The Status of Kenyan Aluminum Recycling Industry

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***Abstract*—** Aluminum enters Kenya as imported products, and Scrap is either recycled locally or exported. A survey was conducted in Nairobi, Mombasa and Nakuru to study sources, quantity and composition of the scrap through a material flow analysis. A questionnaire, site visits and interviews were used to collect data for the year 2015 from 34 scrap dealers and 29 foundries. Further, data on aluminum exports and imports was provided by Kenya National Bureau of Statistics (KNBS). Major sources of the scrap were motor vehicle, household and building parts. Scrap dealers sold 7,059.6 Mt of scrap to the foundries; composed of 38, 37, and 25 % of rolled, cast and extruded scrap respectively. However, the surplus cast scrap (68.4 %) was exported. The foundries consumed 11,028 Mt of: end of life scrap, internal scrap and primary aluminium. A net addition of 36,782 Mt indicates that more scrap will be available in future.

***Keywords*—** Aluminum, recycling, scrap, secondary alloy.

I. Introduction

Aluminum has become a popular engineering material (second to iron) due to its superior properties and recyclability. Properties of aluminum include light weight, high resistance to corrosion, good thermal and electrical conductivity. These superior properties have made aluminum to be widely used in transport (aerospace and automobile), building, household and electrical industry [1]. Aluminum products are usually organised in three main categories: cast, rolled and extruded. Rolling and Extrusion use wrought alloys, which allow less alloying elements than cast alloys, and are then more challenging to recycle.

Aluminum has been recycled without losing its chemical and physical properties. By the year 2006 it was estimated that about 75% of the aluminum ever produced in the world was still in use [2]. This has allowed secondary aluminum processing to be conducted in areas where bauxite is not mined. Secondary processing of aluminum consumes 5 % of the energy used to process a similar quantity during primary processing [3]. Mining and processing of bauxite to produce primary aluminum degrades and pollutes the environment. As a result aluminum recycling is cheaper and conserves the environment.

Kenya does not produce primary aluminum; however it mainly enters the local market as primary aluminum, fabrications and finished products. The primary aluminum is used to dilute scrap during secondary processing of aluminum in the local foundries. Imported semi-fabrications in form of billets, slabs, sheets or extrusions are used to manufacture finished products. Both the imported products and the locally manufactured products enter into use until their end of life. The life spans of different aluminum products have been approximated and found to range between 1 and 30 years [4]. Aluminum scrap collection system in Kenya starts from the village level, and terminates in the major urban centres; whereby the scrap is sold to local foundries or exported. A comprehensive view of the interconnections within the Kenyan aluminum industry can be projected by a material flow analysis.

Material flow analysis (MFA) is defined as the study of physical flows of natural resources and materials through and out of a given system. Dahlström et al [5] conducted an MFA study to provide data on the flows and stocks of iron/steel and aluminum that passed through the United Kingdom (UK) economy. From the study, end of life (EoL) scrap was estimated at 700,000 Mt per year. Another study by Rombach [6] found that the EoL scrap in North America

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and Europe mainly came from automotive, building and packaging industry. These two studies looked at aluminum scrap in general and were particular to Europe and North America respectively. Billy [4] conducted a study of the flow of extruded aluminum in French buildings. From this study the aluminum extruded scrap generated in French building industry was estimated; a Kenyan study can be modeled along these lines, and widened to also include scrap from rolled and cast products.

Several studies have been carried out on Kenyan aluminum industry. Bruno [7] conducted a survey in the Kenyan aluminum foundries. From the survey it was established that the foundries were not undertaking quality control practices while melting the scrap. Weramwanja [8] did a study on Kenyan aluminum material flow, with an aim of establishing a local aluminum processing plant. This was a general study that covered extensively on use of bauxite and aluminum fabrications. In addition to that little information was gathered on quantities of aluminum scrap. Mbuya et al [9] sorted cast scrap that was collected randomly from Nairobi city scrap dealers, and the resulting castings were found to be closely related in chemical composition to the parent components like pistons, cylinder heads and housings.

