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Speech From Head of Research and Community Service Center of State Polytechnic of Jakarta

Sambutan Ketua Pusat Penelitian dan Pengabdian Kepada Masyarakat (P3M) Politeknik Negeri Jakarta

Assalamualaikum Wr Wb

We pray to Allah SWT for all His grace and gift He has given to us all so that the International Seminar on the Results of Researches and Community Services can today be conducted.

This international annual seminar is aimed to provide a dissemitaion forum for the results of researches and community services. This is expected to be a forum for information exchanges, discussion involving many parties: scholars, practitioners, and government. Interaction among different perspectives could become a medium to create technology development and sustainability accurately applicable in industry and society to enhance and support their autonomy in this modern era. For this, P3M PNJ ASAIS 2012 invite scholars, practitioners and government to write and present their papers under the following fields:

1. TECHNOLOGY
   Computer and Information Technology, Telecommunication, Electrical and Electronics, Energy Conversion, Mechanical Technology, Manufacture and Production Process, Production Management, Machinery Maintenance, Heavy Equipment and Automotive Technology, Civil Engineering, Building Structure, Road and Bridge, Water Resource and Environment, Geotechnical, Engineering Materials, Construction Management, Graphics Technology, Animation Technology.
2. COMMERCE
   Finance, Accountancy, Banking, Law, Business Administration, Event Management, Communication, Publishing, e-commerce, e-government, e-learning, e-promotion, Islamic Banking, Islamic Economics.
3. ENVIRONMENT

As the person in charge of this Seminar, we thank the Director of State Polytechnic of Jakarta and all the management; resourcepersons, colleagues from colleges, universities, polytechnics; researchers, and all invitees. And we also thank all members of commitees who have worked hard and are full of spirit to make the seminar happen.

Finally, we look forward to suggestions and critisism so that we can carry out the next international seminar in 2013 better.

Wassalamualaikum Wr Wb

Jakarta, 6 November 2012
Head of P3M,
Politeknik Negeri Jakarta/State Polytechnic of Jakarta

Ir. Budi Damianto, M.Si
NIP. 19580108 198403 1 001

Speech From Director of State Polytechnic of Jakarta
Sambutan Direktur Politeknik Negeri Jakarta

Assalamu'alaikum Wr Wb,

We pray to Allah SWT for all His grace and gift He has given to us all so that today we can attend the International Seminar on the Results of Researches and community Services under the theme of "Creative industry based research and community services to encourage community autonomy", as a basis of knowledge and research development in higher education, both national and international which can be conducted by Research and Community Service Center in State Polytechnic of Jakarta.

The purpose of conducting this seminar is to provide knowledge and concepts exchange opportunity for multidiciplinary scientists to put forward their perspectives in national and state problems under the three defined sciences. Beside that, this forum can also be used to strengthen relationship of researchers from both national and international institutions.

In this instance we would like to thank:

1. Prof. DR. Djoko Santoso, Dirjen Dikti
2. Associate Profesor, Kume Yusuke, Saga University
3. Presenters
4. All boards of committee who have made this happens

We hope that this academic activity can be conducted regularly and the spirit of the research will always sustain and give valuable contribution to the welfare and the development of the nation.

We thank you and hope you gain valuable benefits from the seminar.

Wassalamu'alaikum Wr Wb,

Jakarta, 6 November 2012

Director of state Polytechnic of Jakarta

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TITLES OF COMMERCE AND ENVIRONMENT PAPER

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Making Steel Products by Investment Casting Method Using Local Materials

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Abstract
Investment casting, also known as lost wax precision casting process is the technology used to produce a casting products which have complex geometry shapes, surface smoothness, shape and dimensional precision, thus the resulting products performs high quality and added value. Impeller could be considered as one of the example of the investment casting product. In Indonesia, the investment casting technology has not yet been widely applied. Only few industries use this technology. The manufacturing technology, machineries and materials are still imported. By analyzing the required process and materials, which is then followed by some trials and analysis, this study provides an alternative use of local materials and simple technology to produce good quality products. This can subsequently be applied in small-medium scale industries and in educational institute. The research has resulted a formula of modeling wax, slury and the processing techniques. The experiments performed in this research to produce the impeller used steel (DIN standard GS30Mn5) as the main material.

