Prediction the Effects of Used Material Groups on Alloy Components with Regression Analysis

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Abstract

In the working plant, aluminum materials collected from the markets were classified into three groups as drink cans, pots-pans and crank chambers. These material groups were mixed at different ratios in recycling processes to produce aluminium alloy which meets the customer specifications. In this work, the influences of used material groups on each of produced aluminum components are analyzed by the regression method.

Keywords: Secondary aluminum production, regression analysis, aluminum components, recycling, artificial intelligence

1. INTRODUCTION

Increasing public concern for environmental protection and resource conversion has generated interest in the recyclability of materials. The recyclability of a material is determined not only by the intrinsic characteristics of the material itself, but also by the technological, economical, social and environmental context in

which the material is used. Although, aluminium exists 8 % of the earth, it was being produced in large scales by discovery of the electrolysis method [1,2,3,4]. The global demand for aluminum and aluminum products are increasing because aluminum alloys can offer excellent corrosion resistance with good strength and low density compared with steel [5]. The aluminium production which is produced from base metal is called primary production. Secondary aluminium production is production in which recovery materials were used to product aluminium. Primary production process requires high investment, it is not green and the production costs are high. On the other hand, the secondary production can be done lower costs and it is green. So the secondary aluminium production is increasing day to day. It is known that the re-melting of recycled aluminum saves almost 95 % of the energy required manufacturing pure aluminum from bauxite ore [6].

2. LITERATURE REVIEW

Related with the aluminium recycling process, we see the studies to improve the process by changing the parameters such as making the recycling process at lower temperatures [7] and application of different methods which satisfies high pressure in the recycling process [8]. Another work is production of the aluminium using fluxes by a special designed instrument [9]. Using thermodynamic reactions to reduce some elements in the recycling process is an old method which used industry [10]. In other work, [Verran et al](#) have studied the influence of casting parameters on efficiency in aluminum [11]. In aluminium recycling process, using statistical informations and by changing process parameters, an optimum value between quality and economic value was reached via Taguchi Method [12].

3. THE EFFECTS OF THE MATERIAL GROUPS USED IN RECYCLING PROCESS ON PRODUCED ALLOY

3.1. The Recycling Process

The aluminium recycling process starts with the aluminium demand of the customer as seen in Fig.1. According to customer alloy specifications and quantities, which material groups will be used in process was decided. In that decision, the stocks and the purchasing costs are also taken into account. After that, the mixing are melted by the rotary aluminium melting furnace. While melting process is continuing, the fluxes which protect aluminium from oxidizing and clean the aluminium from unwanted material, are added into the melting metal. Meantime, samples are taken from solution and the components of samples

are analyzed. If deemed necessary, elements such as copper, silisyum are also added into the melting. Afterwards, the melting is transferred to the reverber furnace. Then, the slags over the melting are transferred to the handbarrows from the bottom of the rotary furnaces. The analyses are made in the reverber furnace also. After obtaining the customer specifications, the solution pours to the moulds. The aluminium scraps are classified according to their groups. In this way, economic and effective production that satisfies the customer demands in the shortest time, is targeted. In studied factory, the scraps are divided into three groups and they recorded so as. The first group is soft drink cans. The second one is pots-pans which includes kitchenware's such as saucepan, frying pans. This group includes the highest rate of aluminium and so has the highest price. Third one is called crank chambers which include automotive and white goods materials. This group's aluminium ratio is lower than pots-pans and this group has large scale use aluminium [13,14,15].

Fig. 1. Aluminium Recycling Process in working factory

3.2. Method

Regression analysis is a statistical method to examine the relationship between a dependent variable and one or more independent variables. Using a single independent variable is called univariate regression analysis and using more than one independent variable is called multivariate regression analysis [16]. In this work multivariate regression analysis is used and the formulae of this one can be shown as

$$Y_i = a + b_1X_1 + b_2X_2 + \dots + b_nX_n + \varepsilon \quad (1)$$

In the equation (1), a and b are regression coefficients, X values are independent variables. In the studied factory, 126 production records were analyzed from September 2010 until June 2011. In production, the used materials are divided into three groups as mentioned above. For each production, samples were taken from the finished products and their components analyzed. The records include the quantities of the used material groups and the components of the finished products for each production. For the component analysis spectrometer and SPSS were used for the analysis.

