A novel powder metallurgy-based method for the recycling of aluminum adapted to a small island developing state in the Pacific

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Abstract

Special attention needs to be paid to waste management issues in the Pacific Small Island Developing States (SIDS) in order to prevent rapid overflowing of landfills by scrap metals. Scientific and technological tools are now slowly used to contribute towards sustainable development. In this paper, after discussing the current state of Fiji's scrap metal industry, the casting method which is currently used is discussed. To accommodate the recycling of light weight and low volume scrap aluminum, the application of the powder metallurgy process is proposed. Its methodology is discussed as an alternative to the conventional casting process given the local setting. Results in the latter sections show that low quantities of aluminum can be easily melted and processed for various applications. Waste reduction and recycling at source and higher flexibility for production are few of the advantages of the powder metallurgy process. The properties of the recycled parts make them competitive with raw materials for some non-industry based applications. The paper concludes by discussing areas in which more research will be carried out.

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Keywords: End-of-life products management, Aluminum, powder metallurgy, recycling technology, solid waste, SIDS (Small Island Developing States)

1. Introduction: Sustainable Development and SIDS

Sustainable Development requires that “special attention [is paid] to the developmental needs of Small Island Developing States (SIDS) and the Least Developed Countries” [1]. Indeed, SIDS from the Caribbean, the Indian Ocean and the Pacific are small, remote, in-development, rich with traditional knowledge and made up of unique and fragile ecosystems. Therefore, SIDS are especially vulnerable to current development trends, from economical, social and ecological perspectives [2, 3].

For Pacific SIDS, many issues are extremely important for their sustainable development, like e.g. global warming, capacity building, water and oceans protection, but also waste management [4]. Indeed, SIDS face new challenges with solid waste, especially in urban centers, as both space for landfills and the recycling activity are extremely limited.

Another important issue for Pacific SIDS concern Science and Technology [4]. Science and Technology (S&T) has enormous potential to contribute to sustainable development. In particular, governments should give higher priority to investments in S&T to find solutions for pressing environmental and developmental challenges, and should build up a threshold S&T capacity. Also, integration of indigenous knowledge, emphasis on local, culturally appropriate and low-cost technologies must be supported.

This paper focuses on solid waste management and development of science and technology in Pacific SIDS. It reports recent research aiming at developing adapted and low-cost technologies for recycling and/or adding value to scrap aluminium. First, some background of solid waste management in Fiji is given. Then, current local casting process for recycling aluminium is described and discussed. The third part report potentialities of the alternative powder technology and experimental procedures to test its benefits if introduced in the local industry. Initial results of the experiments are presented and discussed in the fourth part and the paper sums up with conclusions and perspectives.

2. Background of solid waste management in SIDS and in Fiji

2.1 Current situation

The management of solid waste is recognized as "a critical issue for Small Island Developing States" in the Pacific [5]. This is in particular true in the Fiji Islands, where the quantity of waste produced by individuals has been continuously increasing during the last 50 years [6]. With almost 1 kg of domestic solid waste produced per day and per capita in the capital Suva, the waste production in Fiji will soon become as large as in developed countries.

With economic development and modernization, the composition of solid waste has been also strongly evolving in SIDS: a few decades ago, solid waste was almost exclusively organic; today, it contains more and more industrial products and materials, i.e. glass, metals, plastics and hazardous substances [7]. Scrap metals represent as much as 3% in mass of the solid waste produced in Suva and disposed of in the landfill [6].

In front of this problem, many donor agencies and the government have been favoring final disposal facilities, when building brand new sanitary landfills, or upgrading former rubbish dumps. However, these end-of-pipe solutions have limited lifetimes, and due to limited land capacity in the Pacific, SIDS will again face problems in the future to find lands for landfills.

The environmental dilemmas experienced by SIDS from the Caribbean, the Indian Ocean and the Pacific associated with their economic development are starting to be reported in scientific publications. A recent paper deals for example with environmental impacts of intensive agriculture in the Kingdom of Tonga in the Pacific: [8]: benefits of the increase of export of squash are unfortunately balanced by higher costs for importing chemical fertilizers and by large impacts on ecosystems. This example illustrates well the reliance of SIDS upon developed countries as well as the fragility of their ecosystems. Another publication reviews the potential of renewable energy systems for SIDS, in particular for Mauritius, in terms of reduction of transportation and distribution costs, of security of energy supply [9]. However some typical SIDS barriers such as limited institutional capacity restrain the development of these alternative energies. Another recent paper reports the impact of the economic development, in particular with tourism, on fisheries biodiversity in Mauritius [10]. Unfortunately, very few publications report researches on integrated solid waste and industrial resources management in SIDS, in relation to its economic development: it was only possible to find a paper on the application of the industrial ecology concept to a closed and bounded system like one Caribbean SIDS [11]. The most comprehensive appraisal of solid waste management in

SIDS are nevertheless covered by United Nations publications, such as [12], or by reports written by local stakeholders.

