

INNOVATIVE LOST WAX INVESTMENT PLATNIUM

CASTING PROCESS

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ABSTRACT:-

THIS PAPER NARRATES A NEW INNOVATION IN **LOST WAX INVESTMENT CASTING PROCESS**. THE NEW INNOVATIVE TECHNOLOGY GIVES ENHANCED QUALITY OF **GOLD AND PLATINUM JEWELRY** AT REDUCED COST. THE INNOVATION POTENTIALLY REDUCES THE PROCESS TIMING AND AT THE SAME TIME IMPROVES THE QUALITY. THE CONCEPT IS BASED ON THE QUICK AND EFFICIENT REMOVAL OF CARBONIZED WAX AND GASES GENERATED DURING CASTING FROM THE INVESTMENT MOLD.

SOME OF THE DISTINCT BENEFITS FROM THIS INNOVATIVE TECHNOLOGY ARE REDUCED BURNOUT CYCLE TIMING, COMPLETE REMOVAL OF CARBONIZED WAX FROM THE POWDER MOLD, EFFECTIVE REMOVAL OF GASES GENERATED DURING CASTING, REDUCED GAS POROSITY AND SHRINKAGE POROSITY.

THE NEW **LOST WAX INVESTMENT CASTING PROCESS** HAS EFFECTIVELY REMOVED THE REASONS OF POROSITY AT EARLY CYCLE OF BURNOUT. THE INNOVATIVE WAY OF WAX TREE MAKING AND BURNOUT CYCLE HAS REDUCED THE WAX INVESTMENT CASTING TIME CYCLE BY 30% WITH CONSIDERABLE DECREASE IN PRODUCTION LOSS WITH IMPROVED FINISH.

KEY-WORDS: - PLATINUM CASTING, INNOVATIVE CASTING, BURN OUT CYCLE.

1. **BACKGROUND:-**

Lost Wax Investment Casting is one of the most versatile processes and widely used for Gold and Platinum jewelry manufacturing on commercial scales. The process has greatly evolved on its various aspects through the efforts by researchers over last 50 years. The materials and machines used have significantly improved over last few decades adding the versatility of the process and overcoming some of the limitations. However the process still is the most time consuming in the entire production line up. The main implications of the time constraints of this process are to ensure quality castings.

A typical 10 hours burnout cycle is designed to suit the curing requirements of investment powder and burning-out requirements of wax and wax residues. Although the powder mold cures over the entire length of burnout cycle, most of the curing is due to rise in temperature. The hold times are specifically designed to ensure thorough burnout of wax and its byproducts. (Ref. 2, 3).

The other aspect is the time consumed in repairing different problems resulting from the inadequacies of lost wax investment and particularly casting processes. It was observed that about 90% of the problems leading repairing or rejections have their origin in the casting. When it comes to casting, the flowing and filling properties of molten metal are crucial (Ref.1, 4, 6). The flow of metal at the time of casting is governed by following factors: -

1. Permeability of the powder mold,
2. Flask temperature and metal temperature
3. Viscosity of the gas
4. Pressure difference between inside and outside of the flask.
5. Wall thickness of the powder mold.

The effective control over these factors by traditional method has its own limitations and it is difficult to maintain them at optimum levels every time we cast. Hence some innovative approach was necessary to assure the consistency in the casting quality. The new innovation should ensure good metal flow and complete filling of the mold.

2. INNOVATIVE APPROACH:-

To make the production system more efficient, it was necessary to reduce the time for every process without affecting the quality. So the Burnout Cycle was obviously the first choice.

The first approach is to remove the wax completely from powder mold before the burnout cycle starts. But processes such as Steam Dewaxing were unable to remove the wax completely. Some wax is always left in the mold cavity. Also Steam Dewaxing is particularly unsuitable for Platinum Investment powders currently available in the market.

Another approach was to work on carbonized wax rather than the wax itself. The Burnout cycle wastes a lot of time in waiting the carbonized wax to get oxidized completely. If by some means we can get rid of this carbon quickly we can save a lot of time. Any further increase in the temperatures was not advisable as it risks both powder mold and stones. So the idea was to remove it physically than to wait for it to get evaporated. Getting it done physically means something has to enter in the mold cavity, remove the carbon out and leave the powder mold intact. The compressed air or compressed gas was the obvious answer.

The pressurized air effectively displaced the carbon traces from the pores of the mold cavity. But the turbulence in the mold cavities made it virtually impossible for the carbon to escape from mold cavities. This experiment made it clear that the compressed air can clean the mold effectively and quickly, the only problem was to get the carbon traces out of the mold. That led to the introduction of exit gates or vents on all the pieces being casted to provide an exit path for the carbon.

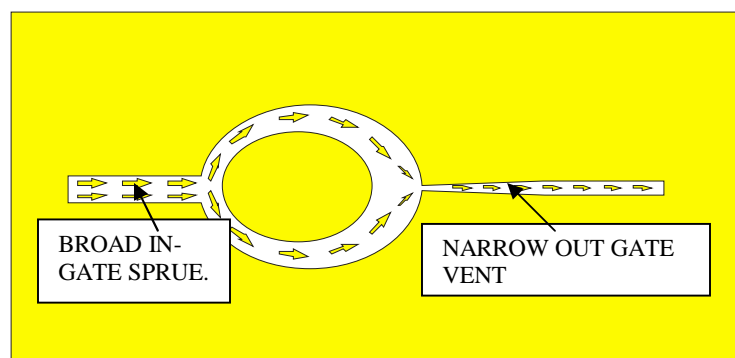


Fig. 1:- SCHEMATIC FOR RETURN GATE

These extra gates are called return gates as compressed air along with traces of carbon escapes through these gates. Return gates were also found to be useful in reducing gas porosity and shrinkage because of escape of flue gases through them during casting. This is based on improved flow dynamics of the molten metal.

