APPLICATIONS AND EXAMPLES

APPLICATION-MATERIAL RELATIONSHIP

Areas of applications are closely related to the purposes of prototyping and consequently the materials used.

In the early developments of RP systems, the emphasis of the tasks at hand was oriented towards the creation of "touch-and-feel" models to support design, i.e., creating 3D objects with little or without regard to their function and performance.

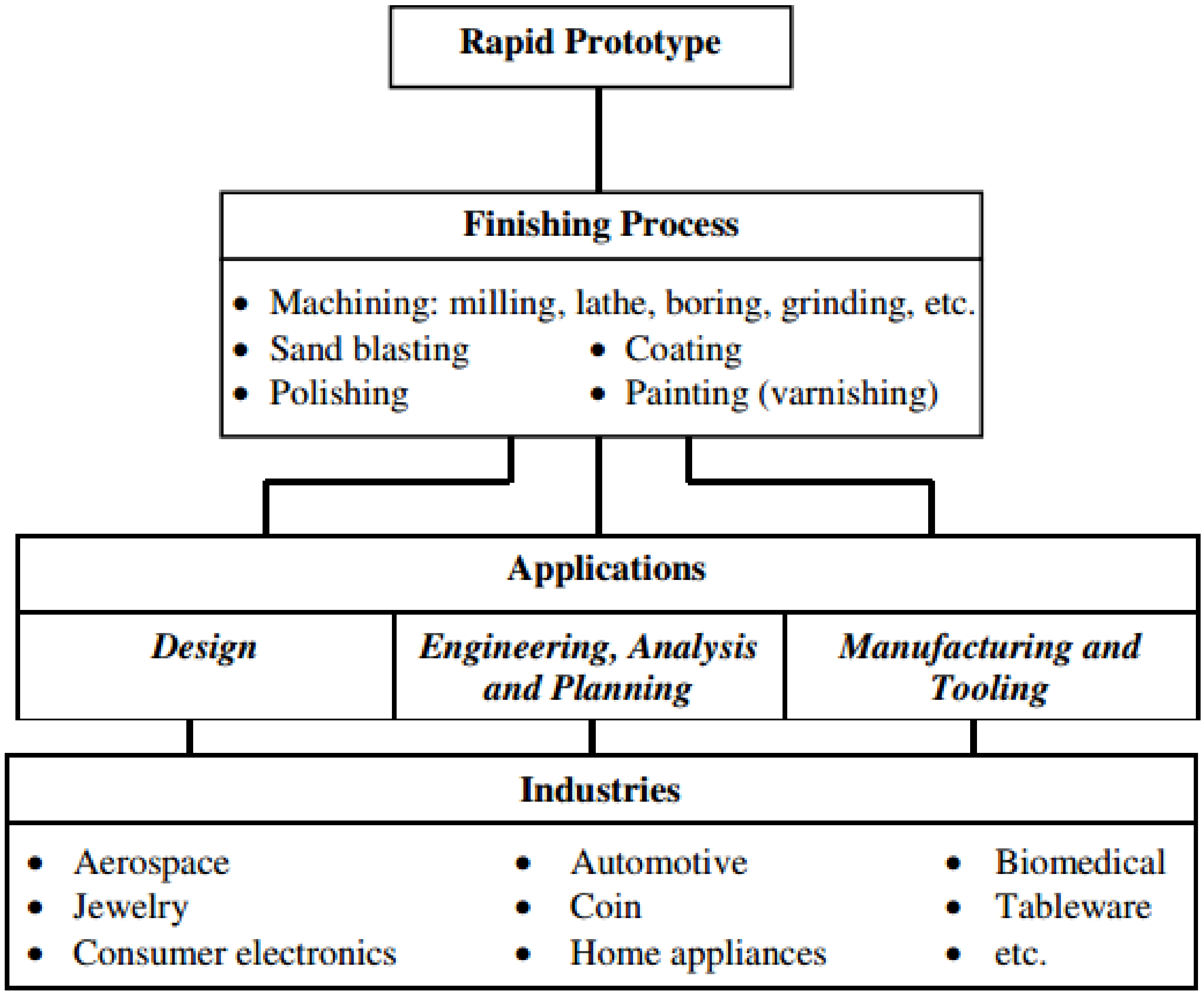


Figure 7.1: Typical application areas of RP

Applications		
Design	***Engineering, Analysis and Planning***	***Manufacturing and Tooling***
• CAD-model verification (design specification) • Visualizing objects • Proof of concept • Marketing and presentation model	• Form and fit-models • Flow analysis • Analysis of stress distribution • Pre-series parts • Diagnostic and pre-surgical operation planning • Design and fabrication of custom protheses and implants	• Tooling mold parts — direct soft tools — indirect soft tools — direct hard tools — indirect hard tools • Casting — sand-casting — investment casting — evaporative pattern casting — die casting • EDM electrodes • Master models

APPLICATIONS IN FINISHING PROCESS

7.2.1 Cutting Processes

In most cases, the resins or other materials used in the RP systems can be subjected to traditional cutting processes, such as milling, boring, turning, and grinding.

These processes are particularly useful for the following:

(1) Deviations in geometrical measurements or tolerances due to unpredictable shrinkage during the curing or bonding stages of the RP process.
(2) Incomplete generation of selected form features. This could be due to fine or complex-shaped features.
(3) Clean removal of necessary support structures or other remainder materials attaching to the RP parts.

7.2.2 Sand-Blasting and Polishing

Sand blasting or abrasive jet deburring can be used as an additional cleaning operation or process to achieve better surface quality. However, there is a trade-off in terms of accuracy. Should better finishing be required, additional polishing by mechanical means with super-fine abrasives can also be used after sandblasting.

7.2.3 Coating

Coating with appropriate surface coatings can be used to further improve the physical properties of the surface of plastic RP parts. One example is galvano-coating, a coating which provides very thin metallic layers to plastic RP parts.

7.2.4 Painting

Painting is applied fairly easily on RP parts made of plastics or paper. It is carried out mainly to improve the aesthetic appeal or for presentation purposes, e.g., for marketing or advertising presentations.

APPLICATIONS IN DESIGN

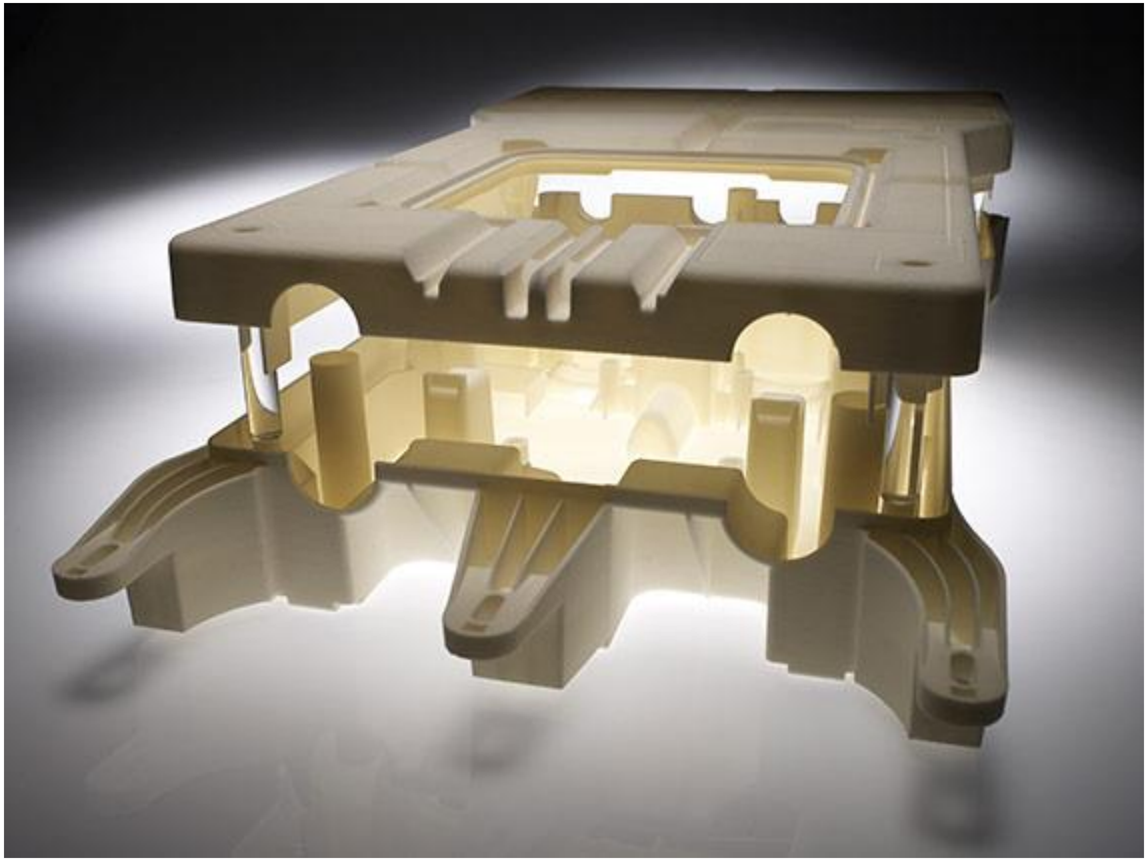
- Visualizing Objects
- CAD Model Verification
- Proof of Concept
- Marketing and Commercial Applications

