Introduction of Composite Technology, Combining Machining with Selective Laser Melting for Metal Powder Forming

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In recent years, in view of shortening product lifecycles, the rapid prototyping (RP) technology has been applied to the manufacturing of injection molds. For example, in Europe metal powder selective laser sintering (SLS) technology or selective laser melting (SLM) technology, which is originally one of the RP technologies, have been used for direct manufacturing of metal parts and further developed for the manufacturing of components of injection molds.

During the forming process based on the conventional selective laser melting (SLM) technology, the inherent defects during laser scanning, such as powder splashing in the bath, spheroidization, and powder sticking, may cause the shaped part to have dimensional inaccuracies and higher surface roughness. The technology combining machining with selective laser melting for metal powder forming process originally developed by the Panasonic Corporation (formerly known as the Matsushita Electric Industrial Co., Ltd.) is exactly the solution to make up for such shortcomings of conventional SLM technology. The composite technology combining machining with SLM integrates the layer-by-layer additive forming technology by selective laser melting (SLM) with conventional high-speed machining technology. It combines the two opposite manufacturing processes, the layer-by-layer additive forming process and the subtractive machining process, and integrates material technology, computer software technology, laser sintering technology and computer numerical control technology. In comparison with the layer-by-layer metal powder forming process realized by simple selective laser melting, this composite technology can be a one-time process for creating an integrated component with conformal cooling and air venting functions, such as high-precision molding parts with complex surface profiles that are difficult to perform follow-up machining processing on. The machining precision can be below ± 0.005 mm, and the hardness after heat treatment can be higher than Hrc 50. The cooling time of the mold components manufactured using this composite technology can be effectively reduced. In addition, the trapped air can be removed, so that the injection molding efficiency can be increased and the quality of the molded products can be improved. Therefore, this composite technology combining machining with SLM is particularly suitable for manufacturing high-precision molds for injection molding.

Manufacturing Process of Composite Technology, Combining Machining and SLM for Metal Powder Forming

The Manufacturing process of this technology is shown in Figure 1. (1) The laser melts the metal powder spread on the metal base plate; (2) Repeat spreading the metal powder and laser melting for the layer-by-layer additive forming until the thickness reaches the effective cutting length of the tools; (3) Perform the cutting action on the side wall of the stacked layers with small-diameter tools; (4) Repeat the selective laser melting, layer-by-layer additive forming, and high-speed machining processes; (5) Eventually, a precise, three-dimensional surface profile of the machined work piece can be obtained. The difference between the conventional SLM technology and the composite technology combining machining and SLM can be distinguished according to Figure 2.

Practical Application-
Auxiliary Fuel Tank for Automobiles (60% Reduction in Cooling Time)

Figure 3 shows the components for the jet pump (JP) and overflow (OF) section of the auxiliary fuel tank used in automobiles which are manufactured using the composite technology combining machining and SLM for metal powder forming. Because the technology can incorporate conformal cooling channels inside narrow parts which are difficult to be cooled using the conventional manufacturing methods, the cooling time for the entire mold is reduced from an original 25 seconds to 10 seconds.

In addition, the accuracy of the dimensions of the plastic parts close to the round base and the snap fit are increased. (See Table 1)

	Evaluation Item					
	①		②		③	
Cooling time	**Steel （water）**		**Laser Sintering （water）**		**Laser Sintering （air）**	
	JP	**SNAP FIT**	**JP**	**SNAP FIT**	**JP**	**SNAP FIT**
25	80	130	59	59	80	94
18	80	130	59	59	_	_
15	80	130	59	58	80	100
10	80	130	58	69	_	_

Table 1 Cooling performance evaluation

Application of Moldex3D Molding Simulation Techniques for Design Verification of Conformal Cooling Channels

How conformal cooling channel designs may achieve the desired results, including reductions in cooling time and improvement of product quality, is often difficult to grasp before the mold trial. But with such tools as molding simulator, it is possible to verify the efficacy of the cooling channel design before mold manufacturing, thus achieving the goal of effective cost reduction.

