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The Development of Investment Casting Technology for the Manufacture of Import Substitution Casting Products by Using of Local Raw Materials

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Abstract

The development of investment casting technology for the manufacture of import substitution casting products by using of local raw materials has been done. Compared to the conventional casting process, investment casting has the advantage of being able to create a complex casting product and produce a product that is near net shape so that it is no need machining process. The objective is as an effort to find an alternative method of making a quality casting product, has high added value with the utilization of local raw materials available in Indonesia so as to reduce the cost of production and dependence on imports of industrial raw materials which are very expensive in the investment casting process. The method of making casting products with investment casting process, including: pattern making, mould making, dewaxing, melting, pouring, finishing and testing. Investment casting technology has been successfully applied to the manufacture of rocker arm, impeller pump and turbine blade with the utilization of local raw materials ie: epoxy resin as a substitute for metal pattern, mixture wax of paraffin and celo resin for the pattern of wax and zircon sand of Bangka as coating slurry for ceramic mould. The discussion of this paper is expected to be a case of developing other casting products needed by Indonesia for industry: medical equipment, agricultural equipment, textile equipment, gun and small armaments, electronics, automotive and electrical components etc.

Keywords: investment casting, epoxy resin, wax pattern, zircon sand, ceramic mould

1. Introduction

Investment casting (Soemardi T.P, et al. 2016; D.L. Datta, 2014) is one type of precision casting technology that has advantages, namely: (1) can produce a casting product with complex geometry specification (Bemblage and Benny, 2011) and almost does not require machining process as conventional casting process, (2) compared to the forging process (Hafid, et al, 2002) can make the product complex and high surface smoothness, can also save the cost of dies making process because to make one product requires five to six times the forging process, (3) casting products produced generally using materials that have high hardness resulting in good product quality, increase productivity and has high added value.

The weakness of the investment casting process is a maximum casting product size of about 5 kg, investment and high production costs, compared to other processes, cost of dies making for expensive patterns, there are some complicated process steps and need to be automatic, foundry cost should be proportional to machining cost when done with other casting process (Parkinar, S.K, 2014; MIDC, 2007).

Investment casting process is one of the oldest metal forming techniques. Its origin can be traced back to 5000 years and was first used in China and Egypt. This manufacturing technique is also know as the lost wax process (Chalekar et al, 2015). Traces its roots to the Sang Dynasty in China from 1776 B.C. to 112 B.C. The method was brought into modern industrial use when American manufacturers applied investment casting to make high quality military parts during World War II. It was found practical for many wartime needs - and during the postwar period it expanded into many non-aircraft applications. Today, investment casting is recognized and used worldwide as a technique for producing close-tolerance metal parts at highly competitive costs (www.spmb.com, 2017).

Casting products that can be produced by investment casting are needed by Indonesia and widely used in various industries, such as automotive, oil and gas, agriculture, textile, electronics, electrical components, weapons/military, health/orthopedies, ornament and jewelery/silver) (Parkinar, 2014), construction, aircraft components, steam turbines and so on (Hafid,2013). More details can be shown in Fig. 1 (Rita, 2012; www.spmb.com, 2017).

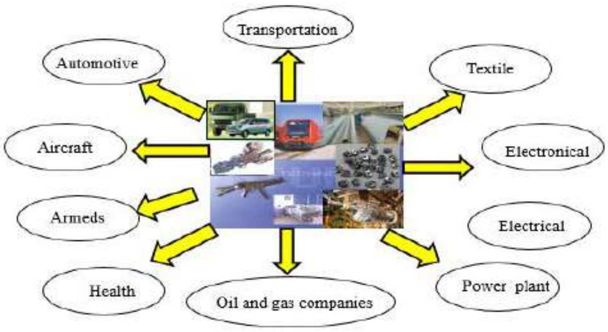

Fig. 1: The application of investment casting products

But in conducting investment casting process technology, foundry industry is still very large dependence on imported raw materials. This causes the selling price of casting products to be high so that the technology is considered expensive. This can be seen from the at least national foundry industry engaged in the field.

Indonesia is a country with abundant natural resources (Adid et al, 2015) which is contained in it is controlled by the state and used for the greatest prosperity of the people and improve the welfare for all the people of Indonesia as stated in the mandate by article 22 of the 1945 Constitution (Anonymous, 2012). Potential natural resources that are likely to be utilized as local raw materials in the investment casting process in order to reduce the cost of production economically is the use of local wax and sand for wax patterns and ceramic molds and epoxy resin material as a substitute for metal patterns.