Although Kenyan aluminum scrap is collected and either sold to local processors or exported, there is no literature on the sources, quantity and the ranges of composition of this scrap. Such data is important to industrial players; especially when planning on raw materials, and development of new products and alloys. Policies for regulating this industry can be formulated based on this data. Consequently it was found necessary to establish the likely sources, quantities and ranges of composition of the scrap through an industry survey.

II. PROCEEDURE

The industry survey data that was to be collected was modelled in form of an aluminum material flow as shown in Fig. 1. The model assisted in identifying the institutions that participated in the survey and data acquisition tools. The institutions included Kenya Association of Manufacturers (KAM), scrap dealers, foundries and Kenya National Bureau of Statics (KNBS). The tools used to collect data included a questionnaire, site visits and interviews.

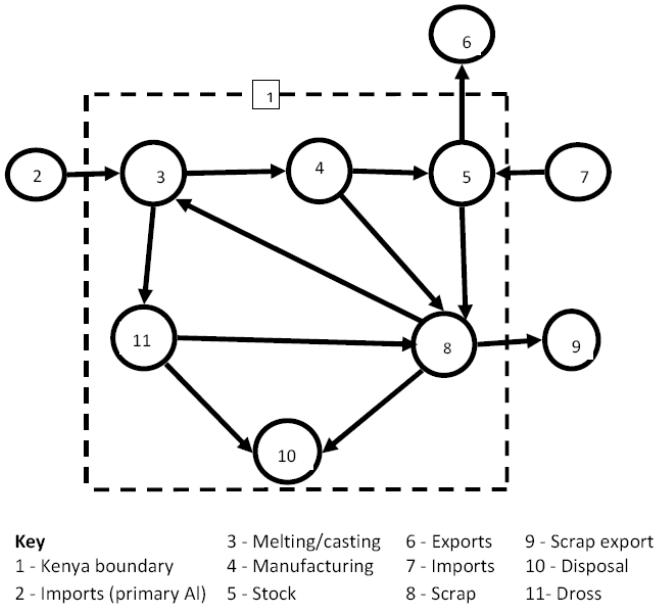

Fig. 1 The Aluminum flows into, out of and within the Kenyan aluminum recycling industry.

An industry survey was conducted in three major towns in Kenya namely: Nairobi, Mombasa and Nakuru. Nairobi is the Kenya's capital city, and Mombasa is the second largest city and the only major sea port. Nakuru is also a major town in the agricultural Rift Valley region. The KAM data base [10] showed that the major aluminum industries and scrap dealers are located in these towns. For the purpose of this research the industries were referred to as foundries. Since not all aluminum industrial players were members of KAM, a preliminary survey was conducted in the towns and their environs to establish additional foundries and scrap dealers. The scrap dealers were the firms dealing with bulky aluminum scrap sourced from small scale dealers located within their home town and other smaller towns. They also bought scrap through tenders from companies and government institutions. The scrap collected was sold to the foundries, and the surplus was exported. A summary of the 34 scrap dealers and 29 foundries that were selected for this survey in the three towns are presented in Table I. A questionnaire of the structure shown in Table II was designed and sent to the various scrap dealers and foundries. The data collected was for the year 2015. Visits were made to different firms. Observations regarding the handling of the scrap were made. Interviews and site visits were conducted to give more information that was not covered by the questionnaire.