3. THEOTITICAL ANALYSIS OF INNOVATIVE APPROACH:-

3.1 Casting Quality & Flue Gases:-

Flue gases are the gases generated during casting process i.e. out of reaction between carbonized wax residue left in the small pores of investment, the investment powder and the molten metal. One can say casting quality is dependent on the effective removal of flue gases during casting.

In the traditional powder mold the only escape way for these gases was through the powder itself. Removal of gases always depended upon the permeability of the powder which ultimately revolved around water to powder ratio. The higher is the ratio, higher the permeability, but always at a cost. Increased water ratio will invite rough casting surface and water marks. (Ref.1, 4) Therefore water to powder ratio is very critical factor to control.

In the 2004 Santa Fe Symposium Mr. Ralph Carter explains permeability of a powder mold (Ref.6) i.e. volume of gas flowing through it, depends upon various factors.

$$F = \frac{K \times A \times (P_i - P_o)}{\mu \times t}$$

Where F = Volumetric Gas flow per unit time at the average pressure.

K = Permeability constant of the material.

A = cross sectional area at the inlet of the material.

P_i = Inlet gas pressure

P_o = Outlet gas pressure

μ = Viscosity of the gas

t = Wall thickness of the powder mould

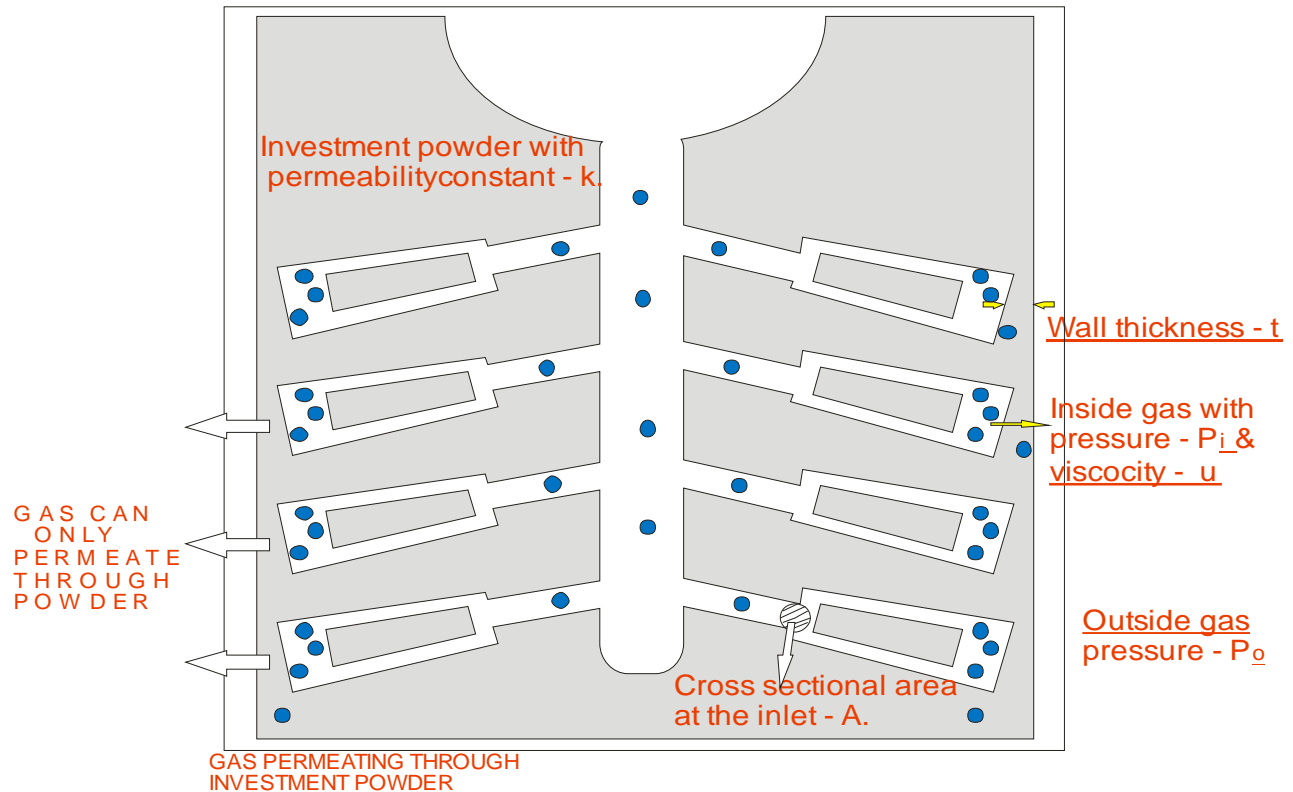


Fig. 2:-. SCHEMATIC SHOWING GASES PERMEATING THROUGH INVESTMENT POWDER

Above parameters which control the gas flow are critical to control and offers a very narrow range of variation to play with. Hence any improvement in the casting quality as a result of variation in the above parameters will be too small to be significant. For example at given permeability, if all the gas is to be removed from powder mould, then the metal solidification rate should be very slow requiring high metal temperature and high flask temperature which will have other ill effects on the casting. Hence by controlling metal cooling rate we have eliminated gas porosity but introduced some other problems as oxidation, cracked investment or brittle casting or discoloration etc. Thus on a traditional process no solution is a perfect solution.