There is an assumption that the investment casting process is a foundry process using high technology that is very expensive, it can be broken because after being studied the technology can be simplified by MIDC which is an R & D institution owned by the Ministry of Industry of Indonesia. Imported raw materials that are still imported can be substituted with raw materials made in Indonesia. In fact, machines and equipment can also be transferred to home-made products.

As an effort to reduce the dependence on the need of imported and hard-made components (spare parts) by conventional casting process, MIDC has conducted R & D in the investment casting field, its tasks and roles must be able to translate, transfered and socialize the investment casting process loaded with new technology to industry small and medium enterprises casting to improve competitiveness to meet the needs of domestic precision casting products (Anonymous, 2012).

The breakthrough to overcome the dependence of the national foundry industries on imported raw materials, this research was conducted in order to create high quality casting products with high added value with the utilization of local raw materials available in Indonesia. It is expected that with the dissemination of investment casting technology that can use local raw materials to SMEs, the foundry will reduce the dependence of various industrial sectors as mentioned above from the invasion of imported casting products.

2. Methodology

The research methodology was conducted through the following steps:

1. Materials and Equipment

The materials used for the investment casting process are as follows: (a) metal material for casting products, (b) epoxy resin FMSC 935, (c) imported wax (filler NF 411 and non filler NC 586) and local wax (mix of paraffin RRT and resin cello), (d) sand zircon import (20 mesh, 70 mesh, 150 mesh) and local zircon sand (350 mesh and 200 mesh), (e) other auxiliary materials: wetting agent, surface active agent, defoamer, acetone, silicone spray.

The machines and equipment used are: (a) wax injection machine, (b) slurry mixer, (c) slurry tank, (d) fluidized bed, (e) de wax vessel, (f) compressor (g) induction furnace capacity 250 kg, (h) burning furnace, (i) impact testing tool (charpy testing machine), (j) zahn cup.

2. The working stages

The working stages in the investment casting process include (Chalekar et al, 2015; DL Datta, 2014; Parkinar, SK 2014; www.trieka.co.id; Hafid, et al., 2010, 2012; www.turbo-cast; www.investment-casting):

a. Dies making from duralumin metal to save the cost of used epoxy resin material.
b. Preparing tools and raw materials for wax molds and ceramic molds

c. Making a wax pattern with wax injection machine.
d. Cleaning the wax pattern with acetone for slurry (zircon sand material and other auxiliary materials) can be attached to the pattern.
e. Assembly a wax pattern into a cluster.
f. Making primary slurry and secondary slurry
g. Dipping the cluster that has been assembled into the slurry continued sanding to be a ceramic mold with a thickness of ± 1 cm.
h. Remove the wax from the ceramic mold by heating at ± 100ºC.
i. Burning ceramic molds followed by preheat process on ceramic mold.
j. Prepare material for melting as per casting product specification to be made.
k. Melting metal material reaches the melting point of the metal used.
l. Pouring the molten metal from the induction kitchen into the ladle.
m. Pouring the metal liquid from the ladle into the mold
n. To knock out and clean the ceramic molds continued cutting into casting products.
o. Visually inspect casting products for defective/defective casting products re-incorporated into the fuser as raw material of liquid metal.
p. Testing: chemical composition, hardness and metallography.
q. Analyze and discuss the research results
r. Conclusing and making suggestions.

To get a clearer picture of the investment casting process steps shown in Fig. 2.