2.2 Towards improved system in Fiji

To deal with the waste problem in Fiji efficiently, more preventative approaches should actually be developed. This is actually the main objective of the Integrated Solid Waste Management Project that was initiated at the University of the South Pacific in 2003 [13]. In particular, recoverable solid waste should be diverted from the flow that is currently buried. A few experiences in Fiji concentrate on the collection and sometimes on the recovery of solid waste. The following experiences have been identified:

- One soft drinks producer maintains a take-back system for PET bottles: individuals bring back and sell post-consumer bottles in three collection points in the country; unfortunately, no information on the collection rate achieved is currently available [14],
- Waste oil from automotive and process industries are collected to serve as feed in a steel rolling process [15],
- The University of the South Pacific and a few hotels are currently setting-up composting units for their own organic waste made of food scrap and green waste [14]: however, the implementation is long as no adapted process and know-how is already available: as was recently done in an African country such as Tanzania (cf. [16]), key parameters of the composting unit such as carbon–nitrogen (C/N) ratio of raw organic waste, the variation of temperature, pH and moisture content will have to be determined for optimal processing,
- Four scrap metals dealers collect scrap metals such as aluminum, copper, lead and ferrous metals from companies and mainly from individuals, prepare them and ship them abroad (mainly Australia, New Zealand and Asia) for recycling [17],
- One company collects scrap metals (steel, copper and aluminium) from individuals and garages and recycle them through casting to produce parts to be used by the local market [17].

Although very valuable, theses initiatives are only economically-driven and the scrap without sufficient value is still landfilled. Therefore, the collected flows remain very limited. Also, this has got impact on the Fiji economy as Fiji imports high value of finished products (i.e. end of life machinery such as tractors and cars, construction materials and consumer goods) and exports low value scraps contained in these products. As shown in [8] for the Kingdom of Tonga, Fiji is a typical SIDS for which imports are usually larger than exports, which result in a strongly negative trade balance. The country could therefore benefit further if processes aiming at recycling or adding value to scrap metal are developed and adopted locally. In addition to more jobs being created, the low cost of recycled metal could assist the cost of some metallic items manufactured locally to drop, or the price of exported scrap materials to increase.

Recycling and adding value to solid waste is indeed an important strategy for Fiji to avoid environmental as well as economical impacts of solid waste. However, due to the small size of the economy, the quantity of waste produced in Fiji, although growing, remains limited and does not justify the implementation of large scale conventional recovery plants. There is therefore a need to develop adapted technologies and systems to recycle and add value to solid waste.

2.3 Current research on scrap metals

This paper reports research aiming at encouraging and facilitating the recycling in Fiji of a valuable scrap metal like aluminium. An integrated approach has been developed and the research focused on various issues such as: evaluation of quantities and of sources of scrap aluminium; improvement of the scrap collection and preparation; development of a new recycling technology; marketing of the produced material. The results presented in the paper concern all these issues but will mainly focus on the development of a novel recycling technology. In particular, the methods of casting and powder metallurgy for recycling aluminum will be discussed. The method of casting is currently used by a local company while the proposed alternative, the powder metallurgy process is still in the process of being introduced to local industry. The quantity of scrap metal discarded by industries and households in the Fiji Islands are ever increasing but the discarded quantities that are forwarded for recycling is significantly less than that of developed countries. This is firstly because of the relatively smaller population and economic development, and secondly, due to the lack of knowledge of the general population on such issues. This puts pressure on local industries to adopt a process that works best with smaller quantities of scrap aluminum.

3. Current local process of aluminum recycling and their limitations

3.1 Presentation of the process

Casting is a conventional manufacturing process that can utilize scrap aluminum. Casting of scrap materials to new usable products is done in Fiji by a local industry. It is a relatively simple process comprising five generic processes;

1. Pattern making – the pattern is representative of the product to be realized and is made of wood for reusability and dimensional stability. The pattern is divided into two parts so that the shape can be easily removed without damaging the mould.
2. Moulding – the mould is made of quarry sand and this is reused numerous times. Sand is shoveled around the pattern and rammed using a pneumatic hammer.
3. Melting- the materials to be melt are put in a *cupola* and heated. These materials are pre-sorted. Since the volume drops with melting, raw material is continually added. To accelerate the process, the molt is regularly stirred. This process lasts for approximately 3 hours.
4. Pouring – the molten liquid is poured in the mold using the two man ladle method. The pouring rate is kept in control so that air inside the mold can easily escape.
5. Machining – once solidified and cool, produced parts that do not have the desired surface and shape are then machined.

