Integration of Numerical Modeling and Laser Sintering with Investment Casting

T. Pintat*, M. Sindel*, M. Greul*, A. Burblies* and C. Wilkening**
* Fraunhofer-Institut für Angewandte Materialforschung, Bremen
**EOS, München

Abstract

Industry has a great demand for metallic prototypes to speed up product development. At present there are several RP-technologies for direct fabrication of metal components in development. Today secondary processing of polymer or wax models, like investment casting or sand casting, is a very common way for the production of metallic prototypes.
There are, however, several problems in investment casting resulting from laser sintered models made of wax or polycarbonate.
Recently a polymer mixture consisting of nylon material and a second polymer has been tested with the laser sinter process in a newly developed sinter machine (EOSINT 350 - 60). Shells for investment casting could be prepared easily with the models in a conventional assembly-line. Several castings of laser sintered models in Al were successfully realized.
In future, integration of modeling based on FEM calculations with RP for castings will become more important. Calculations will support the designer to optimize the structure of components and their processing. A viable method will be presented where a new FEM based calculation method to optimize the structure design of a model is integrated with RP. Optimizing castings with FEM will be supported by integration with RP.

Introduction

Investment casting of laser sintered models

Different casting companies have experiences with casting of wax and polycarbonate models, however, there is no systematic report on investment casting of laser sintered models. Generally wax models are fragile and distore easily, hence polycarbonate models are preferred. Investment casting needs special preparations of polycarbonate models using traditional pattern-making techniques to successfully cast the model /1/. Problems can arise from surface penetration of slurry during shell making, hence the surface needs to be completely sealed. Some casting companies have problems with polycarbonate models during the autoclave process. The material can produce foam during the conventional autoclave process which can cause cracking of the shell /2/.

Integration of modeling with Rapid Prototyping

Simulation as a tool for designers is more effective when it is integrated into the design process from the very beginning. This is true for product as well as process design. Integration of modeling with Rapid Prototyping supports concurrent engineering. A concurrent approach is information driven and relies on computer technology. Computer-aided design, mold filling and solidification simulation and finite element stress analysis are means of modeling castings. Interfacing the output of modeling with RP allows the simultaneous production of an optimized model /3/.

Experimental

Laser sintering and casting

The powder material used is a mixture of Nylon 11 and a second componenet. A micrograph of the powder is shown in Fig. 1. The two components were mixed in a conventional tumbling mixer, different compositions were tested.
Sintering was done with the newly developed EOSINT 350 sinter machine, which is capable of building parts as large as 34 x 34 x 59 cm. The machine is equipped with a 50 W CO_2 laser, the focal diameter is < 0,5 mm and the scan rate is up to 2 m/s. Resolution of the laser beam positioning in x and y is 0.015 mm and accuracy 0.1 mm. The vertical positioning accuracy is 0.05 and the resolution 0.01 mm. Layer thickness can be varied between 0.1 and 0.2 mm. Fig. 2 shows the EOSINT unit.
Burning out of the model and casting was realised in the investment casting assembly line of Thyssen-Feinguß. The standard procedure of autoclave processing at 170 °C and subsequent shell firing was followed. Casting was done in Al-alloy. Usually the castings were finished using sand blasting.

Numerical optimization for lightweight castings and integration with RP

Lightweight castings is an option for weight reduction and optimized materials service. A new numerical modeling method was selected to calculate optimized structures. The FEM based calculation, recently developed by Mattheck et al. /4/ and named SKO (soft kill option) method, simulates a biological optimization. It has the potential to refine structures in a lightweight design. The optimization is similar to adaptive bone mineralization. Bones are able to change their degree of mineralization according to a change in their mechanical loading.
Stresses are calculated by FEM in a selected design area with a constant Young´s modulus over the whole area. Then the Young´s modulus is varied as a function of stresses. In a next step a new stress distribution is calculated with the varied Young´s modulus distribution. The repeated application of this procedure leads to distinguished regions of high and low Young's modulus. Eventually non-loaded parts are removed from the structure. The final result is a design with a minimum weight. Fig. 3 shows an application of this method on a rectangular bar with two supports under a single load /5/.
In order to transfer the optimized structure data directly into the STL format special software was developed at IFAM. Optimized components can be subsequently built as a RP models and investment casted.