The innovative technique does make a prominent breakthrough as the removal of gas is less dependent upon permeability of powder or wall thickness or water to powder ratio. The flue gases are driven out by an escape way provided through exit gating

system. Thus the gas porosity is now controlled by mutual factor i.e. strategic placement of main sprue & exit sprue on both, piece and the tree.

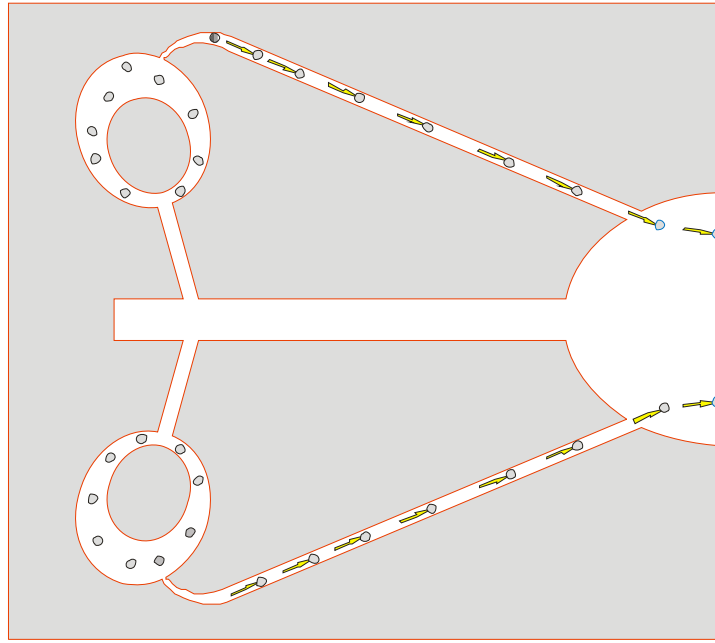


Fig. 3:- GAS EXITING THROUGH RETURN GATES SYSTEM

4. INNOVATIVE METHOD AND MATERIALS:-

This new process does not demand any specific changes in equipments, machinery and raw materials used. The following equipments and materials are used for experimental trials:-

1. Centrifugal Casting Machine – **Yasui KT17**
2. Platinum Investment Powder - **Yasui**
3. Platinum Metal – Pt 950.
4. Vacuum Investment Platform - **Yasui**
5. Programmable Burnout Furnace (Max. Temp. 1200°c)

No specific changes are required to be done on past or future Master models. That means the process is essentially same for Model Making, Rubber Mold, Waxing and Wax-setting as traditional method. However all the care should be taken towards the design of Master and spruing. As faulty design and wrong spruing will always give wrong results. So ideal thing is to follow standard procedure and get optimum results.

4.1 TREE MAKING:-

The significant change in tree making is to provide a new gating system for the removal of carbonized wax. Initially the tree is built with usual process as shown in the *figure no.4*. Even the number of pieces and their orientation on tree-stem will remain same.

The next step is to connect exit gates. No. of main exit gates used are same as the no. of columns running along the tree-stem, usually 3 or 4. They run between the two adjacent columns parallel to the tree. Every main exit gate will be soldered to the Button of the tree. The size of exit gates in diameter doesn't really have any significance in the process. Normally it is about 2mm. in diameter. The length should be slightly more than the maximum size tree. It can always be trimmed to suit various sizes of the tree.

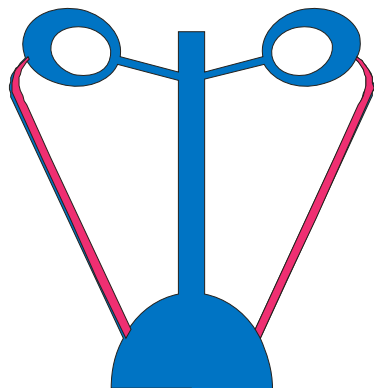


FIG. 4 (A) SCHEMATIC OF EXIT GATE CONNECTED TO TREE BUTTON

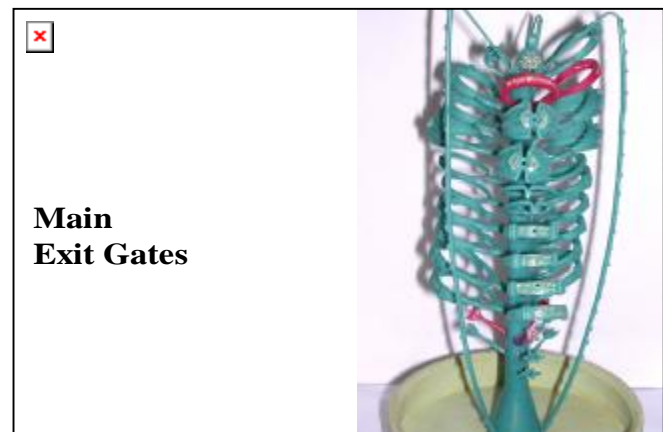


Fig. 4(B):- CONNECTING EXIT GATES TO THE BUTTON OF THE TREE

Now its time to connect exit gates with the pieces. Every piece will have two connections with the exit gates. However the placement of attachment varies with the variation in the design.

These connecting gates are designed with narrowed tips to assist outward flow of compressed air and carbonized wax and to resist the sudden exit of molten metal

during casting. The one end is narrowing into a needle point and the other being broad cylindrical. The placement and attachment of these gates is crucial and all care should be taken. The broader end will be attached to the return vent and the narrow end to the piece.



