Injection Moulds Direct by Laser

New Material for Shortening the Laser-Sintering Process Chain

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New products must reach the market faster and faster. Often, the mould construction stage is the stumbling block to market release. Laser-sintered prototype moulds are already shortening development phases considerably. Now, there is a new material available that makes it possible to use laser-sintered moulds for all phases of the product life cycle. Short runs of 100,000 injection-moulded parts can be made with it.

Speed is extremely important in the developmental stage of a new product. The production of prototype moulds is often the most time-consuming link in the development chain. EOS GmbH, Planegg/Germany, a leading manufacturer of rapid prototyping systems offers a process in DMLS (direct metal laser sintering) and its rapid tooling application called DirectTool, that greatly shortens this time. The much-improved surface quality of the new DirectSteel 20 powder leads to substantially shorter finishing and thus to much shorter project lead times. The following examples show by how much the process chain from CAD to injection-moulded parts now can be shortened. The real-life example of a modem housing described afterwards clearly shows that the short runs produced by this method also find use as end products when, for example, the intended mass-production mould is not ready on time.

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From CAD to High-Quality Injection-Moulded Parts in Three Days

The Swedish automobile group Volvo Car Corporation worked with the Rapid Manufacturing Group of De Montfort University, England, to make a core and a mould cavity for injection moulding an adapter for a car (see Fig. 1). The inserts had a diameter of approx. 60 mm and were about 22 mm high with internal 90° angles which could not be produced by milling. In this case, the inserts were made of the new, extremely fine material DirectSteel 20 on an Eosint 250 M Xtended laser-sintering system (Fig. 2) in a fully automated process. Total building time was 16 hours. After brief micro shot-peening, which took less than an hour, four hours' touching up and then a further four hours for fitting and assembly, the mould was ready to start injection moulding production. Even without ejector pins or surface polishing, it was able to manufacture several hundred injection moulded parts in polypropylene.

This project proves that it is possible to create injection moulded parts within three days of generating the 3D-CAD data. And without any sacrifice in high quality either. Six measurements taken from every mould insert with the help of a co-ordinate measuring machine yielded an average deviation of just 0.032 mm. The maximum deviation was just 0.068 mm. Measurements of surface roughness after micro shot-peening yielded an Rz of about 20 µm and an Ra of around 3 µm.

Successful under the Hardest Conditions

To test the technique under harder conditions, the partners repeated the project using a different mould design and several ejector pins. The second test also proceeded very quickly. It involved injection-moulding several hundred parts in ABS, whose quality even outclassed that of the first test.

Reality Test on the Material

One of the beta customers for the new DirectSteel 20 was Siemens VDO Automotive, the renowned automobile supplier and DMLS service provider. On receiving the powder, Siemens VDO immediately used it for a commercial project. After the mould inserts were made fully automatically, they were micro shot-peened in a few minutes and polished to a smooth, pore-free surface in an hour with an ultrasonic file. The two inserts fitted into the injection mould without any problems thanks to the high building accuracy of the process and very low material removal during polishing. Touching up, which took less than an hour, also needed no more time than typically needed for mould inserts manufactured conventionally. Thus, just a few hours after construction, good-quality technical prototypes were already being injection moulded.

Overview of DMLS Materials

DirectMetal 100

This bronze-based metal powder for layer thicknesses of 100 µm yields good mechanical properties, accuracy and detail resolution, at very high build speed. This material offers the highest build speed and is suitable for applications in which the requirements on detail resolution and strength are not so high.

DirectMetal 50

This bronze-based metal powder for layer thicknesses of 50 µm delivers good mechanical qualities, very good detail resolution and superior surface finishes. It is suitable for the direct production of moulds and inserts for the injection moulding of several tens of thousands of plastics parts.

DirectSteel 50

This fine-grained, steel-based metal powder for layer thicknesses of 50 µm is eminently suitable for building up heavy duty injection moulding and pressure die-casting moulds. Parts sintered with this material have very good mechanical properties, such as tensile strength of 500 N/mm², high precision and good detail resolution.

DirectSteel 20

DirectSteel 20 is a very fine-grained, steel-based metal powder for building up layer thicknesses of 20 µm. The resultant parts offer the same advantages as DirectSteel 50 plus enhanced detail resolution and surface finish. This material is ideal for smaller parts having fine details and for parts which require a high-quality surface finish.

Series Production Moulds

Rapid Product Innovations, Rusko/Finland, which belongs to the Alphaform Group and is a service provider for prototyping and product development, received an order to manufacture a two-part plastic distributor housing for a new modem. The customer wanted to carry out preliminary market tests with these prototypes. For this, it needed a preliminary series of 10,000 identical plastic covers and bases made by injection moulding using standard settings within the space of a few weeks. Rapid Product Innovations used DirectTool to make the mould inserts from the new steel-based material DirectSteel 20. With the aid of these tools, the series of 10,000 plastic covers and bases were injection moulded under standard conditions. After market tests proved positive, the customer placed an order for the series production mould with a mould-making contractor. It transpired that the series production mould was not completed on schedule and so the DirectTool mould had to be used further. Many thousand parts of good quality were produced with it. Thus it was that series production was started with the "prototype mould". Demand for this product increased, but the series production mould still could not be delivered. So production continued with the DirectTool mould. By the end of May 2001, the company had already made 60,000 distributor covers and the same number of bases with the help of the DirectTool mould. Rapid Product Innovations reckons that the magic number of 100,000 will be reached sometime soon. Since three variants of the covers were produced, three different mould inserts were needed, but this did not prove a problem for the DirectTool process.