APPLICATIONS IN ENGINEERING, ANALYSIS AND PLANNING

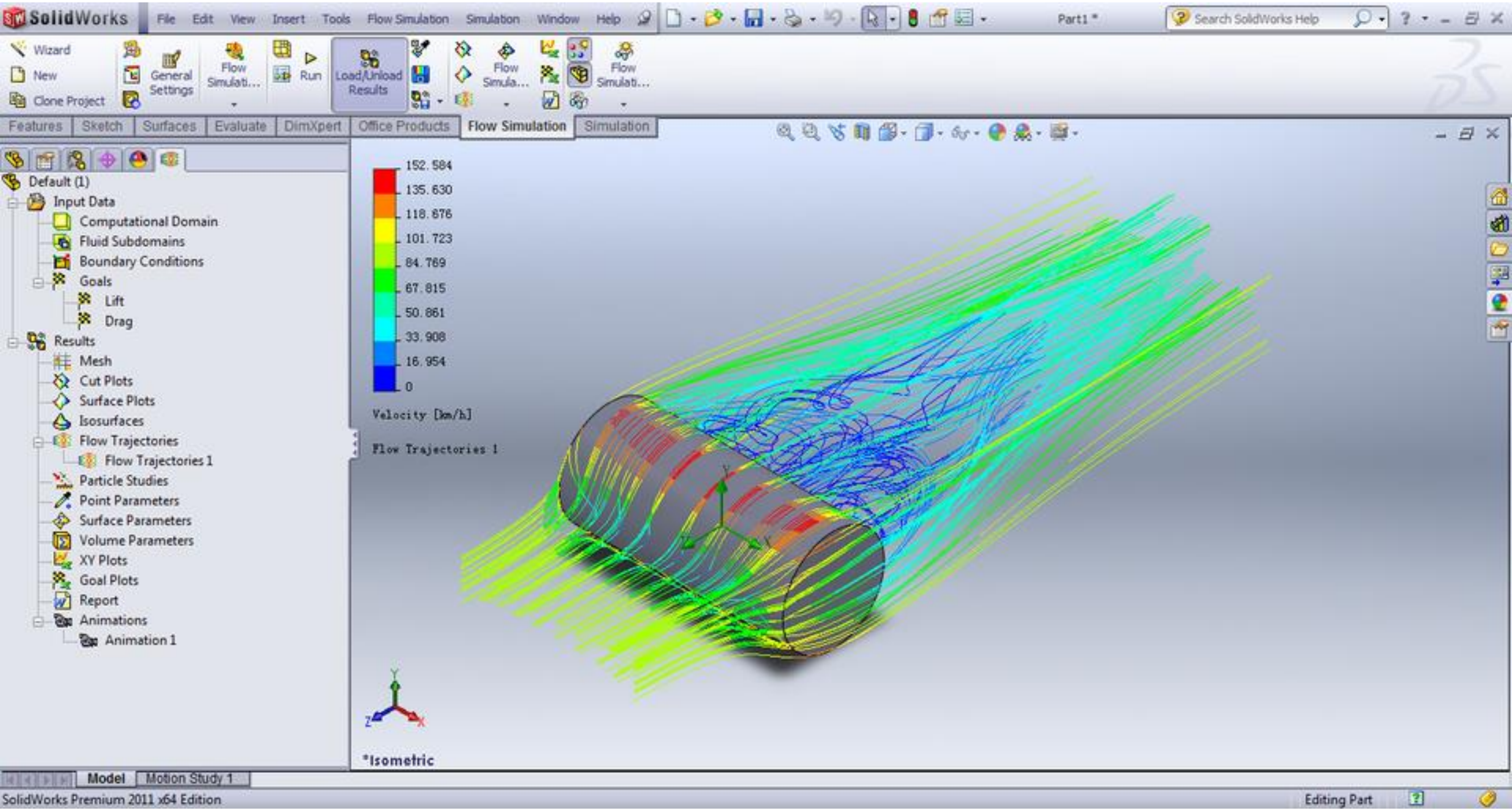
- Scaling
- Form and Fit
- Flow Analysis
- Stress Analysis
- Mock-Up Parts
- Pre-Production Parts
- Diagnostic and Surgical Operation Planning
- Design and Fabrication of Custom Prosthesis and Implant

Figure 7.2: Perfume bottles with different capacity

Form Fit & Function Prototypes



Form-Fit-Function Printing Solution



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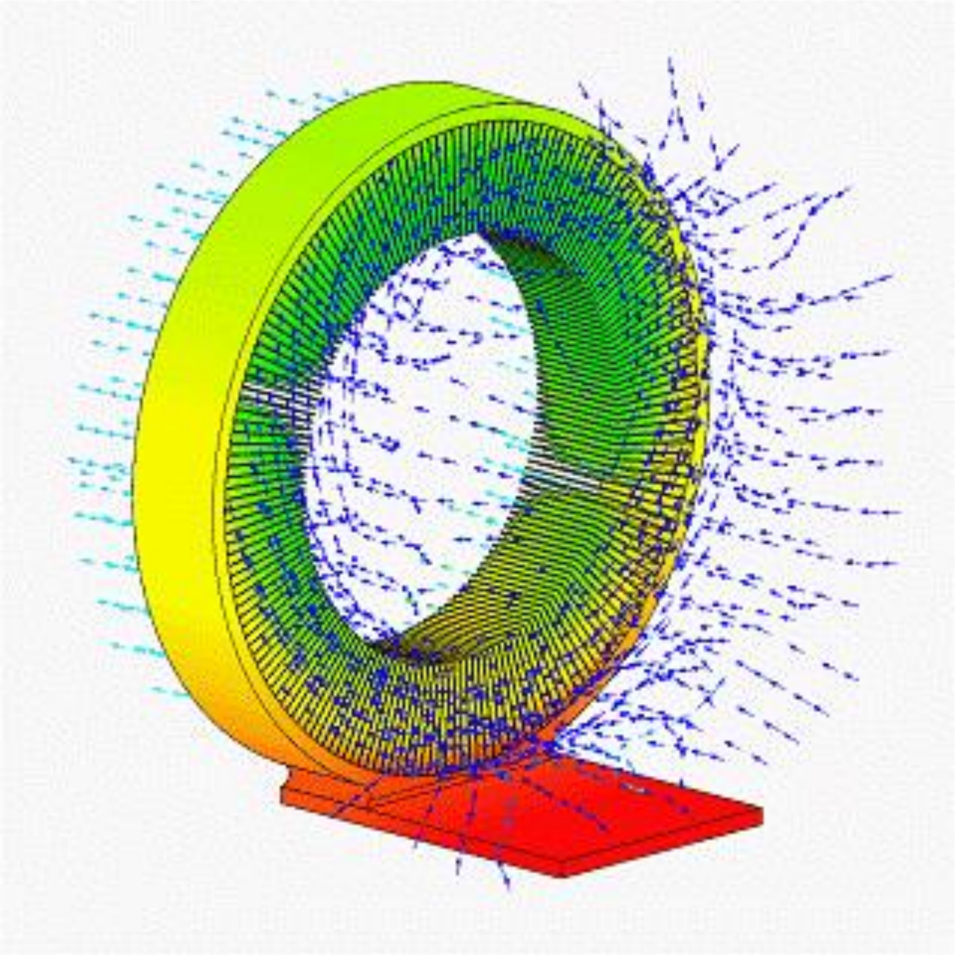

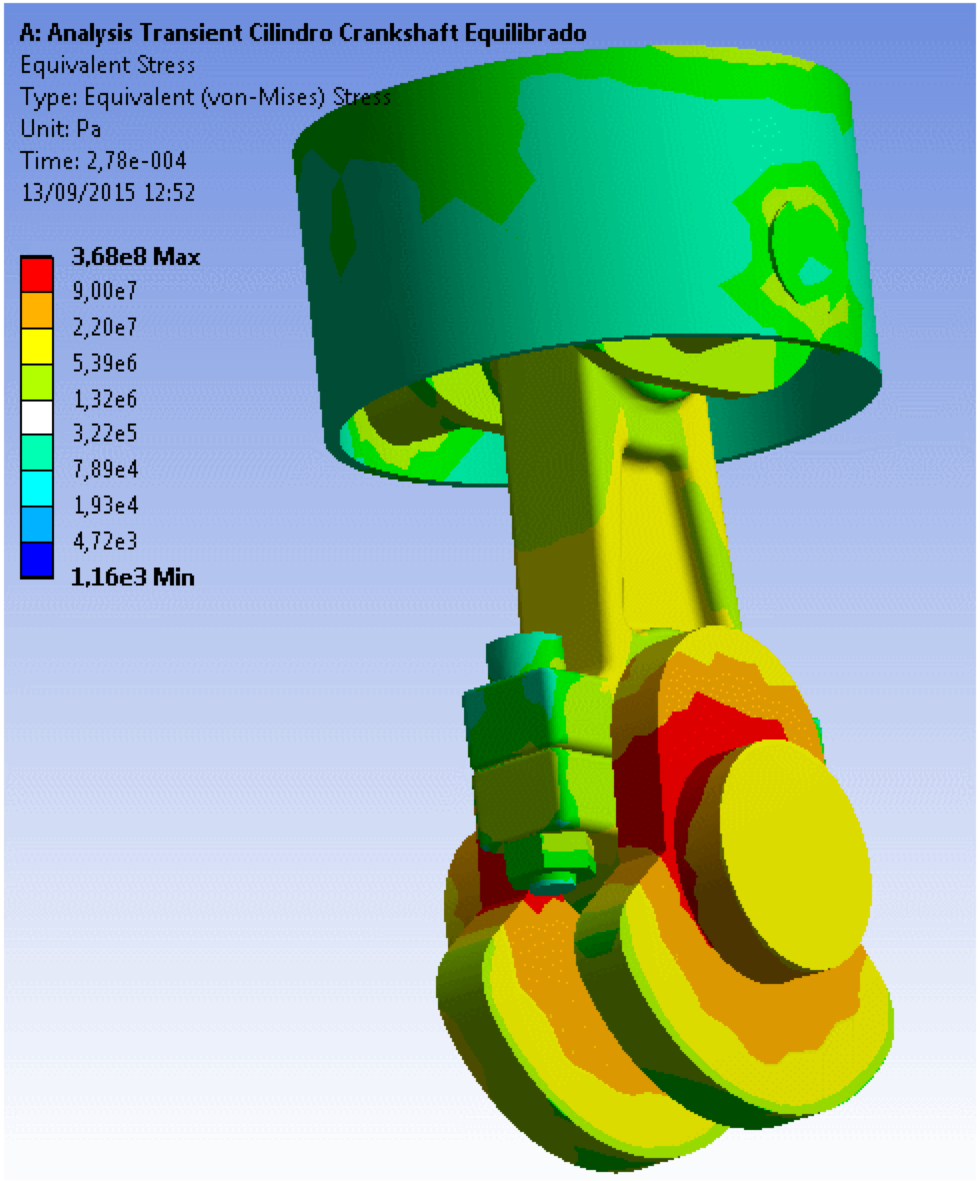
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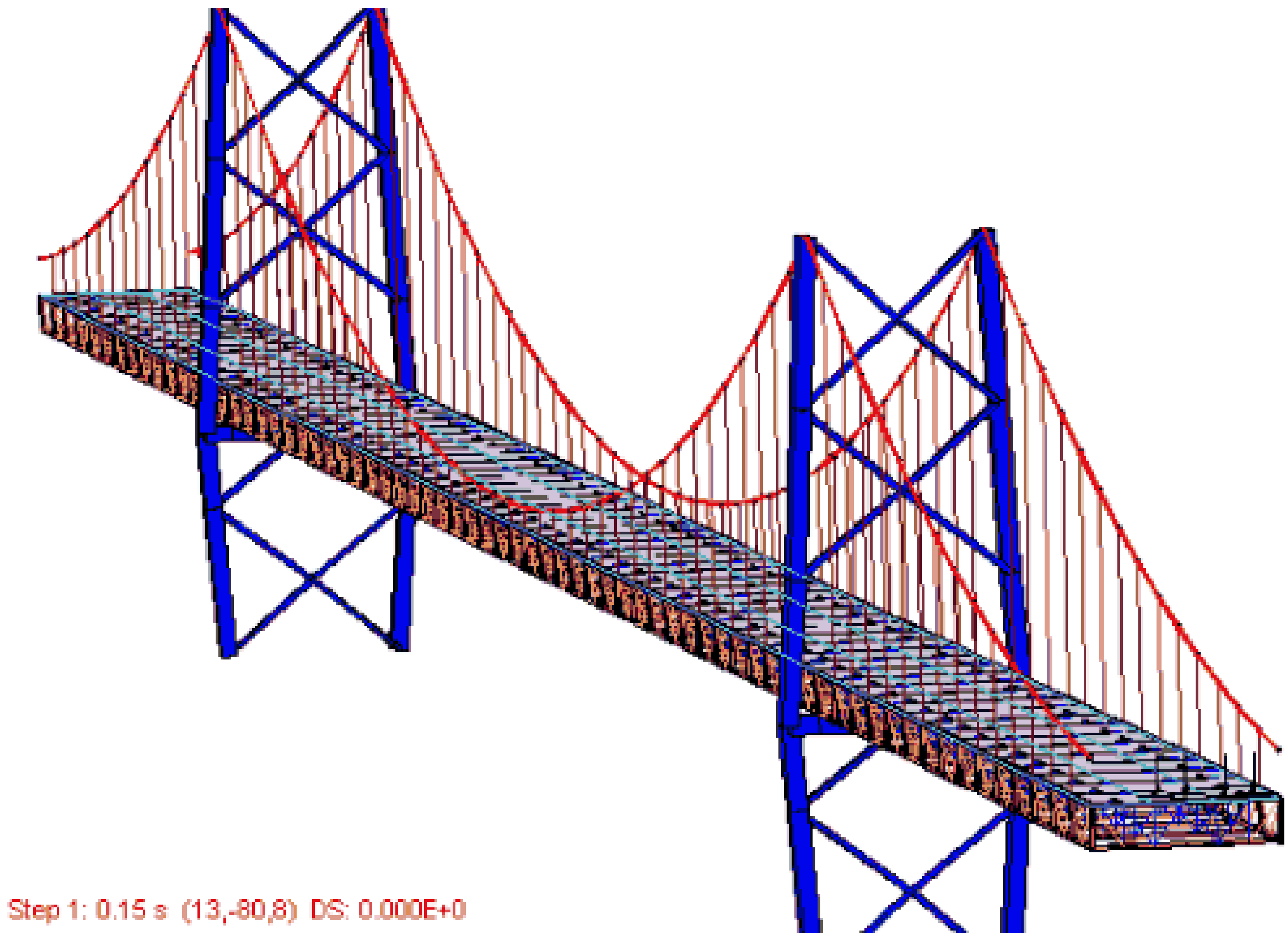
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China Mock up Prototying