Fig. 5:- CONNECTING GATES

The connecting gates are fixed as per the flow dynamics of the molten metal during casting. Typically a jewelry piece is an intricate shape made of one or more formed objects and so is the mold cavity made from these pieces. When the compressed air is forced into the cavity through main sprue, the flow gets divided into many directions depending on the design. All these flows will interact inside generating heavy turbulence at certain points. This process makes it difficult to specifically comment about the placement of connecting gates.

The selection of one or more connecting gates is decided by the size, filigree design and the cross section of that piece. All the attachments are on the opposite end of the main sprue attachment. For example a cluster ring has main sprue at its shank and connecting gates are attached one each tangentially on the either sides of the cluster in order to minimize turbulence and help the smooth exit of flue gases during casting.

Following figures illustrate some typical sprue attachments for better understanding of the concept:-

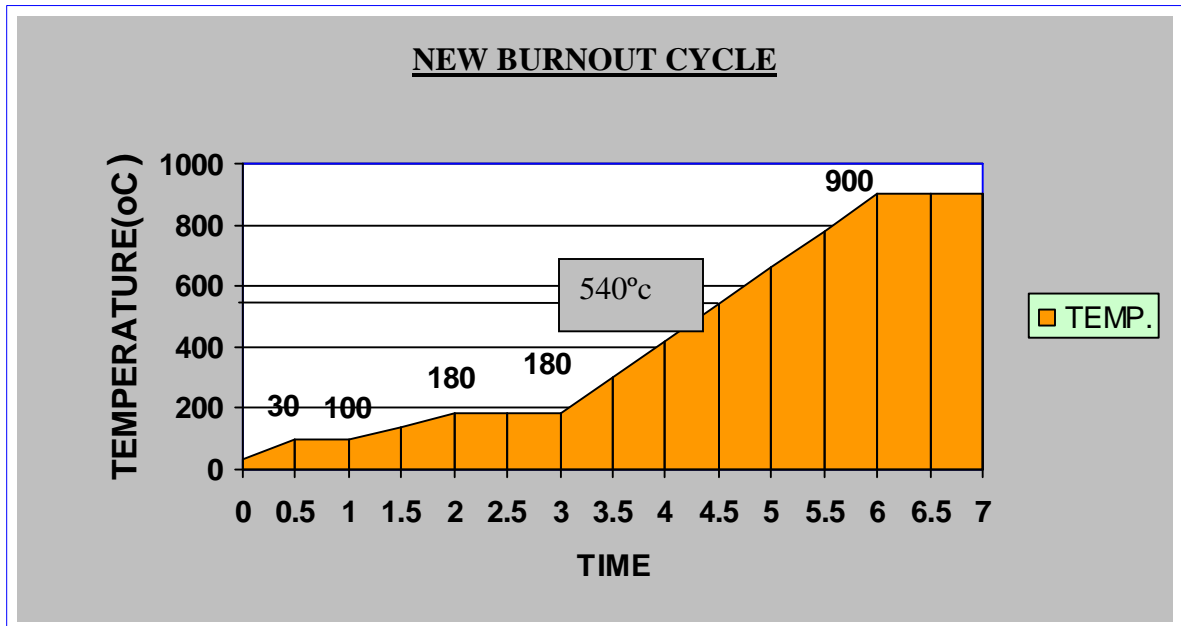


Fig. 6:- Misc. EXAMPLES OF CONNECTING THE GATES

4.2 INVESTMENT:-

There are no modifications required to be done in the existing machineries set up and the process of investment.

4.3 BURNOUT: - New Burnout Cycle



During the burning out process, that is, heating up the investment from approximately room temperature to about 900°C, many physical and chemical processes occur.

BURN OUT CYCLE TIME IN HOUR	FLASK TEMPERATURE IN °C	PHENOMENON TAKING PLACE IN INVESTMENT FLASK(Ref. 2,5)
0.20	55	Wax starts melting
0.50	100	Water starts Vaporizing
1.25	120	Investment begins to loose water
3.5	310	Wax starts carbonizing
4.5	540	Carbonized wax is removed by flush of compressed hot air.
7.0	900	Flask ready for casting.

Table no. 1:- New Burn out cycle phenomenon.

Wax starts melting at around 55°C. Most of the wax in the main and exit sprue systems will slowly melt down on the hearth plate inside the furnace and eventually be evaporated or will collect in the water tank beneath the hearth plate, while most of the wax in the mold cavity will melt and be collected at the base of each cavity.

Over next three hours most of the remaining wax will get evaporated and still remained will start burning into carbon. Till 500°C all the wax will be burnt into carbon.

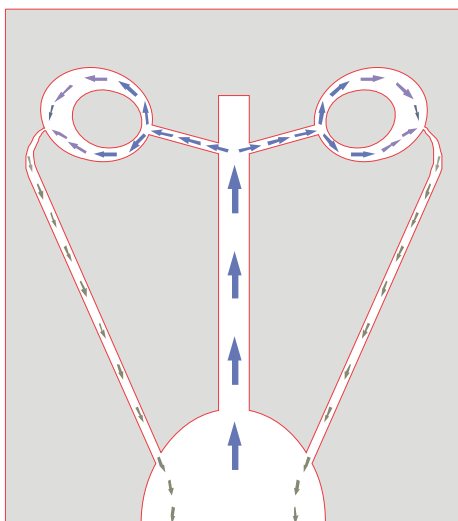
On the other hand the investment slurry starts giving up water at 100°C and stands completely dehydrated till 540°C. At this point the carbonized wax is loosely adhering the inner walls of mold cavity and is ready to be removed by blowing hot air.