Keywords: *Investment casting, wax, ceramic slurry, impeller, GS30Mn5*

1. INTRODUCTION

Along with the increasing needs of foundry products in the manufacture of small dimension, precision and smooth surfaces, metal casting industries are required to develop the technology so that it can fulfill those needs. Investment casting method is one alternative to improve productivity and product quality castings, especially its ability to produce precision, small tolerances, surface finish, minimum machining, shape and size of the complex objects that can not be produced by other casting methods. In addition, investment casting method can be used for very specific types of material retaining high hardness that can not be processed by machining of those casting products so that the results can be directly used. Only a few numbers of industries develop investment casting technology due to some reasons i.e the technology of investment casting it self, and the availability of raw materials and machinery. Most of these materials are imported so the production cost is relatively expensive. The high cost operation problem of investment casting can be overcome by substitution of materials and machinery imported by local materials, as did Hafid et al (2002) in the manufacture of FCD rocker arm 70. Therefore, this research is aimed to produce the optimum formula of wax and slurry in the steel investment casting technology by using local materials.

The main factors affecting the precision of products investment casting are model (pattern), the slurry, process design and the equipment of investment casting involved. The model is highly dependent on the characteristics of the wax against shrinkage, strength, and reaction to the slurry. Slurry quality is highly dependent on the characteristic and composition of materials. Wax is used as a medium for making ceramic patterns, normally use paraffin with a melting point 50 - 70°C, expansion 2%, viscosity of 450 cPs. The melting properties, coefficient of contraction /shrinkage and the ability of paraffin to flow is strongly influenced by their chemical composition. Naturally, paraffin can cause problems due to the expansion of paraffin, which is greater than the expansion of ceramic tiles during the dewaxing step. This subsequently lead to cracking. The original paraffin wax does not meet the desired characteristics, so that additives must be added to improve its characteristics, for example isophtalic acid, petroleum ether, etc. Slurry is used to make a high quality ceramic mold in term of shape and thickness, refractories characteristics, uniform particle size and even the reaction with the liquid metal and the thermal expansion. This research will cover the design of chemical composition of slurry, size/characteristics of base materials of slurry, wetting agents and mold making process. The other factor which plays a role in determining precision products is the process design of investment casting. The research is aimed to produce a slurry formula-based wax and local materials as well as determining the appropriate technology in processing these materials. The outcomes of this study are the formula of the wax and slurry, the processing technique in slurrying, dewaxing, firing and pouring as well as the mastery of investment castingtechnology.

The Outcomes in this research will impact on improving industrial capabilities in for examples producing local spare parts as substitution for which being imported, development in tool and machine manufacturing industries due to increasing capability in producing high precision casting, surface finish through the appropriate materials, increasing the industrial capability of providers of basic and refractory materials for investment casting process, developing the industrial capability in manufacturing prothese for medical need.. This research generally impart great contribution for both public and the society of manufacture industries in providing precision products as well as high quality and low cost by substituting imported materials with local ingredients.

2. THEORY

Basically there are two distinct process for making investment casting molds i.e the solid investment process and the ceramic shell process. The later process has become predominant technique for engineering application.

There are some factors in ceramic shell investment casting process which should be considered :

Pattern materials

The primary material for pattern is wax. It is usually modified to improve their properties through the addition of materials such as resins, plastics, fillers, plasticizers, antioxidant and dyes.[4] There are several waxes available i.e paraffins, microcrystalline, Ozocerite, Candelilla, Carnauba and beeswax. [9]

Additives are often used for improving the wax properties. These additives are polyethylene, ethyl cellulose, nylon, ethylene vinyl acetate, and ethylene vinyl acrylate. Resins are also often used to reduce shrinkage of wax patterns. The most useful resins soften gradually and continuously with increasing temperature, and they do not exhibit the large solid to liquid expansions during heating, or the reverse contractions during cooling.