A detailed illustration of the energy and material flows in the current casting process is given in Figure 1. Further details are given in [18]. It was not possible to measure accurate flows for the process used at the local company, but this will be done in the future.

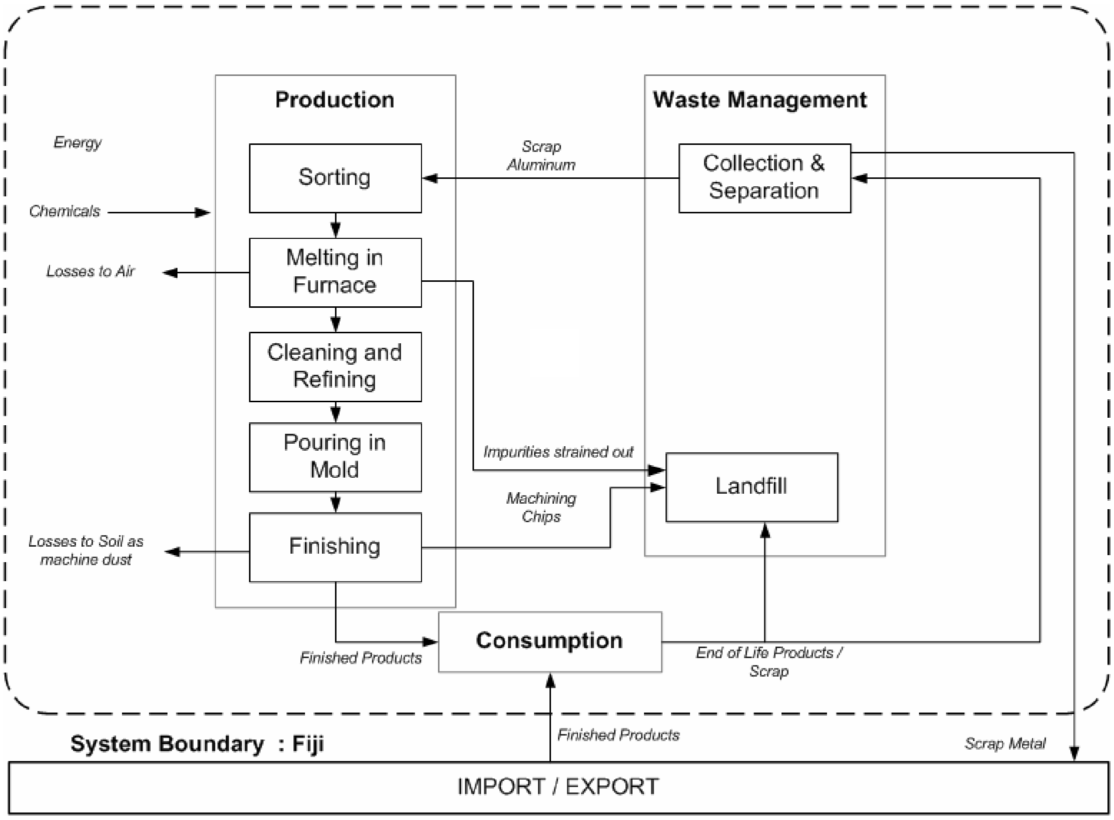


Figure 1 The sand casting process used at a local industry

The method of raw material collection is unique as it is done mainly by concerned citizens who bring over scraps to the factory yard. These consist of old car engines and used machine parts and are sorted on arrival. Sorting consists of removing non-aluminum scraps and then cleaning. Due to the high volume required for the actual casting (46 kg for aluminum), aluminum cans and other light weight aluminum products are not used. All aluminum cast products are produced from scraps. The company sells products to the local industry (e.g. the sugar cane mills) and earns enough by selling produced parts to sustain the process line and it therefore sees no need to find further sources of scrap aluminum. However, a process that can allow the economical use of light weight aluminum can open up new opportunities for them.

3.2. Limits of the process

Output quality

While casting provides parts of various sizes and shapes, stringent quality control procedures restrict its usage by industrial consumers. This is because such cast products are a mixture of various grades of aluminum : therefore their mechanical properties are non-standard and possibly inferior when compared to pure aluminum products or its alloys. Hence, the market for such items is limited. Since the final product of casting is sensitive to the process parameters, there is limited flexibility even in the end shapes that can be produced.

Cast products require sophisticated equipment for quality control particularly to check the presence of trapped air inside the cast and to check for any micro-structural deformities. The local industry is not profitable enough to invest into such test equipment. Nevertheless, when needed by the customers, the product samples are sent abroad for internationally accredited testing.

Production planning

Moreover, to ensure profit, a definite quantity of aluminum must be melted in each run. It also means that there should be enough products ready to be cast. This instantaneous supply and demand balance can sometimes be difficult and expensive to achieve, when considering that the main customer activity (i.e. sugar cane mills) are highly seasonal. In addition, molten aluminum which is surplus and not used in casting, will again have to be molten, resulting in extra consumption of energy.

