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INVESTIGATION OF THE POTENTIALS OF NIGERIAN SALT DEPOSIT AS FLUXING MATERIALS IN SECONDARY ALUMINIUM PRODUCTION

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ABSTRACT

Secondary aluminium has been a major contributor to the total supply of aluminium to the national economy. To obtain high-grade secondary aluminium from scraps, melted scraps are subjected to such treatment as fluxing. Fluxing improves the quality of secondary aluminium products by eliminating the impurities and protecting the surface of the melt from contamination. In this work, fluxing of aluminium scrap was carried out using salt obtained from Keana in Nassarawa State. The preliminary investigation carried out on the salt indicate a high level composition of various cations and anions such as Na^+, K^+, Cl^-, CO_3^-, that are characteristic of aluminium fluxes. Various percentages by mass of Keana salt was used in fluxing melt obtained from aluminium scraps. The results of tests carried out on the specimen using cast samples indicate that the optimum fluxing proportion of this salt is 1.5 wt.% The corresponding values of mechanical properties are UTS= 141N/mm^2; Percentage Elongation= 1.11; Brinnel Hardness = 50HRB; Impact Strength = 51.54J. These values compares well with those obtained using standard Coverall fluxing materials and in some instances, samples fluxed with Keana salt gave better parameters.

Keywords: Secondary Aluminium, Scraps, Fluxing, Salt, Mechanical Properties.

INTRODUCTION

Fluxing is a major metal treatment which is very important especially when the metal to be melted is scrap metals that have been used and dumped and are mixed with many impurities. Fluxing is the process of reaction between the fluxing agent and the gangue material to produce a fusible slag that is easier to separate from molten metal. The idea is to separate the gangue by reducing it to its immiscible slag phase. Separation can then be done by skimming off the slag from the top of the melt. Thus, the slag needs to form a separate phase to ease its separation and this is what is achieved through fluxing. Furthermore, by removing the impurities contained in metal, fluxing improves the mechanical properties of metal. Fluxing is therefore an important treatment of Aluminium along side degassing and alloying.

Aluminium is one of the important metal produced by fused salt electrolysis and is widely used for domestic and industrial purposes. In Nigeria, primary aluminium is produced at ALSCON, Ikot-Abasi in Akwa-Ibom State. Secondary aluminium is obtained by remelting and refining used scrap of aluminium. Although, scrap aluminium is the major source of raw materials for the indigenous producer of aluminium pots and household utensils, the industrial producers of aluminium product do sometimes resort to the use of aluminium scrap by virtue of its comparative low cost when compared to imported or locally produced aluminium ingots (Abubakre and Akinyemi,2000). Industrially, aluminium is being fluxed using standard form of fluxing materials. These imported fluxes are usually sold at exorbitant price and under different trade name with closely guarded chemical composition.

In this work, investigation is carried out on fluxing properties of unrefined salt deposits obtained from Keana in Nassarawa State. The analysis of the chemical composition of the salts shows high level content of such anions and cations as Na^+, K^+, Cl^-, CO_3^-, that are useful component in aluminium fluxing. The result of the investigation shows that a good fluxing material could be obtained from the deposit.

ALUMINIUM PRODUCTION IN NIGERIA

Secondary Aluminium Production

The contribution of secondary aluminium to the total world aluminium production constitute about 25 percent (7 million tones per annum). Aluminium is unique in its ability to be recycled several times with no loss to its qualities and properties. The production capacity of Nigerian Aluminium industry stands at 240,000 tonnes per annum. Of this, secondary aluminium contributes 50,000 tonnes per year. One notable

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characteristic of aluminium consumption in Nigeria is such that, building and household product constitute over 90percent of aluminium consumed in Nigeria while the developed countries use aluminium mostly in Transport, engineering, electrical and appliances. The consumption pattern in Nigeria favours the usage of high proportion of scrap aluminium by the seven major producers of secondary aluminium in the country. These companies spend substantial resources on the importation of fluxing materials, which are mixtures of various salts, which are present abundantly in raw form in the country (Palbakar,1999).

