ICAA 11

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Dear Mr. Babakhani,

You are participating in the ICAA11 conference and you request an official invitation to present at the German Embassy. For your convenience enclosed please find the invitation letter.

Should you need any further information please do not hesitate to contact us via email (icaa11@dgm.de) or fax (+49-69-75306-733).

With kind regards

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Recycling of Aluminium: **Recycling of Aluminium Alloy Turning Scrap via Cold Pressing and Melting with Salt Flux**

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1 Introduction

The recycling of aluminium scrap has significant economic, energy, environmental and resource savings implications. Comparing to the primary aluminium production, aluminium recycling has a great advantage due to lower production cost [1–4].

When metal products are manufactured, considerable amounts of waste in the form of chips and discards are produced. The chips deriving from the machining of semi-finished aluminium products are very difficult to recycle by conventional methods due to their elongated spiral shape, small size, surface contamination with oxides, machining oil, etc [5–8].

During the recycling of the waste, a lot of metal is lost as a result of oxidation and the costs of labour and energy as well as the expenditures on environmental protection increases the general cost of the process [9].

However, there is a different way of recycling metal chips, consisting of direct conversion of chips into compact metal and use of protective salt.

In the present paper, the melting experiments were carried out in an electrical resistance furnace in a laboratory scale at 750°C. For some specimens the NaCl–KCl–KF system was used as the salt flux for protecting metal from oxidation. The objective is to study the recyclability of different pressed samples by weight loss measurement in various conditions including only melting the samples, remelting in the molten AA336 and salt flux. This research is also compares the mechanical properties of samples with each other and with that of the initial ingot of AA336.

2 Experimental Procedure

The chemical composition of chips collected directly from machine shops is summarized in Table1.

Table 1. Typical chemical analysis (wt%) of used material

Al	Ni	Mg	Cu	Si
Bal.	0.94	1.01	1.1	12.47

Aluminium alloy chips were cold pressed at different pressures to determine the compressibility curve. A floating cylindrical die with a diameter of 24mm was used. The samples were initially

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Abstract:

In the present paper, the melting experiments were carried out in an electrical resistance furnace in a laboratory scale at 750°c. For some specimens the NaCl–KCl–KF system was used as the salt flux for protecting metal from oxidation. The objective is to study the recyclability of different pressed samples by weight loss measurement in various conditions including only melting the samples, remelting in the molten AA336 and salt flux. This research is also compares the mechanical properties of samples with each other and with that of the initial ingot of AA336. Observations showed that the pressure of cold pressing has no significant effect on reducing weight loss during melting cold pressed specimens in salt flux.

Melting cold pressed specimens in salt flux and in molten Aluminium alloy produce samples with mechanical properties almost equal to the samples obtained from melting ingot.

Key words: Aluminium scrap, Cold pressing, Mechanical properties, melting, Salt flux

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2 Experimental Procedures

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Table 1: Typical chemical analysis (wt%) of used material

Si	Cu	Mg	Ni	Al
12.47	1.1	1.01	0.94	Bal.

Aluminium alloy chips were cold pressed at different pressures to determine the compressibility curve. A floating cylindrical die with a diameter of 24mm was used. The samples were initially cold pressed at various pressures according to Table 2. The pressed samples were subjected to three procedures: the first series were melted in crucible, the second introduced into molten AA336 and the third series of samples into salt flax.

Table 2: List of produced samples and their production condition

Designation of products	**Production condition**

Ref	Melted ingot as reference specimen
S	Scrap melted at 750^{o}C
CP3	Cold pressed at 300MPa and melted at 750^{o}C
CP6	Cold pressed at 600MPa and melted at 750^{o}C
CP9	Cold pressed at 900MPa and melted at 750^{o}C
SM	Melting the scrap in molten AA 336 aluminium alloy at 750^{o}C
CP3M	Cold pressed at 300MPa and melted in molten AA 336 aluminium alloy at 750^{o}C
CP6M	Cold pressed at 600MPa and melted in molten AA 336 aluminium alloy at 750^{o}C
CP9M	Cold pressed at 900MPa and melted in molten AA 336 aluminium alloy at 750^{o}C
SS	Melting the scrap into KCl, NaCl and KF flux at 750^{o}C
CP3S	Cold pressed at 300MPa and melted into KCl, NaCl and KF flux at 750^{o}C
CP6S	Cold pressed at 600MPa and melted into KCl, NaCl and KF flux at 750^{o}C
CP9S	Cold pressed at 900MPa and melted into KCl, NaCl and KF flux at 750^{o}C

Melting of samples was carried out according to the Table 2.

