authors presented a succinct summary of the several aspects related to the extrusion process that were examined with the aim of improving the quality of the extrudate. Wagdy et al. (2022) presented a revolutionary recycling approach in their latest work, which showcases the environmental sustainability of the treatment process for the aluminum alloy AA2011.The findings of the investigation indicate that the tensile and yield strengths of the specimens were significantly influenced by both the extrusion temperature and the extrusion ratio.

Li et al. (2023) conducted a comparative analysis of the corrosion behavior and mechanical properties of the 5083 Al-Mg alloy fabricated using additive friction stir deposition (AFSD) and the 5083-H112 alloy.

II. METHODS AND MATERIAL

2.1 Machining: Machining is a manufacturing process characterized by the removal of material from a workpiece in order to attain the desired shape, size, and surface finish. The technology in question is widely employed in several industries due to its exceptional precision and adaptability, particularly in the production of components requiring stringent tolerances. Several important factors are involved in the process of machining:

Machining involves many different processes, such as turning, milling, drilling, grinding, and electrical discharge machining (EDM). Machining is the process of removing material from a work item using cutting instruments including drills, end mills, and lathe tools. By-products of this procedure include chips or swarf. Machining's high precision comes from its ability to produce parts with extremely high standards of accuracy and quality. Machining's adaptability extends beyond metals to polymers and composites. Gears, shafts, molds, and components with complex geometries are just a few examples of the many uses for machining in industries including aerospace, automotive, medicine, and electronics.

2.2 Cold Compaction: In contrast, it is possible to shape and consolidate powdered materials into a desired form or product by a shaping process called cold compaction, without the need for elevated temperatures. One of the several materials it assists in producing is powders composed of metal and ceramic. Several crucial characteristics of cold compaction include:

Powdered materials, such as metal, ceramic, or composite powders, are predominantly utilized in cold compaction processes. The powders are commonly compressed within a die in order to form a green compact. The procedure entails the application of pressure to the powdered material contained within a die in order to get the desired shape. The pressure may exhibit variability based on the characteristics of the material and the specific requirements of the end result. The outcome of the cold compaction process is a green compact, which can be described as a preform that closely resembles the final item in terms of shape but does not possess adequate density and mechanical strength. Subsequently, the green compact undergoes additional operations, such as sintering, in order to attain the appropriate characteristics. Cold compaction offers advantages in terms of both shape complexity and component density, enabling efficient production processes. The utilization of this method proves to be highly advantageous in the fabrication of components that present challenges or high expenses when produced through conventional machining techniques.The process of cold compaction finds widespread usage in the manufacturing of numerous components, such as powder metallurgy parts, cutting tools, and a range of wear-resistant items.

The process of machining involves the removal of material in order to produce a final product, whereas cold compaction is a formative technique that molds powdered materials into green compacts, which can then undergo additional processing to get the appropriate qualities. Every process possesses distinct benefits and uses, with the selection thereof contingent upon factors such as the material being used, the intricacy of the item being manufactured, and the specific requirements of the production process.

3. Design of Experiments: The experiments were established using a Full Factorial Design (FFD). Two parameters of interest were selected for investigation, specifically, the extrusion temperature (x_1) and the extrusion ratio (x_2). The experimental design consisted of three levels for each factor. Specifically, the extrusion temperatures were set at 350, 425, and 500 ⁰C, while the extrusion ratios were varied at 6, 8, and 10. The equation $n = n_1 n_2$ represents the relationship between the number of experiments (n), the number of levels n_1, and the number of parameters n_2. The Design-Expert software application was utilized to construct the nine experimental runs as depicted in Table 1.

