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SIMTech achieves unprecedented Liquid Forging simulation on aluminum heat sinks using ProCAST

THE CHALLENGE

SIMTech's patented Liquid Forging technology is a hybrid process between casting and forging, using an open mold die concept. Among the first parts SIMTech decided to manufacture following this process were wrought aluminum heat sinks.

The main challenge was to identify suitable process simulation software able to accurately represent the mold filling, solidification and cooling behavior of a liquid forged part before the start of any trial production. This would avoid waste of material and time in pre-production, and help reduce or eliminate tooling modifications, thus enabling substantial savings in energy, material and tooling costs.

THE BENEFITS

- Improved part quality ;
- Reduced development phase ;
- Savings in energy, material and tooling modification costs ;
- Tool design and process optimization with simulation, allowing development of best fit conditions for real-time manufacturing.

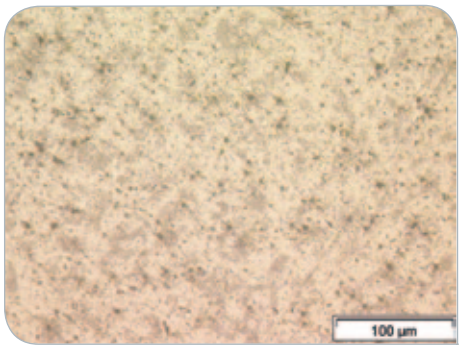
"The process simulation module in ProCAST for Liquid Forging has helped us reduce the time consuming traditional trial-and-error methods in terms of our tooling design and process optimization."

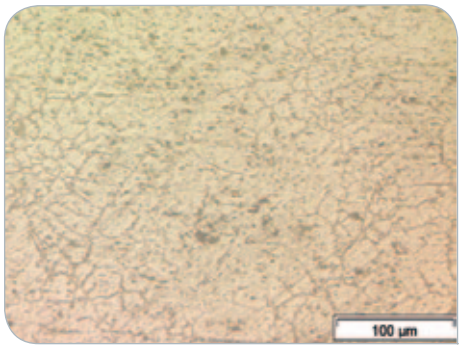
Dr. Chua Beng Wah
Research Scientist,
Forming Technology Group, SIMTech

Liquid Forging of heat sinks

SIMTech's patented Liquid Forging (LF) process, a hybrid of casting and forging processes, produces high-integrity intricate aluminum structures and components. A pre-quantified amount of molten metal is poured into a die cavity and pressurized during solidification to form components in one single process utilizing re-useable dies.

Traditional heat sinks formed by extrusion, die casting and cold forging have design limitations due to process barriers. Manufacturing heat sinks via LF process enables one to come out of such process barriers, but still have a cold forged thermal performance, on improved heat sink design, and at reduced costs.





Microstructural difference between Extrusion and Liquid Forging.

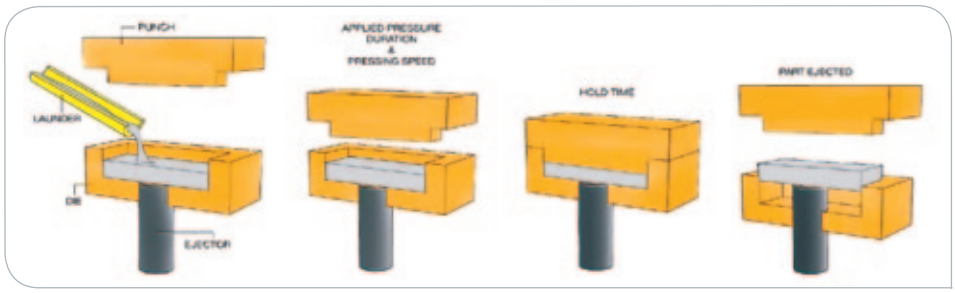
Pin-D46 wrought aluminum heat sink.
Actual weight: 70g.

