The aspects of technology and economy in processing aluminum scrap into fence ornament products at small and middle sized and enterprises in Lampung Province

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Abstract. Increasing building in property sectors causes chain effects in many of its supporting fields. One of them is the fence construction. Fence nowadays is not only a function as separator between a main building and other open spaces but it also has prestige values for the owner of the building. Fence ornaments continue to develop over time from its form, raw material, to its making process. Fence makers start to gradually abandon cast iron for fence ornament raw material. The aluminum becomes an alternative raw material in the fence making process. A research on the technological and economy aspects of aluminum scrap processing into fence ornament was conducted. From the technological aspect, small and middle sized industries were suggested to use batch system (50 kg/batch) with solid-fuel-based crucible furnace. The furnace dimension was 390 mm diameter and 440 mm height. Furnace isolation used fire brick type SK 32 with 240 mm thickness and 700 mm of furnace height. The molding process used sand molds method and used local raw material. Ratio of scrap raw material to ornament product was 1.1-1.3, while ratio of solid fuel use was 1.5-2.1. It took 6 hour/batch for smelting process with temperature of 600-710°C. From economy aspect, it took investment cost of Rp. 210,000,000 to start aluminum scrap smelting business into fence ornament product. The financial analysis obtained net present value (NPV) of Rp. 176,699,790; net B/C (benefit/cost ratio) of 1.84; and internal rate of return (IRR) of 31.12%.

1. Introduction
The positive growth in property sectors indirectly cause chain effects to other supporting industries, and one of them is the constructions of fences with ornaments (for houses, apartments, and office buildings). The fence function now is not only a partition between main building and other open spaces (including roads), but it is also a symbol of prestige for the building owner. The fence ornaments continue to develop along the developing era from their forms, materials, and their making processes. Iron is often used for the fence ornament raw material. It is made by metal casting to produce casted iron. The fence ornament making with iron raw material needs bigger energy with high temperature process of ± 1400°C, while the product characteristic tends to be fragile with less resistance to corrosion. Energy source availability in form of coke for iron smelting is getting more difficult to obtain with more expensive price and these make casted iron ornament is started to abandon by small and middle sized industries of metal casting. The metal smelting and casting processes are processes to change the metal from solid phase in liquid phase by using smelting furnace, and the type of metal raw material and type of furnace to smelt it should be matched [1]. The factors to consider in selecting type of furnace include type of metal to cast, design of smelting
temperature and casting temperature, ability or capacity of furnace to smelt, required operational cost, easiness in operating, easiness in maintenance and minimum pollution side effect for the environment [2].

Aluminum is a light metal and it has a good resistance to corrosion, so that is suitable to use as a raw material in the fence ornament making process in the small and middle sized industries, the aluminum scrap smelting is recycled into varying types of products. One of the products is the fence ornament as it is shown in Figure 1. There are many aluminum scrap recycling technologies from conventional (simple technology) by using crucible furnace to modern (advanced) technology by using reverberatory furnace, open hearth furnace, rotary furnace, and induction furnace [3]–[5]. The basic principle of aluminum scrap smelting process starts with pre-melting process by separating the raw material from impurities. The pre-melting process is conducted by such technologies using magnet, air separation, and color spectrum. The pre-melting process is then continued to purifying process. Based on the energy to use, aluminum scrap smelting can be done with electricity, gas, oil, and solid energy (coal, coke, and charcoal) [6]–[9], but aluminum scrap smelting process by using biomass energy (charcoal waste) is rarely done.

To find out the real, clear, and measured descriptions, a research on aspects of technology and economy of aluminum scrap processing into fence ornament product at small and middle sized industries in Lampung province was conducted. Lampung location was selected for this research because aluminum scrap in this province was currently only sent to metal smelting factories in Java Island. If the aluminum scrap was recycled in Lampung into fence ornament product, then this would improve additional value of the product and in the same time it would supply the fence ornament product demands in Lampung province, where these fence ornament products were usually imported from Java Island. Besides improving additional value of aluminum scrap into fence ornament product, this activity had an objective to improve the use of charcoal waste from charcoal factories in Lampung province. In Lampung province, there are exporters of wood charcoal and active charcoal, where in the product classifications, there is a charcoal product with size of < 2.5 cm and it is categorized as a byproduct or charcoal waste.