Skilled employees are needed to carry out the operations and since the operations are sequential, the employees cannot perform more than one task. Casting therefore has a heavy human resource demand and it is something that makes this process weaker than some new alternatives.

Overall impact on resources management

Despite the local firms success, the positive effects of it on overall solid waste management are not felt in the country. It only recycles a fraction of the total aluminum scrap produced in Fiji. This is summarized in Table 1 below.

Table 1. Estimated quantity of scrap aluminium collected and exported for recycling compared to the quantity recycled locally in 2003 (after [7]).

	Estimated quantity of aluminium collected and shipped abroad for	Estimated quantity of aluminium collected and recycled by casting

	recycling in 2003	in Fiji in 2003
Quantity of scrap aluminium (tons)	256	12

These figures should be compared to the quantity of aluminium that is supposed to be sent to the various sanitary landfills and rubbish dumps of the country. Considering only the capital Suva and six municipal councils of the main island Viti Levu, we estimate that at least 300 tons of scrap aluminum were sent to the landfill in Fiji in 2003 (after [17]).

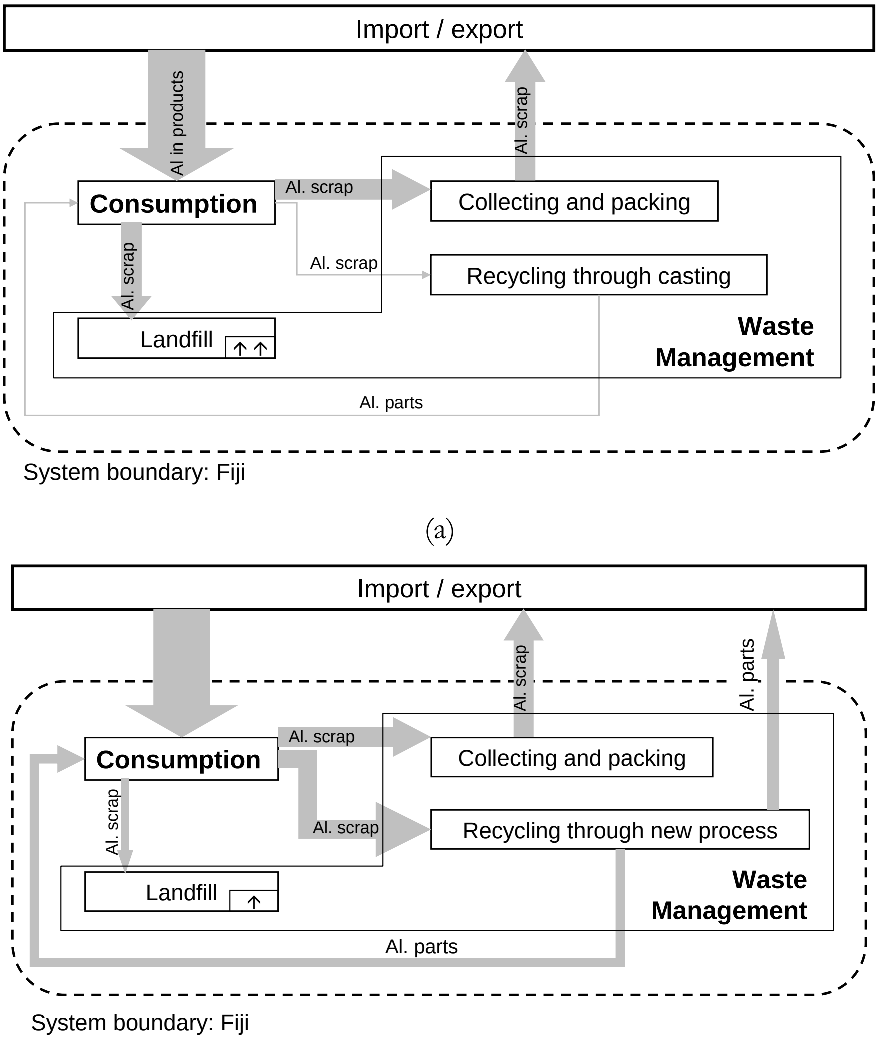
End of life products with significantly lower aluminum content, but which are more in quantity, are left out. Some examples of products left out include aluminum cans, appliance covers and scraps from the building and construction industry. Depending on their value and availability, theses products are either:

- Exported for recycling overseas, implying resource loss and limited economic gains for Fiji, or
- Landfilled locally.

It was shown in this paragraph that there is indeed a need to develop other processes for recycling aluminium scrap more adapted to the Fiji context. In particular, the process should lead to:

- Higher quality materials produced, that should better answer user's requirements and therefore open up new markets both in Fiji and overseas;
- More efficient production planning that should lead to production cost reductions;
- Local recycling of a larger quantity of scrap aluminium, that should eventually reduce the quantity of waste landfilled.