Fillers, are also used to reduce solidification shrinkage of wax. These are insoluble in, and higher melting than, the base wax, and they produce an injectable suspension when the mixture is molten. Fillers do not contribute to the solidification shrinkage of the wax mixture because they do not melt. Fillers that have been used in pattern waxes include polystyrene, various dicarboxamides and related compounds, isophthalic acid, pentaerythritol, and hexamethylenetetramine. The fillers should be in the form of small, equally size spheres.[5] Figure 1 shows the manner in which fillers reduce expansion during heating.

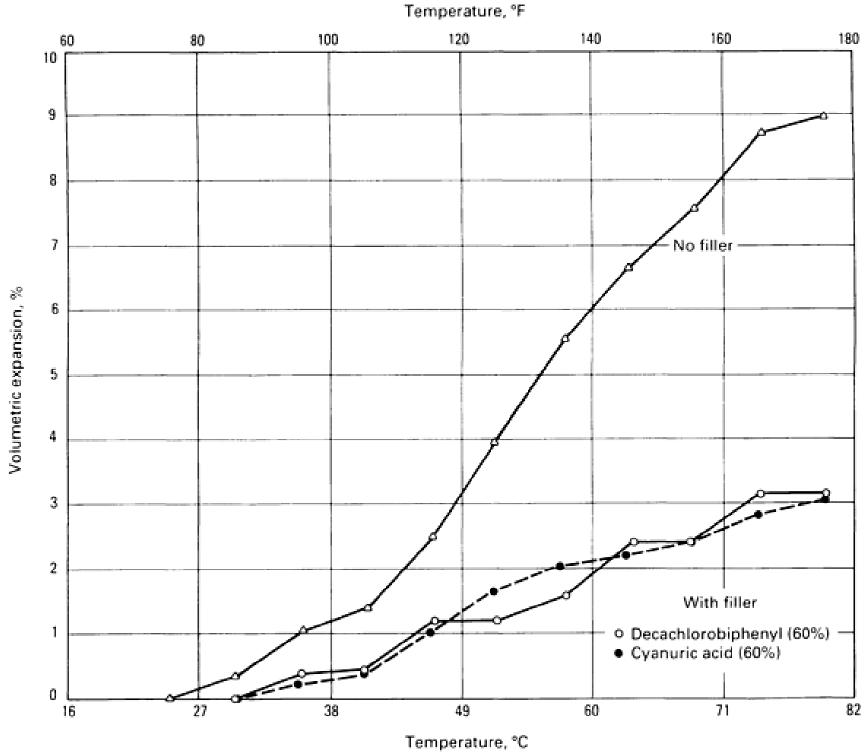


Figure 1. Effects of filler materials on the volumetric thermal expansion of a pattern wax

Mold refractory

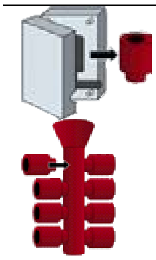
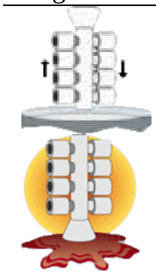
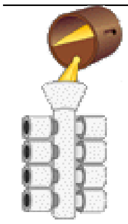
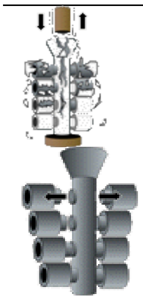
Investment shell molds are made by applying a series of ceramic coatings to the pattern clusters. Each coating consists of a fine ceramic layer with coarse ceramic particles embedded in its outer surface.

