



From 7 days to 7 hours – Investment casting parts within the shortest time

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ABSTRACT

Investment Casting is the oldest known technology to create metal castings. After the 2nd World War this technology underwent a renaissance. Investment Casting companies produce parts for the aerospace, automotive and defence industry.

In the beginning alcoholic-based slurries were mainly used, but in the meantime they are more and more replaced by water-based systems for reasons of economy and of environmental and health protection. This new chemistry is less dangerous but has one big disadvantage: The drying is much too slow.

A high-speed drying technology for ceramic shells was developed, based on the following 3 parameters: Highly accelerated turbulent air, infra-red lights and extremely dry air.

The new technology allows to dry a layer within 30 min. instead of 24 hours and to build a complete shell within 3-4 hours.

Keywords: Shell Technology, High-Speed-Drying, Rapid Prototyping

1. THE CYCLONE DRYING TECHNOLOGY

“We can abandon 45 years of experience in investment casting, at least with regard to the drying of the ceramic shell”. This is the statement of the plant manager of a large investment casting foundry after he had tested the new Cyclone high-speed drying technology. This presentation will explain how the new technology works, the advantages and where it can be applied.

Investment Casting is said to be the oldest known technology to create metal castings. More than 5000 years ago the first bronze cast was made in South-West Asia and India. During and after the 2nd World War investment casting underwent a renaissance. Especially Automotive, Aircraft and Defence Industry count on the highly precise metal parts made by means of the shell technology.

In Germany the manufacturer of sewing machines, Pfaff, rediscovered this technology and several investment casting foundries were founded and offered their services. Most of them specialized in one or two metals, because the shell as well as the melting technology had to be perfectly adapted to the process. In the beginning mainly alcohol-based silica sol was used as ceramic slurry. Nowadays, mainly water-based slurries are applied.

The lower costs for the water-based material was one of the reason for this change, but the main reason was the tightened MAC value (Maximum Allowable Concentration), which finally squeezed the alcohol-based slurries with their sweetish smell that reminds of clue out of the European investment casting foundries. An advantage for human beings, the environment and the margin does not necessarily have to be an advantage for the technology and the process.

All water-based slurry systems have one significant disadvantage: Contrary to the alcohol-based slurries the drying time is much longer. The standard shell building can take one week or even longer. With the conventional alcohol-based binder it was 2 to 3 times faster.

Therefore, it is no surprise that a lot of investment casting companies did not really like to give up the alcohol-based material, as this prolonged the processing time dramatically. This might be the reason why the conversion has not been done up to 100 %. The investment casting process is long and complex. For a better understanding: To achieve a perfect metal part, two other parts, the wax part and the ceramic shell, have to be destroyed. This means, that fast design checks or pilot series are not possible and delivery times of several weeks or even months are more the rule than an exception.

Business for the main customers of the investment casting industry such as Automotive, Aircraft and Motor Industry is booming resulting in a great demand for investment casting parts, extending the delivery time for urgently needed parts.

The basic idea of the new development was to solve this problem. Rapid Prototyping as fast technology does not match with delivery times of several weeks. The challenge was to dramatically accelerate the process. 95 % of the process was drying time; therefore, this had to be drastically reduced in order to make the shell building technology also applicable for the field of Rapid Prototyping.

Basically the task was simple: The water inside the slurry had to be extracted as gentle and fast as possible. The wax part under the slurry had to stay undamaged the bond of the slurry, which is very important for the strength of the shell, should not be effected.

The use of water-binding additives could not be taken into consideration for two reasons: First, the water discharge would only have been delayed and second a changed chemistry in field of investment casting with its very complex processes would not be accepted.

Experiments to accelerate the drying process by using vacuum were not really successful, though the water was extracted surprisingly fast by the vacuum no bound was possible and the shell broke to pieces during the next dipping process.

Finally, the breakthrough for the development could be achieved by deliberately ignoring all well known conventional drying rules for the investment casting. The following logical steps were taken: An extremely turbulent airflow was produced with wind velocity up to 12 m / sec. The tree was slowly and continuously rotating, similar to a chicken in the oven, to achieve a constant flow on the tree.

As the high air speed and the resulting evaporation coolness caused a deviation in temperature of the wax of up to 10°C, this effect had to be compensated. The solution for this problem was simple and cheap: Medium wave infrared lights were installed, to avoid the fluctuation of temperature and to preset it at 25-30°C.