A new recycling process should lead to an improved system that is represented on Fig. 2 with Sankey diagram notations, where in particular scrap would be less accumulated in landfills.



(a)

(b)

Figure 2. (a) Current and (b) future improved system for the management of the aluminium resources within the Fiji Islands system.

4. Development of a novel process to recycle aluminum based on powder metallurgy

4.1. Concept of powder metallurgy

Due to the above, the powder metallurgy process for the recycling of aluminum is proposed. The powder metallurgy process is a combination of sub-processes that include powder formation, blending, compaction, sintering and finishing [18]. The common powder formation processes use molten material to produce powdered particles. Amongst various methods of powder production are atomization, reduction, electrolytic deposition, comminution and mechanical alloying. Production of uniformly sized powdered particles are important. The blending stage involves the mixing of various sizes and shapes of the produced powder particles. The ratio of added particles in the mixture depends on the mechanical and physical requirements of the end product. Mechanical and physical properties such as hardness and toughness will determine how the product behaves under load. Lubricants and binders are also added at this stage to improve the flow of particles in the die and hold the particles together after sintering respectively. In the third step, compaction, blended powders are pressed into desired shapes in dies using either mechanical or hydraulic presses. The produced part is referred to as the green compact. Sintering is the process where the green compact is heated in a controlled atmosphere furnace to a temperature below its melting point, but high enough to allow the fusion of individual particles. They are several finishing processes that are dependent on the end use of the produced part. Materials commonly used for this process include Aluminum, Titanium, Copper and some Nickel based alloys [18-24].

Figure 3 illustrates the powder metallurgy process in detail. On a general view, there is twice the number of major processes as in the casting method. Of these, the first two are the same, except that the chemicals are not used in melting. For the current experimental process, the energy consumption is approximately the same as with the casting method. However, the energy consumption should be lower if economies of scale are achieved. Exact figures on flows crossing the powder metallurgy process are today not available but will be explored in the future. These figures might allow in the future a comparison of the environmental performances of the two processes according to various criteria, not only on the quantity of waste treated locally.