III. RESULTS AND DISCUSSION

Table-1: Mechanical properties of the samples and the original material

Sample	Extrusion Temperature (x_1) in ⁰C	Extrusion Ratio (x_2)	R_m (y)	$R_{p\,0.2}$ (z)	PE (u)
1	340	9	206.95	140.97	9.88
2	340	7	202.65	135.67	1.18
3	490	7	234.45	150.47	21.08
4	490	5	265.45	158.97	21.48
5	415	7	210.95	135.67	20.98
6	415	5	193.95	140.97	26.48
7	340	5	183.65	137.67	21.58
8	415	9	220.95	150.97	23.18
9	490	9	271.95	159.97	25.88

All of the extrusion methods were successful, and the resulting bars were square and solid. Visual inspection was performed on the nine extruded samples before submitting them to physical and mechanical testing. All the extrudates came out with a high quality shine on their exteriors. Inadequate shear deformation was seen in the shape of a floral profile or a pills profile during the early phases of the extrusion process. As a result, the chips were detectable in every sample. Both the extrusion temperature and ratio had no discernible effect on the measured profiles. Figure 5 shows an example where this phenomenon may be seen between two extruded samples.

The density test was carried out using Archimedes's first principle. An Aczet CY 224C instrument was used to measure the density of both the raw material and the extruded samples. The ingot material was found to have a density of 2,900 kg/m³, while the extrudates showed densities between 2,900 and 2,910 kg/m³. Aluminum oxide (AlO3) may be to blame for the increased densities we saw if it was present in the samples. The density of aluminum oxide (Al2O3) can reach a maximum of 4080 kg/m3, which is significantly higher than that of water.

Lloyd LR 300K universal testing equipment was used to analyze the materials' mechanical properties.

Lathes with precisely measured gauge diameters, gauge lengths, and reduction lengths were used to prepare tensile test specimens in accordance with the guidelines laid out in ASTM E8. The measured values for these parameters were 3, 15, and 18 mm. Five millimeters per minute was the measured testing speed. The mean and standard deviation were calculated using data from three independent samples of each extruded sample. Shear fracture was observed in the majority of samples, which was to be expected from a ductile material. However, there were examples of brittle fracture in the samples we tested. The samples were taken from a region close to the beginning of the extrusion process, when insufficient shear deformation prevented reliable inter-chip adhesion. Figure 6 depicts the brittle and ductile fractures separately found in two specimens of sample 9.

The 0.2% offset method was used to calculate the yield strength. The ultimate tensile strength (R_m), yield strength ($R_{p0.2}$), and percentage elongation (PE) of the nine samples and the reference material are shown in Table 1. Any sample in which a brittle specimen displayed extremely low characteristics that were not representative of the total population did not have their standard deviation calculated. Because of this, the aforementioned samples were disregarded, and instead, the median values of the characteristics were used. That works up to about 14.5 percent of applications being turned down.

Sample mechanical parameters were entered into the Design-Expert program. For the purpose of developing mathematical models for R_m , and $R_{p0.2}$, we used regression analysis (RA) and analysis of variance (ANOVA).

A simplified quadratic mathematical model for the variable R_m was presented based on the statistical analyses of regression analysis (RA) and analysis of variance (ANOVA). The results showed that the extrusion temperature was the only model term with statistical significance (p value 0.1). R-squared, the measure of statistical significance, came out to be 0.09. As the difference between the Predicted R-squared value (0.7250) and the Adjusted R-squared value (0.73) is less than the required threshold of 0.1, the observed data demonstrate a reasonable level of concordance. No instances of overfitting were found in the final model. The signal-to-noise ratio was calculated to be 7.353, which is above the minimal acceptable threshold of 3. The mathematical expression of R_m in terms of the real factors is given by Equation (1).

Graph (1) illustrates the graphical depiction of the equation R_m.