Since we know that the ideal cooling system must take into account the distribution, type, fluid temperature, flow rate and cooling time for the fluid channels. An effective fluid channel design matches the fluid channel to the profile of the product, so as to achieve the goal of uniform heat removal. Figure 4 shows an example of a machinery chassis provided by the OPM laboratory. Due to the complex geometry of this product, the core side is designed with a total of two sets of cooling channels distributed close to the product surface. Figure 5 shows the differences between a conventional cooling channel design and the conformal cooling channel design. The Moldex3D was used to analyze the two cooling channel designs and then compare the results with the on-site data. According to the on-site ejection criterion provided by the OPM laboratory, there shall not be any shrinkage of the product surface. Under this criterion, the conformal cooling channels can have a cooling time 10 seconds less than that of a conventional cooling channel (Figure 6). Figure 7 shows the comparison of the sink mark displacement for the conventional cooling channel, with a 30-second cooling time, and the conformal cooling channels, with a 20-second cooling time. According to the results, the values and locations predicted by the software are very close to the on-site cases.

Conclusion

In this article, the composite technology combining machining and SLM for metal powder forming and the application of conformal cooling channels are described. Compared with the layer-by-layer addition metal powder forming using conventional selective laser melting technology, the composite technology not only retains the advantages of flexible manufacturing capability but also has the advantage of high-speed and high-precision machining. It features a one-time manufacturing process for creating an integrated component with conformal cooling channels and air venting functions, which can even be a high-precision molding parts with complex surface profiles that are difficult to perform follow-up machining processing on. In addition, Moldex3D was used for analysis and comparison of the conventional and conformal cooling channel designs, and reasonable verification results were obtained. Moldex3D is an effective tool for design verification of cooling channels to reduce manufacturing costs.

Keyword:：metal powder, laser melting, layer additive, milling, conformal cooling, cooling time, venting.

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References

1・阿部論等，金属光造形複合加工システムによる高機能射出成形金型製作，松下電工技術，Vol.53 No.2，p5-11
2・不破勲等，低密度層からなるガスベントを有する金属光造形金型，松下電工技術，Vol.55 No.2，p17-22
3・浅析金属粉末激光造型复合加工技术，塑胶及金属，2011 年第 2 期，p26-27

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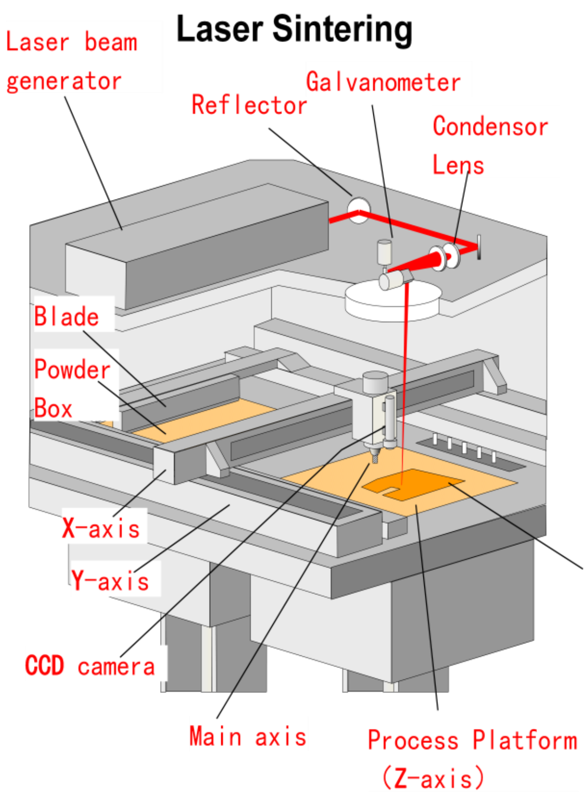


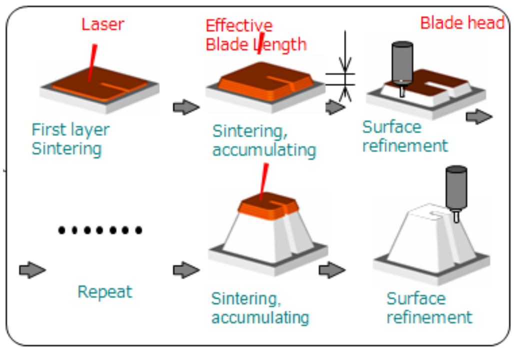
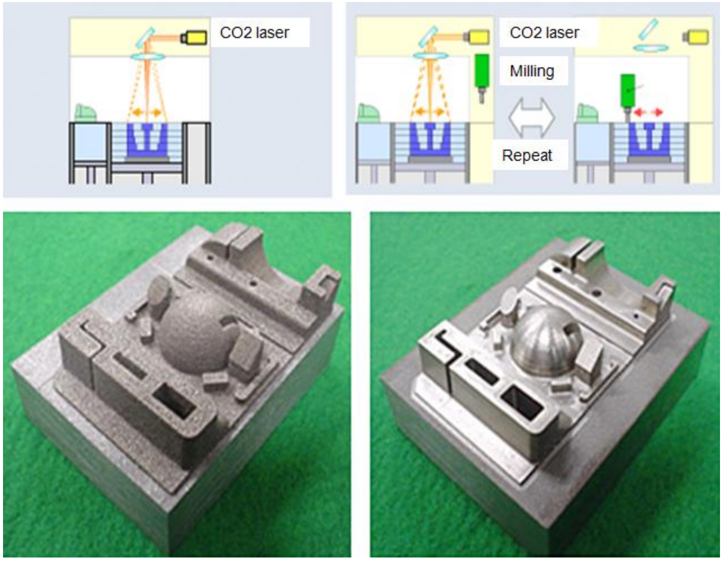