2.5L Plastic Bucket Mockup in Bucket

APPLICATIONS IN MANUFACTURING AND TOOLING

- Rapid tooling is the ability to produce multiple copies of a prototype with functional material properties in short lead times.
- The material can also include functionalities such as color dyes, transparency, flexibility

- Rapid tooling can be classified into

soft or hard, and direct or indirect tooling

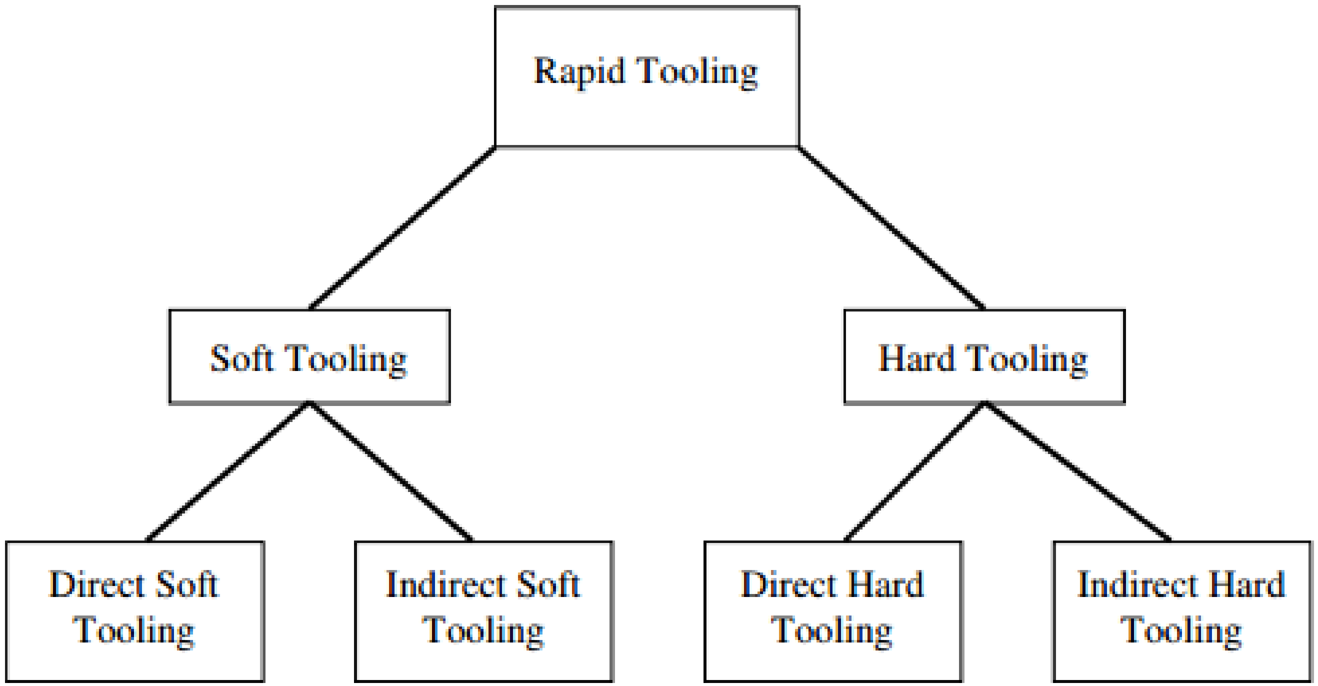


Figure 7.3: Classification of rapid tooling

Direct Soft Tooling

- This is where the molding tool is produced directly by the RP systems.
- Such tooling can be used for liquid metal sand casting, in which the mold is destroyed after a single cast.
- Other examples, such as composite molds, can be made directly using steoreolithography.
- These are generally used in the injection molding of plastic components and can withstand up to between 100 to 1000 shots
- molding tools can typically only support a single cast or small batch production run before breaking down, they are classified as soft tooling.

Selective Laser Sintering® of Sand Casting Molds

Indirect Soft Tooling

- In this rapid tooling method, a master pattern is first produced using RP.
- From the master pattern, a mold tooling can be built out of an array of materials such as silicon rubber, epoxy resin, low melting point metals, and ceramics.

Example
Arc Spray Metal Tooling
Silicon Rubber Molds
Spin Casting with Vulcanized Rubber Molds

Direct Hard Tooling

The advantages of hard tooling produced by RP methods are fast . Less times to create highly complex-shaped mold tooling for high volume production

Laminated Metal Tooling
Direct Metal Laser Sintering (DMLS) Tooling

Indirect Hard Tooling

Processes include the Rapid Solidification Process (RSP)

Indirect methods for producing hard tools for plastic injection molding generally make use of casting of liquid metals or steel powders in a binder system.

Copy Milling

AEROSPACE INDUSTRY

There are abundant examples of the use of RP technology in the aerospace industry. The following are a few examples.

Design Verification of an Airline Electrical Generator

Sundstrand Aerospace, which manufactures inline electrical generators for military and commercial aircraft, needed to verify its design of an integrated drive generator for a large jetliner.

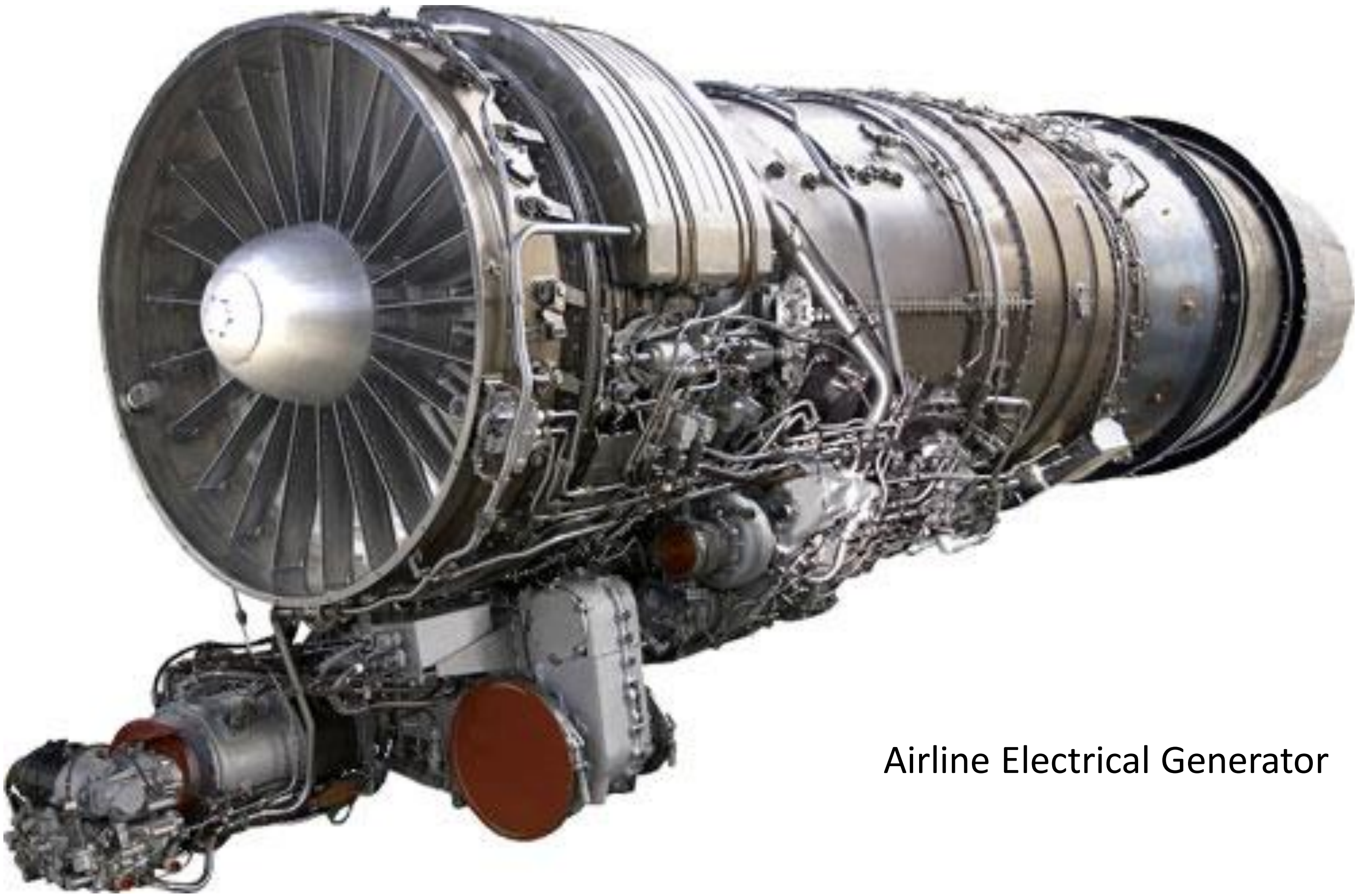
It decided to use LOM to create the design-verification model.