4.4 **DECARBONIZATION:-**

After about four and half hours in the burnout cycle and attaining 540°C temperature the flask is ready to be decarbonized.

To force the air into the mold cavity a normal air gun, as shown in the picture can be used. Also the compressed air with pressure of about 2 to 3 bar (30 to 45 kg/cm²) is sufficient for the process.

At this point the flask is taken out of the furnace and jet of compressed air is forced in the cavity through the button which will eventually erode the carbon off the inner walls and will exit through the return gates.



**Fig 7(A) SCHEMATIC OF
DECARBONIZING PROCESS**

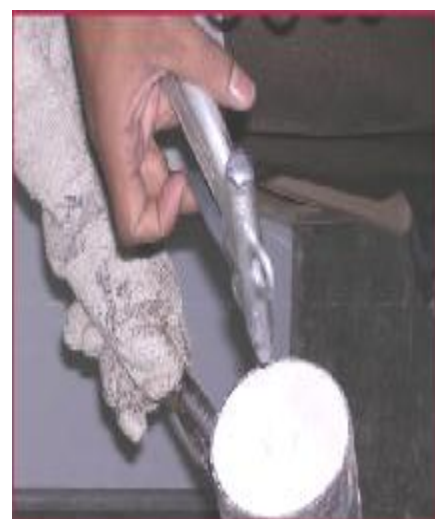


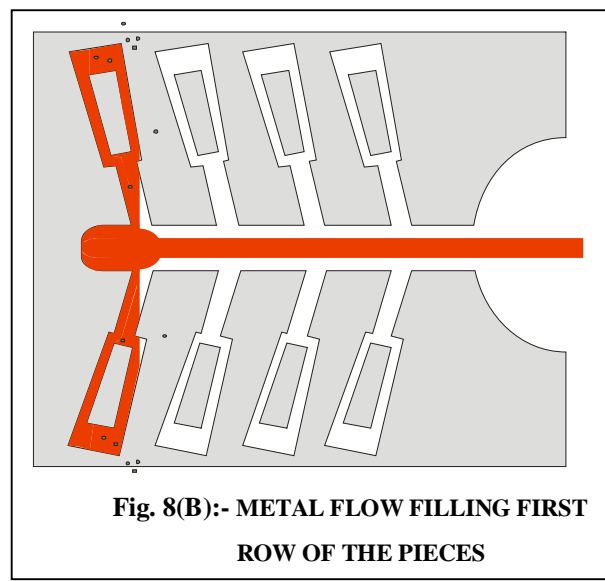
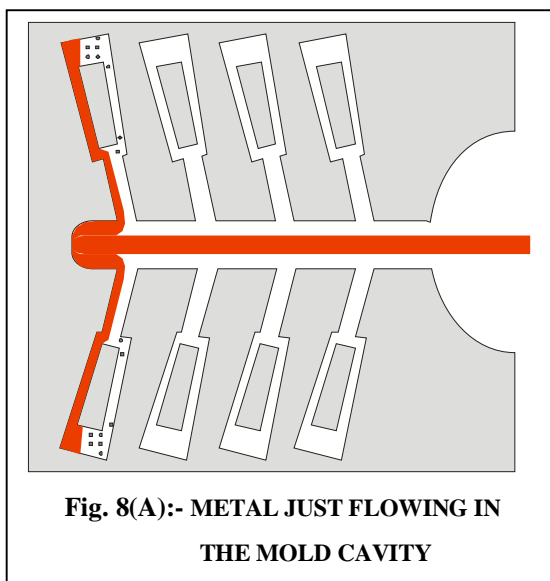
Fig. 7(B):- DECARBONIZING PROCESS

You can observe the carbon coming out of the tiny holes situated in the lateral surfaces of the button-end of the cavity. Force the jet in the cavity four to five times to remove all the carbon and observe carbonized air coming out of the flask. A visual inspection is necessary to make sure all the carbon is removed. If some carbon is still left, put the tree back into the furnace and repeat the process again after half an hour. If the problem persists you can still choose to blow the air just before casting. But be careful about the flask temperature which should be sufficiently high enough for proper casting.