TABLE I
SUMMARY OF THE SCRAP DEALERS AND FOUNDRIES THAT PARTICIPATED IN THE SURVEY

Town	Scrap Dealers	Foundries		
		Casting	Rolling	Extrusion
Nairobi	20	12	4	3
Mombasa	8	2	3	-
Nakuru	6	5	-	-
Total	34	19	7	3

TABLE II
QUESTIONNAIRE STRUCTURE

Issue	Question focus
Cover letter	Introduction from JKUAT
Preamble	Introduction, Benefits of the study, confidentiality, contact person
General company information	The respondent's identification data Name, address, telephone, contact person
End of life (EoL) scrap	Type, Source (local or imports), Quantity, Purpose, destination (local or Export), Re-use
New scrap	Source, quantity
Primary Al	Source, quantity, value, purpose
Melting	Primary Aluminum, EoL scrap, new scrap, Quantity generated, dross generated and destination.
Fabrication & manufacturing	Products (Semis or new products) Quantity, destination, quantity of new scrap.
New goods	Locally produced, Imports, Exports, Quantity
Disposal (Land fill)	Any amount that is not recycled
Research interest	To report the outcome of the survey to the participating groups.

Additional data on imports and exports of aluminum products was extracted from statistical abstract and economic survey reports prepared by KNBS [11], [12].

III. RESULTS

The feedback of the questionnaires was collected, and 28 scrap dealers and 22 foundries responded. The data collected is shown in Table III and IV, and KNBS provided data on aluminum imports and exports shown in Table V.

TABLE III
SUMMARY OF ALUMINUM SCRAP IN METRIC TONNES (Mt) HANDLED BY DEALERS IN YEAR 2015

Town	cast	Extruded	Rolled	Total	cast (export)
Nairobi	2375	2449.2	1569.6	6393.6	1800
Mombasa	141.6	170.4	92.4	404.4	0
Nakuru	115.2	68.4	78	261.6	0
Total	2632	2688	1740	7059.6	1800

TABLE IV
SUMMARY OF ALUMINUM SCRAP IN METRIC TONNES (Mt) HANDLED BY THE FOUNDRIES FOR THE YEAR 2015

Town	EoL Scrap				Internal scrap		Import (Primary AL)	Export (Al products)
	Cast	Rolling	Extrusion	Total	New	Recovery		
Mombasa	0.0	4080.0	0.0	4080	78.0	66.0	1800.0	1734.0
Nairobi	493.2	960.0	1920.0	3373.2	355.1	32.2	1080.0	480.0
Nakuru	162.0	0.0	0.0	162.0	1.8	0.0	0.0	0.0
Total	655.2	5040.0	1920.0	7615.2	434.9	98.2	2880.0	2214.0

TABLE V
ALUMINUM IMPORTS AND EXPORTS EXTRACTED FROM KNBS REPORTS

Commodity (Mt)	2008	2009	2010	2011	2012	2013	2014	2015
Aluminum imports	18,525	25,568	19,962	23,427	24,981	26,963	29,371	
Motor vehicle imports	9,189	9,255	10,912	9,238	10,376	12,918	14,492	15,369
House ware exports	5,631	5,507	5,795	6,311	7,328	8,182	7,879	

The end of life scrap handled by dealers was divided into cast, extruded and rolled. The classification of the scrap was based on the process used to make item from which it was derived from. A total of 7,059.6 metric tons (Mt) were collected in the three towns. Nairobi compared to the other two towns had the highest quantities of scrap in all the three categories as shown in Fig. 2. This scrap was consumed by the casting, extrusion and rolling foundries. However 1800 Mt of surplus cast scrap was exported.

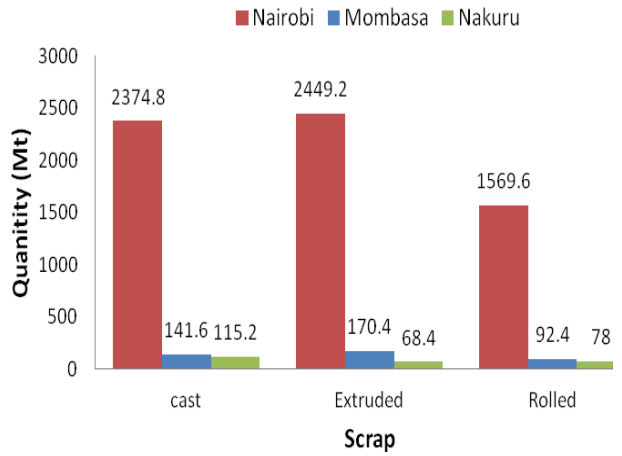

Fig. 2 Categories of the scrap in metric tons (Mt) collected in the three Kenyan towns in year 2015