Engine Components for Fanjet Engine

In an effort to reduce the developmental time of a new engine, AlliedSignal Aerospace used 3D Systems' QuickCast™ to produce a turbofan jet engine for a business aviation jet.

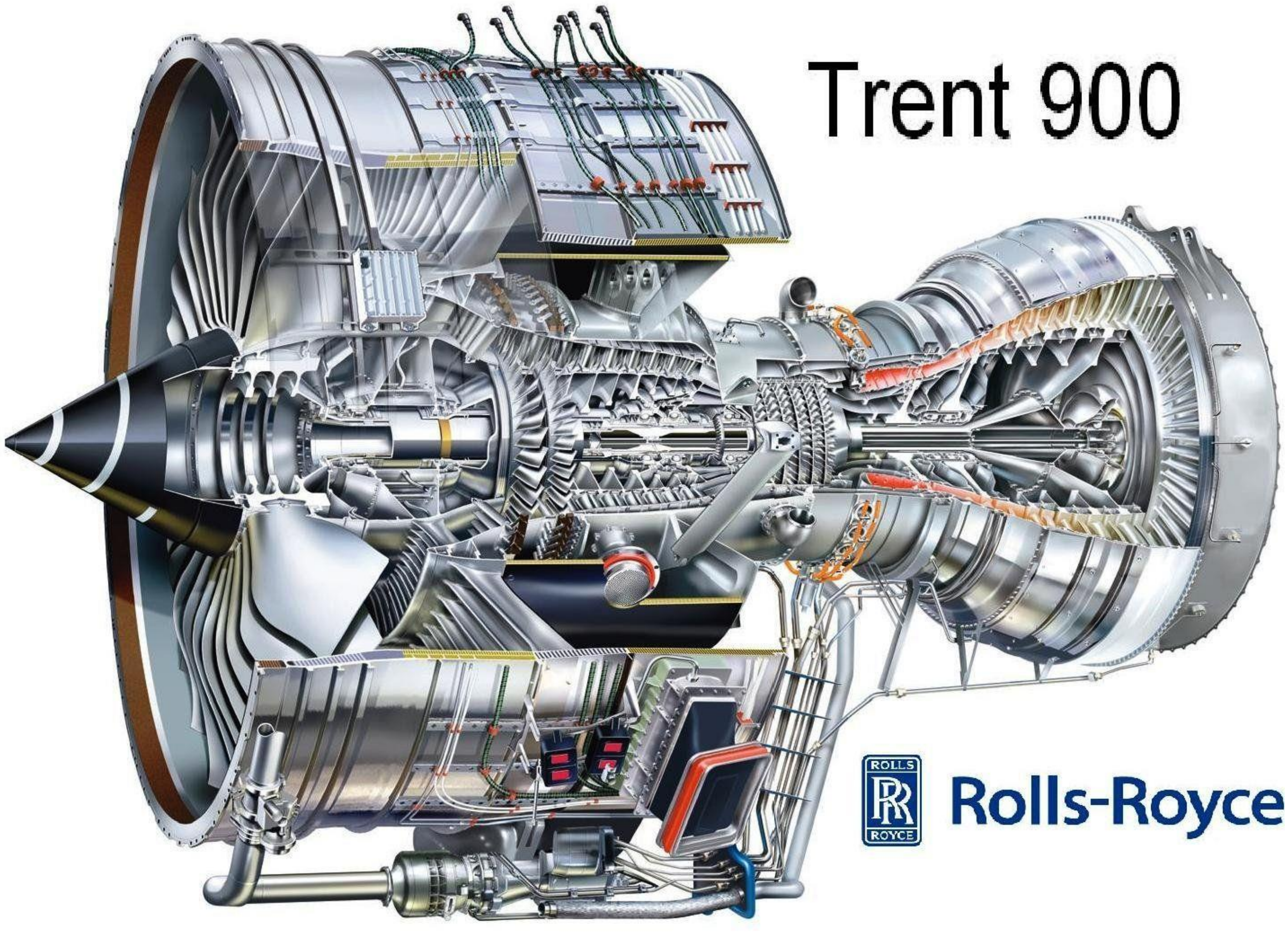
Prototyping Air Inlet Housing for Gas Turbine Engine

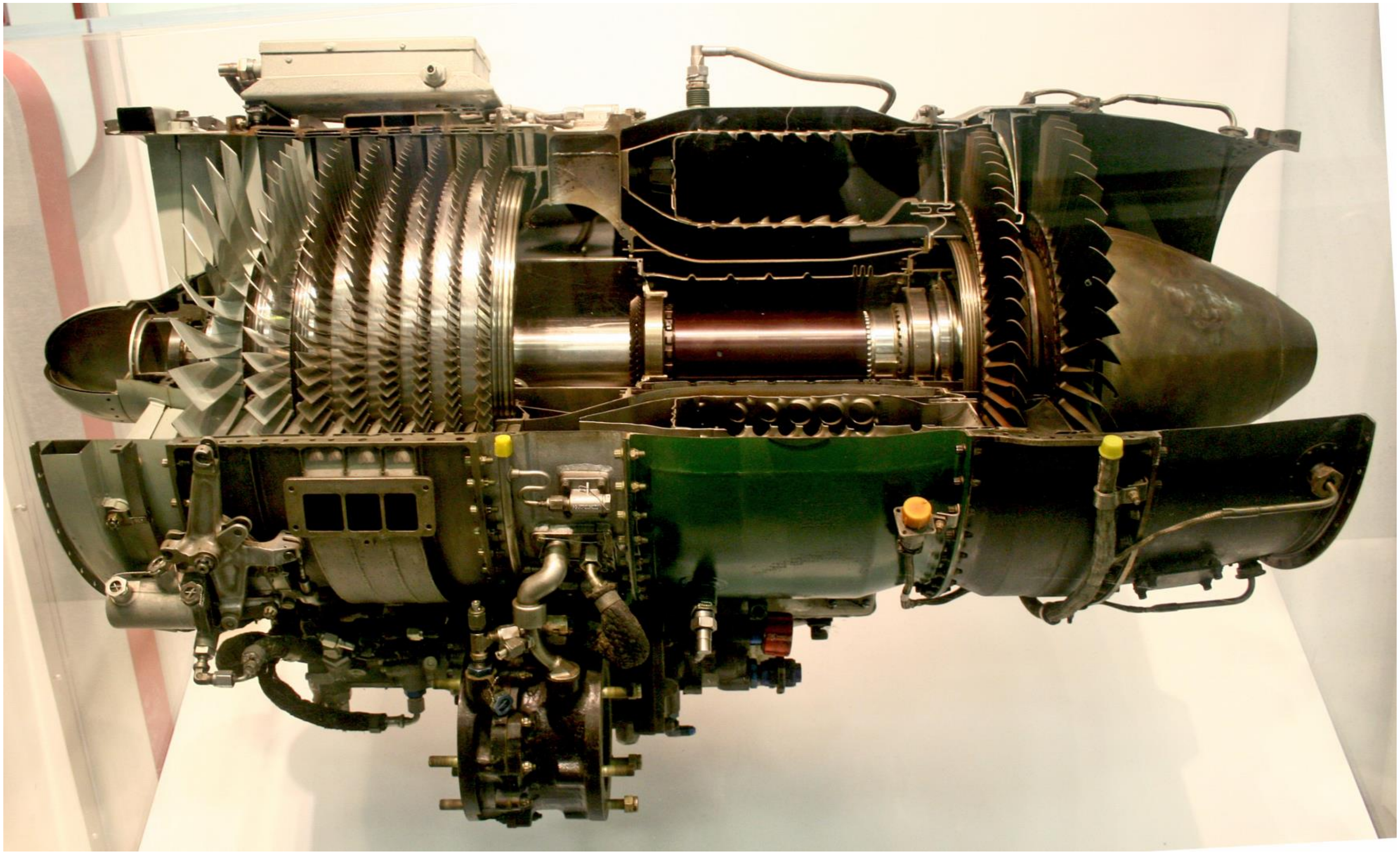
Sundstrand used DTM's SLS®system at a service bureau to build the evaluation models of the housing and then generate the necessary patterns for investment casting, ultimately the method used for the manufacture.