![Figure 1. Various aluminum fence ornaments](image)

2. Methodology

2.1 Aluminum scrap smelting
In this research, the aluminum scrap processing into fence ornament product was done by using crucible furnace. The furnace dimensions were 390 mm diameter and 440 mm height. The furnace isolation was from fire brick type SK 32 with 700 mm of furnace height, 240 mm of fire brick thickness, and 3 mm mild steel plate was used for outer wall of the furnace. The furnace design is shown at Figure 2.

The raw material and energy source should be considered to have optimal results. The raw material and energy source availabilities were adapted with the technology to use. The aluminum scrap to use was adjusted with conditions in Lampung province. In general, the types of aluminum scraps commercially available are shown in Table 1. The energy source came from wastes from charcoal factory byproducts, from briquette factories and active charcoal factories in Lampung Province. These materials were made into briquette to obtain a compact fuel form.

![Figure 2: Technical drawing of aluminum furnace design](image)

The Miscellaneous 1 material type contained of metal waste from machinery processes or components from machinery processes. The Miscellaneous 2 material type contained of automotive components; both two wheels and four wheels vehicles[10].

| Types of materials | Composition |
|--------------------|-------------|
| Pistons            | Cu 1.46 Mg 0.71 Si 12.34 Fe 0.24 Mn 0.46 Ni 0.006 Zn 0.08 |
| Wire               | Cu 0.12 Mg 0.01 Si 0.78 Fe 0.47 Mn 0.06 Ni 0.01 Zn 0.02 |
| Plat               | Cu 0.05 Mg 0.007 Si 0.13 Fe 0.37 Mn 0.015 Ni 0.004 Zn 0.005 |
| Hanger             | Cu 0.48 Mg 0.11 Si 12.28 Fe 0.70 Mn 0.31 Ni 0.02 Zn 0.72 |
| Miscellaneous 1   | Cu 5.87 Mg 0.01 Si 0.14 Fe 0.23 Mn 0.01 Ni 0.003 Zn 0.11 |
| Miscellaneous 2   | Cu 2.86 Mg 0.26 Si 10.96 Fe 0.77 Mn 0.19 Ni 0.1 Zn 0.65 |
| Propeller blade    | Cu 3.66 Mg 0.16 Si 9.28 Fe 0.94 Mn 0.23 Ni 0.16 Zn 2.07 |
| Pan                | Cu 0.17 Mg 0.08 Si 0.22 Fe 0.50 Mn 0.09 Ni 0.004 Zn 0.01 |

The fence ornament making process is started by selecting raw material physically where material is separated from its impurities by macro appearance. The process continues with pattern (model) making of the fence ornament. Material of the pattern (model) comes from wood material. After the pattern (model) is done, aluminum casting process is conducted into fence ornament product by using...
sand casting method. Investment-casting and die-casting methods require more equipment and investment cost than sand casting method. For small and middle sized industries of fence ornaments in Lampung province, sand casting method is more suitable to apply. This is supported by the fact that silica sand availability as the raw material for sand casting can be found easily in Lampung province. Sand casting, though it is least accurate, is the most common and most widely used method of casting which involves the pouring of molten metal into a mould including typically 80% silica sand, 5–10% clay binders (mostly bentonite), 2–6% tempering water and a variety of additives. Sand casting is mostly used for high volume production where surface finish and dimensional accuracy are not critical[11]. In this research, aluminum scrap smelting was done in 650°C – 730°C. Temperature control was conducted with thermocouple. Pouring temperature was maintained being not too high to prevent hydrogen gas absorption to the liquid metal. The metal pouring process into sand mold was done with ladle where slag had to be removed first to prevent product defect from slag. After the liquid metal had frozen, the mould was removed to get the fence ornament product. Final stage was the finishing process including runner cutting, refining, and surface coating.

The gating system of aluminium smelting, the application different depends on simplicity or complexity the casting product. For simple shape and small in dimension, the riser used not too much but with complex shape and big in dimension require to much riser and ventilation hole in many place to flow out the air and the casting fluids can fulfill the hole of model.