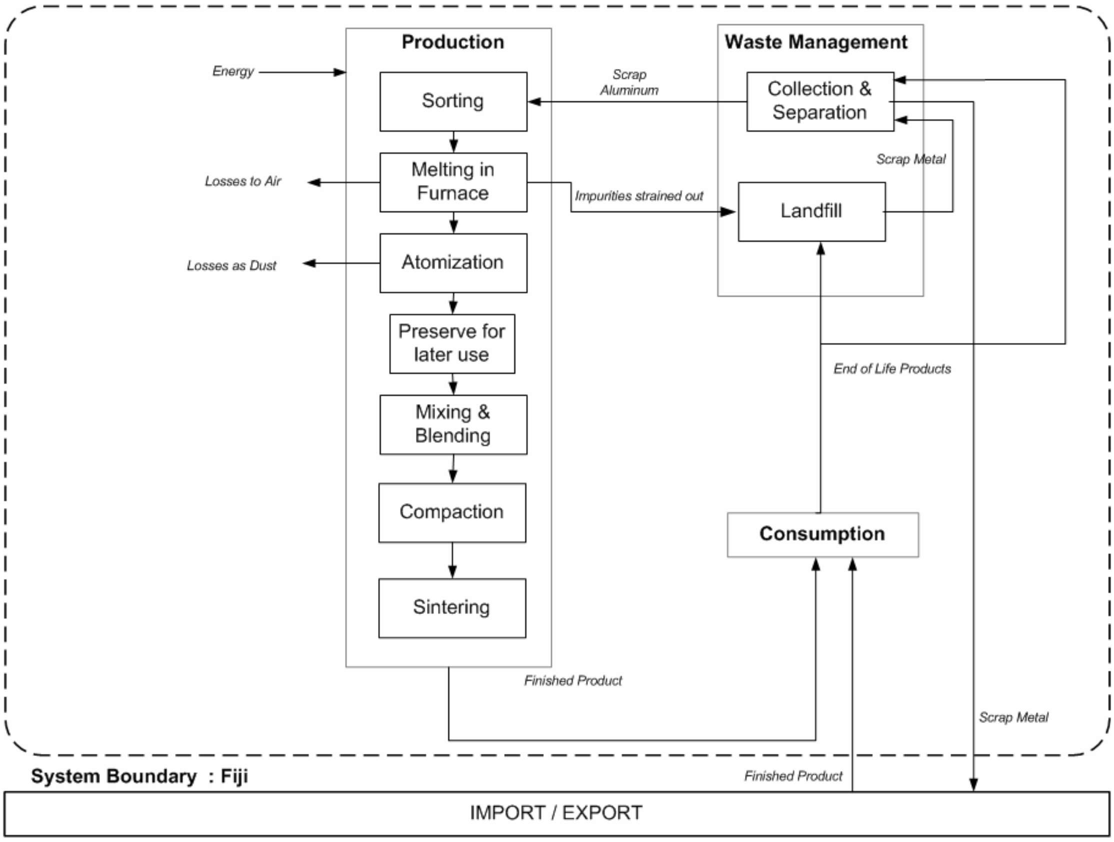


Figure 3 The proposed powder metallurgy process

4.2. Previous Research in Powder Metallurgy

Various researchers have in the recent past looked at distinct aspects of the process. Satoh *et al* researched on the production of powder of an alloy of aluminum and silicon using the centrifugal atomization process which is a process in which the molten metal is poured over a rotating plate in a vacuum chamber [23]. The rotating plate breaks the flow stream sending powdery particles around its periphery. While traditionally presses have been used for compaction, Lee and Thadhani have experimented with shock compression techniques [19]. Results indicate superior packing densities. Li *et al* proposed the liquid phase sintering method to sinter metal matrix composites [20]. Their method deviates from the traditional practice of leaving the material in solid phase during sintering by allowing the green compact to transform to partial liquid form. Traditional methods have nevertheless been in the spotlight. Researchers in Japan have looked at reactive sintering under pressure [21]. All the methods have results suitable for specific applications but need tailor made equipment and are capitally intensive.

Moreover, Smith *et al* simulated the powder compaction process to allow researchers to carry out analysis on the combination of input parameters to achieve the desired product characteristics [24].

Apart from Hywon *et al* [25] who reported on a feasibility study for producing aluminum powder from aluminum foil scrap by dry ball milling using argon and oxygen, there is no literature available on the use of the powder metallurgy process for the recycling of aluminum in both developed and developing countries. This paper therefore communicates a new and innovative process for the recycling of scrap aluminum.

4.3. Merits of the Powder Metallurgy for applications in SIDS

The powder metallurgy process is cheaper than casting in terms of the resources needed. Other researchers like [22] have earlier mentioned that the powder metallurgy process is economical. [22] mentions that the powder metallurgy process allows the manufacture of near net shape parts which have complex geometries. Moreover, the powder metallurgy process can recycle lightweight aluminum and can even be designed to look at low volumes of scraps. Since the sub-processes involved are independent, the process is highly flexible and can be decentralized using different facilities at different locations.

Many other advantages of the powder technology are foreseen in Fiji. Two of them are listed below:

Reduction at source and internal recycling

Instead of machine dust (as in casting), this process produces very fine dust during the atomization process and this cannot be contained. The quantity of this is however, negligible. Moreover, over-flown aluminum powder in the compaction process can be used directly in the next compaction process without incurring any additional energy expense. In the case of over-flown aluminum in casting, it can re-enter the process only if it is remelted.

Higher flexibility for the production

Another advantage of this method, is that the produced powder can be stored for later use. Comparatively, the material in casting has to be used right away. This usually translates to sufficient moulds being ready in time to utilize the entire produced molt. In the powder metallurgy case, the powder production phase can happen without the mold being ready. This also allows flexibility in the collection of scrap as the frequency of collection can be lower than casting and can also open up local or international market for aluminum powder.

4.3. Experimental procedure

In order to validate its adaptability in Fiji, some experiments were carried out. These experiments aimed at determining the properties of the produced parts and also providing ideas on how to improve the process. Furthermore, experiments were needed to verify if scrap aluminum from various sources could be useful as input of the recycling process.

In the reported experiment, the raw material was scrap aluminum from the construction industry and was classified into various categories before melting in the 1032°C furnace at 693°C. The composition and behavior of construction aluminum is standardized and hence is the most appropriate for comparison. The average volume of the scrap pieces were $0.001m^3$ and were collected from the waste disposal site of a construction firm. The pieces were intended for use as aluminum window frames. The temperature during melting was constantly monitored using a Lutron digital thermometer. The temperature of the aluminum was kept higher than the nominal melting temperature of aluminum (660°C) to prevent it from solidifying when poured from the heating cupola.

A two men ladle method was used to pour the liquid aluminum from the cupola to a sprue. The steel sprue was preheated to prevent it from causing the aluminum to solidify. A 10mm hole in sprue provided an exit for the melt. Compressed air at over 400kPa was then applied perpendicular to the direction of flow of the melt. It caused the melt to be blown away from the sprue in forming fine particles.

Formed powder was collected in a 3 m long collection chamber. Various sizes of powder were seen and these were then sieved using sieves of 9.5 mm, 2.5 mm, 500 μm and 250 μm aperture. The 9.5 mm sieve was used first and the 250 μm the last. To bind and lubricate the powder, 3% volume ethanol and 1% mass zinc stearate were used. These were then mixed in a glass container.