4.5 CASTING:-

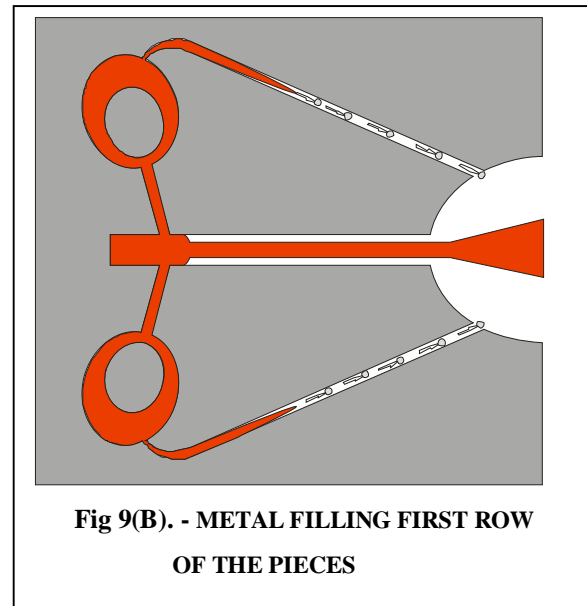
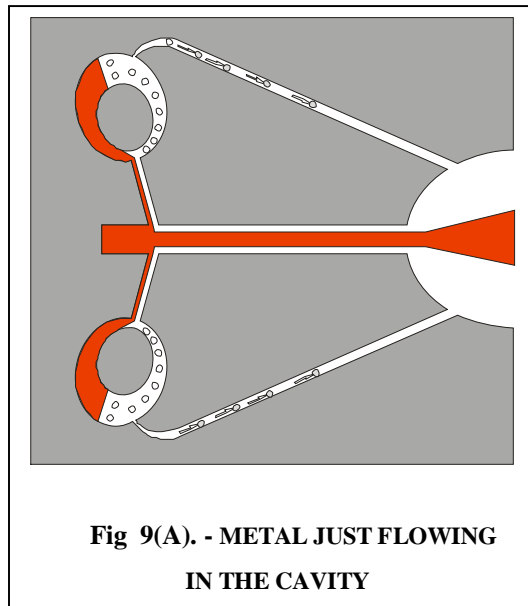
The innovated process doesn't really change anything about the casting. But the extra gating system plays an important role in the quality of the castings produced. It helps in smooth filling of hot metal at the time of casting.

In the centrifugal casting system the molten metal is forced into the mold cavity with a strong centrifugal force. The platinum metal being heavy (high specific gravity) and melting at 1700°C cools very fast. Thus it's just a matter of time before it freezes. Hence very short time is available between the metal thrown out of the crucible and freezing into the mold. This is one of the reasons that the casting is not vacuum assisted.



METAL AND GAS FLOW IN THE TRADITIONAL CASTING PROCESS

In the new innovated process the return gate connections are so strategically placed on each piece that they make the flue gases generated during casting escape quickly through gating system. This also helps in smooth filling of the molten metal into the mold by reducing the turbulence. Return gates also act as metal reservoir reducing shrinkage considerably.



METAL AND GAS FLOW DURING INNOVATED CASTING PROCESS

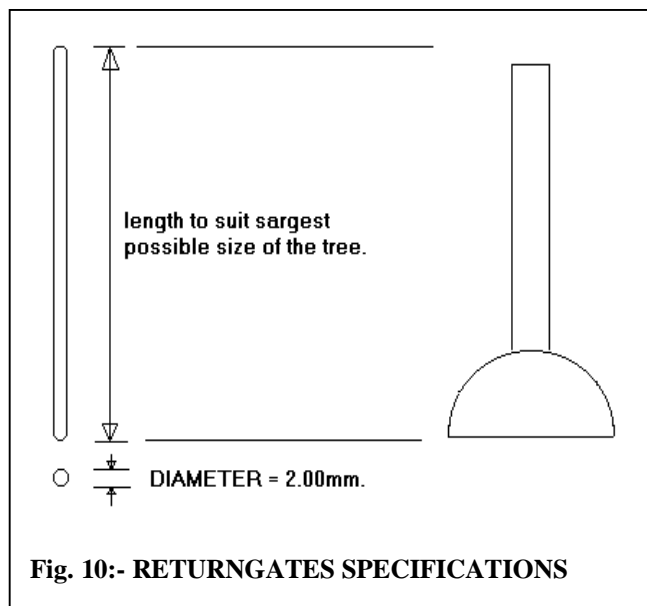
The shape and the size of the narrow tip of the return gating is important to get complete fill of the metal inside the mold and also to provide the escape of the metal and the gases. The average cross section of the mold decides the size of the return gate and is found to be less than half of the entry gate size.

5. DIMENSIONAL SPECIFICATIONS:-

5.1 RETURN GATES:-

Return gates provide an exit path for carbon traces and flue gases during casting process. Also work as metal reservoir for molten metal. Hence they should be smooth and cylindrical. The size of return gates should be big enough to allow all the air exit the mold cavity without leaving traces of carbon stuck inside and small enough to prevent molten metal from gushing out of the cavity during casting.

The diameter of return gate is 2mm. and length should be big enough to reach return path from the top most piece to the button of the tree. For smaller trees, gates can be trimmed to match the length of that tree.

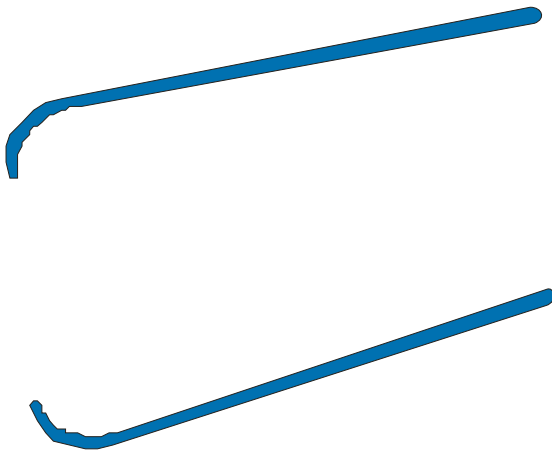


It is advisable to keep the length slightly more than that of the said tree to accommodate different designs.

5.2 CONNECTING GATES:-

Connecting gates serve same purposes as the return gates. They fall first in the exit way for carbonized air, gases and molten metal. Their main function is to connect mold cavity with the exit path. As the jewelry designs vary in shape and size, the connecting gates should be so designed as to suit all different pieces.

The connecting gates are also thin, cylindrical and with bent at one end. Also to resist the flow of molten metal from exiting the mold quickly during the casting it is narrowed like needle at the bent end as shown in the figure.14A and 14B.