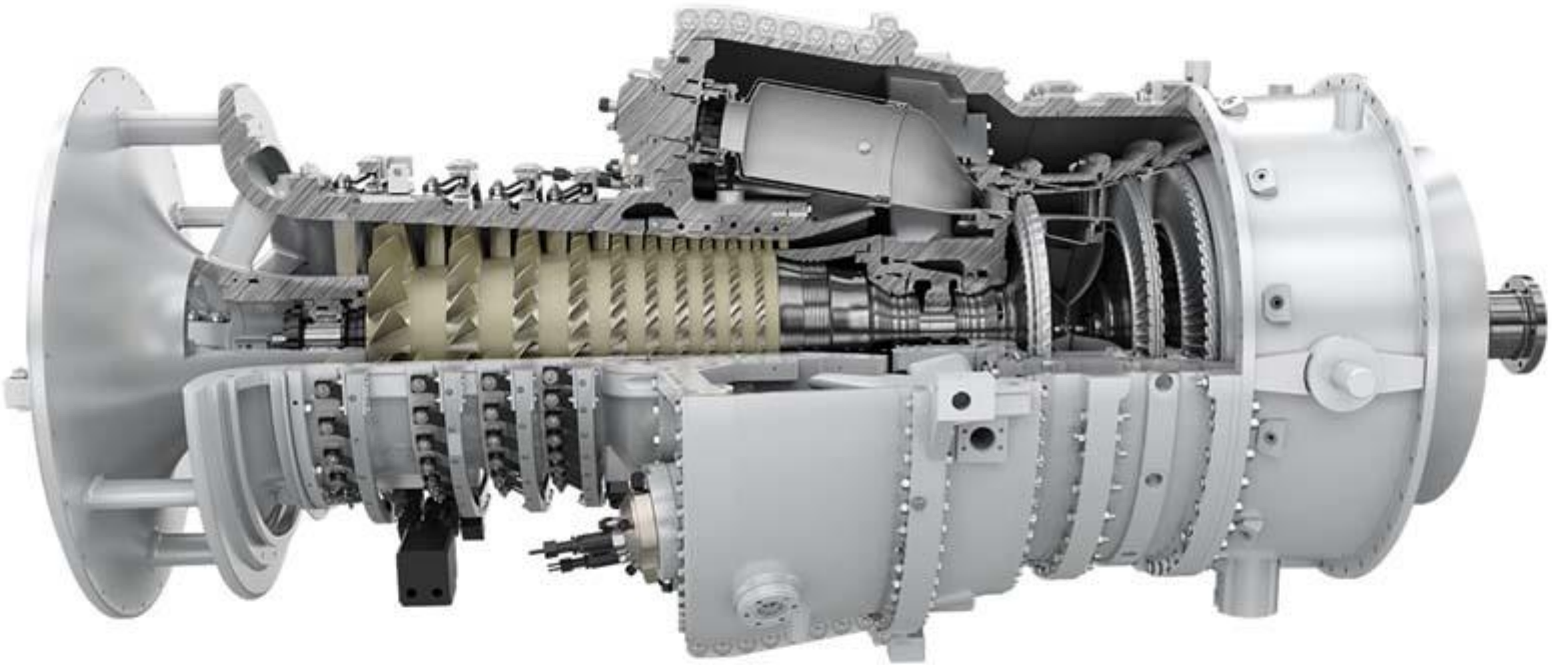
Airline Electrical Generator

Rolls-Royce Trent 900 | turbo-jet/fan





JET FAN



GAS TURBINES

AERODERIVATIVE GAS TURBINES

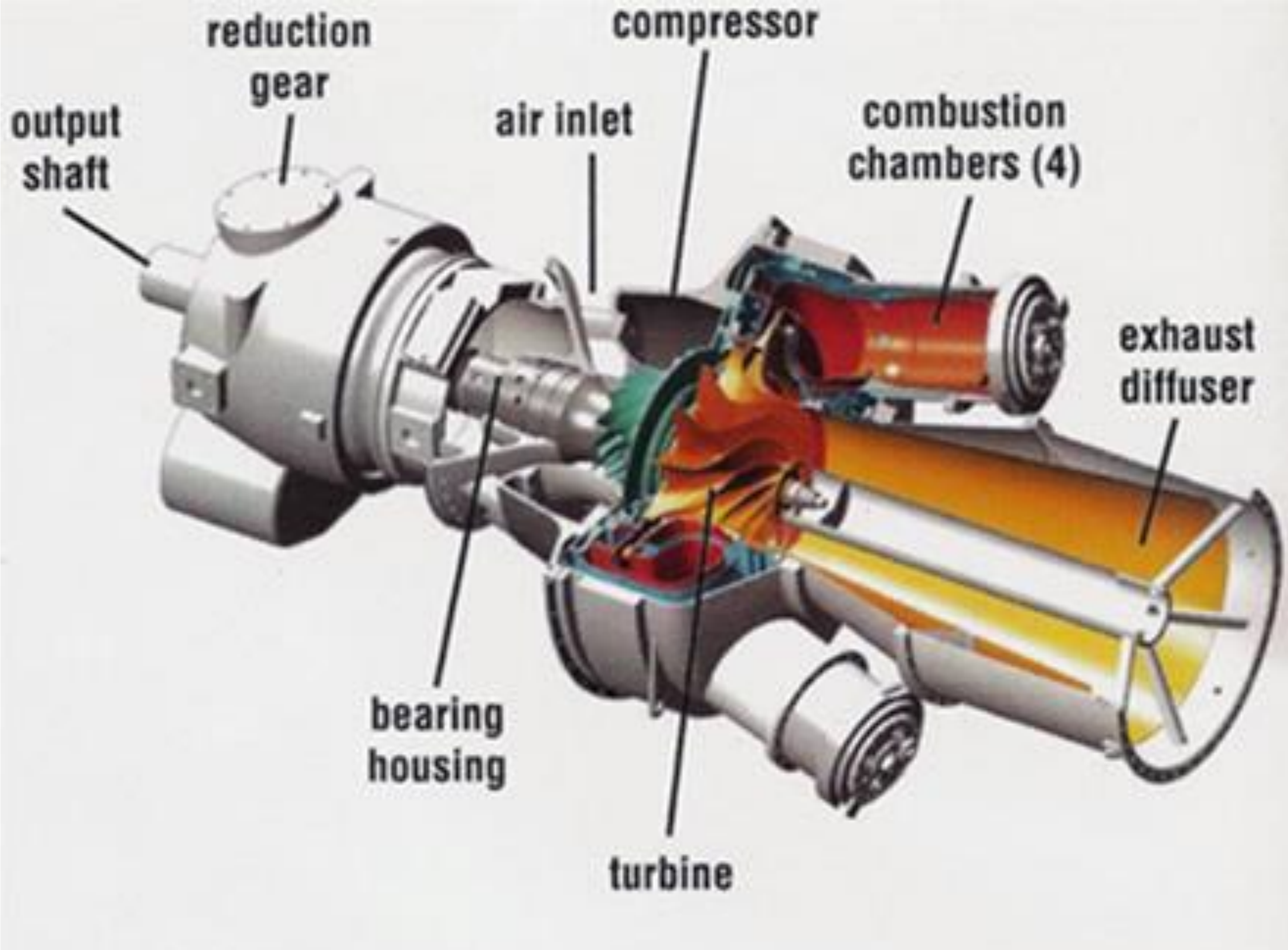


Figure 1. The OP16-3 gas turbine engine

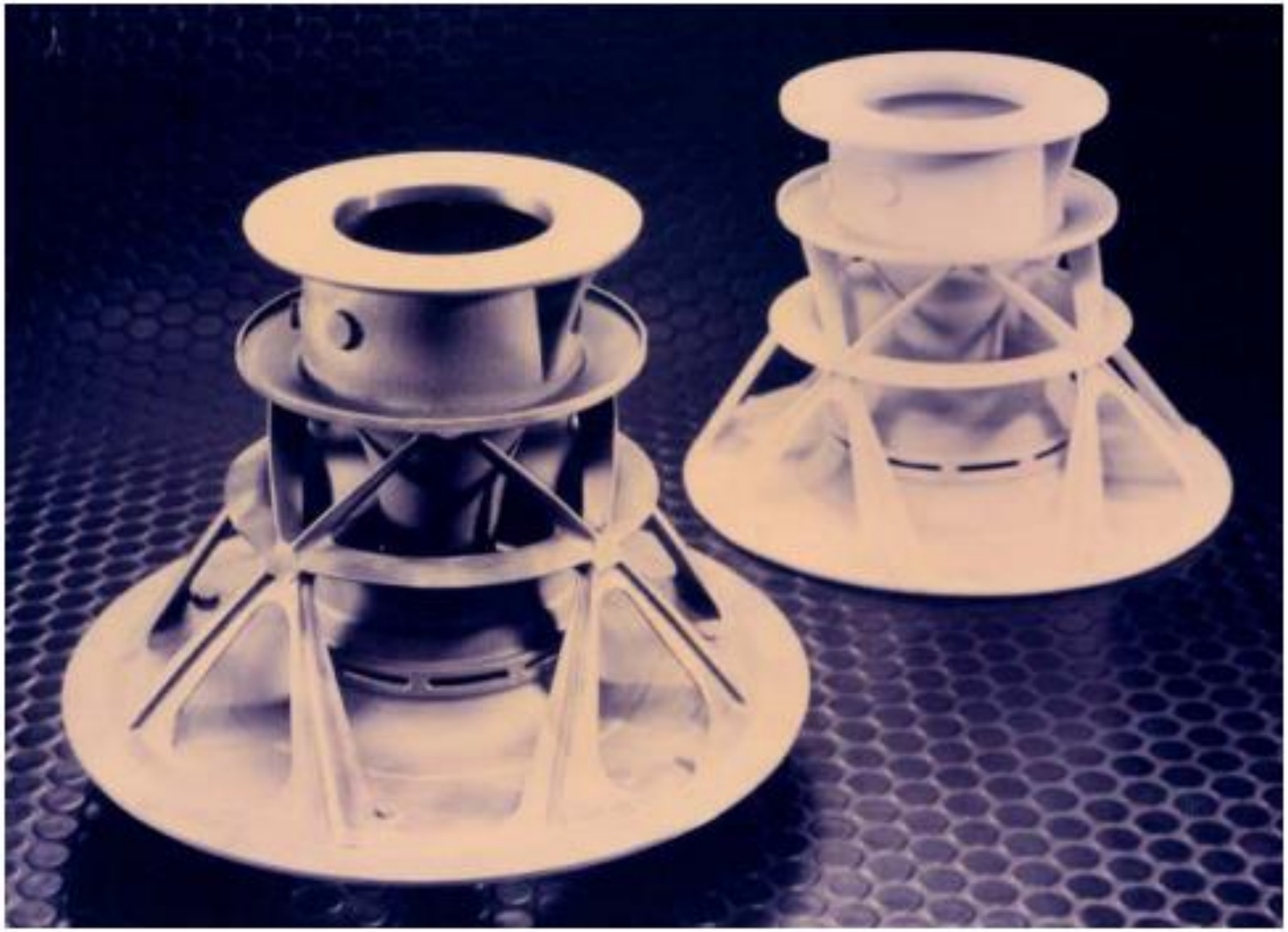


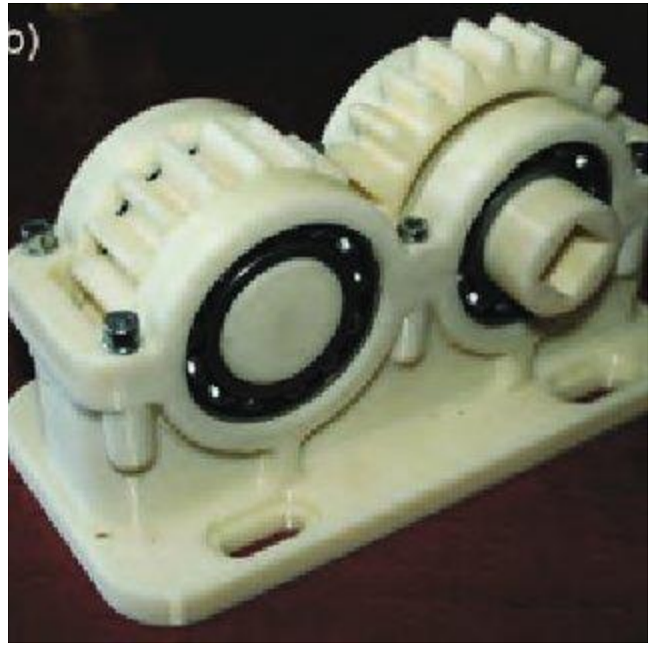
Figure 7.10: Polycarbonate investment-casting pattern (right) and the steel air inlet housing (right) for a jet turbine engine (Courtesy DTM Corporation)

AUTOMOTIVE INDUSTRY

Prototyping Complex Gearbox Housing for Design Verification
Volkswagen has utilized Helysis's LOM to speed up the development of a large, complex gearbox housing for its Golf and Passat car lines.
VW wanted to build a LOM part to check the design of the CAD model and then use the part for packaging studies.

