Description

Image

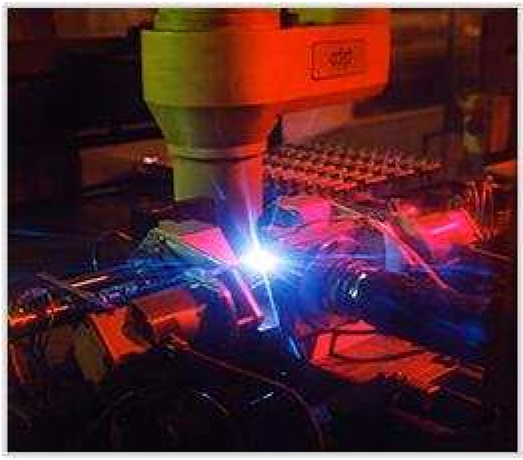


Image caption

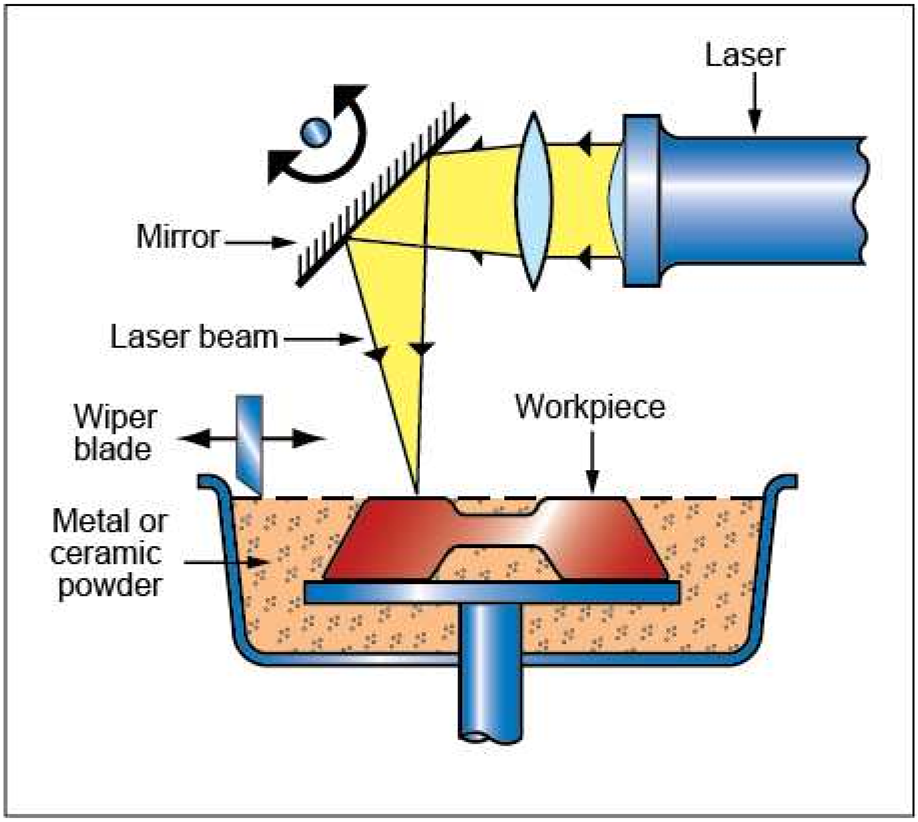
(1) Laser processing in production © TWI Ltd at flickr (2) Laser additive manufacture © TWI Ltd at flickr

The process

SELECTIVE LASER SINTERING (SLS) for metals and ceramics uses a clever trick to create fully-dense parts with good precision, using a similar method to Selective Laser Melting (SLM). The uppermost layer of a bed of powdered material is loosely bonded through slight sintering by a scanned laser beam. A new layer of powder is then swept across the surface by a wiper or milling head and the process repeated, building the model layer by layer. Originally, the metal or ceramic powder would be coated in a polymer binder before being placed in an oven to vaporize the binder and sinter the remaining powder. When complete the very porous model is infiltrated with liquid bronze, which wets and is drawn into the porosity. This gives a fully dense product, with a complex external and internal shape (such as cooling channels) that can be used as a die for injection molding and die casting. There is now a variant of this process, Direct Metal Laser Sintering (DMLS), which uses a higher energy laser to directly melt the outside of the particles during formation to sinter in-situ without the use of a polymer binder. Parts produced in this way may also be infiltrated if a full density is required. Machining is often used after manufacture to reduce the surface roughness. As with other additive manufacturing processes, a CAD solid model is used to create an STL file that drives the scanning system.

The process is also known as Direct Metal Laser Sintering (DMLS) or in-situ shelling.