To make analysis easier, a cylindrical die and punch were prepared. It had a diameter of 21 mm. The powder, mixed with the binder and lubricant was then compressed using the die and punch fitted to a hydraulic press at 3.5MPa. After removal from the die, the shaped compacts were sintered at 585°C in atmospheric pressure.

Before the surface analysis, the shaped compacts were polished and then etched with a solution containing 2% potassium dichromate, 5% nitric acid and 1% hydrochloric acid. In addition, the hardness tests were carried out using a 11 kg load on a 0.59 mm indentor. The hardness number was verified using a Hardmatic digital hardness tester. Table 2 summarizes the process parameters used.

Table 2 Process parameters and characteristics

Parameter	**Characteristics**
Furnace Temperature	1032°C
Melting Period	3-4 hours
Heating Temperature (Melting Temperature of Aluminum)	700°C (660°C)
Sprue	Preheated to 460°C
Average Air Pressure	400kPA
Binders and Lubricants	1% mass Zinc Stearate; 3% volume Ethanol
Die Diameter	21 mm
Compacting Pressure	35MPa
Sintering Temperature (Duration)	585°C (30 mins)
Polishing Solution (Surface)	Aluminum Oxide (Emery Paper P400)
Etchant	2% Potassium Dichromate, 5% Nitric Acid, 1% Hydrochloric Acid

5. Results of the experiments

Basic experiments to characterize the produced parts were carried out at the university metallurgy laboratory. Although not exhaustive, these tests give a fair idea of the products mechanical and physical properties. Moreover, most of these tests are simple and use basic equipment and can therefore be easily re-produced by local industries.

5.1. Density vs pressure

The first experiment focused on compaction with respect to applied pressure on the powder during the compaction process. Compaction was measured via the density of the produced compact before sintering. Figure 4 illustrates the logarithmic increase in compaction as the pressure is increased.

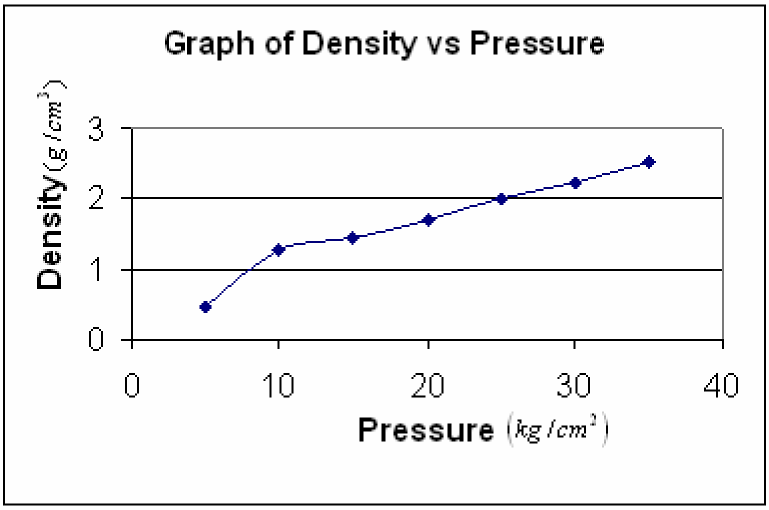


Figure 4 Graph of Density vs Pressure for green compacts

The trend indicates that the product can be further compressed. Maximum compaction would have been reached if with increasing pressure the density did not change or reached saturation. At that point in time, most gaps would have been filled and the product exhibited superior mechanical properties. The average density for parts produced from casting is 2.41 g/cm^3 .

The high pressure used to achieve required densities is available through hydraulic presses, however, it can also be achieved easily through impact drivers. Densities of the products will be dependent on the application it is destined for.

5.2. Compression vs grain size

The grain size can also affect the compression. As Figure 5 illustrates, the compaction percentage increases with grain size. This is largely attributed to the intra-grain gaps mainly found in compacts of large grain size which reduce significantly during compression as the size of the gaps reduce. Smaller grain sizes have smaller gaps which reduce only by a smaller margin.

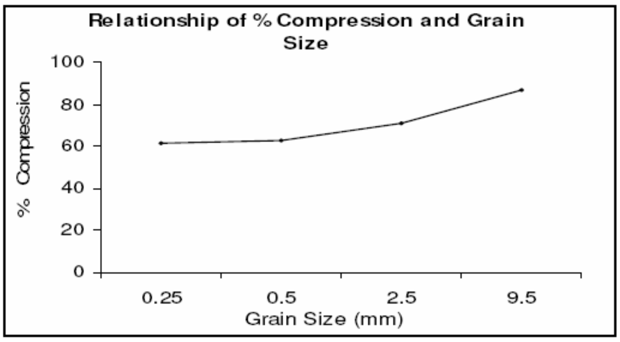


Figure 5 Relationship of percentage compression and grain size

Hence, during powder production, smaller grain sizes should be aimed. Alternatively, if the grain size is larger, higher compression will be required.