$$y = 633.42 - 2.24x_1 - 14.57x_2 - 0.03x_1x_2 + 1.95{x_2}^2 \qquad (1)$$

R-Squared:$r^2 = 0.9$

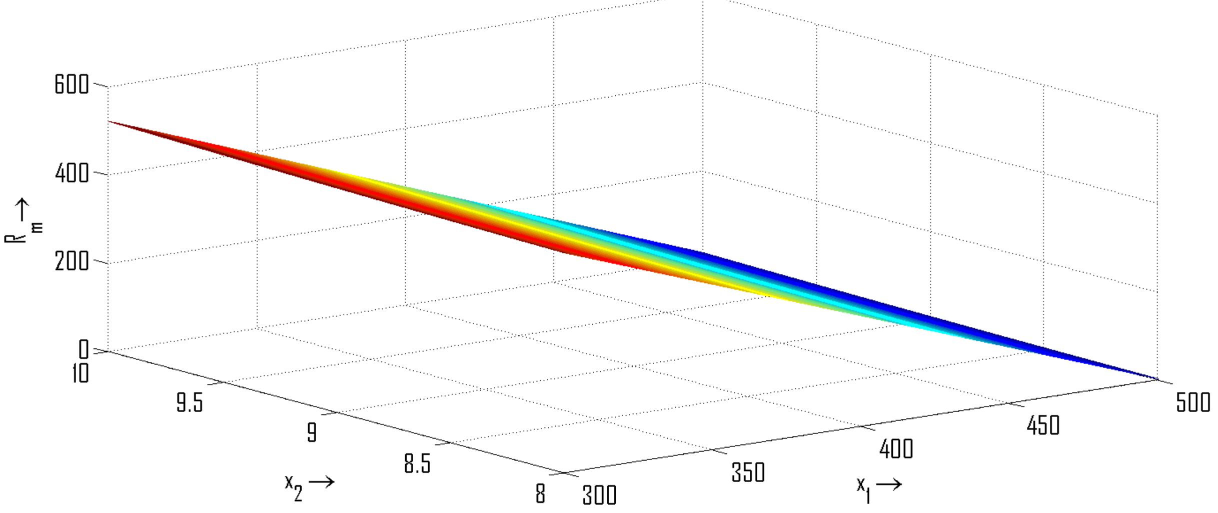
Adjusted R-Squared: 0.73

Residual Standard Error: 15.85 on 3 degrees of freedom.

Overall F-statistics: 5.38 on 5 and 3 degrees of freedom

Overall p-value: 0.1

Source	df	SS	MS	F-statistics	p-value
Regression	5	6760.69	1352.14	5.38	0.1
Residual Error	3	753.35	251.12		
Total	8	7514.04	939.26		



Graph 1: 3D solution of R_m for Extrusion Temperature and Extrusion Ratio

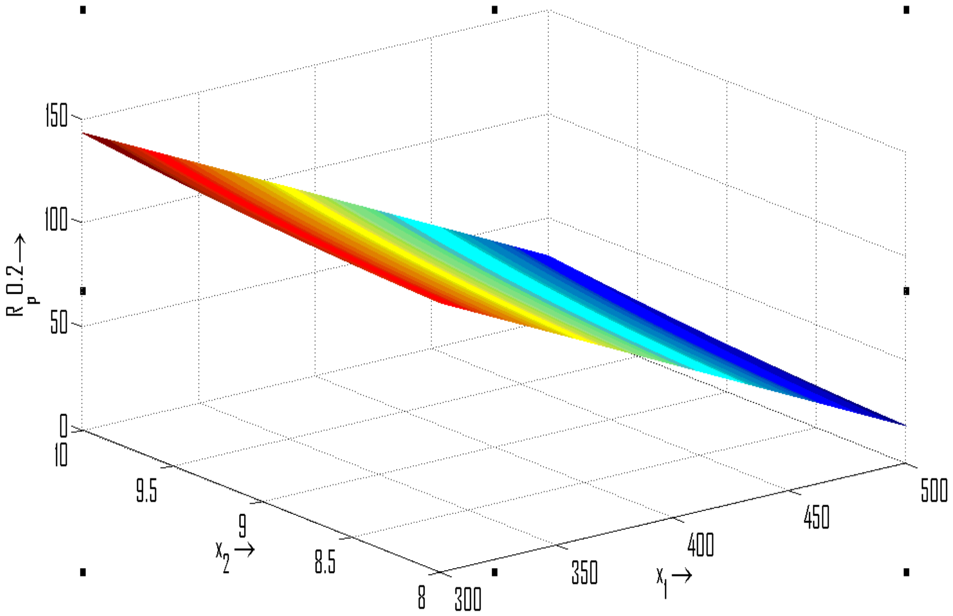
Based on the analysis conducted using regression analysis (RA) and analysis of variance (ANOVA), a reduced quadratic mathematical model has been proposed for the parameter ,($R_{p0.2}$). The findings indicated that both the extrusion temperature and the square of the extrusion ratio were statistically significant model parameters, as evidenced by their respective p-values of 0.11. The coefficient of determination, denoted as R-squared, was found to be 0.89. The Adjusted R-squared value was 0.72. The value of Adeq Precision was determined to be 13.82. The mathematical expression for ,($R_{p0.2}$)., denoted as equation (2), is formulated in terms of the actual factors.