Results and Discussions

Laser sintering of the nylon/polymer mixture and casting

The powder mixture contains nylon and a second polymer, where the nylon material has a different thermal behavior. Due to this difference one component compensates expansion of the other during heating. This is the key for very successful melting and burning out of the material during the autoclave process for investment casting. Due to special scan strategies of the laser beam the surface can be sealed, while the inner of the component is still porous. A successful investment casting and the laser sintered model is shown in Fig. 4

Numerical modeling and integration with RP

As an example a roof structure was optimized by SKO method. The data of the optimized structure were converted into STL-format and a model was built. The model and the casting are shown in Fig. 5. The casting can be used as a functional prototype to immediately test the feasibility of the new design in service. This example shows how new design concepts can be tested very rapidly by integration with RP. Further development is necessary to transfer the method to real world, i.e. a total integration of the modeling software in a CAD environment.

Acknowledgements

C. Mattheck (KfK, Institut für Materialforschung II, Karlsruhe) kindly provided the FEM calculations and structure data. G. Peter (IFAM, Bremen) developed the software to get the STL-format from the FEM mesh.

References

/1/ Rapid Prototyping Report, 4 (1994), 4, p. 1-2

/2/ Private Communications with U. Schneider, Thyssen Casting, Soest

/3/ K. F. Packer, "Concurrent Engineering in the Casting Industry", Global Cast Metals Newsletter published by The Knight International Cast Metals Practice Committee, Feb. 1994

/4/ C. Mattheck and A. Baumgartner, "CAO & SKO: Fatigue-resistant engineering design by simulation of biological optimization mechanism, Experimental Mechanics, ed by E. G. Little, Elsevier, 1992

