FastCast Ceramics – Solutions for Investment Casting

FastCast Ceramics is a spin-off from Karlsruhe Institute of Technology (KIT) that focuses on ceramic solutions for the investment casting industry. Their innovative processing route based on capillary suspensions, suppresses stresses and thus crack propagation. Their first products aim for faster and more reliable shell building, concentrating on an accelerated layer formation as well as a slurry for the reparation of cracked shells. In the future they want to provide a one-for-all slurry that can be used for all layers and enables true recycling of the shell material for the first time.

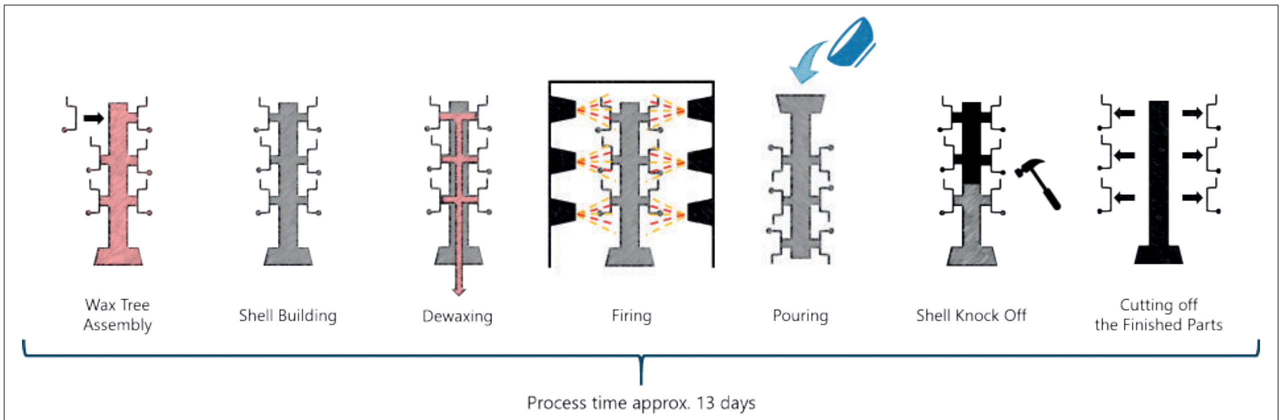

Fig. 1
Schematic drawing of the investment casting process

Introduction

In production, the demand for ever faster production with ever increasing quality and precision in all areas is becoming ever greater. This also applies to the casting industry, including investment casting. Investment casting is a manufacturing process for metallic components, but most of the manufacturing time goes into preparing a ceramic mould. Here, FastCast Ceramics is working on a solution to simplify and accelerate this process.

FastCast Ceramics is a spin-off transforming research from the past 12 years into innovation. At the Institute of Mechanical Engineering and Mechanics (MVM), Karlsruhe Institute of Technology (KIT) a novel suspension-based method to produce open porous ceramics has been developed. This capillary-suspension-based method has been published in 2013 for the first time [1], and then investigated gradually. Today, this method is robust and broadly tailorable and, thus ready for industrial use.

Here are presented current projects as well as future prospects for the use of the company's ceramic slurries.

Keywords
metal engineering, investment casting, recycling, porous ceramics, 3D-printing

Shell building in investment casting

Investment casting is a casting process for the production of metallic components which is characterised by attention to detail, dimensional accuracy and excellent surface properties. Typical components are door handles, hinges, turbine blades or entire radial compressor impellers showing the broad variety of this process. It is used for prototyping as well as for mass production, therefore components produced by investment casting are used in almost all technical systems. A schematic sketch of

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the process is shown in Fig. 1. The investment casting process essentially consists of a total of seven individual process steps:

- A positive model is created, mostly out of wax via injection moulding. The individual wax parts are assembled on a so-called wax tree, to have a suitable casting system as well as to produce more than one part at once
- For ceramic shell building the wax tree is surrounded with a ceramic slurry
- Melting out the wax from the ceramic shell
- Firing the ceramic, to get rid of residual wax and strengthen the ceramic shell
- Pouring molten metal into the ceramic shell
- After solidifying of the metal, the ceramic shell is knocked off
- Cutting the metal parts from the sprue and polishing of the finished metal bodies.

