INVESTIGATION OF THE ELECTRICAL INDUCTION FURNACE USED FOR ALUMINIUM RECYCLING

Gottmyers Melwyn J[1], Dr. C. Bhagyanathan Ph. D[2]

[1]P.G Student, M.E Manufacturing Engineering, Sri Ramakrishna Engineering College, Vattamalaipalayam, Coimbatore-641022
[2]Associate Professor, Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Vattamalaipalayam, Coimbatore-641022

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Abstract - *Aluminium had been extracted from the chief ore bauxite due to its abundance in nature, but the gas emissions produced by the process has made researchers and industrialists to look for alternatives. Since then the aluminium has been reprocessed and have been accessible in the secondary form with similar characteristics from its antecedent. A lot of recycling methods have been followed, this research work would give a detailed account of the induction (electrical) method used to obtain secondary aluminium alloys. To accomplish this machined aluminium scrap (He9) alloy was melted in the induction furnace. The recycling efficiency of the furnace, its performance compared to the combustion process (coal, natural gas and oil) were also closely analysed. The exertion also involved monitoring of the energy ingestion of the induction furnace and the best furnace that is appropriate for the industry was also determined through the work.*

Key Words: Secondary aluminium, aluminium scrap (He9), induction, energy consumption, process efficiency

1. INTRODUCTION

The ore from which most aluminium is presently extracted, bauxite, is a hydrated aluminium oxide. Aluminium is a good electrical conductor; it is ductile and can be readily cast and machined. Aluminium is the perfect 'eco-metal'. Very little aluminium is lost in the re-melting process. Increased recovery, dismantling and sorting of spent products has led to even greater recycling of aluminium is recycling becomes increasingly important so does the life cycle of aluminium. Along with the energy savings, recycling aluminium saves around 95% of the greenhouse gas emissions compared to the 'primary' production process. Recycled aluminium is a valuable commodity, so most recycling centres will accept your used scrap. Moreover, aluminium can be recycled indefinitely with no limit on the number of times the metal can be reused. According to the Aluminium Association, an industry trade group, recycling just one can saves the amount of energy it takes to watch the Super bowl in other words, the amount of energy needed to power a television for three hours. In recent years more extensive use is being made of the induction furnace for melting of many nonferrous alloys. High-frequency furnaces of the lift-coil type are limited by crucible size to about 90-lb heats of aluminium. Motor generator sets of 5 to 1000 kw providing frequencies up to 10,000 cycles may be used. Low-frequency furnaces in sizes ranging from 60-500 kw at frequencies below thousand cycles and having pouring capacities of 200-5000 lb of aluminium are available and are capable of melting 5 to 7 lb per hour per kw rating of the furnace. Low-frequency furnaces have a characteristic that they must be started with a heel of molten metal, and so are emptied only when cleaning is necessary. Since melting is rapid and no combustion products are present, oxidation losses are at minimum.

2. LITERATURE SURVEY

Literature survey on evaluation of induction furnace and the efficiency of aluminium recycling process along with the process parameters are given in this section. The requirement of furnace is to provide the required heating and make sure no by-products are produced in the process. The efficiency of the process plays a major role in any work environment.

William H. Macintosh gave a review on the recovery of secondary aluminium and demonstrated that the Induction furnaces offer several advantages over direct-fired furnaces: low melt loss, good metal quality, and high efficiency. This paper analyzes the advantages of using an induction furnace for secondary aluminium recovery.

Vivek R. Gandhewar et al. gave a review on present practices followed in Induction Furnaces. Through a literature review account of various practices presently being followed in steel industries using Induction Furnaces has been carried out with a view to gather principal of working. Apart from this a pilot study has also been carried out in few industries in India. We provide some recommendations for the productivity improvement. Due to non-availability of the proper instrumentations the effect of the ill practices cannot be precisely judged. If this is properly measured, the percentage of productivity improvement in steel melting Induction Furnace can be calculated. The review is carried out from the literature in the various journals and manuals.

Angela O. Nieckele et al. analysed the factors that affect the choice of liquid or gas fuel to be used in an industrial furnace can be of extreme importance, having a direct effect on its performance, on the level of pollutants emissions, and on the equipment working life. These factors are highly dependent on the combustion process and on factors such as the flame shape and the temperature and heat flux distributions within the furnace. In the present work, numerical simulations were carried out, using the finite volume method, with the purpose of analyzing and comparing the combustion process inside an aluminium furnace when operating with two types of fuel: a spray of liquid oil and a jet of natural gas, both reacting with air. The results showed the possible damages that may be caused by the combustion process if long or too intense and concentrated flames are present, increasing the wall temperatures and compromising the heat flux on the aluminium surface.