2.2 Study of financial aspect
The objective of financial aspect study was to find out the funding estimation and the business cash flow to find out the feasibility and properness of the business plan. The financial aspect concerned with the fund need and its source, determination of cash flow policy, study about capital cost, analysis of sensitivity, assessment on the business plan appropriateness through varying methods (PI, NPV, IRR, PP), determining rent or buy for the fixed assets, and business priority selection. The need for investment fund was classified based on the tangible fixed assets (land, building, factory and machinery), and intangible fixed assets (patents, license, pre-costs and costs before operation). Investment funds were required for fixed assets and gross working capital (indicating all required investment for current assets)[12].

2.2.1 Net present value (NPV) method
The Net Present Value (NPV) is the difference between the present value of present investment and future values of net cash inflows (operational cash flow and terminal cash flow)[12]. The Net Present Value method formula is as follows:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1 + K)^t} - I_0$$

where NPV is questioned NPV value, \(t\) is year –t, n is number of economic year, \(CF_t\) is net cash inflow during year -t periode, K is discount rate, and \(I_0\) is initial investment at year 0.

Assessment criteria:
- If NPV > 0, business investment proposal is feasible
- If NPV < 0, business investment proposal is not feasible
- If NPV = 0, the company value remains the same either the business investment proposal is feasible or not feasible

2.2.2 Internal rate of Return (IRR) Method
IRR method is used to find out a discount rate that makes the net present value of all cash flows to expect in the future, or cash inflows and cash outflows of initial investment\cite{12}. The formula is as follows:

\[
I_0 = \sum_{i=1}^{n} \frac{CF_i}{(1 + IRR)^i}
\]  

(2)

Where \(I_0\) is initial investment at year 0, \(t\) is year-t, \(n\) is number of economic year, \(CF_i\) is net cash inflow during year \(-t\) period, \(IRR\) is questioned discount rate value.

The IRR value can be obtained with trial and error. It is conducted by estimating present value of cash flow from an investment with a reasonable interest rate, for instant 10\%, and then it is compared with the investment cost. If the investment value is smaller, the estimation can be done with higher interest rate, and it is continued the same way until the investment cost equals. Alternatively, it can also be done with smaller interest rate until the estimation produced the equal investment value with the present value. The IRR formula for interpolation is the following:

\[
IRR = P_1 \times \left( C_1 - \frac{P_2 - P_1}{C_2 - C_1} \right)
\]  

(3)

Where \(P_1\) is interest rate 1, \(P_2\) is interest rate 2, \(C_1\) is NPV 1, \(C_2\) is NPV 2.

The assessment criteria are that when IRR value is bigger than predetermined rate of return, then the investment is acceptable.

3. Result and discussion

3.1 Aluminum scrap smelting

The aluminum scrap smelting technologies in common are shown in Table 2. Table 2 shows that smelting technology with crucible furnace is selected for fence ornament product making for the following reasons. The crucible furnace is proven to be reliable. It has simplest construction with fixed position, where liquid metal can be picked up with ladle. This furnace is very flexible and multifunction for small and middle sized smelting compared to other types of furnaces.

The testing result by using the smelting furnace as it is shown in Figure 2 produced maximum capacity of 50 kg liquid aluminum. This maximum capacity was obtained by putting the raw material (aluminum scrap) gradually into the furnace, and it took 6 hours for the aluminum scrap to melt. The ration of material use was 1.1\(-1.3\), while the ration of fuel use (wood charcoal waste with size of <2.5 cm) was 1.5\(-2.6\).

The lowest raw material use ratio of 1.1 was obtained by using aluminum scrap material from pan, and the highest ratio of 1.3 was obtained by using propeller and miscellaneous 1 aluminum scrap materials. The temperature of smelting process based on the use of varying types of aluminum scrap is shown in Figure 3. The raw material from propeller and miscellaneous 1 (Table 2) required higher processing temperature compared to raw materials from pan, wire and so on. The Fe and Cu contents were relative high compared to other types of aluminum scraps, and this required higher demand of energy and processing temperature. However, in the fence ornament product making, there were no special specifications of types of aluminum scraps. The material use considered the availability of the raw materials. The small and middle sized business of metal casting paid more attention to obtain raw materials which were easy to smelt with cheapest technology of processing.