The foundries used a variety of aluminum including EoL scrap, internal scrap and imported primary aluminum to process products as shown in Table IV. The EoL scrap was supplied by contracted dealers, and its consumption was highest in Mombasa as shown in Fig. 3. New scrap consisted of scrap generated during melting and processing of aluminum. Foundries were recovering aluminum from dross. The rolling and extrusion foundries were exporting primary aluminum to dilute the impurities when melting the scrap. About 2214 Mt of aluminum products were exported; while the rest were consumed locally.

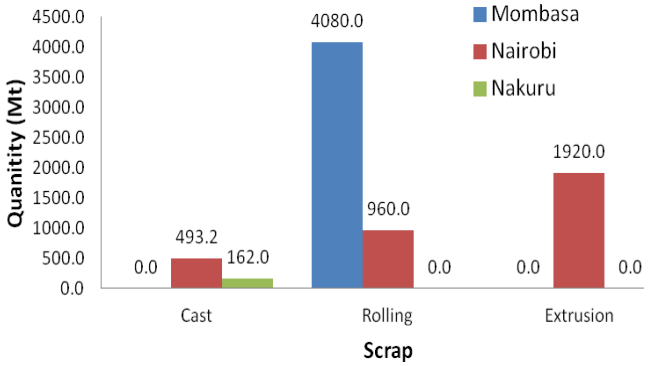

Fig. 3 EoL scrap in metric tons consumed by foundries in the three Kenyan towns in the year 2015

The KNBS reports [11], [12] gave the data on aluminum imports and exports shown in Table V. Aluminum entered the country as billets, rolled sheets and plates, and sections. Imported aluminum in the year 2015 was approximated as 30,000 Mt using linear forecasting shown in Fig. 4. Motor vehicles from Japan, Europe and North America have been reported to contain an average of 140 kg of aluminum [13], [14]. Therefore, the units of imported motor vehicles were multiplied by 140 to obtain 15,369 Mt of aluminum brought into the country in 2015. Aluminum house ware export for the year 2015 was 9000 Mt.

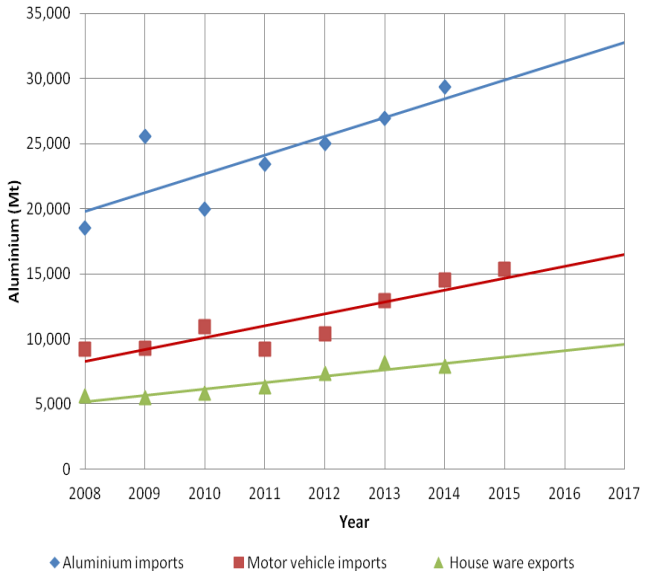

Fig. 4 Kenyan aluminum imports and exports

IV. DISCUSSION

Scrap dealers responded by 82.4%. The reasons for non response include: that two dealers were out of business and another one had just started the business; another three pulled out without giving reasons. The response from foundries was 75.9%, and reasons were not given for non response.