Figure 1 Laser sintering facilities and processes



（A）　　　　　　　　　（B）

Figure 2 SLM technology (A) and hybrid technology (B) comparison

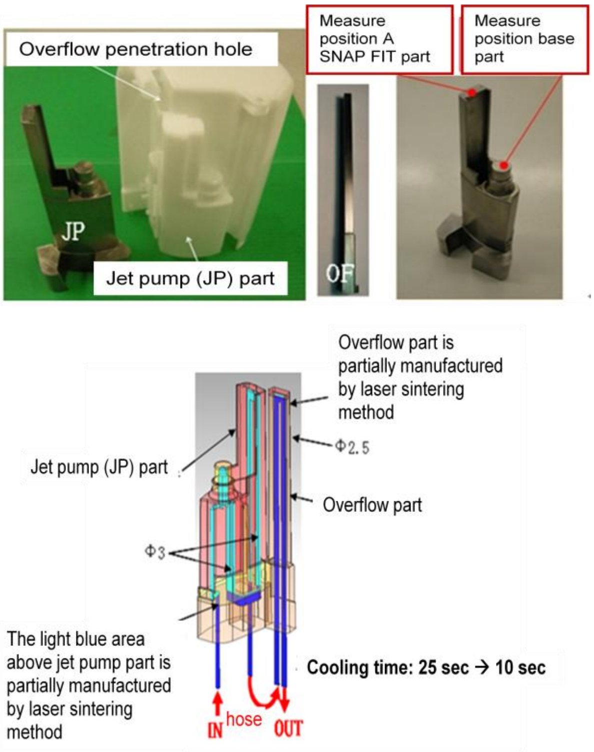


Figure 3 Auxiliary gas tank cooling improvement case

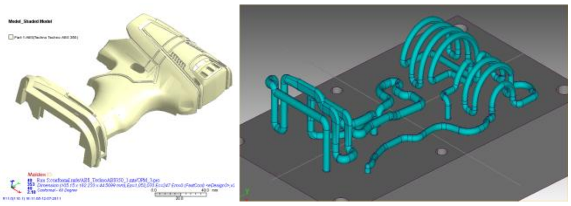
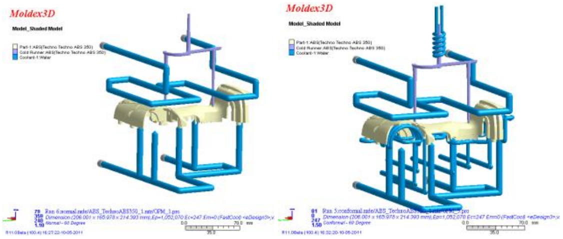


Figure 4 Machine tool cover model and conformal cooling design

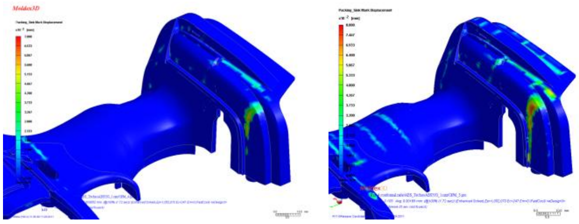


(A) (B)

Figure 5 Conventional (A) and conformal cooling (B) design

(A) (B)

Figure 6 (A)Conventional and conformal design cooling time comparison (B) Sink mark location



(A) (B)

Figure 7 Sink mark displacement comparison

(A) Conventional cooling (B) conformal cooling