The lowest fuel use ratio of 1.5 was obtained by making fuel (wood charcoal waste) into briquette. The highest fuel use ratio of 3.0 was obtained when using wood charcoal with size of < 2.5 cm. These two types of fuel were required initial burning process (startup) with coke at ratio of 0.05 from
aluminum scrap raw material. The use of startup fuel was required to maintain processing temperature of 750°C and to ease initial burning of fuel feeding the process was going on.

Table 2. Aluminum scrap smelting technologies

| Type       | Description                                                                 |
|------------|-----------------------------------------------------------------------------|
| Heart Furnace | Heart furnace is certainly the classical furnace in metallurgy and has been used early times by our forefathers for processing their bronze or, in later periods, their iron[6] |
| Reverberatory Furnace | The basic technology for the fuel-heated furnace is the reverberatory furnace. Its name originates from the kind of heat transfer. It is assumed that the most of the energy is passed onto the metal by radiation following the principle of reverberation. In practice, this is, however, only the case when furnace is filled with liquid metal[6], [7] |
| Induction Furnace | An induction crucible furnace having a crucible surrounded by an induction coil member that is prestressed in axial direction by ring members disposed at opposite ends of the coil member and connected together by a plurality of tie rods extending parallel to the axis of the coil member and distributed uniformly about the periphery of the crucible one of the ring members being fixed to a base frame of the furnace, includes spacer means disposed between the ring members and the coil member and having inner and outer diameters matching those of at least one of the members[7], [8] |
| Rotary Furnace | These furnaces follow a design principle that differs very much from that of the hearth furnaces. It comprises a refractory-lined steel vessel that rotates around central axis. Scrap is charged through one of the front ends. The only burner is also arranged at one front end. Traditionally the rotary drum furnace has a fixed axis |
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That means the centre line of the rotation remains in the horizontal position[7], [9].

Crucible Furnace
Crucible furnace major application is in small or midsize capacities, having a wide range of alloys. They are used as holding and casting furnaces in sand or die-casting plants. Heating is by means of charcoal, gas or oil burners that heat the metal in crucible from outside. The furnace can be designed as tiltable unit for easy pouring. The crucible furnace may also be heated by electrical resistors[6], [7].

The aluminum scrap smelting occurred at 650-750°C. The 5°C temperature decrease occurred at the time of feeding wood charcoal briquette process, while in feeding wood charcoal of size < 2.5 cm the temperature decreased insignificantly. This condition was because briquetting required mixture of starch powder and water as adhesive agent, so that the water content increased and this was different with wood charcoal (size <2.5) with lower water content. The briquette size was compact, dense, and bigger than wood charcoal (size < 2.5 cm), and it made more difficult for initial burning, so that temperature decrease occurred in the fuel feeding process. The experiment result showed that the aluminum scrap smelting process by using crucible furnace with wood charcoal briquette and charcoal waste (size < 2.5 cm) required higher ratio (1.55 and 2.65) compared to the same system with different types of fuels, where the fuel ratios were 0.5 for LPG, 1.3 for coal briquette, 1.17 for diesel fuel, 1.4 for lubricant waste, and 1.28 for kerosene.

Figure 3. Fuel consumption ratio and temperature process

The lowest fuel use ratio of 1.5 was obtained by making fuel (wood charcoal waste) into briquette. The highest fuel use ratio of 3.0 was obtained when using wood charcoal with size of < 2.5 cm. These two types of fuel were required initial burning process (startup) with coke at ratio of 0.05 from aluminum scrap raw material. The use of startup fuel
3.2 Economy aspect

The review on the economy aspect of aluminum scrap smelting into fence ornament product was conducted with 50 kg liquid metal capacity production. Based on field studies in ornamental shops and welding workshops with face to face questionnaire, the demand for fence ornaments reached approximately 5,000 kg/month and most of the ornaments were imported from Java with high tax costs and long shipping. To be seen from initial investment, the processing technology by using crucible furnace was lower than by using other types of technologies. The required investment value is IDR 210,000,000. This investment value is distributed for the following costs shown in Table 3. The estimation of annual operational cost for both fixed cost and variable cost is presented in Table 4. The estimation base uses 25 working days/month and 12 effective months in one year.