3.3. Hypothesis

The regression method schematic results prepared to analyze by hypothesis whether quantity percentage of Ag, B, Bi, Ca, Cd, Cr, Fe, P, Mg, Mn, Na, Sn, Pb Zn, Zr elements found in aluminium alloys change according to the usage percentage of pots and pans, drinks cans and crank chambers used as input in process are shown in Figure 2. Si and Cu are added to the process when necessary. Moreover, in the measurement results it is seen that Be, Co, V, Li and Sr values are very low. On the other hand, the differences between the groups are very low in Ti and Ni values. As a result, in aluminium alloys a hypothesis is not developed for Be, Co, Cu, Li, Ni, Si, Sr, Ti and V values. For a more detailed statement, the hypotheses in Table 1 are developed.

Fig.2. Regression scheme

Table 1. Hypotheses about

H_0	X element value of produced products does not change according to the usage percentage of pots-pans, crank chambers and drink cans used as input in the process.
H_1	X element value of produced products change according to the usage percentage of pots-pans, crank chambers and drink cans used as input in the process.

The values of variable X : Ag, B, Bi, Ca, Cd, Cr, Fe, P, Mg, Mn, Na, Sn, Pb Zn, Zr

3.4. The Results of Regression Analysis

As a result of regression analysis, each of Ca, Cd, Na, Sn, Pb elements used in the process and the material groups which are soft drink cans, pots-pans, crank chambers, were found to be statistically insignificant ($p > 0,05$). Therefore, the model results related with these elements are not included in this study. On the other hand, each of Ag, B, Bi, Cr, Fe, P, Mg, Mn, Zn elements and the material groups which used in the process, were found to be statistically significant ($p \leq 0,05$). The prediction results of statistically significant regression models are shown for each element in Table 2.

Table 2. Predictions in multiple regression

	Constant	Post-pans pertangace	Drink-cans pertangace	Chamber pertangace	Significiance	R ²
Silver (Ag)	0,002 (0,001)*	-0,0000141 (0,015)*	-0,0000123 (0,035)*	-0,0000357 (0,009)*	0,049*	0,075
Bor (B)	-0,002 (0,002)*	0,0000485 (0,000)*	0,0000565 (0,000)*	0,0000255 (0,082)**	0,000*	0,516
Iron (Fe)	-5,958 (0,000)*	0,079 (0,000)*	0,084 (0,000)*	0,054 (0,000)*	0,000*	0,783
Chrome (Cr)	-0,213 (0,000)*	0,003 (0,000)*	0,003 (0,000)*	0,002 (0,135)	0,000*	0,325
Phosphours (P)	0,004 (0,000)*	-0,0000306 (0,000)*	-0,0000331 (0,000)*	-0,00000726 (0,626)	0,000*	0,282
Zirconium (Zr)	-0,006 (0,001)*	0,000076 (0,000)*	0,0000748 (0,000)*	0,000059 (0,134)	0,000*	0,475
Bismuth (Bi)	0,004 (0,001)*	-0,000003 (0,782)	0,000006 (0,582)	-0,000022 (0,381)	0,005*	0,087
Magnesium (Mg)	0,318 (0,011)*	-0,002 (0,077)**	-0,003 (0,025)*	-0,001 (0,647)	0,006*	0,111
Mangenese (Mn)	-0,051 (0,829)	0,005 (0,052)**	0,004 (0,096)**	0,002 (0,679)	0,000*	0,244
Zinc (Zn)	0,472 (0,025)*	0,000 (0,855)	0,001 (0,493)	0,003 (0,516)	0,002*	0,131

* P (Possibility) < 0,05

** P (Possibility) > 0,05

Because many production processes do not have crank chambers and the percentages of crank chambers when it is used in the production were low, the contributions of crank chambers insignificance in the model have been neglected for some elements. The estimated coefficients of regression models for bismuth and zinc, in 0,10 significance level, are observed statistically insignificant. Antimony, lead, bismuth, tin and bismuth elements in alloy are lost because of metallic sodium. For that reason, they can be observed insignificant [14,17].