Slurry is a basic component for making ceramics. Slurry is basically consists of refractory materials, a binder and the solvent. Based on the layer of investment casting mold the slurry are grouped into primary and backup slurry. After the firing process and at pouring the primary slurry will come into direct contact with the liquid metal. Thus, the main properties required for the primary slurry is high sintering temperatures, high melting temperature, unreactive to the liquid and having a very fine grain size. Fine grain size will produce high quality castings with smooth surfaces, which would then be able to improve or ensure the precision, size and shape of the casting. Backup slurry is an supporting material added to slurry after the primary slurry formed. Basic refractory materials commonly used in investment casting is mullite (alumino silicate) ($Al_6Si_2O_{13}$), silica (SiO_2) or zircon, (zirconium silicate, $ZrSiO_4$). These refractories materials are blended with binders materials such as colloidal silica, ethyl silicate and sodium silicate.

3. METHODOLOGY

Technically, investment casting method consists of several stages, as illustrated in Table 1, the ceramic mold is formed by dipping the wax pattern into slurry, draw off wax pattern from ceramic mold by dewaxing process to produce cavity in the mold, pouring molten metal and knocking the mold.

Table 1. The Experimental Stage

Processes	explaination
 Stage 1	Casting wax into the mold is done by gravity or injection method. Attaching the fins pattern to the cylinder plate.
 Stage 2	Coating is done by dipping the wax pattern that has been assembled into a ceramic slurry. Dipping is done repeatedly until ceramic layer is of ± 5 mm thick. Dewaxing, a wax pattern is drawn off from the ceramic mold by melting the wax so that it will create cavities in a ceramic mold left by the melted wax pattern
 Stage 3	Firing is heating the mold at the temperature of 1000 - 1100 ^{o}C in order to sinter the ceramic mold so that its strength is increased. Pouring is carried out at temperature of 800 ° C, the reason is that thin sections can be fully charged and the mold will not fracture due to thermal shock.
 Stage 4	*Knockout* knocking is done by vibrating the mold or hit it with a hammer. Gating system is cut using hand grinders

In general, investment casting wax is a complex composition of several components such as synthetic or natural waxes, synthetic or natural resins, organic fillers and water (Argueso, 1986). Additives are used to improve the properties of wax. Resins or plastics are added to strengthen the wax. Fillers are made of fine powder. in general, isophtalic acid, polystyrene, bisphenol A and hydrofill are used as filler (Wolff, 1999). These components were added to improve the properties and control the shrinkage or dimensions of the wax. The most preferred properties of the overall mentioned above is the volumetric expansion. This property affects the dewaxing process in order to obtain crack-free mold and the final model dimension. Malkin (1989); Thompson (1959) and Roberts (1980) recommend the following aspects to produce a good wax systems: apply the lowest possible temperature to nearly congealing point, use the temperature dies as high as possible, perform the injection process at the highest pressures as possible.

To overcome the crack that may occur in the ceramic mold, the wax melting is done in a pressurized room, so that the pressure due to the expansion of the wax can be compensated by external pressure. In general, melting of wax is done in an autoclave. Firing of ceramic mold is performed after dewaxing process. In addition to form and stabilize the ceramic, the firing process also removes any remaining wax or a wetting agent that may be still stuck in the ceramic mold. The temperature of the mold is held at 800^{o}C when pouring the molten steel. This is done to avoid thermal shock which can be experienced by a mold that can cause mold cracking. Moreover holding at a high temperature is necessary for liquid metal to flow fluently in the mold and reduce the risk of shrinkage.

4. RESULTS AND DISCUSSION

Optimization Parameter of Wax

Parameters are set to get the optimum wax formula, which are:

% volume and diameter shrinkage according to the standard wax,max 2%

Fineness of the wax surface

Hardness and elasticity that resembles a standard wax

The ability of slurry in binding / adhesion

Optimization Parameter of Slurry

Parameters are set to get the optimum slurry formula, which are;

A layer of slurry with a certain thickness

The ability of slurry to adhere to the wax

The strength of the slurry coating after dewaxing and firing (no cracks, smooth surface)