3. EXPERIMENTATION

3.1 SORTING

Aluminium alloys are used in several sectors and applications in combination with a lot of different materials, such as metals (steel, copper, zinc) or, in other cases, rubber, plastic, and glass. The Al scrap inevitably contains residuals of such materials that oblige refiners to properly screen the scrap before melting to enhance recycling efficiency and reduce the presence of impure elements. Undesired particles and elements may be reduced during the melting by refining processes, but this is challenging due to thermodynamic barriers. The physical separation (sorting) of solid scrap streams is a reliable solution to prevent the commingling of metals and elements, even if the technical benefits are not completely evident.

Different types of scrap require various sorting methods and different results can be obtained. Thus, it is necessary to understand when the benefits outweigh the required investment. Sorting casting and wrought Al alloys, for instance, allows the production of high quality wrought alloys that are actually not possible with mixed scrap, however, sorting technologies for this issue have high capital investments and high running costs.

The sorting technologies normally used for Al recycling aim to separate aluminium scrap from other materials, such as other metals or rubber. The research and the innovative technologies are now oriented not only to separate Al scrap, but to recognize the alloy group and, if possible, the specific Al alloy.

3.2 PREHEATING OF THE SCRAP

Pre-heat oven is used to pre-heat scrap before it is added to the furnace. The heat comes from the recuperator and does not require the use of additional gas. Pre-heating is done to remove water from the scrap. The presence of water when the metal is placed in the furnace will cause an explosion as the water rapidly vaporizes.

3.3 MELTING IN THE INDUCTION FURNACE

An induction melting furnace for aluminium is designed specifically for the purpose of melting lower density metal, employing exactly the right temperatures and evenly distributing the heat. This is vital in melting such metals as aluminium if you want to preserve the expected lifetime of aluminium and its quality. The ideal melting furnace for aluminium will offer precise temperature controls in order to achieve this goal

The charge is introduced into the furnace and the melting of the aluminium scrap is done by the induction process, melting of aluminium takes nearly 7500C and it is held at that temperature for some more time for uniform melting. Once this is completed the melt can be poured.

3.4 POURING

The molten metal is poured into the ingots specifically preheated and coated with graphite. Preheating is done to avoid the huge temperature difference between the cast and the ingot as it might lead to certain casting defects. Graphite coating is done for easy removal of the cast from the ingot.

3.5 HOURLY ANALYSIS

Two 80kg aluminium scraps were melted separately and during the melting period in the induction furnace every hour the parameters were noted down; this is done to monitor the melting process keeping the process parameters at stake. The parameters noted down each hour would be the temperature of the materials inside the furnace and the energy rating along with the state of the metal. The temperature is measured using the thermocouple since there may be variations in the display. Meanwhile the energy rating is noted from the display.

3.6 LOAD VARIATION

In order to determine the efficiency of the process, the furnace was loaded with scraps ranging in weight from 30kg to 80kg in steps of 10kgs at a time this was done to determine the efficiency of the process at various loads. The yield obtained in the various processes have to be determined.

4. RESULT AND DISCUSSION

4.1 CHEMICAL ANALYSIS

Table 1: Chemical Composition

CAST	Al%	Si%	Cu%	Fe%	Mg%	Mn%	Ti%
BEFORE MELTING IN THE FURNACE	98.85	.60	0.008	0.05	.45	.02	.01
AFTER MELTING IN THE FURNACE	98.7	.55	.005	.22	.40	.02	.01

Sample material is evaporated by spark discharge inside the instrument. In this process, the released atoms and ions are excited and emit light. This light is directed into the optical systems and measured using CCD* technology. Calibration data are already stored in the instrument's memory. The measured values are compared with these data. The measured values are converted into concentrations and then displayed on the screen.