Nigerian Salt Deposits with Potential Fluxing Properties

Bateman (1951) viewed salts as soluble products of rock weathering occasioned by infrequent rains to depressions without outlet. As a result of rapid evaporation, a high concentration of included salt is obtained. Salts could also be formed as deposits in depressions between sand dunes, and during rains depressions formed saline lakes of greater or less concentration (Raeburn and Jones, 1934). The depressions that usually result from deflating action of the wind in deserts may become escavated below the water table, leading to the development of a lake. Saline lakes include the oceanic type, alkali or soda lakes, sodium sulphates lakes and borates, nitrate, magnesium and potash lakes.

As a result of the occurrence of salt in saline lake residue or as efflorescence on soil in arid or semi arid region, large deposits of different varieties of salts occur in the lake Chad region of the country. A comprehensive review of the wide spectrum of salts occurring in this region and analysis of some of them was carried out by Ako (1984). Table I highlights some of these salts that have potential of being utilized as fluxing materials in aluminium industry.

Aluminium Fluxing

Flux is a mineral substance or mixture of mineral substances that is added to the melt with the aim of removing from the melt the remnant of fuel and harmful substances in the form of slag, and also lowering the melting temperature of the slag, changing its viscosity and fluidity. In some instance, the fluxes preserve and protect the metal from oxidation, refine it and enhance the regulation of slag formation during the melting processes.

Molten aluminium alloy are extremely reactive and combine readily with other metals, gases and sometimes with refractories. Because of its reactivity, molten aluminium is easily contaminated. The principal contaminants are iron, oxides of metals and hydrogen. Molten aluminium has high surface tension by the formation of oxide film. This makes the casting of thin section from aluminium sometimes difficult. (Perry and Green,1997).

Oxidized metal is a harmful inclusion in molten aluminium. Oxide content is most difficult to control when the alloy contain magnesium. The oxides of aluminium and magnesium are formed quickly on the surface of the molten bath, making a thin tenacious skin that prevent further oxidation as long as the surface is not disturbed. Molten aluminium also reacts with moisture to form aluminium oxide releasing hydrogen. Oxides on

Table I: Some Famous Salt Deposits in Nigeria (Ako, 1984)

S/N	Types	Source	Extent of Distribution	Present Uses
1.	Galo (Sodium Chloride, predominates)	Tejuidda	Kano, Zaria	Medicinal and Culinary
2.	Kige (Sodium Chloride predominates)	Chad shores, Mangari	Borno, Mandara	Culinary
3.	Mangul (High Sodium Chloride content)	Mangari	Borno, Mandara, Sokoto caliphate	Medicinal and Culinary
4.	Beza (Best Sodium Chloride salt)	Kawar, Agram,Asben, Taodeni	Sahara, Sokoto caliphate, Borno	Medicinal ,Culinary and Ink making
5.	Gishirin Foga (Sodium Chloride predominates)	Dallol, Foga	Western Sokoto caliphate, Borgu, Songhay	Culinary
6.	Dan Awai (Sodium Chloride and impurities)	Awe	Bauchi, Kano, Zaria, Jos plateau, Benue basin	Culinary
7.	Dan Keana (Sodium Chloride and impurities)	Keana, Adjacent sites	Nasarawa, Benue basin	Medicinal and Culinary
8.	Kakanda (Adulterated Sodium Chloride)	Niger-Benue confluence	Benue-Niger valleys, Kano, Zaria	Culinary

Table II: Chemical Composition of Fluxes for Aluminium Foundries (Mogilevand Lev,1988).

FLUXES	Weight Percentage of the Component, %					
	NaCl	KCl	NaF	Na_3AlF_6	CaF_2	$MgCl_2.KCl$
Flux 1	45.0	55.0	-	-	-	-
Flux 2	37.0	50.0	-	6.6	6.4	-
Flux 3	35.0	50.0	-	15.0	-	-
Flux 4	-	-	-	-	-	100.0
Flux 5	-	-	-	-	15.0	85.0
Flux 6	-	-	-	-	-	85.0
Flux 7	30.0	47.0	-	23.0	-	-
Flux 8	-	-	-	-	40.0	60.0
Flux 9	47.5	47.5	-	5.0	-	-
Flux 10	35.0	40.0	15.0	10.0	-	-
Flux 11	56.5	11.5	25.0	7.0	-	-
Flux 12	50.0	10.0	30.0	10.0	-	-