Optimization results of Wax

Based on data obtained from 13 variations in the wax composition, volume shrinkage is remain found. The linear shrinkage has met standards. The effect of blending beeswax into paraffin increased strength and adhesion of wax to the slurry. Paraffin tend to be brittle that may causing crack on pattern, in addition paraffin leaves a high content of oil on the pattern surface which cause the surface to be slippery and restrict the adhesion of slurry . The addition of beeswax also increase resistance of wax pattern to cracking. The effect of addition of 20% arpus / gondorenum / gum resin improve the surface texture of wax which becomes more finer and a few increasing in hardness but the melting point of wax is higher because arpus tend to has a higher melting point (at least 78oC). Pouring of wax is done at a temperature of 75oC and metal patterns / dies is heated to about 50oC due to this condition will yield the best surface texture. The reason of dies heating to a temperature of 50oC is to avoid freezing of the defective wax or uneven surfaces. The temperature of dies lower than 50oC still produce surface defects on wax pattern. It can be concluded that the the wax formula gives better results when the composition ratio of beeswax to paraffinis (30 : 70) by the addition of 20% arpus to the total weight of wax, and then pouring of wax into dies is performed at 75oC during heating of dies at the temperature of 50oC.

Design of Wax Pattern Dies

Dies are divided into two parts, the main disc and blades. Figure 2 shows the design of the impeller. Figure 3 shows dies design of the main disk and figure 4 shows dies of blade. Blades and assembling parts are shown in Figure 2-4.

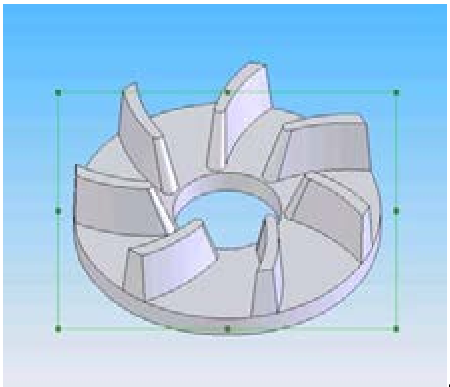

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Figure 2. Impeler

Figure 3. disc mold

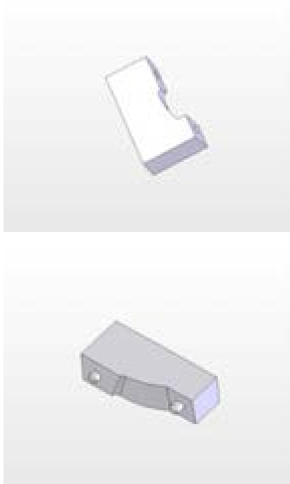

Figure 4. The Impeler blade mold

Assembling process will produce a model consisting of the prototype of product and its gating system, which allows the metal fluid enter the cavity. Table 2 describe assembling method of the model. The best results were obtained by the method of melting.

Table 2. Assembling Wax Model

No	Method	Materials	result
1.	adhesion	Lem Kuning	adhere easily. Low bonding strength. Bonding is flexible and easy to change
2.	adhesion	Quick Bonder (alpha-cyanacrylate)	adhere easily, high bonding strength but it can not persist for long time. The adhesion have no plasticity.
3.	Melting		Partial melting of the surface of the model and then combine them. The molten part solidify quickly, thus it is hard to be bonded. The propeties of the wax on the bonding interface is the same as the properties of the wax model.
4.	Adhesion	wax	The assembling is done by dipping the blade into the molten wax and put it into the main disc. Bonding strength is low, The binder solidify faster so the adhesion is difficult.

Figure 5 shows the results of modeling wax. Assembling is done by partial melting of

Figure 5. Wax model

Optimization Result of Slurry

Some variables are set in the experiment of slurry. The Formulas and the analysis are presented in Table 3. Tested wax contains beeswax: paraffin (30:70) and 20% arpus, the viscosity of slurry is set to + 100 cps.