$$z = 337.79 - 0.56x_1 - 27.78x_2 + 1.91{x_2}^2 \qquad (2)$$

Graph (2) shows the graphical representation of the Rp0.2 equation.
R-Squared:$r^2 = 0.89$
Adjusted R-Squared: $r_{adj}^2 = 0.72$
Residual Standard Error: 4.38 on 3 degrees of freedom.
Overall F-statistics: 5.05 on 5 and 3 degrees of freedom
Overall p-value: 0.11

Source	df	SS	MS	F-statistics	p-value
Regression	5	484.92	96.98	5.05	0.11
Residual Error	3	57.56	19.19		
Total	8	542.48	67.81		

Graph 2: 3D solution of R_p 0.2 for Extrusion Temperature and Extrusion Ratio



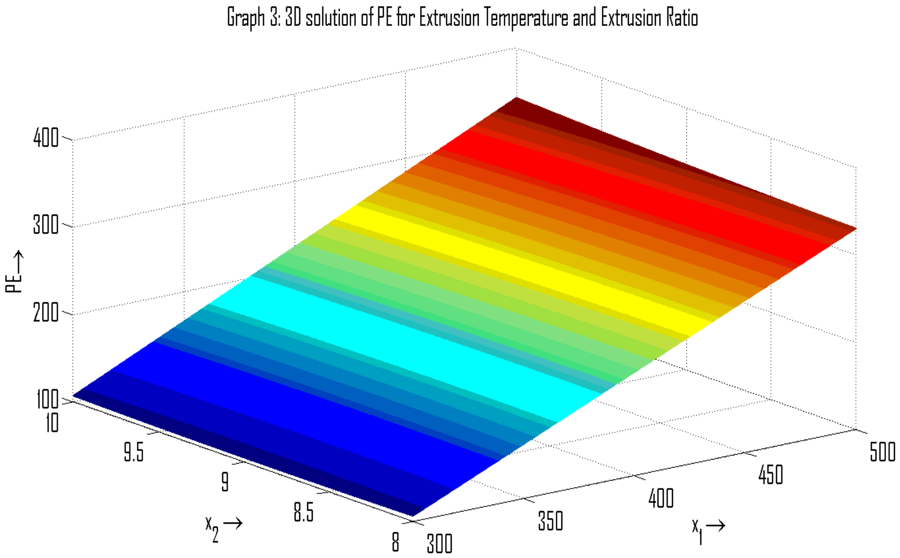
Based on the principles of regression analysis (RA) and analysis of variance (ANOVA), a simplified quadratic mathematical model was proposed for the variable of interest, namely PE. The findings indicated that both the extrusion temperature and the square of the extrusion ratio were statistically significant model parameters, as evidenced by their respective p-values of 0.04. The coefficient of determination, denoted as R-squared, exhibited a value of 0.95. The value of the Adjusted R-squared was 0.87. The value of Adeq Precision was determined to be 12.12.

The mathematical equation of PE in terms of the actual factors is represented by equation (3).

$$u = -19.76 + 0.88x_1 - 40.29x_2 + 0.03x_1x_2 + 1.75{x_2}^2 \qquad (3)$$

Graph (3) shows the graphical representation of the PE equation.
R-Squared:$r^2 = 0.95$
Adjusted R-Squared: $r_{adj}^2 = 0.87$
Residual Standard Error: 3.52 on 3 degrees of freedom.
Overall F-statistics: 11.38 on 5 and 3 degrees of freedom
Overall p-value: 0.04

Source	df	SS	MS	F-statistics	p-value
Regression	5	703.58	140.72	11.38	0.04
Residual Error	3	37.1	12.37		
Total	8	740.68	92.59		



