PREVENTION OF CERAMIC
Shell defects

By

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If foundries adopt a pro-active attitude towards the manufacture of sound cast components with an emphasis on prevention rather than cure then the possibility of manufacturing defective castings can be minimised.

The four principle factors that determine the manufacture of a sound ceramic shell mould are:

- **Selection & Application of Materials**
- **Control of the Process**
- **Operator Competence**
- **Type & Utilization of Equipment**

Good quality material can be purchased from reliable suppliers but if this is used incorrectly by the foundry then poor quality ceramic shell moulds will be produced resulting in defective castings. The absence of good control of the process and the lack of operator skill or understanding of the process will lead to defects in the castings due to poorly manufactured ceramic shell moulds. The type and utilization of the equipment will have a profound effect on the production of ceramic shell moulds. If the equipment is not suitable or is badly maintained then the foundry will produce defective castings.

REMOVAL OF DEFECTS

In the case of positive defects such as ***pimples, air bubbles, finning, surface roughness and bulging,*** the castings can be salvaged by cleaning the surface using various hand grinding tools. Although these defects will not be logged in the reject rate records they represent an increase in the re-work time in the finishing department and in the production cost. Generally speaking, the negative defects such as spalling, scabs, inclusions, rat tailing and dipcoat lift cannot be re-worked and would be considered rejected castings.

The shelling defects found in investment casting components are broken down into the following process parameters:

- **Primary Dipcoat Related**
- **Back-up Dipcoat Related**
- **Process Drying**
- **Final Drying**

PRIMARY DIPCOAT RELATED DEFECTS

Pre-dipping Preparation

An essential part of ceramic shell mould building is to ensure that the wax assembly to be primary coated is free from any surface blemishes and the die release agent is completely removed. If the wax assembly surface has traces of die release agent then the finished casting produced will show ***surface roughness*** due to the primary slurry not adhering sufficiently to the wax surface causing localised thinning. On large flat surface areas or thin edges the wax pattern must be thoroughly etched with a degreasing solution to ensure that the primary slurry adheres to the wax surface and avoids ***primary coat lift***. The degreasing agent must be completely removed from the wax assembly by washing with a continuous flow of water.

The degreasing agent should be monitored at regular intervals by measuring the

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specific gravity to ensure that the solvent is not contaminated. After degreasing, the wax assembly must be allowed to stabilise at the ambient mould room temperature for a period of time to avoid **primary coat *cracking/lifting*** due to the variation in temperature between the slurry and the wax assembly.

Additions

A primary slurry which has incorrect quantities of wetting agent or insufficient anti-foaming agent in its formulation will produce localised ***pimples/roughness*** on the surface of the casting. If the primary slurry has incorrect quantities of wetting agent the surface of the pattern will not be evenly covered and will produce localised ***roughness.*** Insufficient wetting agent in the slurry will create a foamy mix and produce a ***pimply surface*** on the casting. To overcome this problem small additions of anti-foaming agent should be added to the mix.

It should be borne in mind that if the foundry is using a proprietary binder then the supplier's recommended additives should be used otherwise non-compatible additives may cause the slurry to gel. Care should be taken when making additions as too much or too little will alter the rheology of the slurry.

Contaminants

The refractory materials used in making up a slurry should have a very low iron content. A high iron content in the slurry would be instrumental in causing a metal/mould reaction and producing castings with ***slag defects*** and a ***rough surface*** finish. Foundries should use a refractory material with a very low iron content and stainless steel equipment to minimise the occurrence of these defects.

The primary slurry bath must be free from contaminants such as excessive de-greasing agent, broken wax and dry slurry material from the tank as this will cause positive defects on the cast surface of the component.

Slurry Temperature

It is important that the slurry temperatures are maintained within 2-3^{o}C of the ambient temperature of the mould room. If the slurry temperature exceeds the ambient temperature of the room then will be a tendency for the primary coat to lift or crack due to the thermal expansion difference between the wax and ceramic material. This will lead to ***mould breakdown, rat tailing*** and ***ceramic inclusions*.**

Slurry pH

If the pH is out of control the primary slurry will shows signs of gelling. This will affect the viscosity causing the primary slurry to loose its binding strength and produce ***spalling*** of the primary coat.

A downward shift of the pH will cause the primary slurry to gel. This may be due to bacteria growth, salts (calcium, magnesium) from water additions and leaching out of the electrolytes in the refractory materials (zircon, aluminas, cobalt aluminate) producing agglomerations in the slurry. These clusters of partially gelled concentrates of silica will deposit themselves on the wax surface and will not be seen by the operator when covered by stucco material. When the molten metal comes into contact with these low refractory clusters it will penetrate to the surface of the primary coat producing a ***rough surface finish***.

Slurry Thickness

A primary slurry with a low viscosity/density will produce a rough surface finish of the casting due to molten metal penetrating between the pores of the stucco material. If the primary slurry applied to the wax assembly is too viscous

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due to poor process control, insufficient or uneven draining this will produce a localised thick coating causing the dipcoat to spall during dewaxing or casting due to insufficient adhesion between the primary and back-up coats.
The slurry must be controlled and maintained to its set target viscosity/density at regular intervals during the shift. If necessary a % silica content check should be done daily until the slurry has been stabilised.