The production time of the entire process is about 13 days, of which the shell building alone takes about 10 days. So, although it is a metal process, the ceramic is crucial to the process. The ceramic shell build-up is nowadays a complex process which is schemed in a simplified manner in Fig. 2 (left). The wax tree is dipped into a ceramic slurry, its wet surface sanded with ceramic particles and subsequently dried. This process is repeated 8–11 times to gain an adequate shell thickness to withstand the dewaxing as well as pouring in of the molten metal without cracking. To accelerate time and reduce the number of repetitions to the mentioned 8–11 times, three slurries and sands with different grain sizes are used. While the first layers are formed with relatively fine particles to obtain optimal geometrical accuracy, the back-up layers are built with coarser grains to fasten up the process. In addition, the primary coat is often made of zirconia, while the later layers are alumina or aluminosilicate based, leading to uneconomical recycling processes [2].

Back-up slurry

FastCast Ceramics utilises the capillary suspension phenomenon to develop novel slurry formulations for shell building in investment casting. Capillary suspensions are three-phase liquid-liquid-solid systems containing a particulate phase and two immiscible liquids, where one of the liquids

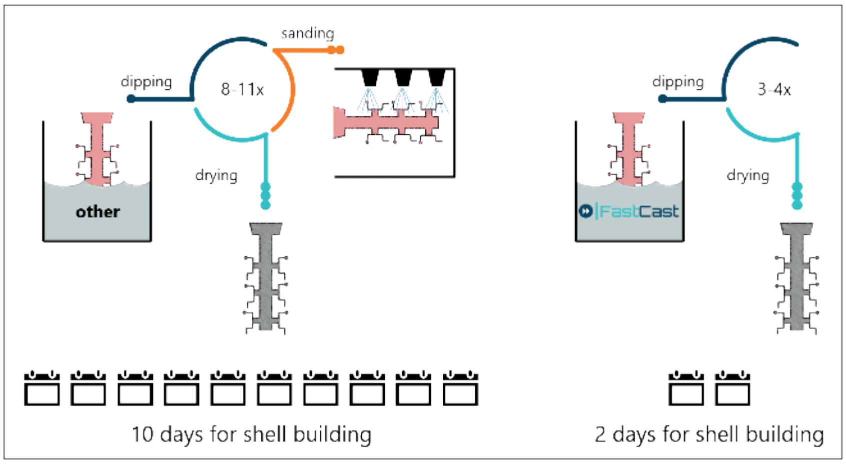

Fig. 2
Schematic drawing of (left) todays and (right) FastCast approach for shell building in investment casting.

Fig. 3
Lab-scale investment casting process, from the wax model, its coated counterpart to the final metal part. Here, there are applied 3 layers of one slurry without additional sanding

(secondary phase) is in the minority. The secondary phase forms capillary bridges between the individual particles, hence forming a sample spanning network altering the suspensions rheological behaviour from fluid-like to paste-like [3]. Capillary suspensions can be used as precursors for highly porous ceramics, independent of the material. The processing route, achievable porosity and pore size is elaborated elsewhere [1, 4, 5]. Due to low shrinkage and reduced cracking probability of capillary suspensions during drying they are ideally suited for an application as shell building material in investment casting [5, 6]. Rheologically, they are low viscous under shear, thus enabling coating of complex shapes while their intrinsic yield stress ensures relatively thick layers.

The FastCast Ceramics Back-up slurry is related to commonly applied ceramic slurries for investment casting shell building. It contains of coarse particles (a relatively pure α-Al_2O_3), a silica sol as binder to assure high green body stability as well as fired strength as well as rheological additives. The slurry shows good long-term stability without stirring and has an organic fraction is below 1,5 mass-%. This approach enables shell building within 3–4 dipping steps, while eliminating the sanding procedure. By this, shell building is completed in less than two days. The slurry concept presented promises to accelerate the entire process while reducing dust load and meeting all requirements, as high dimensional accuracy, high green body stability, sufficient fired strength to withstand casting pressure, and low enough fired strength to be knocked-off easily after solidifying of the metal, as well as high gas permeability.

Slurry for shell repairment

A second slurry development especially for reparation of cracks within ceramic moulds after dewaxing is ongoing. This slurry mainly differs in its rheological properties from the back-up slurry, and is more like handcrème. The cracked ceramic mould can be kitted by simply applying the slurry onto the fractured area. The slurry will dry with low shrinkage and due to the ceramic mould's inner porosity adhesion to the ceramic will be sufficient. For larger crack areas, and especially deeper cracks, it might be beneficial to prewet the ceramic mould with water, to fill the pores and slow down drying during the application. Otherwise the slurry might not be able to penetrated through the whole depth of the crack. With this, the company offers an easy solution to repair smaller cracks after dewaxing, and ensure mechanical stability during the subsequent casting process.