Dealers in Nairobi collected 90% of the EoL scrap. This was contributed by the fact that 59% of the dealers were based in Nairobi, and had both branches and agents country wide. Nairobi was found to generate a lot of scrap from its numerous industrial activities and large urban population. Further, the city dealers were contracted to supply bulk scrap to Kenyan foundries, and whenever there was surplus the government allowed them to export it. The EoL scrap collected by dealers consisted of cast, rolled and extruded aluminum in the following proportions 37, 38 and 25% respectively.

Cast scrap mostly originated from automotive components like engine blocks, wheels, cylinder heads, pistons and gear box casing. However, a small proportion was found to arise

from industrial machines like motor housings. From the literature review, these components are cast from 3xx.x alloys which are silicon based, and with additions of magnesium and/or copper. Silicon based alloys have been found to be popular because of their excellent castability and superior mechanical properties. Local foundries consumed 31.6% of the cast scrap, and the surplus was exported. The government only allowed export of surplus nonferrous scrap; in order to protect the local market.

Rolled and extruded EoL scrap was made up of aluminum wrought alloys, and particularly 3xxx and 6xxx series alloys respectively. Rolled scrap was found to be composed of house ware (pots, pans and urns), vehicle parts (radiators and panels), used beverage cans, sheets and pipes. Further, structural rolled scrap (structural plates and automotive body panels) was present, and was suspected to be composed of 5xxx series wrought alloys. Extruded scrap originated mainly from automotive and building structures. Extruded motor vehicle structural components included frames (space, seat, door and window), beams, tread plates, hand rails, carriers and general automotive trim. Building and construction structural scrap consisted of frames (door, window and green house), office partitions, door handles and locks. Extruded scrap also consisted of 15.7 Mt of electrical scrap inform of cables and bus connectors. The electrical scrap was handled by 12% of the dealers who were accredited, so as to curb rampant thefts and vandalism. All the wrought scrap was consumed by extrusion and rolling foundries.

The foundries were found to consume 11,028 Mt of aluminum, which was composed of Eol scrap, primary aluminum and internal scrap in the following percentages 69, 26 and 5 respectively. The EoL scrap consumed by the foundries was higher than the amount supplied by dealers by 45%. This is an indication that there were other suppliers outside the towns that were surveyed. The pattern of consumption of the scrap clearly indicated that Kenyan