Similarly, if the primary slurry has not had sufficient mixing or aging time then the finished castings will have ***pimples or metallic globules*** on the surface.

Primary Coating and Application of Stucco
Surface roughness will also occur when using a correctly controlled slurry if the wax assembly is unevenly primary coated by the operator. This will produce a thin dipcoat on the wax assembly and allow the stucco material to penetrate the dipcoat resulting in a ***rough surface finish*** on the cast component.

If the operator allows the primary coated assembly to drain for too long then localised drying of the coat will take place and the primary stucco will not key onto the dry patches. This will cause ***delamination*** of the primary coat and produce ***ceramic inclusions***.

Alternatively, minimal and uneven draining of the primary coated wax assembly will cause localised ***spalling*** of the primary coat due to poor adhesion between the primary and back-up coats.

If the stucco material is too fine or has a poor distribution range then this will cause ***delamination*** of the primary coat from the back-up coat.

Drying Procedure
Before applying a back-up slurry to a primary coated assembly it is important to ensure that the coating is set and any loose stucco material is removed otherwise the following ceramic defects may occur: ***rat tailing, primary coat lift, spalling, bulging, scabbing, mould cracking***. If the primary coat is not set then it will be washed away leaving poor surface adhesion for the back-up slurry.

BACK-UP DIPCOAT RELATED DEFECTS

The defects associated with back-up slurries are usually due to poor packing caused by using high viscosity/density slurries, incorrect dipping/draining or stucco programme. If a back-up slurry is too thick or unevenly drained in corners or cavities of the component then there will be a build-up of slurry producing spalling or scabbing on the cast face. Similarly, if the loose stucco material is not removed from corners or cavities of the component then the next back-up coat will not key to a firm layer of shell producing ***mould breakdown*** during dewaxing or casting.

As previously mentioned in the primary slurry the control of the pH is essential to avoid premature gellation of the back-up slurry. The same precautions should be taken to prevent bacteria growth and drifting of the pH due to contaminates such as electrolytes and salts. The partial gellation of the slurry will lower the strength of the ceramic shell mould which will crack on dewaxing and produce ***ceramic inclusions***.

PROCESS & FINAL DRYING

The dry bulb temperature of the mould room must not be allowed to fluctuate more than $\pm 2^{o}$C as this will cause the wax

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material to expand/contract producing the primary dipcoat or back-up dipcoat to crack resulting in ***ceramic inclusions***.

As the ceramic coat is drying water is evaporating and cooling the surface of the wax pattern. The rate of cooling and the drop in temperature will cause the wax to shrink. When the water stops evaporating the cooling will stop and the wax will return to room temperature. The ceramic coat does not expand at the same rate as the wax and the difference in force can cause the coating to crack. The lower the relative humidity or a faster rate of evaporation due to excessive air movement can produce a greater difference between the wet bulb and dry bulb temperatures.

If the wet bulb temperature exceeds more than 5/6^{o}C due to the evaporation of the ceramic coat it will cool and shrink the wax producing stresses in the primary coat. A humidity of 50% should ensure that the temperature (evaporation rate) should not exceed 5/6^{o}C. See Fig. 1. After the first back-up coat has been applied the drying times and relative humidity can be reduced to speed up the inter-coat drying.

The completed ceramic mould should be dried to ensure that sufficient moisture is removed and the shell has reached its optimum green strength to prevent the mould from cracking during dewaxing.

All photographs of defects have been taken from BICTA's Manual of **"Investment Casting: Recognition and Definition of Flaws".**

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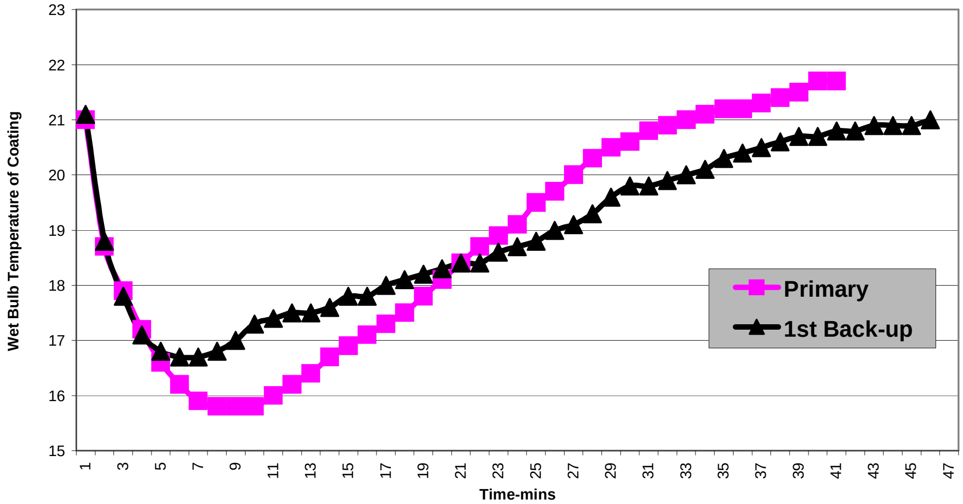
Fig 1: Drying Profile of Primary Coat & 1st Back-up
Room Conditions % RH 50±2%: Dry Bulb Temp. 21±2 C



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