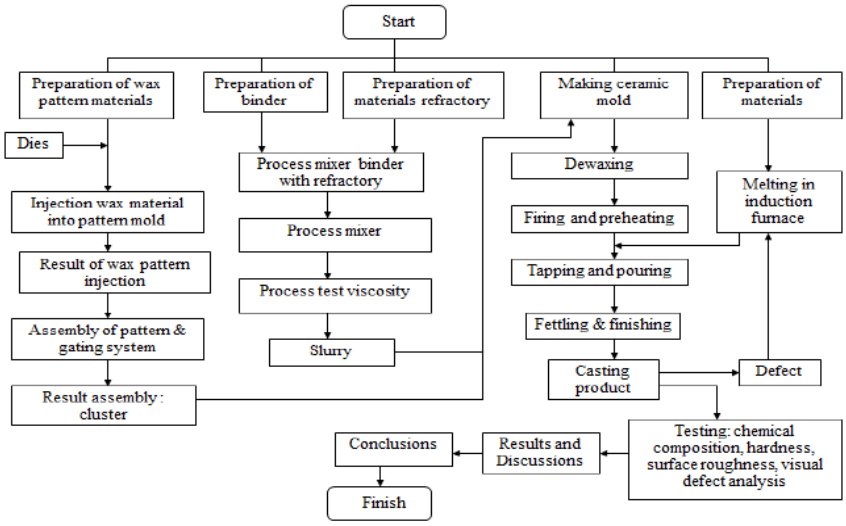

Fig. 2: Flow chart of metodologies research

3. Result and Discussion

3.1. Investment Casting Tehnology

In this research, there are several important steps in investment process:

1. *Dies* Making

Pattern dies used is made of aluminum metal machining process. However, in this study used epoxy resin FMSC 935 with consideration:

a. Molds making of FMSC 935 epoxy resin material requires a relatively faster machining time compared to using metal materials.
b. The required cost is cheaper than the mold of aluminum metal (Al)
c. The process of making the mold is relatively cheaper.

2. *Pattern Making*

The material used for pattern making is wax because the wax characteristics have a liquid temperature and a low viscosity of liquid (Hafid et al, 2009). This condition allows the wax to be mixed, injected, assembled and melted out of ceramic mold. The wax used in this study is imported wax (filler 411 and NC 586) and local wax (beeswax, resin wax, carnauba wax, paraffin wax) (A. Wahid et al, 2000; Bemblage and Benny, 2011; Parkinar, SK 2014). Fig. 3 shows the wax pattern of the injection results.

The process of injection of wax into pattern mold (dies pattern) using injection wax machine capacity of 5 ton grant from National Institute of Advanced Industrial Science and Technology (AIST) Chubu Japan. The best parameters to be controlled during wax injection time into the pattern mold are wax temperature (± 64°C), nozzle temperature (± 30°C), injection pressure (1.75 Mpa) and injection time (15 seconds) (Hafid, 2013). To get the best pattern, then when the first injection first need heated dies.

3. *Making of ceramic mold*

In this research, the utilization of local sand zircon from P. Bangka as one of the alternative raw material of imported sand zircon. Ceramic mold making process is done by coating the cluster with slurry. After being drained for a while, clusters that have been coated with slurry are immediately scattered with zircon sand until the entire cluster is covered by a zircon (Fig. 4). After drying process at room temperature, this process is repeated several times until the desired ceramic thickness (between 0,25 to 0,5 inch) is obtained.

In the manufacture of ceramic mold used 2 types of slurry, the primary slurry and secondary slurry. Stages of manufacture are as follows:

a. Primary *slurry*:

Zircon sand material from P. Bangka the 325 mesh pound that has been ground into a slurry container. Add colloidal silica, surface active agent and defoamer into the container and then stir with a continuous mixer until homogeneous. Calculate the slurry viscosity by means of zahn cup no 4 with a viscosity time of 43 seconds (standard time of 40 second viscosity). The result is the primary slurry solution can be attached well to the cluster of wax patterns then drained a few moments and directly scattered sand zircon P. Bangka 200 mesh. The coating process with primary slurry is only done once. Cluster is dried at room temperature minimum 12 hours.

b. Secondary *slurry*:

Making it the same as primary slurry just does not use surface active agent and defoamer. Calculate the viscosity of about 10-12 seconds. Then cluster wax pattern coated/immersed into secondary slurry, after drained a few moments immediately scattered sand zircon Bangka 200 mesh. After drying between 5 - 7 hours then repeated the same process again. Furthermore the secondary slurry process is repeated again as much as 4x up to 7x again with the sand dissipated are: 200 mesh, 150 mesh, 70 mesh, and 20 mesh. Drying process at each process for at least 5 hours. Finally after the above process is done, before the dewaxing process the whole cluster first coated once again with secondary slurry and dry at least 1 day.

