

# Artikel Widarto 13

*by* Widarto 13

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**Submission date:** 18-Aug-2020 11:12AM (UTC+0700)

**Submission ID:** 1370875873

**File name:** 13-Artikel\_Terindeks\_Scopus\_Spiral\_Finned.pdf (729K)

**Word count:** 2829

**Character count:** 13810

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Citation: *AIP Conference Proceedings* **1931**, 030066 (2018); doi: 10.1063/1.5024125

View online: <https://doi.org/10.1063/1.5024125>

View Table of Contents: <http://aip.scitation.org/toc/apc/1931/1>

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# Spiral Finned Crucible Pot

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**Abstract.** Innovation on a crucible furnace to increase its efficiency in aluminum melting has been done. The innovation was a spiral finned crucible pot. The inclination of the spiral finned was vary of 5, 10, 15, and 20 degrees. The spiral finned effects was determined from the performance test result. A crucible pot without fin was also tested as a control. The crucible pot was examined at the same process condition. The crucible pot with the inclined fin of 10 degrees gives an optimum performance. It gives effective heating rate so that more efficient in LPG consumption. Therefore it saves energy in the aluminum melting process.

## INTRODUCTION

Casting is a process in component making by melt a metal and poured it into a mold. The steps of this process are pattern making, mold making, metal melting, metal pouring, cleaning and examining the casting product. Melting the metal is the important step on casting process that done using a furnace. Various furnace can be used to melt the metal such as crucible, induction, cupola, electric arc and so on. Crucible furnace is the simplest and oldest furnace that still used until recent time. Based on the energy source, there is three types of crucible furnace, i.e. solid, oil and gas fueled. [1 – 4]. Liquid petroleum gas (LPG) is one kind of gas energy that widely used as energy source for crucible furnace.

The main feature of crucible furnace is the use of crucible pot. The crucible is the pot that have a wider upper diameter. It can be made from steel, cast iron graphite, or ceramic. Steel and cast iron usually used to melt a metal that has low melting temperature such as aluminum. The pot is placed in the furnace on a support block. The crucible furnace has two holes. The first hole at the bottom side is to input the heat from the energy source, and the other hole is at the upper side to throw out the combustion waste. The crucible pot shape allows the heat flows smoothly on the outer wall of the pot from bottom to top. However, there are still difficulties to control the heat flow in the furnace thus it does not move around the pot perfectly.

The main concern in enhancing the crucible furnace performance is increasing the heat efficiency. Several innovations to enhance crucible furnaces performance has been done (Table 1). In general, the innovations were modification combustion system in order to increase the heat efficiency. However, those innovations make the crucible furnace structures and constructions become complicated. It is difficult to implement, especially for small and middle industries. A simple construction of combustion system on crucible furnace was introduced by Soemowidagdo [5]. The combustion waste pipe is extended and deflected called economizer (Fig. 1). The diameter of combustion waste pipe should be same as the diameter of the heat input pipe. This is to maintain the pressure in the furnace chamber stable. This modification makes heat restrained longer in the furnace. But, this modification does not make the heat that generated flows around the crucible pot perfectly.

TABLE 1. Innovations to enhance crucible furnaces performance.

Innovation	References
Damper to control crucible furnace temperature	[6]
Combustion chamber mechanism	[7 – 8]
Pipes and damper to control heat	[9]
Pipe/s for throw out combustion waste placed near or contact with heat input pipe/s to enhance heat efficiency	[10 – 14]



FIGURE 1. Crucible furnace with economizer [5]