IV. CONCLUSION

Our research shows that recycled aluminum alloy 2014 tensile strength has increased significantly when hot extrusion was introduced. According to the results, the tensile strength of the material has increased considerably from its original form. Recrystallization and grain refinement phenomena inherent to the hot extrusion process are responsible for the observed improvement. Increased mechanical performance is a key factor in many engineering applications, and the material's increased tensile strength makes it more suitable for those uses. After the hot extrusion process, the statistical analysis showed that the yield strength had increased significantly. The decrease in grain size and the rise in dislocation density both contribute to the observed increase in tensile strength, which is consistent with this result. Improved resistance to plastic deformation under external forces, as indicated by the increased yield strength, is beneficial in structural and load-bearing applications. Tensile and yield strength were both increased in the hot extruded material, while percentage elongation was reduced. The increase in strength is responsible for the decreased ductility. When selecting a material for a certain application, engineers and designers must weigh the material's strength against its ductility. The selection process needs to be guided by the required mechanical properties of the final product. Hot extrusion, as shown by statistical analysis of recycled aluminum alloy 2014 chips, is an effective way for improving the material's mechanical properties, especially its tensile and yield strengths. However, the decreased ductility is an important trade-off to consider. Because of these findings, businesses and manufacturers that are interested in using recycled aluminum alloys for a variety of purposes can make educated decisions about the suitability of the material for their specific needs.

More study and testing may be needed to perfect the hot extrusion method and improve the material's qualities in line with strict technical standards.

V. REFERENCES

[1]. Wagdy B., El-Wahab A., El-gamasy R. (2022): “Statistical analysis of solid-state recycled aluminum alloy 2011 chips by hot extrusion”, Engineering Science and Military Technologies, 6(2): 86-94.

[2]. Li Y., Yong B., Zhang M., Wang H., Gong W., Lai R., Li Y., Li Y., Teng J. (2023): “The corrosion behavior and mechanical properties

of 5083 Al-Mg alloy manufactured by additive friction stir deposition", 213:110972.

[3]. Tekkaya A.E., Schikorra M., Becker D., Biermann D., Hammer Nand Pantke K. (2009): "Hot profile extrusion of AA-6060 aluminum chips", J. Mater. Process. Technol., 209: 3343–3350.

[4]. Gronostajski J.Z., Marciniak Hand Matuszak A. (1996): "Production of composites on the base of AlCu4 alloy chips", J. Mater. Process. Technol., 60 719–22.

[5]. Schikorra M., Pantke K., Tekkaya A.E., Biermann D. (2008): "Reuse of AA6060, AA6082, and AA7075 aluminum turning chips by hot extrusion", Advanced Technology of Plasticity, 9:371

[6]. 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", J. Mater. Process. Technol., 143:792–795.

[7]. Ab Rahim SN, Lajis MA, Ariffin S (2015) A review on recycling aluminium chips by hot extrusion process. Procedia CIRP 26:761– 766.

[8]. Tang W, Reynolds AP (2010) Production of wire via friction extrusion of aluminum alloy machining chips. J Mater Process Technol 210:2231–2237

[9]. Yusuf NK, Lajis MA, Daud MI, Noh MZ (2013) Effect of operating temperature on direct recycling aluminium chips (AA6061) in hot press forging process. Appl Mech Mater 315:728–732

[10]. Misiolek WZ, Haase M, Khalifa NB, Tekkaya AE, Kleiner M (2012) High quality extrudates from aluminum chips by new billet compaction and deformation routes, high quality extrudates from aluminum chips by new billet compaction and deformation routes. CIRP Ann Manuf Technol 61(1):239–242

[11]. Peng T, Wang QD, Lin JB (2009) Microstructure and mechanical properties of Mg–10Gd–2Y–0.5Zr alloy recycled by cyclic extrusion compression. Mater Sci Eng A 516(1–2):23–30.

Cite this article as :

Rupesh Kumar Gupta, Dr Mahendra Yadav, Suryakant, "An Empirical Study of Hot-Extruded Recycled Aluminium Alloy Chips in 2014", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 5, pp. 517-525, September-October 2023. Available at doi : https://doi.org/10.32628/IJSRST52310572

Journal URL : https://ijsrst.com/IJSRST52310572