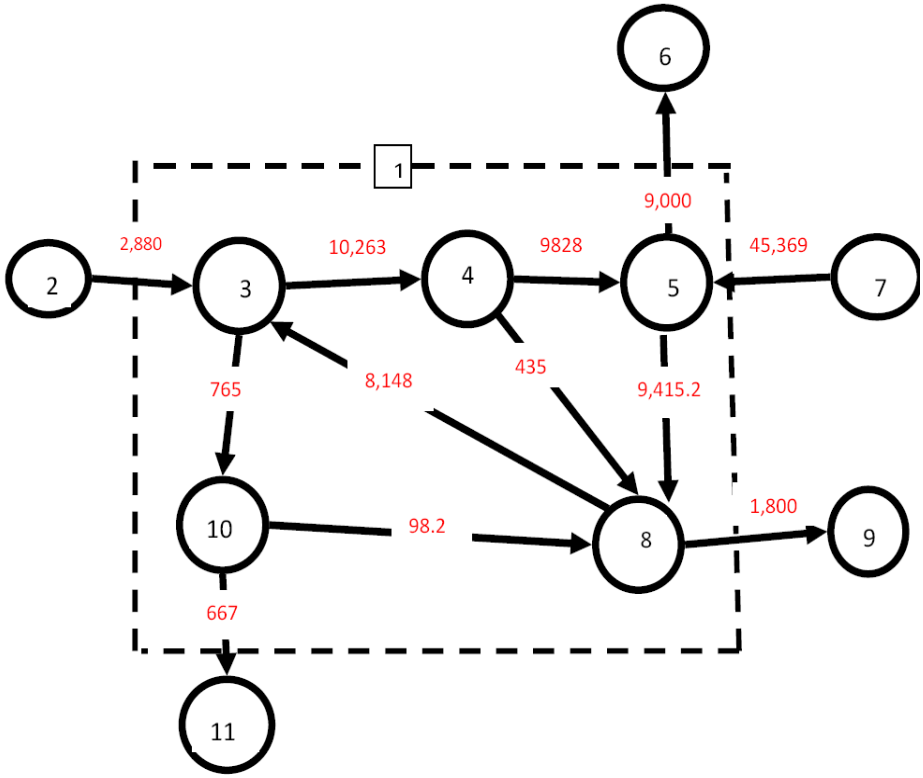

Fig. 5 The Aluminum flows in metric tons (Mt) into, out of and within the Kenyan aluminum recycling industry for the year 2015

foundries can be categorized as casting, rolling and extrusion. The 533 Mt of internal scrap generated by the foundries was used together with the EoL scrap. Casting was performed by small scale informal foundries concentrated in Nairobi and Nakuru. Nakuru foundries were buying cast scrap from Nairobi to cater for the deficiency of 29%. Rolling foundries in Mombasa consumed 81% of the EoL rolled scrap. Imported primary aluminum was added to dilute this scrap. The extrusion foundries were in Nairobi and used the extrusion EoL scrap mixed with the related internal scrap,

and diluted with imported primary aluminum. Internal scrap of 98 Mt was recovered from dross generated by 64% of the foundries.

Dross has been found to contain about 20% aluminum, and most foundries reported a recovery of about 10% aluminum. From these figures the dross generated by the foundries was found to be 765 Mt.

Aluminum was found to enter the country as imported motor vehicles and other goods. The number of imported vehicles continued to increase from year 2008 to 2015 as shown in Figure 4, as a result of sustained economic growth. Consequently the amount of aluminum contained in motor vehicles also increased, and 15,369 Mt were imported in the year 2015. The vehicles were used in the country. Other aluminum imports consisted of primary aluminum for foundries, extruded sections for automotive and construction industries, house wares and many other goods. In the year 2015 the aluminum imports amounted to 30,000 Mt. Exports of 2214 Mt by foundries was lower than the 9000 Mt reported by KNBS. This is an indication that there were other industries that were importing aluminum semi-fabrications, and later exported finished products after value addition.

The data that was collected on the flow of aluminum was summarized as shown in Figure 5. The aluminum products in the market were being increased by imports and local manufacturing, and simultaneously reduced by export and scraping. By applying the law of mass balance, the net addition of aluminum products in the Kenyan market for the year 2015 was 36,782 Mt. This meant that the future aluminum scrap will continue to increase. For the foundries to achieve maximum benefit of this scrap they need to explore on the development of new alloys that will minimize the use of costly primary aluminum. This will make their products competitive both in local and international markets. Further, ways of minimizing loss of aluminum through dross should be sought, and explore opportunities of value addition to cast scrap before exportation.

V. Conclusions

The status of the Kenyan aluminum recycling industry, based upon year 2015 data has been investigated. The following conclusions can be drawn from work:

i. Percentages of the aluminum scrap collected from Nairobi, Mombasa and Nakuru were 90.6, 5.7 and 3.7 respectively, and the scrap was derived from automotive, construction, house hold and electrical components in the following percentages 44.2, 32.5, 20.6 and 2.7 respectively.

ii. The available scrap was categorized as extruded, cast or rolled, and occurred in the following percentages 38.1, 37.3 and 24.6 respectively.

iii. The Kenyan foundries consumed all the extruded, rolled and their internal (new, recovery and process) scrap, and added 2880 Mt of imported primary aluminum to dilute the scrap; however, only 31.6 % of cast scrap was consumed while the surplus was exported without value addition.

iv. The fact that sum EoL scrap consumed by foundries and the cast scrap exported exceeded the quantity handled by the dealers by 45 %, indicates that there were other dealers (outside the three towns surveyed) supplying scrap to the foundries.

v. The net addition of 36,782 Mt of aluminum in the Kenyan market indicated that in future aluminum scrap would be available for the Kenyan foundries.

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