5.3. Hardness

The Brinell hardness number (BHN) of the new product in different grain sizes was compared to that of the raw scrap aluminum which has a hardness of HB 51. The results are summarized by Table 3. The BHN of scrap aluminum is higher than pure aluminum as the scrap aluminum is not pure aluminum but aluminum alloys.

Table 3 Comparison of Brinell hardness number

Grain Size	BHN
9.5 mm	45

2.5 mm	36
500 μm	47
250 μm	42

From the above results, the hardness number decreases with decreasing grain size. Larger grains have high internal hardness and thus are much more resistant to wear. However, the produced part compares very well with the original hardness number of the material.

A cast sample has a BHN of 76. This however can vary depending on the cooling method used on the fresh cast. Quenched cast samples, as in this one, have high hardness. The BHN demand from customers will vary on application.

5.4. Conclusions from the experiments

The results of the experiments give an overview of the characteristics of the part produced. The density and hardness numbers compare well with the raw scrap material and suggest that it could be used for similar applications. However, due to the different nature of the two processes, the grain sizes cannot be compared. The density indicates that the part maintains the primary characteristic of aluminum being a relatively light material and promotes its use in such applications. Moreover, the hardness numbers are indicative of its mediocre resistance to wear compared to the quenched cast products.
Despite slight inferior mechanical characteristics of produced parts, the novel process seems worth being developed considering its numerous advantages at the production plant.

6. Discussion

6.1 Possible industrial implementation of the process

As mentioned in Section 1, high capital costs have prevented the establishment of a aluminum recycling plant in Fiji. Moreover, despite having large quantities of scrap aluminum, the quantity is not sufficient for the long term sustainability of a conventional aluminum recycling plant. However, we showed earlier that a powder metallurgy-based process could be set-up at an industrial scale. The key question is now to define which of the two following models should be adopted.

1. Only half of the entire process is invested. This would include the sorting, melting and atomization processes. The powder could then be sold or exported to firms for making numerous end products. This would add value to the scrap and, with higher density of the shipment, this could decrease the cost of trucks and boat transport of the processed scrap, and therefore bring obvious benefits to the Fiji economy. The savings could be used to implement more efficient scrap aluminum collection methods. Such a process could be implemented in several islands in Fiji.
2. The entire process plant is set-up. Since there will not be enough aluminum to keep the plant running daily, days could be dedicated to individual processes. For example, sorting could happen on day 1, and the rest of the processes could happen on consecutive days. A day also could also be dedicated to the collection of scrap aluminum. The plant could be run daily if Fiji became a transfer platform for all scrap coming from other SIDS in the Pacific where value would be added to scrap.

The choice between the two models should be done in the future by investors and the government according to several criteria such as: investment and maintenance costs, annual economic profitability, number of job created, recycling rate of scrap aluminium, and overall environmental performances.

6.2. Foreseen benefits for the overall solid waste management in Fiji

Both models cannot be used for the conventional process of casting as the processes in casting are strongly bounded by the material flow time. The new method can easily be adopted by local industries. Even firms already involved in casting can diversify into this new process. Approximately 10 kg aluminum is needed for a single process. This equates to 0.004 cubic meters of recycled aluminum that can be produced from it (given that maximum density is equal to $2.5 g/cm^3$). With only one production line, running the process twice daily, approximately 6000 kg per year of useless aluminum could be diverted from the landfill and could find its place in the market again. The setting-up of several dozen of lines in the country would bring not only space economy in landfills, but also added value to the Fiji economy and create job.

7. **Conclusion and perspectives**

A novel method for aluminum recycling in the Fiji Islands has been proposed after studying a conventional recycling method, casting, which cannot easily recycle light and low volume end of life aluminum products. The preliminary results indicate the viability of this process in Fiji and characteristics of the products further strengthen the point. Higher flexibility and waste reduction at source makes the process competitive as other processes.

Future work includes:

- further experiments on the powder metallurgy process, in particular testing the influence of several types of scrap on the process performances and on the output quality,
- a comprehensive materials flow analysis of aluminum in the country to identify future sources of inputs for the process,
- a material, energy and labor balance of the two concurrent processes, to identify environmental and social advantages and drawbacks and
- the extension of the process to cater for other scrap metals such as steel.

8. Acknowledgements

The authors acknowledge the financial assistance provided towards this project by the University of the South Pacific Research Committee (South Pacific), Fonds Pacifique and Champagne Ardennes Regional Government (France). We also thank all the students who have been involved so far in the Integrated Solid Waste Management project.

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