4.2 HOURLY ANALYSIS

This was done to determine the energy rating of the process Efficiency Calculation

For Melt of 80 Kg of LM-25

Table 2: Hourly Analysis for Energy Consumed

Time (Hrs.)	Temperature (*C)	Input (kWh)	Observation
0	26	5574.4	Solid
1	329	5601.8	Solid
2	423	5628.4	Solid
3	524	5654.7	Solid
4	628	5683	Semi-Solid/Next50% addition
5	680	5710.4	Semi-Solid
6	756	5737.1	Melt
7	784	5755.5	Melt/ Pour
8	743	5755.5	Offline/Pour
	Total Energy spent	181.1	
	Avg. Energy / Hrs.	25.87142857	

As shown in the table the average amount of energy required per hour is 25kw

The yield obtained by melting 80kg aluminium scrap was 76kg

4.3 SPECIFIC ENERGY CONSUMPTION

181kwh energy is used to produce 76 kg of aluminium ingot
Therefore, Specific Energy Consumption =181/76
= 2.381kwh

Quantity of Heat required to melt the Charge
Melting point of aluminium is about 660^{o}C at standard atmospheric conditions. Thus in order to obtain enough fluidity, choose pouring point of aluminium, Tp =800^{0}C.
$Q = \rho v\,(C_a\,(T_a - T_o) + h_{fo} + C_a\,(T_p - T_a))$
Where, Density of aluminium, ρ = 2700kg/m^3
, Volume of material V = 0.08792m^3
Specific heat of aluminium, Ca = 0.9kJ/kg^{0}C,
Melting point of aluminium, Ta = 660^{o}C
Latent heat of fusion of aluminium hfo= 398kj/kg;
Atmospheric Temperature to = 28^{0}C

Q = 2700 x 0.08792 (0.9(660 -28) + 398 + 0.9 (800-660))
Q = 237.4((0.9x 630) + 398 + (0.9 x 140)) = 900 MJ

4.4 MELTING TIME CALCULATION

The melting time matters a lot as, during this period, induction furnace draws heavy current from the supply mains and inject harmonics into the system.

The melting time is calculated as follows:

Input Power available = 22 kW
Power consumption for Ingots = 238 kWh/ton
Thus, Melting Time = (238/22) *x 1 hour = 10.81 hours
Thus, for melting 100kg of aluminium scrap, it requires 10.81 hours. The melting time varies from scrap to scrap.

4.5 COMPARISON STUDY

As mentioned earlier various industrial analysis were made and the procedures followed in the industries were analysed the yield and energy required to produce 100kg melt was studied in brief and a comparison was drawn between those industries and the induction furnace for melting aluminium. The energy calculations for other methods were done by converting it into kwh.

The amount of fuel burnt multiplied by the calorific value of fuel multiplied by a factor of 1.02246 (considering atmospheric conditions) and these three divided by 3.6

Gas units to kwh
(Fuel burnt*1.02246*CV of fuel)/3.6
Calorific value of LPG: 27 MJ/kg
Fuel required to melt 100 kg Aluminium: 40 m3
: (40*27*1.02264)/3.6
= 306 kwh
Therefore 306 kwh of energy is spent using coal as fuel to melt 100kg of aluminium

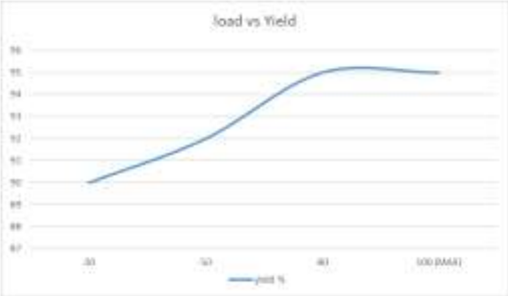
Table 3: Yield and Energy Consumed

Melting Type	Yield	Energy required (kwh)
INDUCTION (ELECTRIC)	95%	238
LPG	90%	390
Furnace oil	93%	190
Coal	88%	306
gas	85%	326

The tabulation shows that the electric (induction) heating is a better process than other types as the yield is high for induction furnace consuming lesser energy than other processes.

4.6 LOAD VARIATION

Aluminium scraps were added in the following weight measures separately 30kg, 50kg, 80kg and 100kg this was done to determine the efficiency of the process when subjected to different loads of aluminium scrap the results of the same are tabulated here.



5. CONCLUSIONS

Electrical energy is found to be an advantageous method to melt the aluminium alloys for production of secondary aluminium scrap. The results clearly show that the amount of aluminium yield obtained is comparatively higher than the process where combustion of fuels (coal, natural gas, oil and petrol) is carried out.

One of the main reason for the electric process is that the melting of the material is carried out by the process of induction, in case of combustion there is always a loss due to the reactions of the elements in the melt with the fuel and escape in the form of combustion by-products.

In industry point of view when the energy consumption is less the particular industry or organization would enjoy a lot of benefits in the form of saving the expenditure for fuel and the same can be used for other miscellaneous costs or overhead costs that occur in the industry. The most important factor is that environment friendly process. Almost all mechanical process cause pollution to a higher level but by consuming less energy a lot of benefits can be sought by the industry.

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