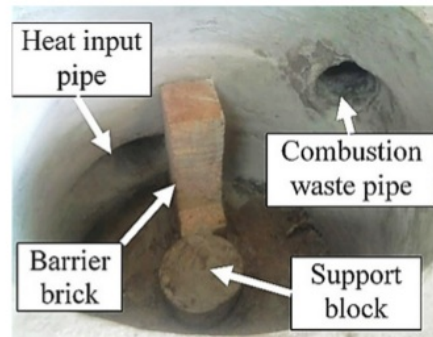


FIGURE 2. The crucible furnace inside construction

In the crucible furnace, the heat is input into the furnace in tangential direction of the furnace wall (Fig. 2), so that the pot will be surrounded by heat. In fact, the heat only flows in the bottom side of crucible pot. A barrier of refractory brick should be placed as shown in Fig. 2 in order to maintain the gas burner from turn back pressure of heat flow. It is clear that the heat flows at the bottom side of the crucible pot and then move up to the combustion waste pipe. Tanaka *et.al.* [15] developed a guide way in the inside wall of crucible furnace. This guideway made from cast refractory. It is surely lead the pressured heat flows around the crucible pot and it has been proven improve the furnace efficiency. However, there is difficulties in making the guideway. A mold is needed to cast the refractory material to make this guideway. Precise consideration must be taken to make the mold in order to get the perfect guideway.

This article will discuss a crucible pot with spiral finned to improve the crucible furnace efficiency. The concept is similar to guideway but the pressured heat will flow around the pot through the spiral fin. The fin is easy to make since it is made from steel plate that welded to steel crucible pot.

## EXPERIMENTAL METHODS

The crucible furnace with economizer is used in this study. A gas burner system applicate to burn LPG as the energy source. The crucible pot made from steel pipe of outside diameter 220 mm with thickness of 8 mm. The height of the crucible pot is 220 mm. A steel plate of 10 mm thick welded to the bottom side of the pipe. Spiral fin made from steel plate of 3 mm thick and 40 mm wide and then welded to the crucible pot. The spiral finned crucible pot design is shown on Fig. 3.

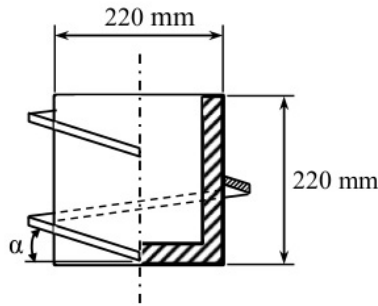


FIGURE 3. Design of spiral finned crucible pot

The spiral fin made with inclination angle  $\alpha$  that vary of 5, 10, 15, and 20 degrees. A crucible pot with no spiral fin was noted as 0 degree. However, the pot with no spiral fin has a vertical fin made as barrier substituting the barrier brick. The inclination of the fin was made no more than 20 degrees since it will give only one or two spiral line. This spiral inclination will determine the spiral pitch and the number of spiral line.

The first step of experiment procedure is weigh 4 kg of aluminum, melted, and let it freeze in the crucible pot. The second step is weigh the initial weight of LPG. After that, the aluminum that had prepared in the first step is heated until it is melt. The temperature changes of crucible pot is then recorded every 5 minutes until the aluminum melt. Finally, weigh the final weight of LPG. LPG pressure, gas valve, and air valve were controlled in similar condition.

## RESULTS AND DISCUSSION

The inclination angle of spiral fin directly determines spiral pitch and the number of the fin. Fig. 4 shows that the increase of inclination angle will increase the spiral pitch and decrease the fin number. This fact means that there is an optimum condition due to the fin inclination angle. The spiral fin on crucible pot could lead the heat flow from the gas burner. This was shown by the mark of heat flow on inside furnace wall. The mark of the gas combustion follows the inclination angle of the fin. The crucible pot with fin angle of  $5^\circ$  has the narrowest pitch. This condition makes the heat flow from gas burner is not smoothly moving around the crucible pot. The input pipe diameter of 76.2 mm that wider than the pitch of fin angle of  $5^\circ$  cause the gas burner blast could not completely flow through fin pitch. As a result, there is some heat does not flow around crucible pot.