As wax and ceramic shell do not only react to super cooling but also to overheating, the airflow had to be air-conditioned to keep the temperature in certain limits. Air-conditioning, connected with a bypass to the main current, regulates the temperature exactly (+/- 1 degree).

Last but not least, the humidity of the accelerated air is additionally kept down to 10-15 % by a dehumidifier.

All parameters, especially the chamber and shell temperature as well as the humidity are being controlled by a complex sensor system. The data is sent to a PLC control, which regulates the whole process.

The result achieved with key figures far away from the conventional investment casting process was overwhelming. Drying times of so far 24 hours per layer could be reduced to 30 min; a shell with 7 layers was finished in less than 4 hours. And contrary to the well-known doctrine, that an advantage in one field has to be paid with a disadvantage in another one, the effect was vice versa. As a by-product of the new high-speed drying technology the bond became more intense resulting in a stronger shell (Fig. 4.1).

A stronger shell can even save one or two layers, increasing the permeability of the shell. This causes a better quality of the cast, especially in the field of the single crystal technology, the supreme discipline of investment casting (fig. 4.1, 4.2, 4.3, 4.4).

This means, that the new development, which was basically meant to reduce the production and delivery times, has several positive effects with regard to increase of quality and cost saving.

The next step was to develop a machine realizing the new technology. As Rapid Prototyping was the main focus, a „mini-factory” for the fast production of shells was developed, requiring only 2 m² (Fig. 4.5).

The high-speed drying chamber is the heart-piece of the system. But it also includes two slurry tanks for primary and back-up slurry as well as two rainfall sanders for the fine and the coarse-grained sand. The different parts are connected with a linear drive, which brings the tree from one station to

the other. The whole system is controlled by a PLC control and a touch-screen with click-wheel and self-explaining software.

The reaction of Rapid Prototypers were very positive, as besides the extremely short processing times, this technology allows a perfect cast of all meltable alloys. The processing of titanium, stainless steel and super alloys is now also possible in the field of Rapid Prototyping – this is a revolution.

The conventional investment casting industry observed the development with interest but also with scepticism and hesitation. But after a while curiosity became stronger and the new technology was tested.

After finding out that the technology works with all wax and slurry materials and that it accelerates the drying by factor 20 the astonishment was great:

The most frequent comments were “it is so obvious and simple” or “why has no one else thought about it before”. The prejudices were replaced by enthusiasm and the next step was to develop machines that make this new technology applicable for the serial investment casting.

Separate drying chambers were developed and whole drying tunnels (Fig. 4.6) which accelerate the whole investment casting process with turbulent air, infrared light and dried air, opening the door to Rapid Manufacturing. Together with the investment casting industry and their experiences in practise, further progress will be made and the development is far away from being terminated.

We would like to finish with the quote made by a philosopher a long time ago: "Nothing is stronger than an idea when the time is ripe for it!"

2. HOW DOES INVESTMENT CASTING WORK?

Investment Casting and Lost Wax Technology – two expressions for the same process:

One or several wax parts are attached to a central stem or a casting system. The so-called wax-tree is dipped into a ceramic fluid, the so-called slurry and afterwards sprinkled with refractory sand. The tree resembles an escalope, which has been coated with bread crumbs. In former time, this was done manually; nowadays a computer-controlled robotic arm is applied.

After the sanding process the layer has to dry up to one day before the dipping and sanding can be repeated. Depending on the geometry of the part 7 – 20 layers are build. After a final drying process the wax is de-melted in an autoclave by steam and heat. The empty ceramic shell is then burned at 900 – 1200°C, ready for the cast.

After solidifying of the metal the shell is knocked off and the rest is removed in a sandblast cabinet. After separation from the stem and the finishing process the metal part is finished and passes the quality check.

With all these different intermediate steps investment casting is a quite complex technology, demanding a lot of know-how

and experience. Two parts have to be destroyed, the wax part and the ceramic shell, to get the final metal part. A mistake cannot be discovered before the end of the whole process. But investment casting is also the technology that allows the production of very precise and highly stressable metal casts. Metals such as titanium, super alloys such as for example chrome-cobalt can only be cast with the investment casting technology. As the demand is growing continuously, the investment casting industry is booming like never before. There is hardly any investment casting foundry that does not expand or at least thinks of it.

3. THE NEW TECHNOLOGY ACCORDING TO EXPERTS

With the new high-speed drying, we do not only reduce our development and production times drastically, we can also produce at lower costs.