Prototyping Advanced Driver Control System with Stereolithography
The SLA models generated on 3D Systems. Designed to blend an advanced Audio System, a hands-free cellular phone, Global Positioning System (GPS) navigation, Radio Data System (RDS)

Creating Cast Metal Engine Block with RP Process
The Mercedes-Benz Division of Daimler-Benz AG initiated a program of physical design verification on prototype engines using SLA parts for initial form and fit testing.
Their first project was the design and prototyping of a four-cylinder engine block for the new Mercedes-Benz "A-Class"car

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AUTOMOTIVE INDUSTRY

Using Stereolithography to Produce Production Tooling

Ford first built the SLA model of the cover and fit it over the wiper motor to verify the design

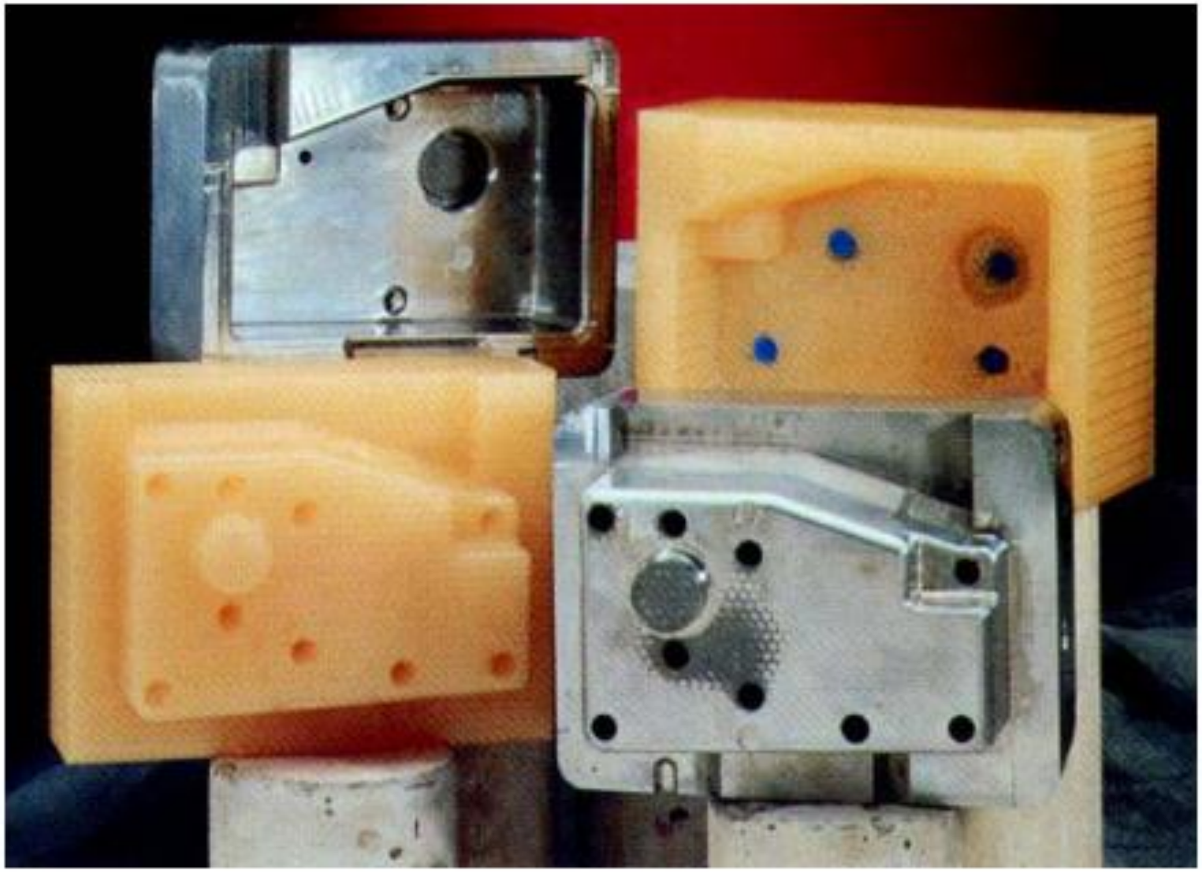


Figure 7.11: QuickCast™ generated patterns and the investment cast inserts for the rear wiper-motor cover

BIOMEDICAL INDUSTRY

Operation Planning for Cancerous Brain Tumor Surgery

The plastic RP model used by the surgeon was fabricated by the SLA from a series of 2D CT scans of the patient's skull.

This case study is an excellent example of the potential impact of rapid prototyping in the medical arena.

- Before proceeding with the surgery, the surgeon wanted another examination of the tumor location,
- But this time using a three-dimensional plastic replica of the patient's skull. By studying the model, the surgeon realized that he could re-route his entry through the patient's jawbone, thus avoiding the risk of harming the eye and motor functions.
- Eventually, the patient lost only one tooth and of course, the tumor.

Planning Reconstructive Surgery with RP Technology

Due to a traffic accident, a patient had a serious bone fracture on the upper and lateral orbital rim in the skull.

In the first reconstructive surgery, the damaged part of the skull was transplanted with the shoulder bone, but shortly after the surgery, the transplanted bone had dissolved.

Using rapid prototyping, a SLA prototype of the patient's skull was made and then used to prepare an artificial bone that would fit the hole caused by the dissolution.

This preparation not only greatly reduced the time required for the surgery, but also improved its accuracy.

Craniofacial Reconstructive Surgery Planning

Restoration of facial anatomy is required in cases of congenital abnormalities, trauma or post cancer reconstruction.

The patient had a deformed jaw by birth, and a surgical operation was necessary to amputate the shorter side of the jaw and change its position

The difficult part of the operation was the evasion of the nerve canal that runs inside the jawbone.

Such an operation was impossible in the conventional procedure because there was no way to visualize the inner nerve canal.

CAD model reconstructed from the CT images, it clearly showed the position of the canal and simulation of the amputating process on workstations was a good support for surgeons to determine the actual amputation line.