During LF, pressurized solidification eliminates shrinkage and gas porosity in the heat sinks, enabling better thermal conductivity. It is possible to achieve high aspect ratios (increased surface area), as it enables manufacturing complex thin featured heat sinks. Elliptical and circular shaped fins enhance heat removal by convection, but without any additional secondary operations like machining, milling, etc, thus reducing cycle time, material waste and costs associated. The absence of runner and feeder systems ensures high material yield, thus providing a near net-shape process. The LF process is applicable to the manufacturing of cast, wrought and non-standard aluminum alloys in the electronics, aerospace and automotive industries.

Implementing LF process simulation

To reap the full financial benefits of this new technology, SIMTech used process simulation during the development stages, to have a better idea of the problems that could occur in manufacturing.

For such a non-standard technology, there was no readily available simulation software in the market. After three months of comparative evaluation of potential simulation solutions, ProCAST was selected as the most appropriate tool for SIMTech's Liquid Forging process. ESI provided support in adapting the process simulation module to this new technology and in defining boundary conditions which fit best the particular process configuration.



Liquid Forging: a hybrid process between traditional casting and cold forging leading to finer structure, geometry and aspect.

Optimizing design & process

Aluminum alloy series 60xx were used to produce heat sinks following the Liquid Forging process. This can be considered a non-standard alloy, as it is uncommonly used for casting. The first step consisted in defining the right thermal and fluid properties for this alloy, and then represent the real Liquid Forging process inside the simulation software, by means of boundary conditions and process parameters. The main aspects to study in such a simulation are filling and solidification behavior.

Due to the intricate shapes of the heat sinks, and no additional areas being designed as flow-offs in the cavity, it was important to determine optimal filling pressures to have the right melt filling speeds and to fill the entire cavity. The right filling pressure and speed should nullify the back pressures and prevent any undesirable pre-solidification in the filling phase.

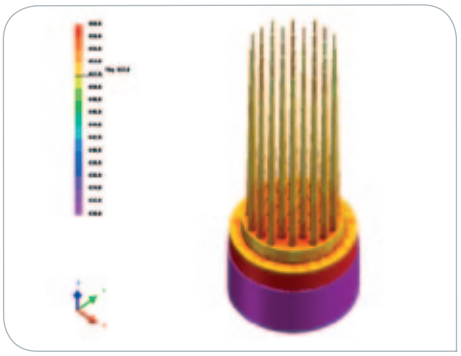
By modifying the vent design with simulation, engineers were able to evaluate the behavior of molten metal under different back pressures. This helped re-design the vent size and locations, which are key parameters in tooling design for Liquid Forging dies. The optimized vents effectively prevented unwanted air or gas entrainment in the fins.

Simulation also allowed good insight into the temperature evolution during solidification. This helped adapt the part and tool design to maintain a progressive solidification towards the pressurized sink bottom, and thereby to avoid any formation of shrinkage pores.

Smaller vent sizes reveal insufficient filling due to back pressure, while 100% filling is observed in dies with well designed vents.

Results

The process simulation of Liquid Forging inside ProCAST provides an accurate representation of the entire process, including provisions to analyze the molten metal filling behavior, effect of back pressure due to varying vent designs, solidification, and shrinkage porosity formation. Simulation provides an effective solution to the technical challenges posed by the new market opportunities this hybrid process creates.



ProCAST simulation of temperature distribution at the end of the die filling.

To find out more about ESI's Casting Simulation Suite, please visit: www.esi-group.com/casting

ABOUT SIMTECH

The Singapore Institute of Manufacturing Technology (SIMTech) develops high value manufacturing technology and human capital to enhance the competitiveness of Singapore's manufacturing industry. It is a research institute of the Agency for Science, Technology and Research (A*STAR), creating intellectual capital through the generation, application and commercialization of advanced manufacturing science and technology, nurturing research scientists and engineers by providing opportunities to do use-inspired research for industry and contributing to Singapore's industrial capital by collaborating in projects and sharing research expertise & infrastructure with industry. SIMTech has completed more than 900 projects with more than 500 companies, big and small, in the electronics, semiconductor, precision engineering, medical technology, aerospace, automotive, marine, logistics and other sectors.

ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping for manufacturing industries that takes into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus eliminating the need for physical prototypes during product development. The company employs about 850 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.

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