Table III: Chemical Analysis of the Composition of Keana Salt and Coverall

S/N	Fluxes	Chemical Composition, %					
		Na^+	K^+	Ca^+	Mg^+	$CO3^-$	C^+
1.	Keana Salt	34.47	0.85	0.099	0.08	5.67	58.05
2.	Coverall	26.51	0.96	3.19	-	0.99	34.25

the surface of the molten bath can be removed by surface cleaning fluxes. These fluxes usually contain low melting point ingredients that can react exothermically on the surface of the bath. The oxides separate from the metal to form a dry, powdery, floating dross that can be skimmed. During fluxing, some dense oxide may sink to the bottom, and can be removed by gaseous fluxing or by allowing it to settle at the bottom

The only gas that dissolves significantly in molten aluminium and can cause porosity if not removed is hydrogen and the amount of dissolved hydrogen increases sharply with increase in temperature. Hydrogen is introduced into molten aluminium by moisture and dirt in the charge, and by the products of combustion. Thus in aluminium foundry practice, additional degassing may be required to remove hydrogen.

The degassing fluxes also help to lift fine oxides to the top of the bath. Removal of hydrogen by degassing is a mechanical action; hydrogen does not combine with the degassing agent.

Basically, for the removal of impurities such as oxides from molten aluminium, industrial fluxes, sold under different trade names, are used. The chemical composition of a different fluxes for aluminium alloys are stated in Table II

EXPERIMENTAL PROCEDURE

Materials.

The salt used for fluxing was obtained from Keana in Nasarawa State. The chemical composition of the Keane salt and the Coverall used are presented in Table III. The scrap aluminium used was obtained from Minna metal scrap yard and consist of condemned piston sleeves of automobiles.

Melting and Casting Procedure

The melting operation was carried out using electric resistance furnace capable of raising temperature in excess of 1200 ^{0} C The crucible was charged with aluminium scrap and heated to 700^0 C. The molten metal was poured into a 320g crucible up to a 250g mark. The metal in the small crucible was then fluxed with 0.5 wt. % of Keana salt. The salt was thoroughly stirred into the molten metal and the resulting dross was skimmed from the top of the molten metal. The clean melt was then poured into the prepared mould for casting. Specimens so obtained were subjected to tensile, impact and hardness test. The same procedure was repeated for 1.0wt. %, 1.5wt. %, 2.0wt% and 2.5wt% of Keana salt. The control specimens were casted from a melt fluxed with 1.5wt. % Coverall (Specimen C) and another melt not fluxed at all (0-wt.%)

Mechanical Tests Procedure.

The tensile test was carried out on the Monsato Swidon Wiltshire tensometer using a standard test specimen (Brandes and Brook

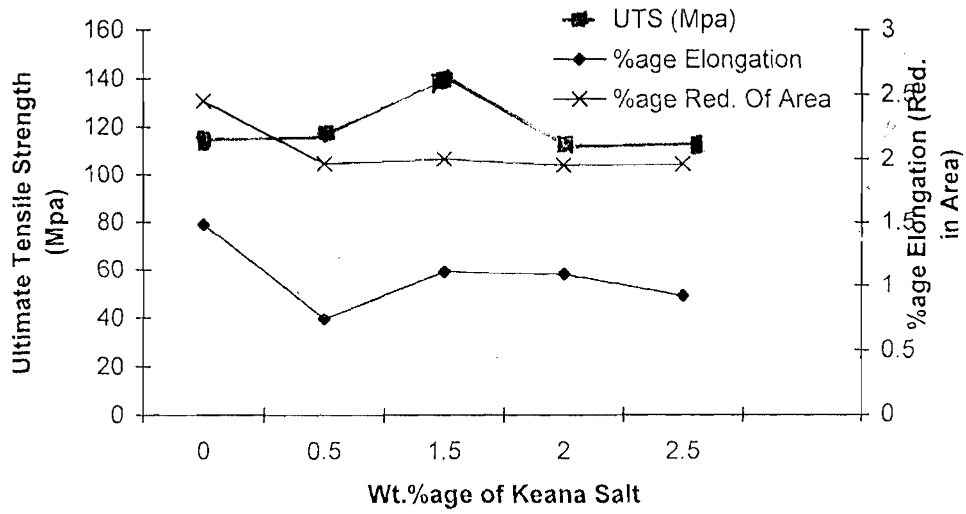

Figure1:Tensile Strength and Ductility Properties of the samples fluxed with Keana Salt.