FIGURE 4. Spiral finned crucible pot: (a) inclination angle  $10^\circ$ , (b) inclination angle  $15^\circ$

Fig. 5 shows the time needed for melting the aluminium. It can be seen that crucible pot with fin inclination angle of  $10^\circ$  requires 30 minutes to reach  $700^\circ\text{C}$ . This means that crucible pot with fin inclination angle of  $10^\circ$  requires 30 minutes to melt 4 kg aluminium and gives a better heat efficiency. The fin inclination angle of  $10^\circ$  makes heat produced by gas burner stay longer in the furnace and flow surrounds the crucible pot about twice. This is will heating the crucible pot faster so that the heat transferred better to the aluminium. On the contrary, the crucible pot with spiral fin inclination angle of  $5^\circ$  is less efficient in transfer the heat generated by gas burner. According to the explanation above, narrower pitch fin than the diameter of input pipe cause the flow of heat spread. Some of heat flow follow the spiral line, but some other move upward directly to the combustion waste pipe through a small gap between the crucible fin and the inner furnace wall. As the result, not all of heat generated by gas burner stay longer in the furnace to heating the crucible pot.

Compared to Tanaka et.al [15] that develop a spiral line, called guideway, on the inside wall of the furnace, the phenomenon in this experiment is different. In the crucible furnace, the generated heat by gas burner is blast by a blower thus it has pressure. Therefore, the blown heat has a tangential force and it will flowing surround as it is being retained by the inside wall of the furnace. In Tanaka's experiment the heat generate by gas burner will heating the crucible pot wall by convection mechanism and it is transferred to aluminium conductively. It is obvious that some of heat that flowing surround does not contact with outside crucible pot wall. In this experiment, the fin from steel plate and the crucible pot heated conventionally and then transferred conductively to the aluminium inside the pot. Thus, there are much more heat contact with the spiral fin and crucible pot wall. This explain how the spiral fin keep the heat that were generated longer in the heating chamber of the furnace.

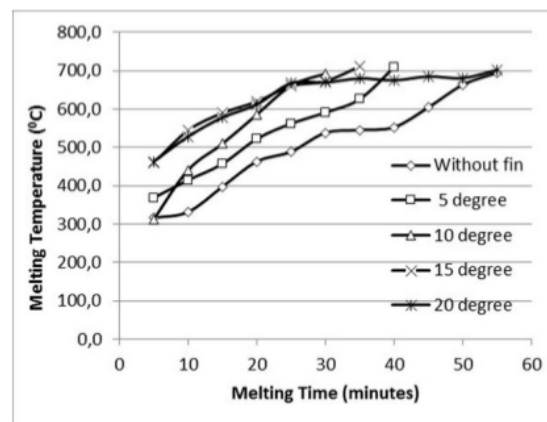
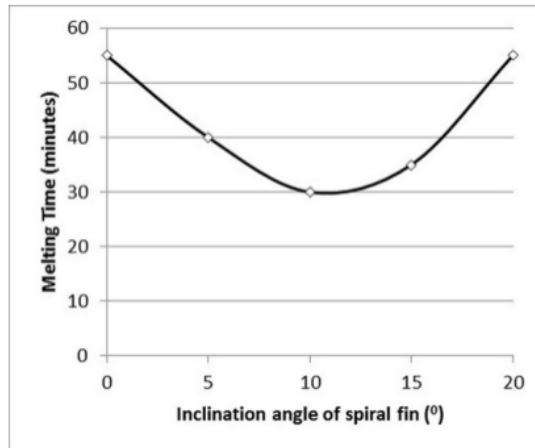