And this case is not an exception. Often, series production moulds cannot be manufactured on schedule by conventional methods and so the supposed prototype mould ends up being used to injection mould the actual run. The mould-making sector has long since recognised this potential and integrated DMLS technology into its product line. In an intelligent combination or when used as an alternative for short runs, a great deal of time and money can be saved. Today, mould lives are already around one hundred thousand injection-moulded parts.

Rapid Product Innovations runs a prototype and mould-making operation with various conventional and rapidly processes and is thus able to choose the right production technology or combination to suit project requirements. In the aforementioned case, both cover and base had a relatively simple outer geometry, while the insides had ribs and other, more complex geometries. It was therefore decided to mill the mould inserts for the two outside faces from aluminium and to manufacture the mould inserts for the insides by DirectTool, that allowed the operations to be carried out in parallel. The DirectTool inserts were produced on the Eosint M 250 Xtended laser sintering system from RPI and then micro shot-

The EOS Group

EOS was founded in 1989 and is now the leading European manufacturer of systems for rapid prototyping, tooling and manufacturing. It has an base of more than 300 installed systems in more than 20 countries. With annual sales volume growth of over 30 % since 1997, EOS is the fastest growing established company in the industry. Headquartered in Planegg near Munich, the EOS Group has its own subsidiaries or distribution partnerships in the major European and Asian markets.

The Eosint laser sintering systems very quickly generate moulds and parts directly from 3D-CAD data and are used in the most diverse sectors for fast, cost-effective product development right through to small runs.

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peened. Both the DirectTool inserts and the milled inserts were polished in the relevant places, and then the mould was assembled and finished. Four sliders were made for undercuts by means of DMLS and small steel pins were turned and integrated. Injection moulding was carried out fully automatically on a 750 kN machine with a cycle time of 50 seconds. The parts were manufactured from flame-retardent PC/ABS.

Steel-based Powder DirectSteel 20

The steel-based powder DirectSteel 20 is a further development of the proven metal powders for direct metal laser sintering and have been adapted to the respective application. DirectSteel 20 allows layer thicknesses of 20 µm and thus a very good detail resolution. The surface quality of parts made with it is good enough in many cases, without polishing and with brief micro shot-peening, for use in injection moulding. The shot-peened surface is similar to the structured, contoured surfaces frequently employed for injection moulded plastic parts that are traditionally made by means of erosion or etching.

Where a polished surface is required for technical or aesthetic reasons, this is easily attainable. The much enhanced surface quality in comparison with earlier powders leads to substantially shorter secondary finishing times. The high density combined with the compacting effect of shot-peening makes it possible to produce even a mirror-like finish. Mechanical qualities are also improved. The tensile strength of 600 N/mm² is higher than for typical mould-making aluminium alloys. Uses are thus also possible in heavy duty applications. For example, about 500 aluminium parts have been produced in a DirectSteel 20 mould in a pressure die-casting project.

DMLS – The Outcome of a Successful Partnership

The present success of direct metal laser sintering (DMLS) is the result of a long-standing collaboration. It started in 1994 with contact between the Finnish company Electrolux Rapid Development and EOS GmbH. Electrolux was one of the first European companies to use rapid prototyping and had also developed a special, very-low-shrinkage metal powder for sintering at atmospheric pressure. EOS had successfully developed and commercialised laser sintering with polymer powder.

These two innovative companies were interested in finding out if these developments could be combined. After highly promising preliminary test results, a collaboration agreement was reached and, within a year, the first DMLS equipment was developed and installed at Electrolux. As early as 1995, the Eosint M 250 was released as a standard product. The first material was a bronze-based metal powder which was used to make parts and moulds in layers 100 µm thick.

The technology soon established itself as a rapid, accurate process for rapid tooling.

As a result of the close collaboration between the two companies, a finer powder was commercialised back in 1997 for 50 µm layers. The first steel powder was released in 1999. In the new 20 µm steel powder, a major milestone has been reached in the direction of rapid manufacturing. With an installed base of over 65 Eosint M systems in 15 countries, DMLS has established itself well. The DMLS development team from Electrolux Rapid Development has now become an EOS subsidiary called EOS Finland.

The services sector is now called Rapid Product Innovations and is part of the Alphaform Group, with which there is still close co-operation.

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Fig. 1. Mould inserts of DirectSteel 20 for adapters of a car (Photo: EOS/Volvo)

Fig. 2. The laser-sintering system Eosint M 250 Xtended is the only commercially used rapid-prototyping system for the direct laser sintering of inserts for injection moulding and pressure die casting, of vulcanising moulds and of prototypes made of steel-based and other metallic powders

Fig. 3. Micro shot-peened mould insert for a car-steering angle sensor housing

Fig. 4. A highly polished DirectTool mould insert for the cover of a hammer drill