The labors were two persons, one person was a supervisor and administration altogether, and another man was making fence ornament pattern model and product finishing. The smelting process required special labor with separate labor contract system.

| Table 3. Investment cost components | Type of Cost | Total Cost       | Volume |
|------------------------------------|-------------|------------------|--------|
| Building                           | IDR 144,000,000,00 | 120 m²          |        |
| Land                              | IDR 40,000,000,00 | 400 m²          |        |
| Equipment                          | IDR 3,000,000,00 | 1 unit          |        |
| - Crucible                        | IDR 4,000,000,00 | 1 unit          |        |
| - Blower                          | IDR 10,000,000,00 | 1 unit         |        |
| - Furnace                         | IDR 5,000,000,00 | 10 m³           |        |
| Other equipment                    | IDR 4,000,000,00 | 1 package       |        |

| Table 4. Operational cost components | Fixed Cost                  | Variable Cost                  |
|-------------------------------------|------------------------------|--------------------------------|
| Electricity                        | IDR 24,000,000               | Raw Material for Production    | IDR 439,500,000               |
| Employee’s Salary                  | IDR 44,200,000               | Employment wage                | IDR 150,000,000               |
| Transportation                     | IDR 15,800,000               | Total of Variable Cost         | IDR 589,500,000               |
| Land and Building Taxes            | IDR 65,000                   | Total of Operational Costs (FC+VC)| IDR 673,565,000              |
| Total of Fixed Cost                | IDR 84,065,000               |                                |                                |

The cost for finished fence ornament product was IDR 10,000/kg. The ratio of aluminum scrap raw material use was 1.3 and the fuel ratio to the finished product was 2.1. The average price of aluminum scrap in Lampung province in the collector trader was IDR 13,000 – 18,000/kg. The wood charcoal price was IDR 2,000 – 2,500/kg. The minimum selling price of fence ornament from producer level in Lampung province was 52,000/kg, it could be higher when particular model or detailed products asked by customers were able to supply by the producers. The market potential for this product in Lampung province is widely open, because current products are supplied from by producers from Java Island. The financial analysis derived net present value (NPV) of IDR 176,699,790 and internal rate of return (IRR) of 31.12%.
Comparing the fuel use ratio and processing technology by using crucible furnace, this experiment result is still economically possible, despite of higher ratio of fuel use as it is shown in Table 5.

| Type of fuel       | Ratio | Cost Unit | Total of Cost |
|--------------------|-------|-----------|---------------|
| Coal briquette     | 1.30  | IDR 3,000 | IDR 3,900     |
| Diesel fuel        | 1.17  | IDR 8,000 | IDR 9,360     |
| Oil Waste          | 1.40  | IDR 3,500 | IDR 4,900     |
| Kerosene           | 1.28  | IDR 7,000 | IDR 8,960     |
| LPG                | 0.50  | IDR 7,500 | IDR 3,750     |
| Experiments - Wood charcoal briquette | 1.50  | IDR 2,200 | IDR 3,300     |
| Experiments - Wood charcoal of size <2.5cm | 2.60  | IDR 1,000 | IDR 2,600     |

If startup burning cost with coke ratio of 0.05 is added with coke price of IDR 7,000/kg, the total of fuel cost per kilogram of raw material was IDR 3,650 by using wood charcoal briquette and IDR 2,950 by using charcoal waste with size of <2.5 cm. Table 6 shows that the lowest total of fuel per kilogram of raw material is by using wood charcoal waste of size < 2.5 cm.

4. Conclusion
The aluminum scrap processing into fence ornament product can be conducted with a simple technology by using solid fuel based crucible furnace. The raw materials of aluminum scraps may come from varying types, while solid fuel can be obtained from waste of charcoal factory which is available in Lampung province. Financial analysis result shows that the fence ornament making in Lampung province in small and middle sized industries is viable and proper to do.

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