**Fig. 11(A):- SHEMATIC DIAGRAM
OF CONNECTING GATES**



**Fig. 11(B):- CONNECTING GATES KEPT READY
FOR ATTACHMENTS.**

6. RESULTS:-

Innovated Casting Technology Results:-

The different types of test samples casted are-

1. GRID STRUCTURE HAVING SIZE 4cm. X 6cm.
2. THIN WAFER OF 0.6mm. THICKNESS HAVING SIZE 4cm. X 6cm.
3. RING WITH FILLIGREE DESIGN

The test samples casted using innovative method are shown in fig no. 12, 13, 14.

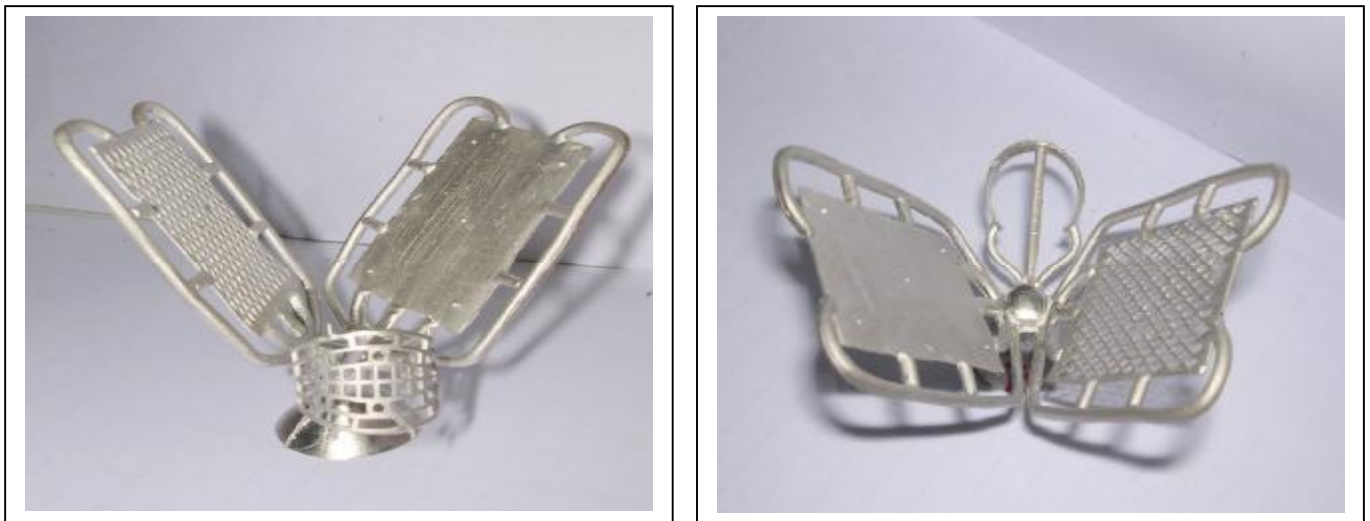


Fig. 12 SUCCESSFUL CASTING OF TEST TREE



Fig. 13. GRID STRUCTURE AND THIN WAFER CASTED IN PLATINUM



Fig. 14 SUCCESSFUL CASTING OF TEST TREE

7. FUTURE SCOPE:

The innovation is very promising about its long term benefits. In addition to reducing the cost of the production this process can further reduce the cost of equipments used.

All the recent improvements in lost wax investment technology work towards inventing new machines & new materials to control different crucial parameter & make the process more consistent. But this innovation has changed the focus from parameter-control to physical-interaction. In future the real impact of this innovation can be seen on following fields.

7.1 Investment powder:

The investment powders currently available in the market are manufactured to suit various requirements of the lost wax investment casting process. Gas Permeability is one such major virtue of these powders. But new innovation virtually eliminates the process of gases filtrating through the porous powder. On the other hand it provides a smooth path for the gases to escape through return gates. Thus permeability factor can be sacrificed to either strengthen some other characteristic of the powder or to minimize the raw material costs involved in the Lost Wax Investment Casting Process.

7.2 Burnout Furnace: -

The crucial Burnout Cycle used for burning out wax and curing of investment powder is necessary to induce desired characteristics in the powder mold for smooth castings. Different temperatures and the time durations have their own significant roles to play in the process of burnout. The new innovation can lead to the use of ordinary powders requiring less stringent process control. That means expensive temperature controllers may be unnecessary and can be replaced with simple, less sophisticated, cheaper controllers.

Also a new furnace is under development that will have a facility in built to decarbonize the flasks automatically. This furnace will contain the compressed gas connections as shown in the *figure 15*.