Fig. 3: Wax pattern of the injection results

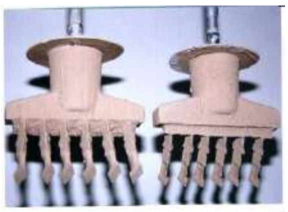

Fig. 4: Ceramic slurry made of domestic zircon sand

4. *Dewaxing*

Eliminating the wax pattern from ceramic mold is called dewaxing, its processing through 2 stages, namely: (a) warming wax pattern by using fire that burns until wax melts and out of gating system, (b) to remove wax which still attached after first stage used de wax vessel. Then the mold is immersed in de wax vessel containing water with a tempetarur around which is set to reach 110ºC with the condition of the gating system at the top. Allow a few moments until the remaining wax is lifted entirely to the surface of the water.

5. *Firing dan Preheating*

Heating ceramic molds at a temperature of 1,000ºC for 2 hours in a firing furnace with diesel fuel as preheating before pouring. Firing process is a sintering ceramic mold for increased strength. The thing to note is that the temperature used for firing is adapted to the type of melting material and the amount of casting products as well as the thickness of the ceramic molding wall. This firing process other than as preheating to ceramic mold, as well as the process of removing the remaining wax that is still slightly attached to the ceramic wall.

6. *Melting*

The melting is done in the induction kitchen of 250 kg capacity to reach the melting point of the metal used. The process of pouring liquid metal from the kitchen into the ladle is then poured into a mold that is still in a hot state until the liquid metal fills the entire mold cavity which is then left to stand still to freeze and cool.

7. *Mold removal*

After the pouring is finished and the molten metal poured into the ceramic mold frozen then carried out the mold removal and cleaning of casting products. After clean casting of ceramics then cutting casting products. Casting products results (rocker arm, impeller pump, turbine blade, etc) by using investment casting can be shown in Fig. 5.

8. Testing of casting product

In this research, we have done several tests on the result of casting product: (1) chemical composition, (2) metallographic test done to see microstructure from samples of casting (3) surface hardness test (4) surface roughness test and (5) dimensional checking and (6) visual defect analysis based on casting product observation results.

Fig. 5: Casting product results by using investment casting

3.2. Potential of Local Raw Materials

To realize the independence of technology by increasing the added value of local natural resources, the potential of quartz sand reserves in Indonesia is very abundant in the areas of P. Bangka and Belitung, Rembang (Central Java), Tuban (East Java) and Sintang, Melawi, Pangkalan Bun and Kumai (West and Central Kalimanten). Local Silica fuse can be used in the process of making ceramic molds because the characteristics of silica sand (SiO_2) fulfill the requirements as raw material for the manufacture of silica fuse because it has SiO_2 content above 99,5% and Fe_2O_3 content below 0,05%. The selection of silica fuse instead of zircon flour can reduce the cost of production because it is much cheaper (Hafid, et al. 2012; S.B. Pratomo, et al., 2014).

In order to obtain a good casting product, the zircon sand utilized for casting process should has a ZrO_2 content not less 64%. Testing reveated that ZrO_2 content of Bangka is only 28.29% so that we (the researcher) suggest that Bangka is not good to be used as primary slurry because it will contact directly metal fluid, but it can be used as sand materials during sanding process (Hafid, 2013).

The local wax raw materials that can be used for candlestick patterns are paraffin, damarselo and arpus mixtures, as well as the ratio of paraffin, carnauba and wax (60%; 20%; 20%).

4 Conclusion

The development of investment casting technology for the manufacture of import substitution casting products by using of local raw materials has been done, namely: local silica and zircon sand for ceramic mold, mixture wax of paraffin and cello resin for the pattern of wax, epoxy resin as a substitute for metal pattern (dies). Local fused silica can be used for making ceramic molds because it has SiO_2 content above 99.5% and Fe_2O_3 levels below 0.05%. Bangka zircon sand can be used for sanding process because the testing result has ZrO_2 content of about 28.29% (minimum standard 64%) and can not be recommended for primary slurry material because it will experience direct contact with metal liquid. Mixture wax of paraffin and cello resin can be used for pattern of wax with optimal injection temperature (64^oC), nozzle temperature (30^oC), injection pressure (1.75 Mpa) and injection time (15 seconds). Need to the development other precision casting products making for industrial needs: medical devices, automotive, oil and gas, textiles, electronics, electrical components, weapons/military, health/orthopedies, ornament and jewelery/silver) and so on.

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