To evaluate the influence of pressing conditions and salt flux on the recyclability, two types of measurements were carried out:

- Quantometric analysis on all specimens
- Weight loss percent of produced samples were calculated using the following equation:

$$X = \frac{M_1 - M_2}{M_1} \times 100 \qquad (1)$$

Where, M_1 is the initial weight of scrap and M_2 is the weight of produced specimens.

The consolidated materials were characterized by optical and electronic microscopy and some of them were also characterized by tensile strength.

3 Results and discussion

3.1 Compressibility Curve

Figure 1 presents the compressibility curve for the AA 336 aluminium alloy chips. From this curve, the optimum result was obtained at a pressure of about 900MPa; this pressure can produce compacted chips with a density of about 2.5g/cm^3.

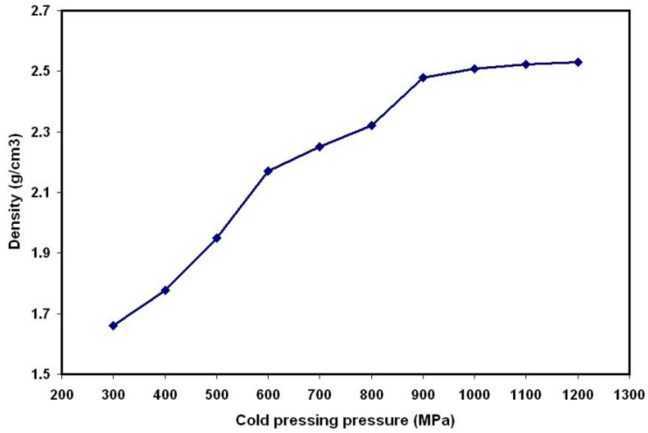


Figure 1. Compressibility curve of AA 336 aluminium alloy scrap.

3.2 Weight Loss

The weight of charged crucible before and after the experiments was measured.

The weight loss percentages of produced samples listed in Table 2, are shown in Figure 2. It is noticeable that the weight loss of the Salt flux samples (SS, CP3S, CP6S and CP9S) is the lowest.

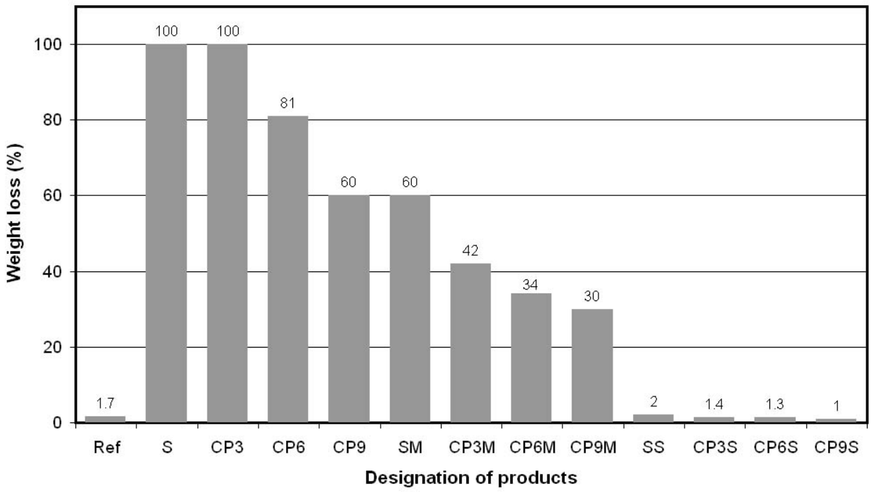


Figure 2. Weight loss of produced samples.

It can be observed that an increase in the pressing pressure produces higher degrees of consolidation. However, even the highest level of pressure dose not yield satisfactory results, since some weight loss is still present, which implies the need for an additional process; i.e. using protective salt flux to eliminate oxidation of cold pressed samples.