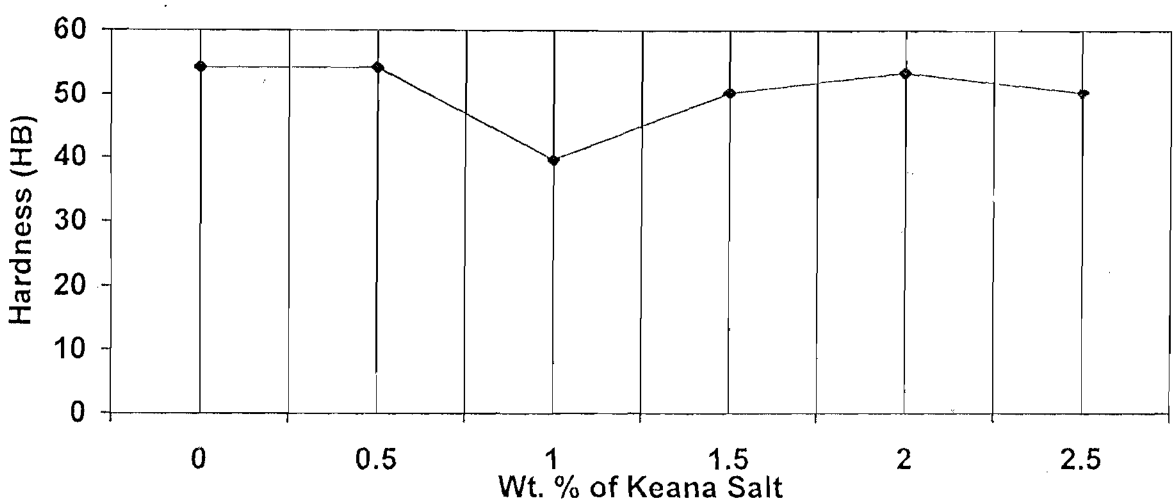

Figure 2: Hardness Values for the samples fluxed with Keana salt.

1992). The machine generated the load-extension graph, the analysis of which gave various strength parameters such as Ultimate Tensile Strength (UTS), percentage elongation and percentage reduction in area.

The hardness test was carried out using the Rockwell hardness-testing machine. The indenter used was a 1/8 " indenter (3mm) and a load of 1000 N was applied. The hardness value was read directly off the digital display. The impact test for determining the toughness of the fluxed materials using a V-notch charpy test specimen was carried out by allowing a heavy pendulum to fall from a fixed height thereby impacting kinetic energy to the specimen.

EXPERIMENTAL RESULT AND ANALYSIS

The result of the tensile strength carried out on the specimen obtained from melts fluxed with Keana salt is presented in Fig. 1

The sample fluxed with 1.5wt. % of Keana salt showed the highest Ultimate Tensile Strength of 141.21Mpa. This value is 19 percent improvement over the unfluxed sample. However, this value is slightly lower than the tensile strength attained with the control Coveral specimen (162.24MPa). The ductility properties of the samples fluxed with Keana salt were lower for all the specimen compared to the unfluxed sample.

The hardness characteristic of the samples from the melt fluxed with Keana salt is slightly lower than the unfluxed sample (Fig. 2). While there is no noticeable change in the hardness with 0.5 wt. % fluxing, a drastic fall was observed with increase of fluxing proportion to 1.0 wt. % with the least value of 39.67HB. The sample with maximum strength has a hardness value of 50.33 HB.