Process schematic



Material compatibility

Ceramics	✓
Metals - ferrous	✓
Metals - non-ferrous	✓

Shape

Circular prismatic	✓
Non-circular prismatic	✓
Flat sheet	✓
Dished sheet	✓
Solid 3-D	✓
Hollow 3-D	✓

Economic compatibility

Relative tooling cost	low			
Relative equipment cost	high			
Labor intensity	high			
Economic batch size (units)	1	-	10	

Physical and quality attributes

Mass range	0.1	-	20	kg

Range of section thickness	0.8	-	100	mm
Tolerance	0.2	-	0.8	mm
Roughness	8	-	125	µm
Surface roughness (A=v. smooth)	C			

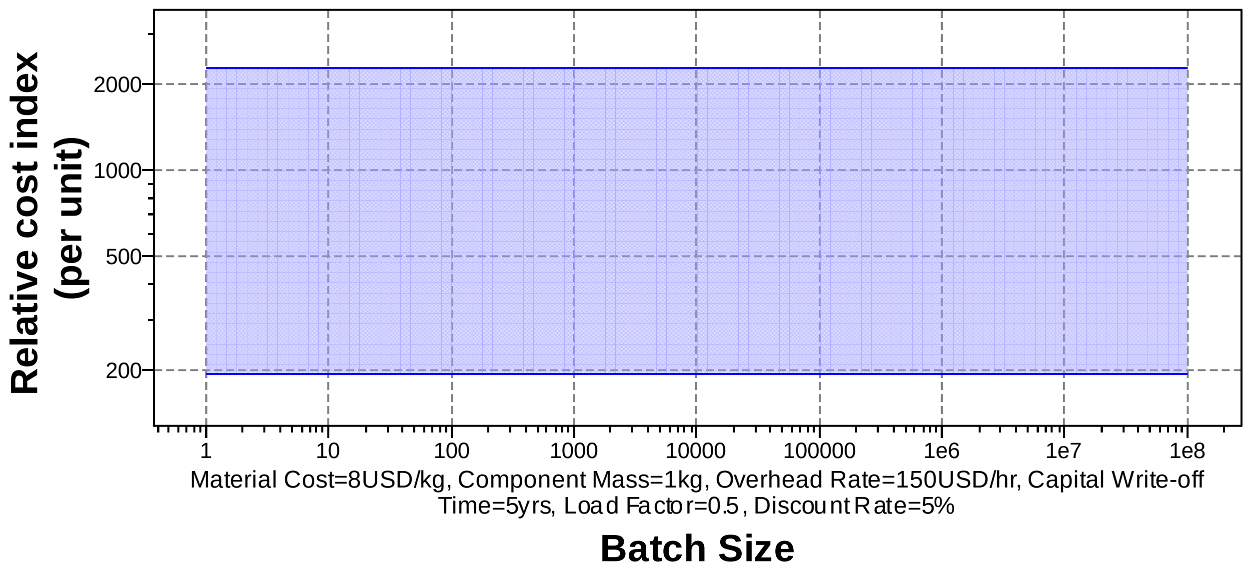
Process characteristics

Primary shaping processes	✓
Discrete	✓
Prototyping	✓

Cost model and defaults

Relative cost index (per unit)	* 193	-	2.25e3	

Parameters: Material Cost = 8USD/kg, Component Mass = 1kg, Batch Size = 1e3, Overhead Rate = 150USD/hr, Discount Rate = 5%, Capital Write-off Time = 5yrs, Load Factor = 0.5



Capital cost	1.8e5	-	8.5e5	USD
Material utilization fraction	* 0.5	-	0.7	
Production rate (units)	* 0.08	-	1	/hr
Tooling cost	* 0	-	0.1	USD
Tool life (units)	1e5	-	1e6	

Supporting information

Design guidelines

All shapes can be made. High complexity levels are possible. Parts are made without full melting so are not fully dense, with distributed porosity throughout. Does not require support structures in addition to the main body of the object so complex structures can be produced with minimal wastage and machining.

Technical notes

The build envelope (L x W x H) ranges from 100 x 100 x 80 mm for dentistry to 400 x 400 x 400 mm.
Typical layer thickness is 20 - 100 µm. The laser has a scan speed of around 7 m/s.

In principle, copper, steel and nickel alloys can all be processed in this way, provided they are available in powder form. Due to its application in die-making, stainless steel (later infiltrated with bronze) is the preferred choice. This gives a product with a density of 7500 kg/m^3, thermal conductivity of 23 W/m.K, modulus of 163 GPa, tensile strength of 580 MPa and strain to failure of 0.9%. Applied to ceramics, SLS can create molds of up to 20 kg in weight. Operates in inert gas.

Typical uses

The process, applied to metals, is generally used for injection molding and die-cast tooling as well as dentistry. When applied to ceramics it is used to make sintered ceramic molds for metal casting.

The economics

Powder bed fusion is the most expensive type of additive manufacturing due to the inert environment in which it must operate. It can cost around $800,000 for an industrial SLS machine.

The environment

Direct exposure to the laser beam must be avoided. The prototype can be crushed into powder for reuse, although due to the addition of bronze this should be mixed with pure alloy powder for best results.

Links

MaterialUniverse

Reference