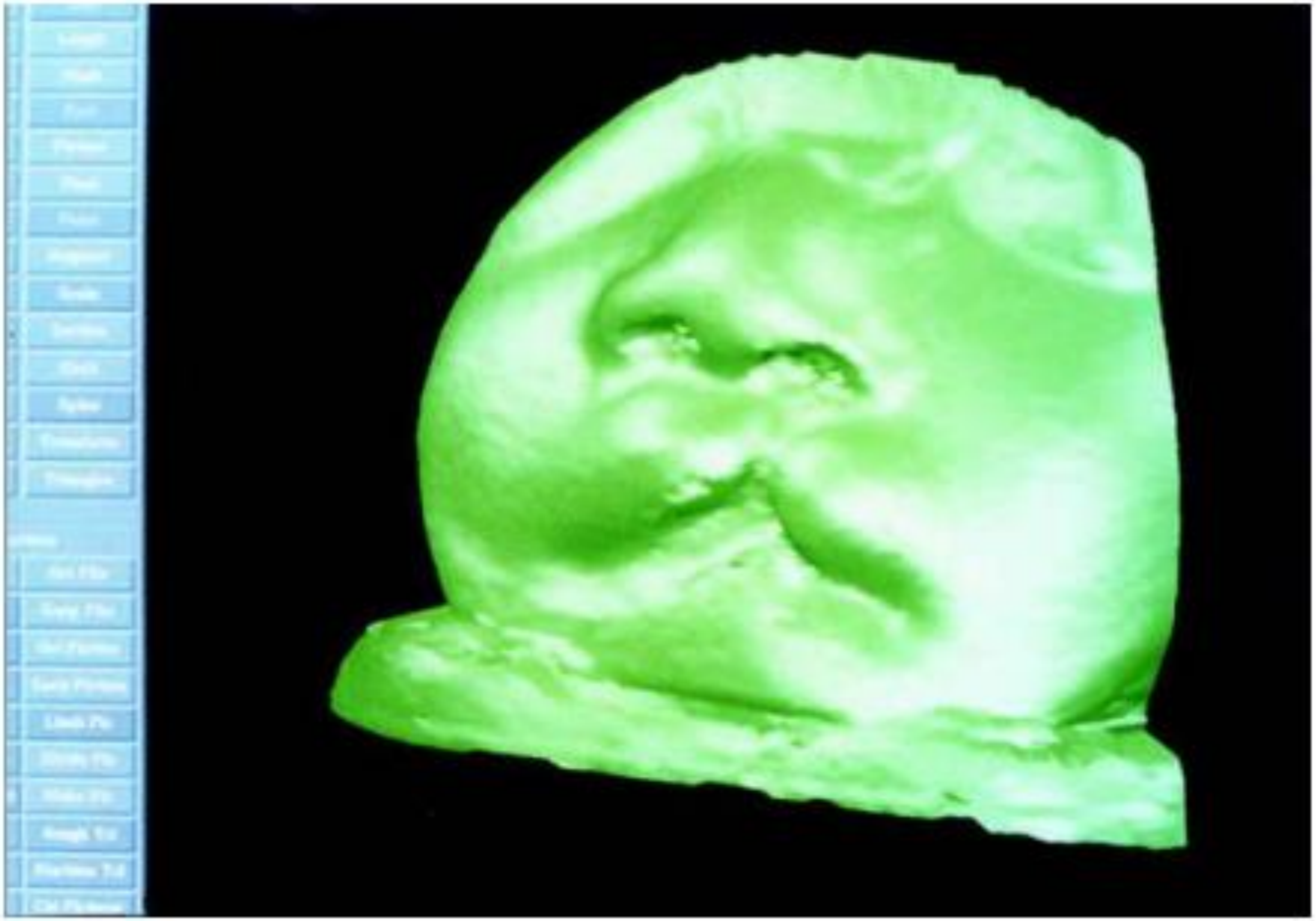


Figure 7.12: CAD model from laser scanner data of a patient's facial details

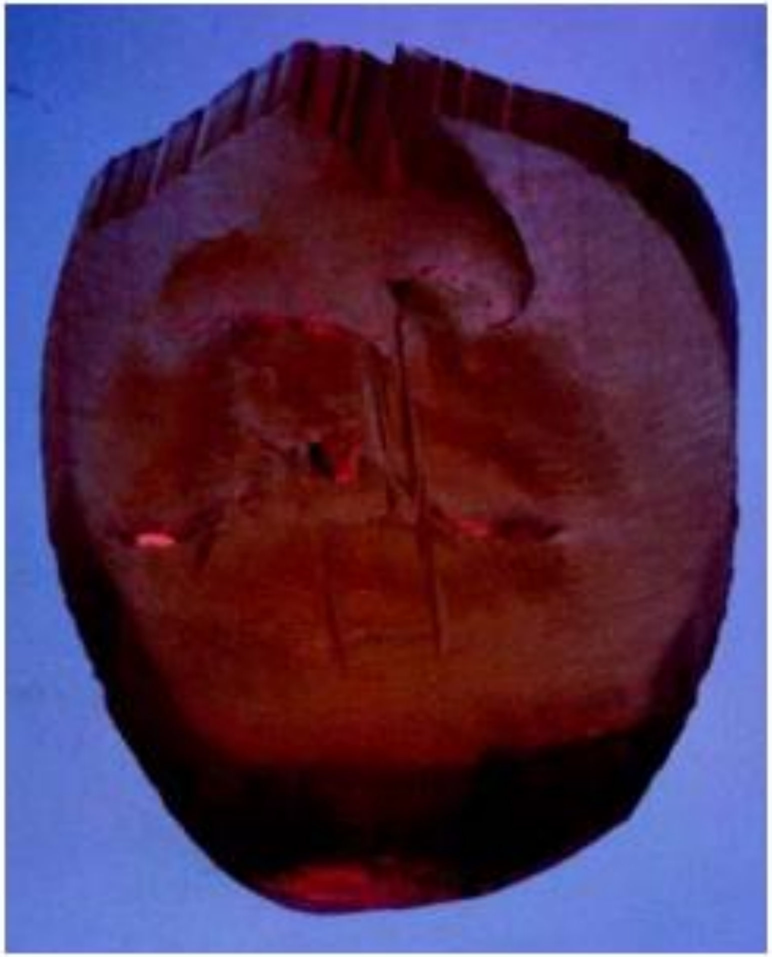
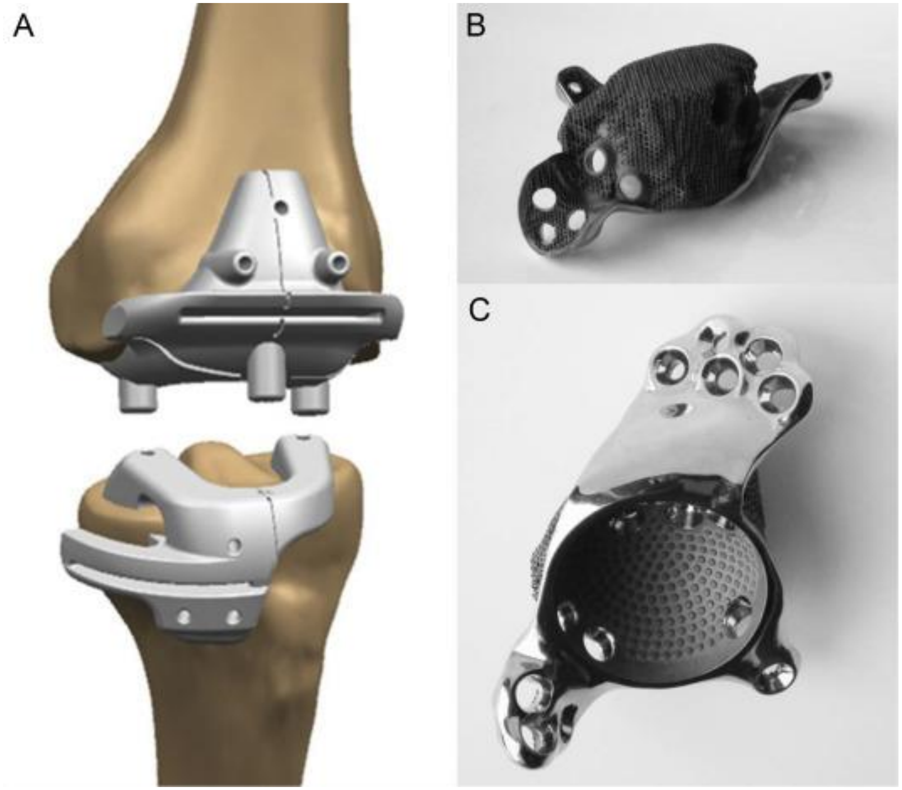


Figure 7.13: SLA model of a patient's facial details

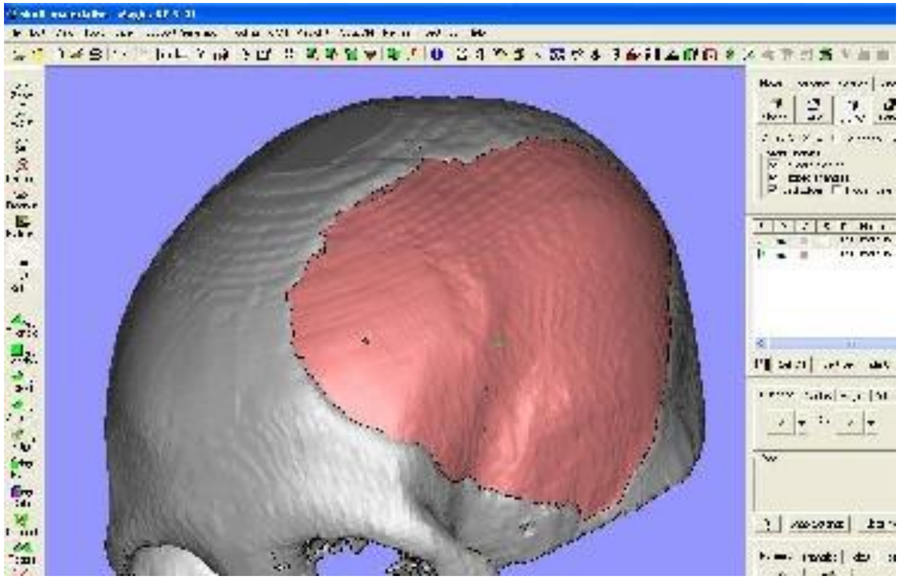
Knee Implants

Engineers at DePuy Inc., a supplier of orthopedic implants, have integrated CAD and RP into their design environment, using it to analyze the potential fit of implants in a specific patient and then modifying the implant design appropriately

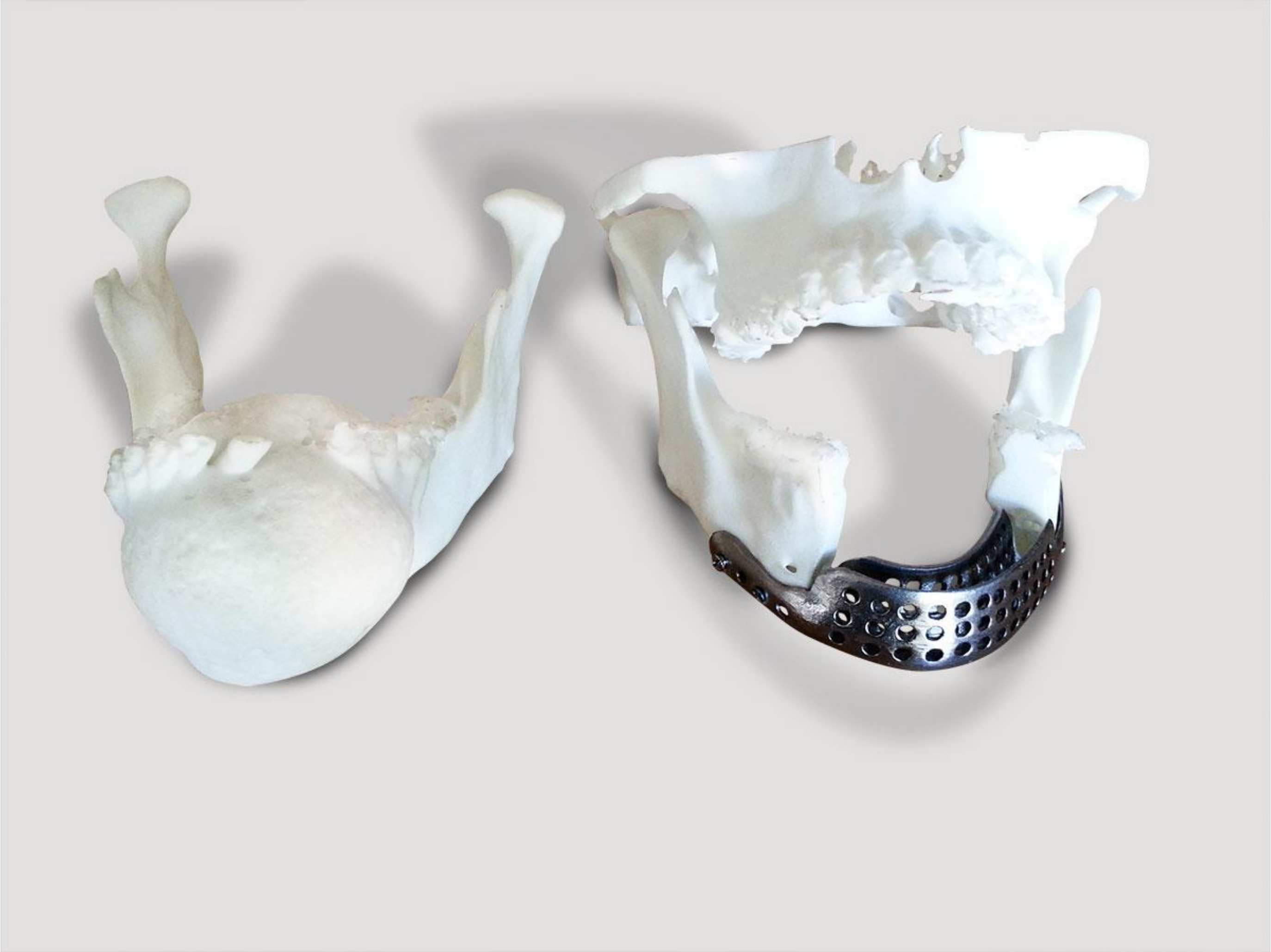
SLA plays a major role in the production process of all the company's products, standard and custom.