Table 3. Slurry Formulation

No	Formula	observation
1	$Al_2O_3 : SiO_2$ (50 :50)	Slurry is adhered but fragile
2	$Al_2O_3 : SiO_2$ (50 :50) + 10 % bentonit on total weight of oxide	Adhere strong enough
3	$Al_2O_3 : SiO_2$ (50 :50) + 10 % Poly Vinyl Alcohol on total weight of oxide	Adhere strong enough but cracks in fourth layers
4	SiO_2 : clay (50 :50)	Adhere, cracks in second layers
5	layer 1 : Colloidal silica : tepung Zr (135 mL : 600 g) + 1 mL Poly Vinyl Alcohol 5 % layer 2 : Colloidal silica : tepung Zr (135 mL : 600 g) layer 3-5 : Colloidal Silica : tepung Zr (158 mL : 600 g), after dipping, sprinkled with Zircon powder 325# layer 6-7: Colloidal Silica : Zr powder (158 : 600 g), after sprinkled with mulit powder 60 #	Stick well

The result of observation to formula in experiments 1 and 2 are less well to the formation of the ceramic layer. Each coating process result in slurry thickness of about 1-2 mm which dry within 24 hours at room tempeprature. At the fourth layers, slurry was cracked. The analyses of this phenomenon are:

High viscosity of slurry and the dipping process of wax resulted an uneven surface of the slurry.

Slurry is less homogenous due to manual mixing and tend to produce lumps. However, the dispersed slurry is stable enough without any precipitation.

a fair amount of air bubbles has generated during mixing / homogenization of the slurry so it caused the holes when the drying process and initiating cracks on the surface of slurry.

In terms of the bonding strength, the slurry adhered well onto the surface of the wax without treatment by washing the surface and dipping it into wetting agent.

Figure 6 shows the results of the model with a slurry coating process.

Figure 6. Ceramic molding

The melting process of wax is conducted in some variation as shown in table 4.

Table 4. Dewaxing methode

No	Method	Result
1	Heating in an oven	The temperature of wax and mold increased almost simultaneously.The wax expanded rapidly which finally compressed ceramic molds from the whole directions. Because the expansion level of wax is higher than the ceramic mold and the absence of outlet for ceramic in each section, then the ceramic molds were broken
2	Evaporatio n in free air	Evaporation is done by passing steam into the wax surface. Because melting of wax is only performed at the part which contact with free air, then the expansion during melting can be directly eliminated by the drainage of the wax so that this process can be done without causing a crack in the ceramic mold. Wax melting process is running very slow.
3	Melting in *pressure cooker*	This process is done by evaporation accompanied by pressure which come from the outside of the ceramic molds. The expansion of wax and mold due to heating can be compensated by providing pressure on the mold, so it doesn't cause cracks on mold.

Firing

Firing was carried out with several goals: to remove water from the mold, to remove residual wax from the mold, changing the colloidal silica which is used as a binder into that as a refractory material and stabilize the mold by sintering of sand or refractory materials.

Sinter point of refractory sand materials must be tested to produce good mold. Preheating in the oven until the temperature of 200 ° C performed for 2 hours. Firing was carried out in the oven and the burner (Fig. 7) at 50 ° C above the sinter point of refractory materials. During the combustion can be observed the formation of water vapor at a temperature of 100 ° C, followed by the burning of the wax residue. In the sintering temperature of the mold reinforcement occurs. Some parts of the backup slurry on the outer mold aside from the bond.

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Figure 7. Burning of mold

Casting

The metal used to test the ceramic mold is low manganese steel DIN standard GS30Mn5 with 0.3% carbon content and manganese content of 1.25%. Casting was carried out at liquid metal temperature of 1610oC. This higher temperature allows for observation of the ceramic mold strength at high thermal loads. Casting process is done in several stages. Heating of ceramic mold to 800 ° C, metal smelting, sand bed preparation, pouring metal into molds, cooling, spending the casting form mold, cleaning and testing.