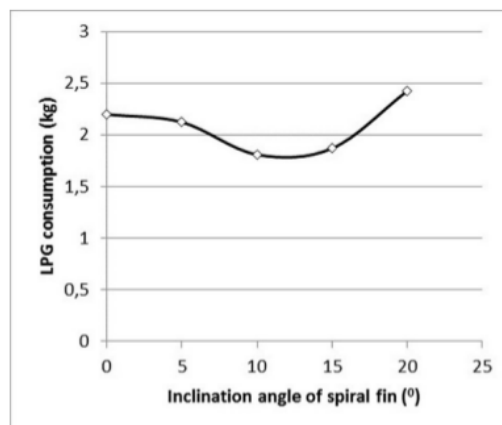
FIGURE 5. Time needed for melting



**FIGURE 6.** Effect of inclination angle fin to melting time

The melting time of crucible pot with spiral fin inclination angle of  $15^{\circ}$  and  $20^{\circ}$  is almost same compared to the crucible pot with  $10^{\circ}$  inclination angle of spiral fin. However, the experiment for those both variation was started at about  $450^{\circ}\text{C}$ . Thus, both of it need less melting time. The crucible pot with spiral fin inclination angle  $15^{\circ}$  and  $20^{\circ}$  gives almost same result. According to Fig. 4, the spiral number of the crucible pot with spiral fin inclination angle  $15^{\circ}$  and  $20^{\circ}$  almost same. Both have about one spiral of fin. Thus with both of it, the generated heat only about one time surrounding the crucible pot. It is explaining that both do not give optimum result when used to melt the aluminium. The effect of inclination angle to melting time is shown in Fig. 6. It is clear that curve of Fig. 6 affected by spiral pitch and the spiral number.

Observation on color changing of crucible pot during melting process shows that crucible pot with spiral fin inclination angle of  $10^{\circ}$  had already turned into red although the inside wall of the furnace has not yet. Furthermore, for crucible pot with spiral fin inclination angle of  $15^{\circ}$  and  $20^{\circ}$  had turned into red while the inside wall of the furnace also turns into red. This shows that the crucible pot with spiral fin of  $10^{\circ}$  is more effective in absorbing heat generated by gas burner. This demonstrates that the crucible furnace efficiency could be improved by adding spiral fin on the crucible pot. Observation on the crucible pot with spiral fin inclination angle of  $5^{\circ}$  also appear to be more quickly turned into red. However, the narrowness of the gap between the fins causes a slight back-pressure on the gas burner. This condition makes the heat flow which move surround crucible pot become disturbed. Furthermore, some of the heat move upward directly to the combustion waste pipe as discuss earlier. This explains that the crucible pot with spiral fin inclination angle of  $5^{\circ}$  increase slower.



**FIGURE 7.** LPG consumption

Fig. 7 shows the LPG consumption to melt aluminium. It can be seen that the crucible pot with spiral fin inclination angle of  $10^{\circ}$  requires less LPG, which is 1,808 kg to melt 4 kg of aluminium. The LPG required by the crucible pot with spiral fin inclination angle of  $15^{\circ}$  is almost same, i.e., 1.868 kg. This is related to the melting time. The longer of melting time, the LPG consumption is increased. However, as it is discussed earlier, on the crucible pot with spiral fin inclination angle of  $15^{\circ}$  the experiment start at higher temperature which is about  $450^{\circ}\text{C}$ . The other variation requires LPG consumption above 2 kg. This condition shows that it is less efficient. This proves that the addition of the spiral fin affects the effectiveness and efficiency of the crucible furnace.

However, there is a limitation on this study due to the crucible pot dimension. It has been declared that the inclination angle of the spiral fin determine the spiral pitch and the spiral number which is based on the discussion above it is affecting the heat efficiency. According to this, it can be seen that the dimension of the crucible pot, which that comprises of height and diameter, will also directly determine the spiral pitch and the spiral number. Therefore, the experiment result of this study is valid only for crucible pot dimension used. Further experiments are needed to examine the effect of crucible pot dimension variable.

## CONCLUSION

The using of spiral finned crucible pot could improve the efficiency of a crucible furnace to melt aluminum. It reduces the melting time and saves energy in aluminum melting process. The crucible pot with inclined angle fin of 10 degrees gives an optimum performance. It gives effective heating rate so that more efficient in LPG consumption. However, the crucible pot dimension is also affecting the spiral pitch and spiral number. Thus, the crucible pot dimension is one factor that should be considered.

## ACKNOWLEDGMENTS

<sup>3</sup> The authors are grateful for the financial support of the Ministry of Research, Technology and Higher Education, Indonesia. The authors wish to thank to the Dean of Faculty of Engineering Yogyakarta State University for using facilities of Material and Processing Laboratory.

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