/5/ C. Mattheck, "Design in der Natur", Rombach, Freiburg i.B., 1992, S.51

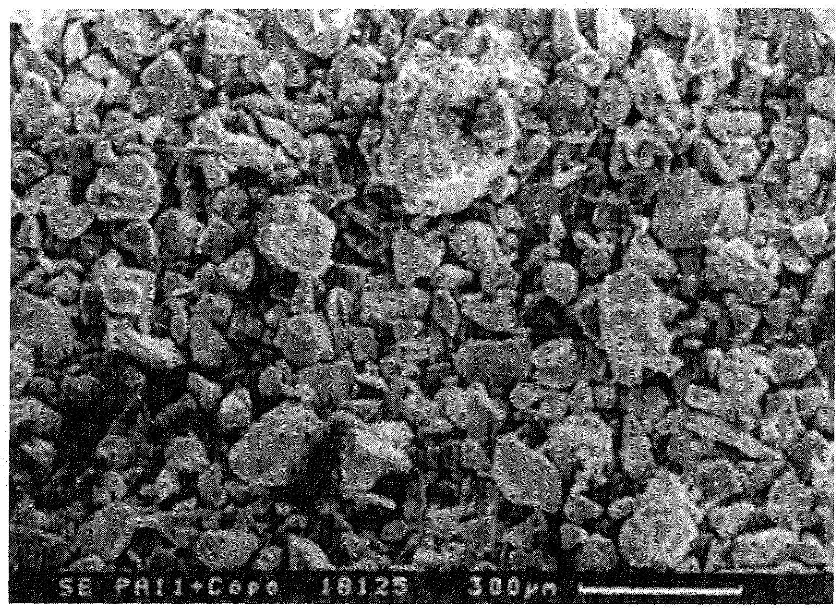

Fig. 1: Polymer powder mixture used for laser sintering for investment casting

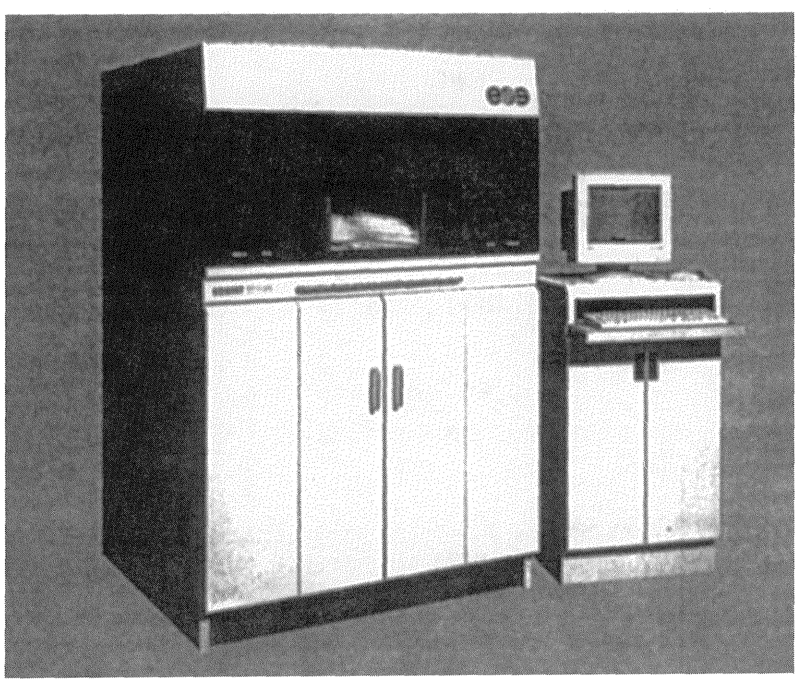

Fig. 2: Laser sinter machine 350-60 from EOS

a) design area

b) optimized structure

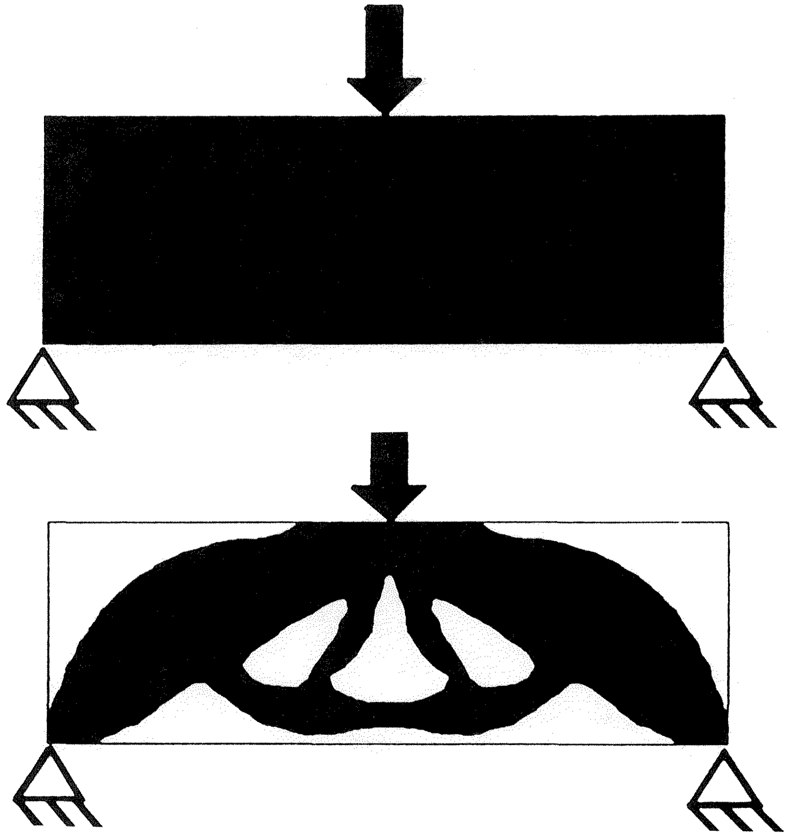

Fig. 3: Rectangular bar with a single load on top (a), and optimized shape after the SKO-calculation (b)