The fracture of ceramic molds which were observed after the metal casting process indicates that the folding lines has the same contour as the lines on the wax models. This indicates that the slurry and the ceramic mold which were formed as a whole has been able to produce a contour in the mold that was the same with wax models. Surface smoothness of slurry is excellent so as producing a smooth cast surfaces. There is no reaction between the ceramic mold and liquid metal, because the mold did not adhere to the casting. The high-strength of ceramic mold was characterized by the absence of cracks in the mold during the casting process. The mold stability was also good due to the absence of cracks that caused by increasing in temperature during the casting process followed by a decrease in temperature during the cooling process. Figure 8 shows the casting resulted from this research using GS30Mn5 materials. Contours of the objects have been well produced indicated by the sharpness of the contours of the object at an angle. There is shrinkage at the surface of the main disc as a result of lack of liquid supply to compensate for the contraction. Measurements are performed on the object indicates that the total contraction on the disc diameter of 1.1%. This shrinkage is smaller compared to casting in sand molds for the same metal.

Figure 8. casting products.

5. CONCLUSION

Conlusion

Local beeswax and paraffin can be used as a base wax for investment casting. The formula of wax gives better results at the composition ratio of beeswax : paraffin (30 : 70) and the addition of 20% arpus to the total weight of wax, this is supported by casting of wax at 75oC and heating the metal dies at 50oC. Gravity casting has been able to fill the entire cavity of the mold. Shrinkage occurs at the surface of the disc and the inlet. With the addition of mold pressure and temperature increase (to 50oC), contour of the object is well formed. Method of assembling should be done by melting the surface of the model.

Slurry is less homogeneous due to manual mixing and tends to produce lumps. However, the slurry is stably dispersed without deposition with the aid of polyvinyl alcohol wetting agent 5%. A fair amount of air bubbles is generated during mixing / homogenization of the slurry so that when the drying caused the holes and initiate cracks on the surface of slurry. In terms of bonding strength , the slurry adhered well onto the surface of the wax without treatment by washing the surface and dipping it into wetting agent. Dewaxing can be done with water vapor pressure to compensate for expansion. Pressure magnitude and duration of evaporation depends on the shape and dimensions of the mold. After dewaxing process, the mold is heated at a temperature of 200°C for 2hours firing the mold with a burner produces a better uniform burning on the outside and inside the mold. Wax residue can be removed easily with the use of these burners. Firing temperature is the same with sintering temperature of refractory material used. Holding mold temperature at 800oC for liquid steel casting has successfully prevented cracking molds during casting.

Recomendations

Use wax with different melting points for the sprue and model. Melting point of wax sprue should be lower to facilitate expenditure of wax in the mold. Modeling should be done by the method of injection in order to have a better contour. Gravity modeling of the charging should take into account the distortion of the larger forms. Further research is necessary in designing equipment that can be applied to investment casting for a simple small-medium scale industries.

6. REFERENCES

Journal article

[1] S. Saau and S. Viswanathan (1999), Critical Material Properties For Predicting Pattern Tooling Dimensions In Investment Casting, Metals and Ceramics Division Oak Ridge National Laboratory Oak Ridge, TN 37831-6083

[2] Hafid, Tatang T., Rudi S. R., A. Wahid, Mitsuo Ninomiya (2002), Implementasi Teknologi Investment Casting Dalam Rangka Pembuatan Produk Cor Substitusi Impor Dengan Pemanfaatan Bahan Lokal, Jurnal Riset, p. 45 – 57.

[3] Sylvia, J.G. (1972), Cast Metals Technology, Philiphine : Addison-Wesley Publishing Company Inc.

[4] Solomon, P (1975), Disposable Pattern, Composition for Investment Casting. U.S. Patent 3,887,382.

[5] J. Booth, Pattern Waxes for Investment Casting, *Foundry Trade J.,* 6 Dec 1962, p 707

Electronic publication, information from the internet

[6] www.freepatentsonline.com/image-4758613-1.html

[7] www.hitchiner.com

[8] Timothy M. Wolff, M. Argueso & Co., Inc.,Muskegon, Michigan, Investment Casting Waxes : Influences Which Eliminate Wax Pattern Defects.pdf.

Refference books

[9] ASM Handbook. Vol.15, Casting.