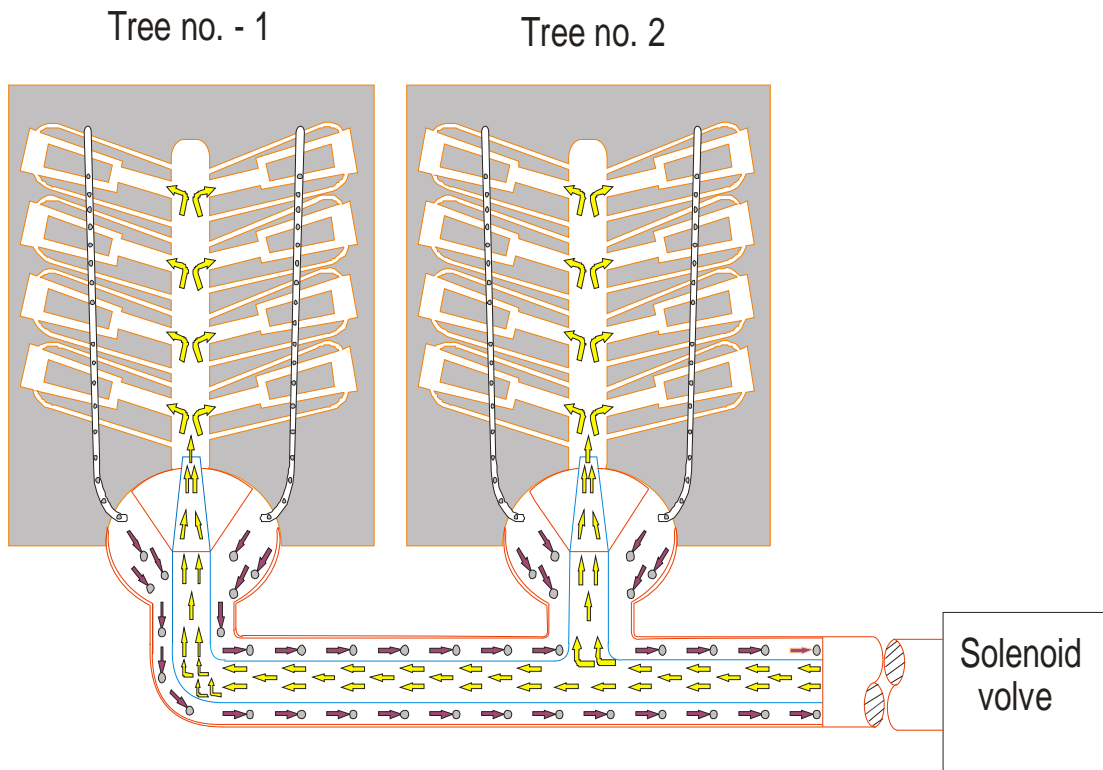


Fig. 15:- DECARBONIZATION IN THE INNOVATED FURNACE

The gas-blowing nozzles can be provided beneath two or more flasks. The furnace hearth plate can be rotated such as to adjust other flasks with the blow-jets. The piping will contain two con-centric pipes. One will take hot compressed air to the nozzle & other will return carbonized air to the suction-pump filter. It can be chosen to blow the air once or many times when the desired temperature in reached. The furnace will help

automatically decarbonizing the flasks and will eliminate the necessity of taking the flask out of furnace before it is ready for casting.

7.3 Casting Machine:

Casting Machines used for **Lost Wax Investment Casting Process** have gone more and more sophisticated over last decade. A promise of best possible casting makes an investor to invest high capitals to set-up a manufacturing facility. The customers are made to pay for the machine as well as the R & D cost for that machine. Platinum casting machines came a long way before finally emerged into centrifugal casing machines.

Machines these days are microprocessor controlled and demand many external accessories such as gas bombs, gas regulators, vacuum pumps and stabilizers with some odd power requirement. These entire extra things are said to be crucial for controlling the quality of your castings.

The new innovation may change everything about the way the quality of casting is determined by these factors. A semi automatic machine with ordinary vacuuming arrangements and cheaper inert gases combined with manual controls can give quality castings.

Thus the proper implementation of the innovation will ultimately lead to very cost effective quality jewelry production.

8. TECHNICAL AND ECONOMICAL BENEFITS:-

The biggest impact of this innovation will be on the cost, quality and waste in the commercial scale Jewelry Manufacturing. The burnout cycle energy consumption is one of the major overheads incurred by these companies. Our innovation has brought down this cost significantly.

- Due to effective removal of the carbonized gases and also the gases produced at the time of casting the gas porosity and shrinkage porosity were found to be reduced to great extent.
- The return vent has provided complete filling of the different shapes and sizes of casting
- The reduced porosity has effect on reduced work in filing and finishing process.
- The casting surface is found to be improved as investment powder is not over heated to make the powder more permeable.
- The manufacturing time for making jewelry item is significantly reduced by the new process. The 10 hours burnout cycle is shortened to 7 hours and also the further finishing time is reduced due to improved quality of casting.
- There is direct saving of electrical energy cost by 30% and decreased labour cost up to 30%.

9. DISCUSSION:

The rediscovered wax tree and investment burnout process has now been successfully extended to the mass production of Silver, Gold and platinum jewelry pieces with and without stones. The successful trials have been performed for casting from burn out of resin model. There are significant technical benefits in the casted metal improving the fine grain size due to reduction of porosity. The entrapped gas was effectively removed due to vent designed to push the metal smoothly. The saving in process time by 3 hours will reduce the electrical furnace energy by 30%. The improved surface finish due to reduced porosity has resulted into most economical and improved quality manufacturing.

The success of quality casting also needs proper selection of return gate, which depends on complexity and size of design in tree.

In this modified process there is no discoloration and no additional cost towards additives for investment powder. The additional burning of investment powder to make it more permeable is not required. This is due to removal carbon and sulphur gases through return vent without passing through investment powder. The rediscovered lost wax investment casting process will have further impact on materials used for investment powder and also the complex high cost casting machines. With use of **CAD – CAM** giving resin design and there after direct casting to get casted pieces will have further impact on cost and quality in jewelry manufacturing.

10. This new innovative process is patented for the following: -

1. Wax tree venting design procedure
2. Modified Investment Burn out cycle
3. Wax Burn Carbon removal casting technique

11. ACKNOWLEDGEMENTS:-

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