3.5. The Graphs of relationship between used materials and products

The effects of the percentage of used soft drink can, pots-pans, crank chamber groups on the percentage of the produced alloy components are studied graphically. From Figure 3 to the Figure 10, are the graphs of the estimated element (Ag, W, Fe, Cr, P, Zr, Mg, Mn) percentages models according to the used percentage of three groups calculated from the regression.

Fig. 3. The effects of used material groups on iron percentage of alloy

Iron (Fe): The percentage of the iron in the drink cans is low. For that reason, attitude of employees is heating the solution to high temperatures when they use high percentage of drink cans. Therefore the iron which has been in the furnace passes to the alloy. So the percentage of the iron is high for the aluminium alloy which used drink cans.

On the other hand for the alloys in which crank chamber usage is high, the alloy is taken in low temperatures from reverber furnace and so the iron which deposit in the bottom of furnace doesn't mix to the alloy. Therefore the percentage of the iron in crank chambers is measured low. For the pots-pans, the percentage of the iron is also high.

Fig. 4. The effects of used material groups on boron percentage of alloy

Boron(B): Because boron brings grain refining in alloy structures and prevents pores, it is measured high values used in drink cans, also pots-pans. The boron percentage in the alloys which used crank chambers were measured low.

Figure 5. The effects of used material groups on chrome percentage of alloy

Chrome (Cr): It is seen that the chrome percentages of the aluminium alloys produced by using pots-pans group has the same value (%0,07) as drink cans group. The alluminum alloy chrome value in which is used the crank chamber is calculated below the zero value by regression method. Because the workers have selected the materials which have high percentage of aluminium from the pots-pan group when they use crank chambers in the production.

Fig.6. The effects of used material groups on manganese percentage of alloy

Manganese(Mn): The highest manganese percentage is in the alluminium alloys which used pots-pan, the second one is in the used soft drink can group and the lowest one is in the used crank chamber group. The manganese has been added to the pots-pan and drink cans to achieve the hardness, so that is an expected condition.

Fig.7. The effects of used material groups on zirconium percentage of alloy

Zirconium (Zr): Zirconium percentage is very low values for all alloys used different material groups as expected.

Fig.8. The effects of used material groups on magnesium percentage of alloy.

Magnesium (Mg) : Sodium chloride causes loss of magnesium at temperatures above 800 ° C. Large amounts of magnesium losses through passing salt bath [10]. The magnesium percentage is expected high for drink cans. However, in the recycling process, attitude of employees is heating the solution to high temperatures when drink cans are used in production, as mentioned above. So, the magnesium in the drink cans burns. On contrary, iron is expected high for crank chamber. For that reason, the alloy is taken in low temperatures from reverber furnace when crank chambers used. Therefore the magnesium doesn't burn and remains in alloy.

Fig.9. The effects of used material groups on silver percentage of alloy

Silver (Ag): The percentage of silver is calculated the same for pots-pans and drink cans and that is calculated low for crank chamber. When the crank chambers were used in alloy, the materials were selected from the pots-pans group which have high percentage of aluminium. So the silver value in aluminium alloy in which is used the crank chamber group, is calculated below the zero value

Fig.10. The effects of used material groups on phosphorus percentage of alloy Phosphorus(P): Phosphorus levels are very low for all groups.

4. CONCLUSION

Type of used materials is an important factor for the components of aluminium alloy in aluminium recycling process. In the working factory, used materials are divided into three groups as pots-pans, drink cans and crank chambers. They recorded for each production process in the working factory. The aim of this work, measuring effectiveness of the use of the material groups and developing a system to predict the alloy components of aluminium alloy before the production according to used material groups. So multiple regression analysis is applied for each of Ag, B, Bi, Ca, Cd, Co, Cr, Fe, Mg, Na, Ni, P, Pb, Si, Sn, Sr, Ti, Zn, Zr elements in alloy components. As a result of regression analysis, each of Ag, B, Fe, Cr, P, Zr, Mg elements and the material groups used in the process which are soft drink cans, pots-pans, crank chambers, were found to be statistically significant ($p < 0,05$). So for these element equations are generated and the found models are interpreted. When the models are examined, it was observed that the aluminium alloys are not affected only from the material groups but also the workers attitude towards the used material groups. In the future, if used materials are further divided into subgroups in the working factor, more accurate estimates could be made. In addition, after each production, regression analysis can be made automatically by prepared software and so artificial intelligence can be used to increase the effectiveness.

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