All-in-One Solution

With the All-in-One Solution, the company aims for a single slurry that can be used for all layers, including the face coat and that does not need any additional sanding step (Fig. 2 right). This slurry will be based on high purity alumina, and therefore should not interact with the molten metal, even at elevated temperatures. To ensure that our alumina system is suitable for foundries, our industry partners have satisfactorily tested the compatibility of the company's slurry with various metal alloys. An uncoated wax model, the coated model as well es the resulting metal part is shown in Fig 3. With the All-In-One approach, we are still in the laboratory scale, and we are constantly making progress. Only if we get rid of the zirconia/zirconium silicate we will have the chance of a real recyclability. As soon, as

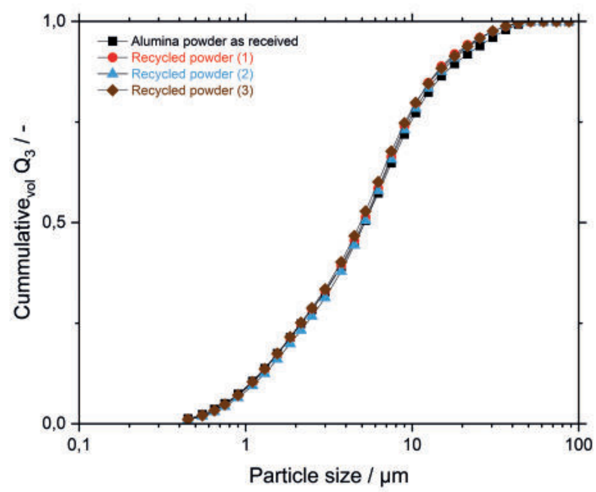

Fig. 4
Particle size distribution of an alumina powder as received as well as after firing at 900 °C for 2 h and a subsequent milling step ("recycled powder")

we have to separate different materials we will lose any economic efficiency. This slurry has to combine all requirements, like an excellent shape accuracy, fast layer build up, high green body stability, low reactivity with molten metal as well as good knock-off ability. FastCast Ceramics is constantly developing towards this goal, while being aware of the challenge.

Recyclability

We believe that our All-in-One Solution enables true recycling of the shell material for the first time, and therefore will be a big step towards a real cycling economy. The company's slurry will only contain one coarse particle fraction and a silica binder as solids. Since the shells are typically burned at relatively low temperatures (for sintering of ceramics), the coarse alumina particles can be easily separated afterwards. At the moment, there is a first research project running, working on the proof of principle. With a simple ball milling step, we are able to reach the initial particle size distribution after firing the ceramic shell at 900 °C for 2 h as shown in Fig. 4. The particle size distribution perfectly aligns with the initial alumina powder after ball milling. In the next step, there will be analysed the silica content of the recycled material. This is a crucial test for the goal of high recyclability, since a highly pure alumina is necessary for an application in investment casting. With a working proof of principle, we will need to further develop this method, especially towards shells hat has been used for casting as well as upscaling.

Outlook – 3D-Printing of porous ceramics

FastCast is also developing a water-based ceramic slurry for robocasting. This technique enables 3D printing of complex parts in short times. Currently, the company is working on the reliability of our printing system in order to be able to print parts economically as soon as possible. The results give confidence, that we will be able to produce large parts (300 mm × 200 mm × 300 mm), limited by the printer's assembly space. Initially, we plan to process 3D-printed components on a job-by-job basis, testing our system for robustness and adjusting it if necessary. In the second step, we plan to offer our ink as well as the know-how and the suitable printer directly and thus enable 3D printing on site. Applications might be in prototyping, insulation materials, filters, adapted heat-resistant components and casting cores. A more general perspective on the opportunities of the capillary suspension route was presented in the October 2022 edition of ceramic forum international [5].

Conclusion

FastCast Ceramic is a young start-up build on an innovative slurry-based approach for highly porous ceramics. The slurries are water-based, can be applied to every powder material and typically show very low organic content <1,5 mass-%. The focused market is the shell building in investment casting, where the technology perfectly aligns with the existing requirements. FastCast Ceramics is currently working on different slurries: A back-up slurry, which enables quick layer build up and adequate stability – high enough for dewaxing and casting, but still low enough to ensure easy shell knock-off. A slurry that can be applied on cracked ceramic moulds to get back mechanical stability, and therefore reduces reject rates. And the All-In-One slurry, which can be used for the whole shell building process. This would also enable true recycling of the shell material, leading to a true circular economy. FastCast Ceramics will be present at GIFA 2023, please visit us at our booth B18 in hall 12 from 12–16 June 2023 in Düsseldorf.

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