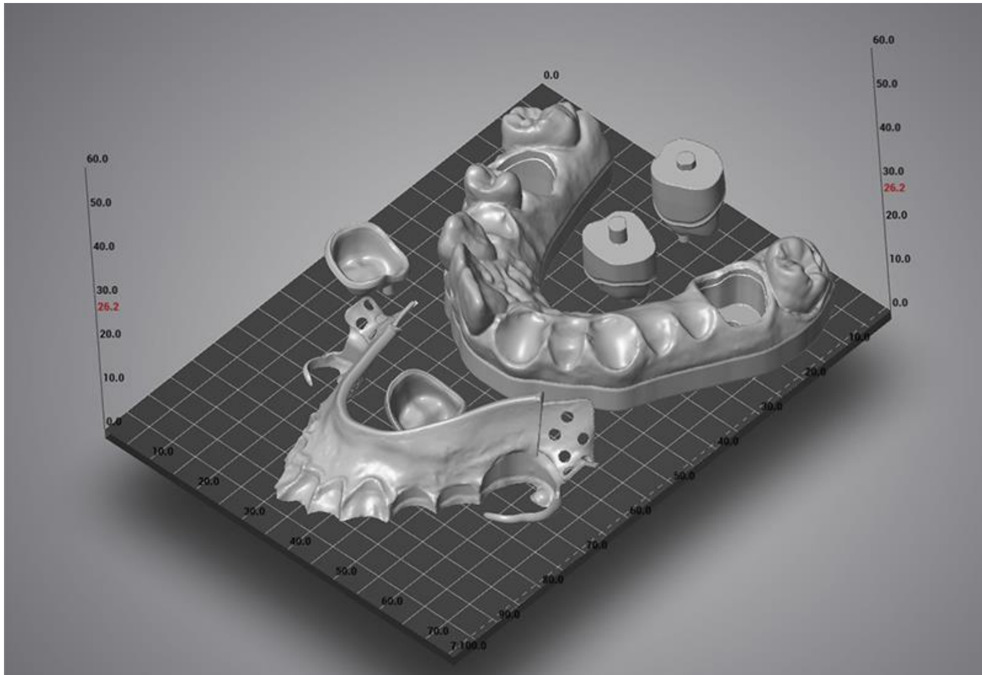


Rapid Prototyping



Mandibular implant



[3D printed shoulder bone]

JEWELRY INDUSTRY

The jewelry industry has traditionally been regarded as one which is heavily craft-based, and automation is generally restricted to the use of machines in the various individual stages of jewelry manufacturing.

In an experimental computer-aided jewelry design and manufacturing system jointly developed by Nanyang Technological University and Gintic Institute of Manufacturing Technology in Singapore.

The SLA (from 3D Systems) was used successfully to create fine jewelry model.

In an experiment with the design of rings, the overall quality of the SLA models were found to be promising, especially in the generation of intricate details in the design.

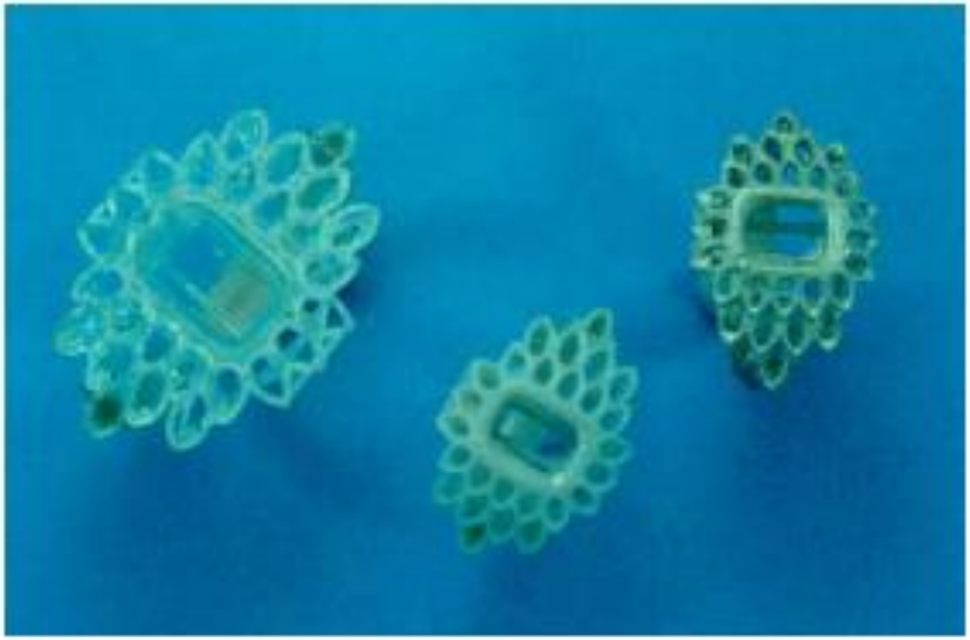


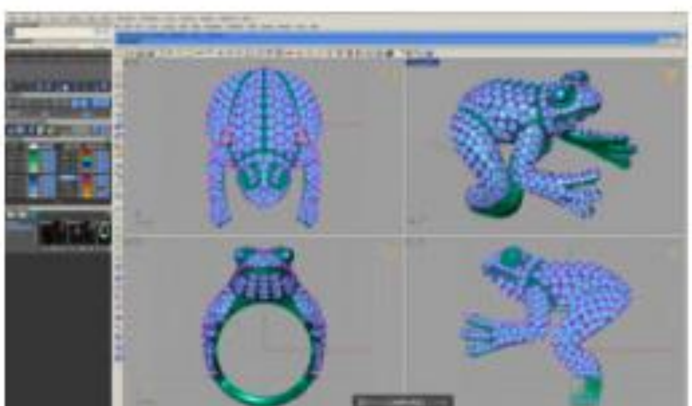
Figure 7.16: An investment cast silver alloy prototype of a broach (right), the full-scale wax pattern produced from the silicon rubber molding (center), and the two-time scaled SLA model to aid visualization (left)

Silver Jewellery Manufacturer

Step #1: Design

Step #2: Sourcing stones, silver

Step #3: Computer Aided Designing



Step #4: Rapid Prototype

Step #5: Model Making

Step #6: Rubber Mold

Step #7: Waxing process

Step #8: Casting

Step #9: Grinding

Step #10: Filing and Assembly

Step #11: Polishing

Step #12: Stone setting

Step #14: Rhodium plating

Step #15: Quality control

COIN INDUSTRY

The mint industry has traditionally been regarded as very labor-intensive and craft-based.

The SLA (from 3D Systems) was used successfully with a Relief Creation Software to create tools for coin manufacture.

working methodology consists of several steps.

Firstly, 2D artwork is read into ArtCAM, the CAD/CAM system used in the system, utilizing a Sharp JX A4 scanner.

The second step is the generation of surfaces. The shape of a coin is generated to the required size in the CAD system for model building.

The third step is the generation of the relief. In creating the 3D relief, each color in the image is assigned a shape profile.

The fourth step is the wrapping of the 3D relief onto the coin surface. This is done by wrapping the three-dimensional relief onto the triangular mesh file generated from the coin surfaces.

The fifth step is to convert the triangular mesh files into the STL file format. This is to be used for building the RP model. After the conversion, the STL file is sent to the SLA to create the 3D coin pattern which will be used for proofing of design

TABLEWARE INDUSTRY

The tableware industry, CAD and RP technologies are used in a integrated system to create better designs in a faster and more accurate manner.

The general steps involved in the art to part process for the tableware include the following:

(1) Scanning of the 2D artwork.
(2) Generation of surfaces.
(3) Generation of 3D decoration reliefs.
(4) Wrapping of reliefs on surfaces.
(5) Converting triangular mesh files to STL file.
(6) Building of model by the RP system.

SLA advantageous to use in tableware design as the material is translucent thus allowing designers to view the internal structure and details of tableware items like **tea pots and gravy bowls.**

The use of LOM has its own distinct advantages. Its material cost is much lower and because it does not need support in its process (unlike the SLA), it saves a lot of time in both pre-processing (deciding where and what supports to use) and post-processing (removing the supports). Examples of **dinner plates**

- LOM prototype is able to recreate the floral details more accurately.
- The dimensional accuracy is slightly better in the LOM prototype.
- SLA is about 20% faster than the LOM process.

In the ceramic tableware production process, the LOM model can be used directly as a master pattern to produce the block mold. The mold is made of plaster of Paris. The result of this trial is shown in Figure 7.21.

Figure 7.21: Block mold cast from the LOM model of the dinner plate (Courtesy of Oriental Ceramics Sdn. Bhd., Malaysia)

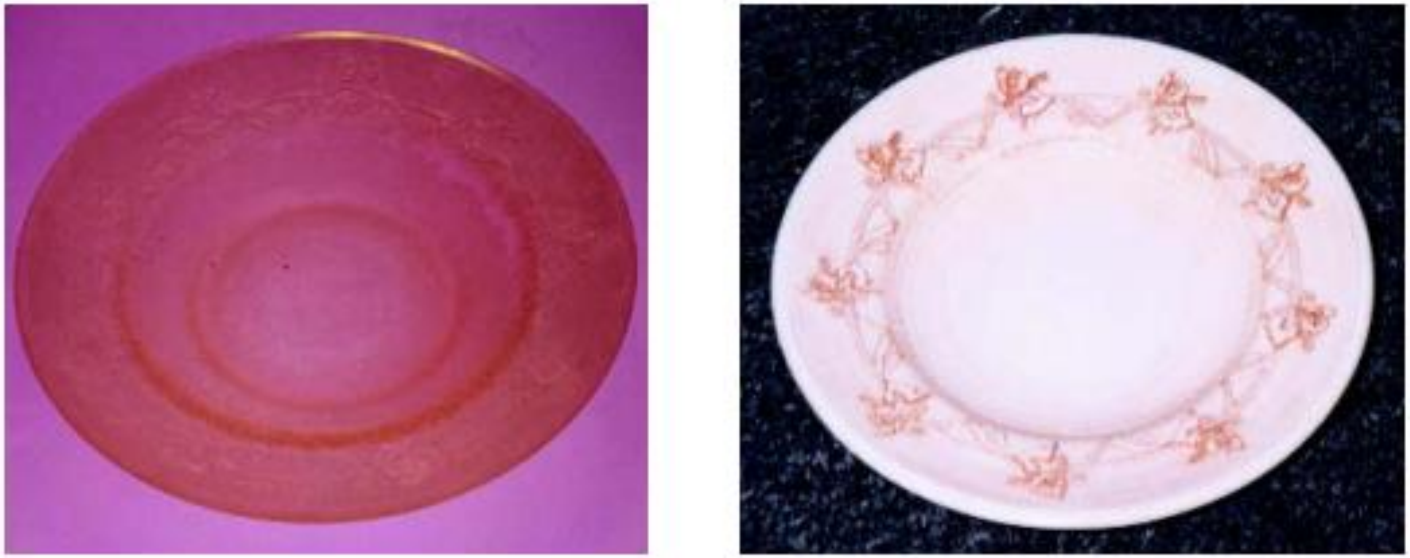


Figure 7.19: Dinner plate prototype built using SLA (left) and LOM (right)

Figure 7.20: LOM model of a tea pot (Courtesy of Champion Machine Tools, Singapore)