Dipl.-Ing. Wilfried Jedamski, Head of ceramic mould production Doncasters, Bochum, D

For the first time the new drying procedure enables us to reduce the production times of ceramic moulds significantly. It is not an exaggeration to talk about a quantum leap.

Dr. Jörn Großmann, formerly Managing Director Buderus

Feinguss, Moers, D

With the aid of the high-speed drying we have beaten all records. The result surpasses all our expectations. Even most complicated structures can be produced perfectly – there is no measurable difference to our previous slow technology.

Hans-Walter Katz, former Plant Manager Aluminiumfeinguss Soest, Soest, D

This development means a revolution for investment casting. It is so important that it will be used in all major investment foundries within the next five years.

Klaus Didschies, Expert for Investment Casting, Greenford UK

Since the end of 2004 we have been working with the new technology and we know that it works. We not only produce much faster, but we are also more cost-effective than our competitors in Eastern Europe and Asia.

Peter Freitag, Managing Director Freitag Prototypen, Hildesheim, D

The technique of high-velocity drying, which was originally developed for prototyping, has an enormous potential. We recommend the application in serial investment casting.

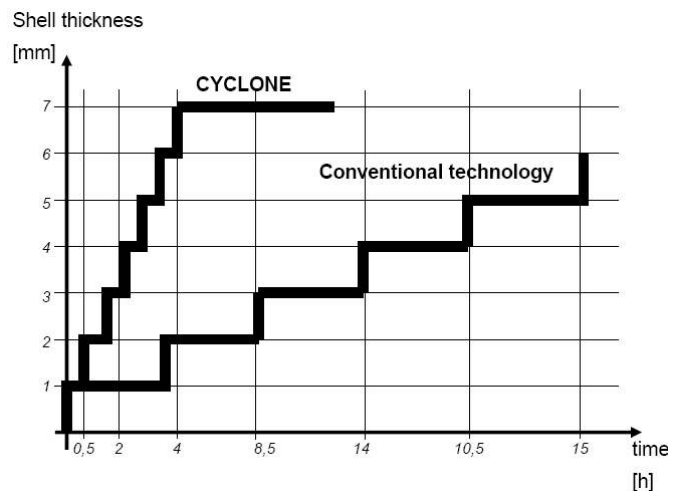
Bernhard Milde, Plant Manager, Feinguss

4. DIAGRAMS AND PHOTOGRAPHS

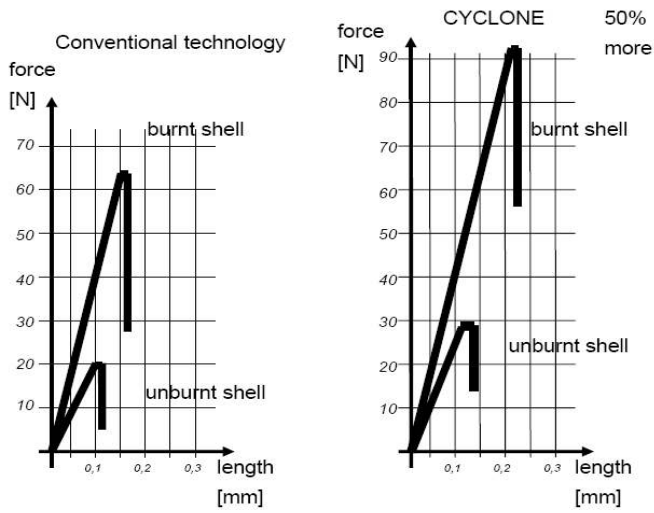
4.1 Process schedule

	production of a wax model
0:00	wax model
0:25	1. layer
1:00	2. layer
1:45	3. layer
2:15	4. layer
2:45	5. layer
3:15	6. layer
3:45	7. layer
4:15	dewaxing is finished
6:00	ceramic shell is burnt
7:00	metal part is casted and solidified debedding and finishing