The impact strength of three samples were compared: the unfluxed sample (0 wt.%); sample fluxed with coverall (C) and sample fluxed with 1.5 wt. % Keana salt (Fig.3). Sample fluxed with

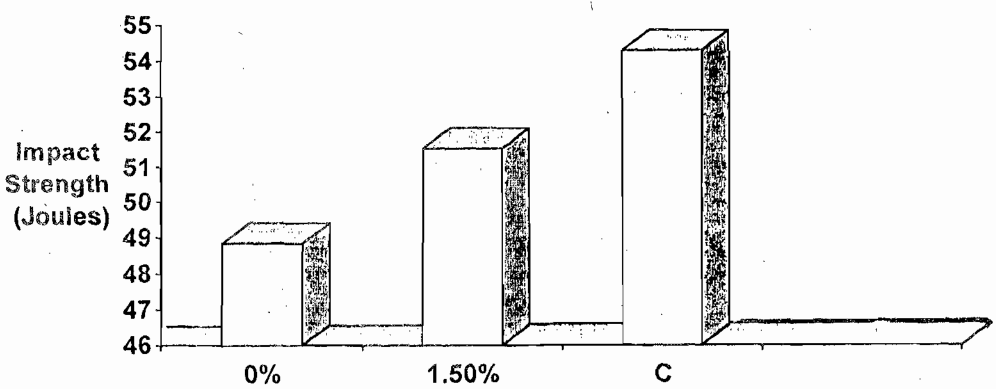

Figure 3: Impact Strength of Fluxed Specimens and the Control

coverall shows the best impact strength while the impact strength values for sample fluxed with Keana salt falls midway between the unfluxed sample and sample fluxed with coverall.

The harmful components in aluminium melting process are principally iron, oxides and hydrogen gas. While the choice of the melting crucible could partly solve the problem posed by iron, hydrogen and oxide could only be eliminated by fluxing. Hydrogen is removed by gaseous fluxing termed degassing.

The chemistry of removal of oxides shows the need for certain active ions that will dissolve the oxide and form with oxygen a less dense and non – soluble component that will constitute the dross(Perry and Green,1977). Chloride ion from Keana salt play this role by combining with the oxygen of the oxides of Aluminium or magnesium to form chlorates of various cations that eventually float as dross. The cations present either play a positive role of modifying the aluminium or combining with chlorate ions to form dross or negatively influence the properties by constituting impurities in the melt.

CONCLUSION

The good potential of Keana salt as fluxing material is vividly hinted at by the result of the present work. Little difference is noticed in the mechanical properties of sample fluxed with this salt and that fluxed with coverall. However, a detail study to evaluate the accurate chemical composition of this salt is necessary to facilitate evolving appropriate process design that will eliminate unwanted components and impurities leaving a pure and refined aluminium flux

References

Abubakre O.K. and Akinyemi I.D., 2000. Invcstigation of the fluxing properties of Zn-C Dry cell powder on Al –Alloy, Proc. 2nd Engineering Conf. Federal University of Technology, Minna. pp.133 – 138.

Agboola , T.O., 2000. Investigation of the effectiveness of locally sourced fluxing materials in aluminium foundry. B.Eng. Thesis, Federal University of Technology. Minna., 45pp. (Unpublished)

Ako P.A.E., 1984. Analysis of Kanwa Samples for Anions, M.Sc. thesis, Ahmadu Bello University, Zaria.147pp. (Unpublished).

Bateman, A.M., 1951. The formation of Mineral Deposits. 2nd Edition; John Wiley. ,New York 194pp.

Brandes E.A and Brook G.B., 1992. Smithels Metal Reference Book. 7th Edition, Butter worth – Heinemann, Oxford, U.K. 1560pp.

Mogilev V.K. and Lev O.I., 1988. Foundry Handbook" Machine Tool Publisher, Moscow. 165pp.

Pabalkar V.V., 1999. Nigerian Aluminium Industry – Scope and Prospect. Proc. of 16th Annual Conf. of Nigerian Metallurgical Society, pp1-8 Abuja.

Perry R.H.and Green D.W. ,1997. Perry's Chemical Engineering Handbook. 7th ed. McGraw Hill Incorporated, New York.

Raeburn, C and Jones, B., 1934. Geological Survey of Nigeria. V. 15, 56pp.