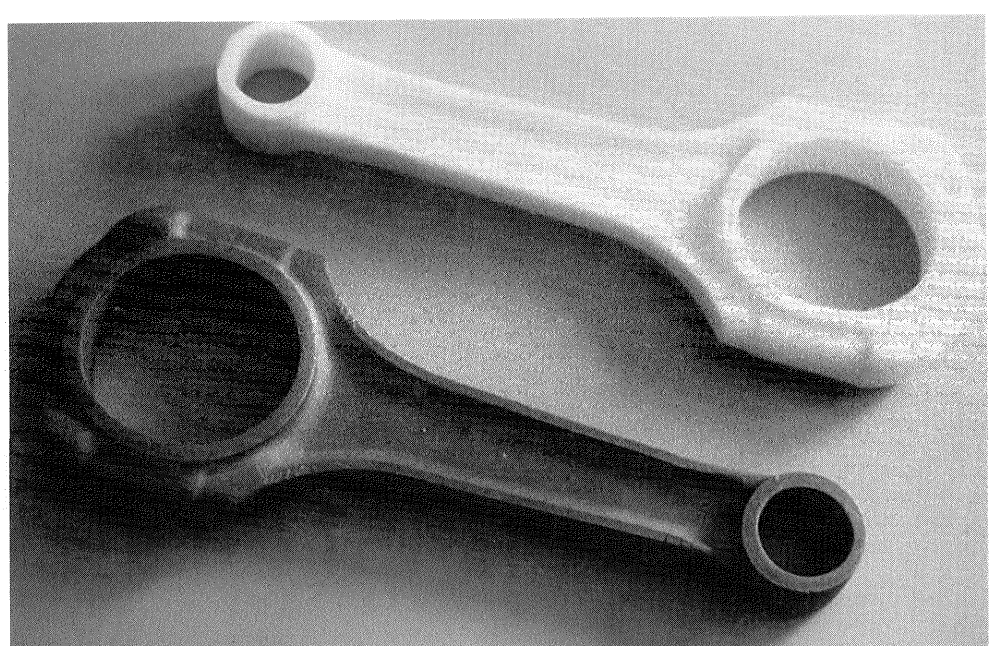

Fig. 4: Laser sintered model of a connecting rod out of the polymer mixture and investmet casting in Al

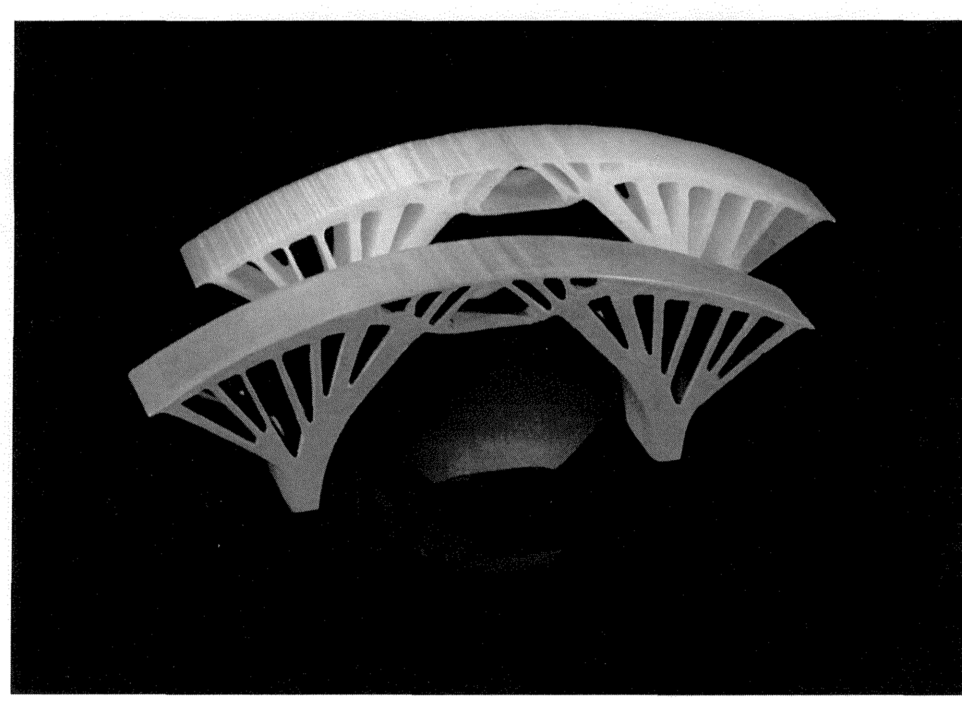

Fig. 5: RP-model built from converted data of the FEM-calculation and investment casting out of Al.