4.2 Time / Layer Thickness

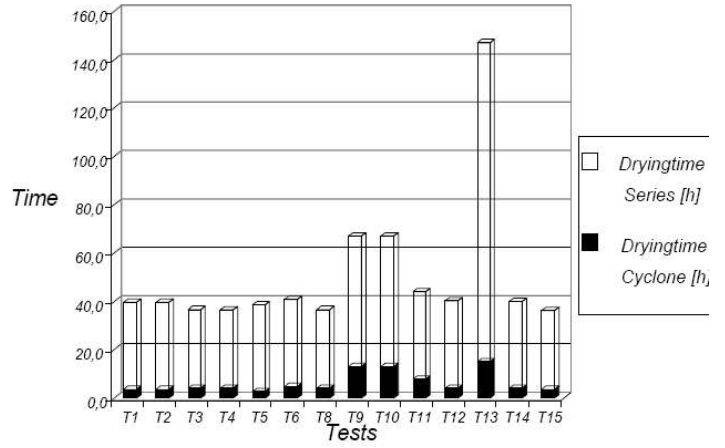


4.3 Strength of burnt shell

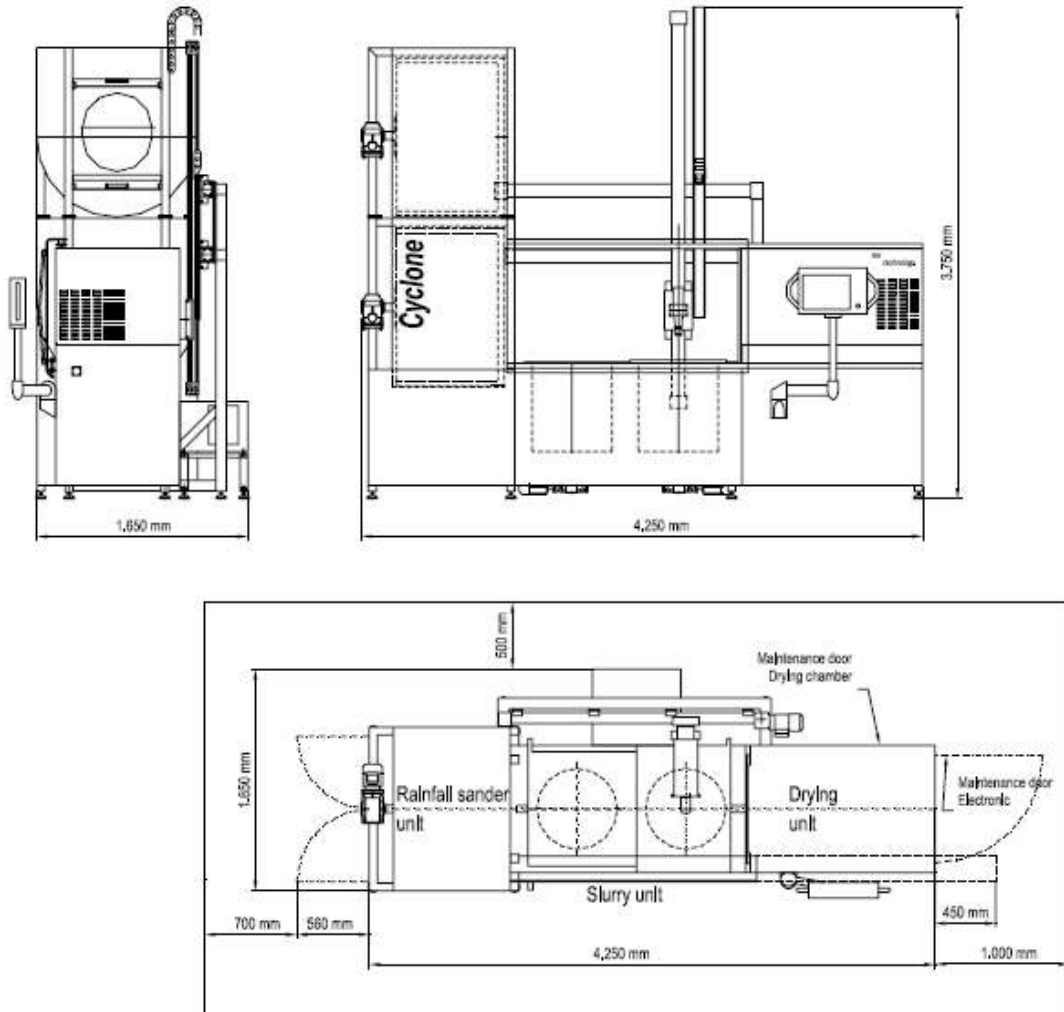


4.4 Test Results

Drying time serial production compared to Cyclone technology



4.5 CYCLONE



4.6 High-Speed Drying Tunnel