3.3 Chemical Analysis

The chemical compositions of the recovered samples are given in Table 3. Comparing with Table1, it is noticeable that the major elements of all products are in the range of AA 336 aluminium alloy ingot (reference specimen).

Table 3: Chemical composition (wt %) of samples produced in this study

Designation of products	Chemical composition (wt%)				Comments
	Si	Mg	Cu	Ni	
Ref	12.30-14.25	0.00-0.60	1.30-1.60	0.90-1.00	Reference specimen
S	-	-	-	-	Complete oxidation of products
CP3	-	-	-	-	Complete oxidation of products
CP6	13.60	0.22	1.46	0.97	-
CP9	13.31	0.32	1.44	0.99	-
SM	13.02	0.42	1.42	0.96	-
CP3M	12.85	0.56	1.41	0.95	-
CP6M	13.40	0.37	1.41	0.94	-
CP9M	13.97	0.38	1.39	0.93	-
SS	13.92	0.02	1.36	0.93	-
CP3S	14.20	0.23	1.43	0.91	-
CP6S	14.13	0.24	1.44	0.91	-
CP9S	14.22	0.19	1.40	0.89	-

These results corroborate that the material is properly consolidated.

3.4 Mechanical Properties

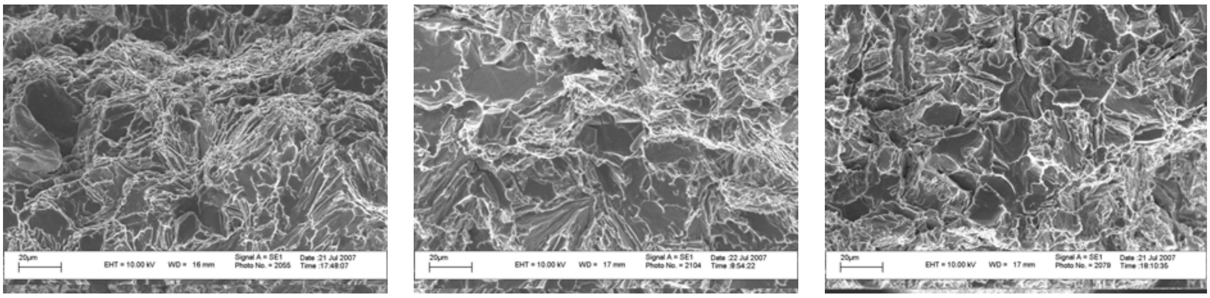
The ultimate tensile strength, elastic modulus, elongation and hardness of the best recovered samples are depicted in Table 4.

Table 4: Mechanical properties of samples Ref., CP9M and CP9S

	Ref.	CP9M	CP9S
Ultimate Tensile Strength (Mpa)	207.68	201.21	199.89
Elastic Modulus (Gpa)	125.3	126.7	124.6
Elongation (%)	2.06	2.01	1.99
Hardness (HB)	59.2	59.1	58.5

It is shown that ultimate tensile strength, elastic modulus, elongation and hardness of cold pressed specimens melted with salt flux and molten aluminium alloy were almost the same as melted ingot.

Examination of fracture surfaces by SEM reveals that, ductile fracture is prominent (Ref. and CP9S samples). It can also be seen that with increasing the weight loss, the fracture surfaces tend to change towards cleavage mode (CP9M); representative examples are given in Figure 3. This behavior could be caused by the presence of oxides inclusions corresponding to high weight loss which decrease the ductility.



(a) (b) (c)

Figure 3. Fracture surface of samples (a)Ref, (b)CP9S and (c)CP9M.

4 Conclusions

The findings in this investigation can be summarized as follows:

a. Higher cold pressing pressure leads to higher density of cold pressed samples and lower weight loss of products but increasing the pressure over 900MPa has no significant effect on increasing green density and decreasing weight loss.

b. The pressure of cold pressing has no significant effect on reducing weight loss during melting cold pressed specimens in salt flux.

c. Major elements of all products are in the range of AA 336 aluminium alloy ingot.

d. Melting cold pressed specimens in salt flux and in molten aluminium alloy produce samples with mechanical properties almost equal to the samples obtained from melting ingot.

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