New Advances in Printed Sand

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Abstract: Printed sand-molds and cores have become indispensable in foundries to produce prototypes and small series. But, the process offers far more advantages than just a shorter production time. Complex geometries can be created without additional effort in pattern making and core assembly [1]. These and other advantages have convinced BMW and GE Vernova (beforehand GE Renewable Energies), for example, to produce certain cast components in series using printed sand. The requirements range from several hundred thousand of cores per year in the case of BMW to very large molded parts with lateral dimensions of 7 x 9 m in the case of GE Vernova printed in a single piece. This article presents the two use cases and their respective additive production solutions from the perspective of the 3D printer manufacturer. The possibilities and limitations of the current Binder-Jetting technology are shown and an outlook on future possibilities is given.

1 Introduction

At first glance, the requirements in the following two applications could hardly be more different: BMW produces very delicate cores for Aluminum cylinder head casting in large numbers, several hundred thousand cores per year to be precise.

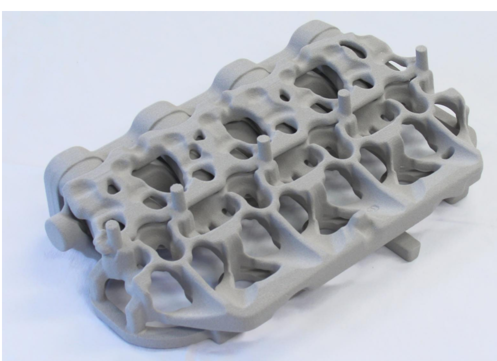

Figure 1: BMW 4-cylinder combined water-jacket core

As the wall thicknesses in the casting are only a few mm, the demands on the accuracy of the cores are immensely high; +/- 0.3 mm is permissible for dimensions of approx. 600 mm. For environmental reasons, the use of an inorganic binder system was required [2]. In addition, manual intervention was to be kept to a minimum. This project was carried out in collaboration with Loramendi - a leading supplier of foundry equipment

For GE Vernova, on the other hand, the focus is on the wind power components to be cast. Here we are typically talking about cast parts with dimensions of several meters and a casting weight of up to 80 tons [3]. For this purpose, the molds should be printed in as few parts as possible and with a maximum duration of 3 days per full mold. The material used is recycled sand from the foundry and furan resin.

2 Solutions

For the BMW application, voxeljet worked with the customer and joined forces with Loramendi to decide on a combination of several printers and an automated pre- and post-processing line. In principle, another variant with fewer or just one printer, but with a larger build area, would also have been possible here. Ultimately, the cost of handling larger boxes and automated post-processing was deemed too high. The core of the system therefore consists of five 3D printers, each with a build volume of 1300 x 600 x 500 mm.

Figure 2: BMW core printing cell, developed by Loramendi & voxeljet

The printers have a special application system that combines two recoaters with a print head in the middle which spans over the entire width of the build area. This allows one layer of sand to be processed per pass. Printing up to 6 water jacket cores in one job box thus takes just a few minutes. The finished job box is then transported via a conveyor system into an industrial microwave, where it is processed for a few minutes. At the same time, an already emptied box moves into the printer fully automated and the printing process starts again. In the microwave, the printed sand is heated to over 100 °C and the inorganic binder hardens immediately. After the microwave, the unbound sand is automatically emptied from the job box and the printed cores are cleaned by a robot. The process concludes with an optical measurement of the component, which can then be fed into the serial casting process.

For the large-scale casting application, voxeljet had to go in a different direction with the printer. GE Vernova Fraunhofer IGCV and voxeljet AG created a joint research partnership to develop the world's largest 3D printer to optimize the production of major components of offshore wind turbines. The desired sand mould size of up to 9 x 7 x 3 m means that a sand mass of several hundred tons must be processed. This is where our existing VX4000 concept comes into play, where the printer works with a stationary platform and lifts its printing-axes layer by layer, printing both job box walls and molds as construction progresses. This has the advantage that only a relatively small weight must be moved for the sand application device, offering less engineering efforts to further reduce cost. In addition, the molding sand for each layer rests during the curing process and therefore experiences little disturbance that could affect accuracy. Furthermore, the consortium decided to assemble the respective mold using individual printed plates of maximum 1 m in height. This makes it easier to clean and to handle the molds. The basic idea in the research partnership is that after printing the respective mold plate, a steel frame is placed over the mold parts, which may need to be backfilled with molding sand. The mold plate can then be lifted off the building platform and cleaned using the steel frame and crane. This is followed by the insertion of chill plates where needed and the application of coating before the mold plate is loaded into the casting pit. Depending on the mold size, several printed mold plates are stacked on top of each other and then cast. The printer itself consists of 8 vertical axis units that lift a frame layer by layer, on which the traversing units for the print head and sand coater are located. The print head consists of several indivi9dual print modules approximately 1 m wide which, depending on the print speed requirement, can be constructed in such a way that the axis only needs two passes over the construction field to print the entire layer.

The recoater is also made up of individual modules to simplify maintenance. In addition, the recoater is designed so that it can apply layers of up to 0.7 mm in height. The maintenance units for the print head are located on one side of the printer and the sand feed for the recoater on the other.

The entire sand feed concept is designed so that circulating sand from the foundry is taken from the silo and fed to a batch mixer. It is also planned that the unprinted sand produced when cleaning the molds will also be fed back into the batch mixer in predetermined quantities. In the mixer itself, the activator is added in the appropriate quantity. The mixed molding sand is then transported directly to the printer. This concept makes it possible to limit the amount of sand to be disposed of to a minimum.

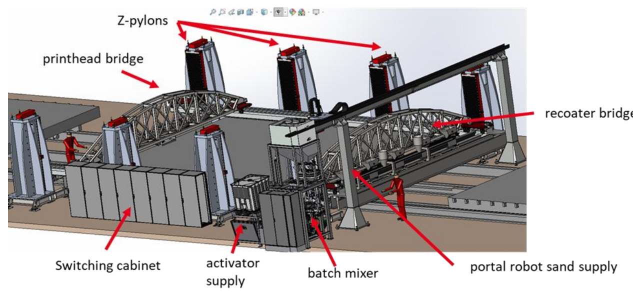

Figure 3: Large Format Printer Layout

3 Conclusion

The BMW application shows that it is technically possible to 3D print and successfully cast sand cores in very large quantities, even in the demanding inorganic material set. The challenges here include the properties of the binder, which requires very precise process control, and the control of many other critical variables that influence the process, such as the sand composition and climatic conditions. The combination with microwave hardening limits the application to core geometries with thin surrounding walls. Nevertheless, this is the first breakthrough in printed sand cores for mass production, which can be transferred to other applications, other geometries and other molding materials as well.

The second application with GE Vernova is still in the development phase. Nevertheless, it is already clear that printing the molds can also bring considerable advantages here and this is technically – despite the huge dimensions - feasible. For the continued success of this technology, it is important to utilize the possibilities that arise with printing, e.g. in terms of freedom of design.

References

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