

Rapid Prototyping Applications

RP Applications

- Functional prototypes
- Patterns for casting
- Medical models
- Artworks
- Models for engineering analysis

Functional Models

RP process most widely used is SLS

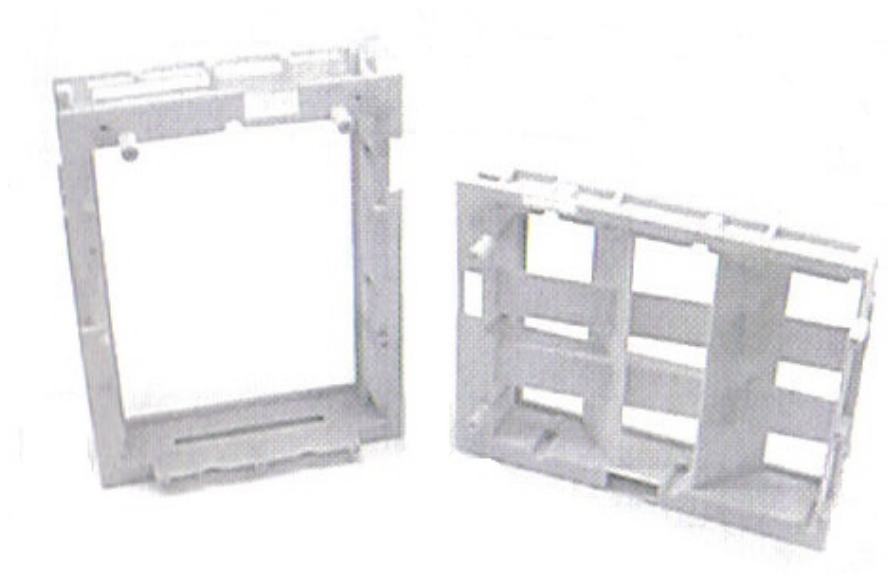
Materials available:

- Initially: Nylon based materials
 - Standard Nylon
 - Fine Nylon
 - Fine Nylon medical grade
 - Nylon composite – Nylon powder/Glass beads (PhotoForm)
 - Generally, cost effective between 1 – 5 parts
- 1999: 2 new materials replaced the Nylons
 - DuraForm PA
 - Glass reinforced DuraForm GF
 - Relatively easy to finish to smooth appearance

Functional Models

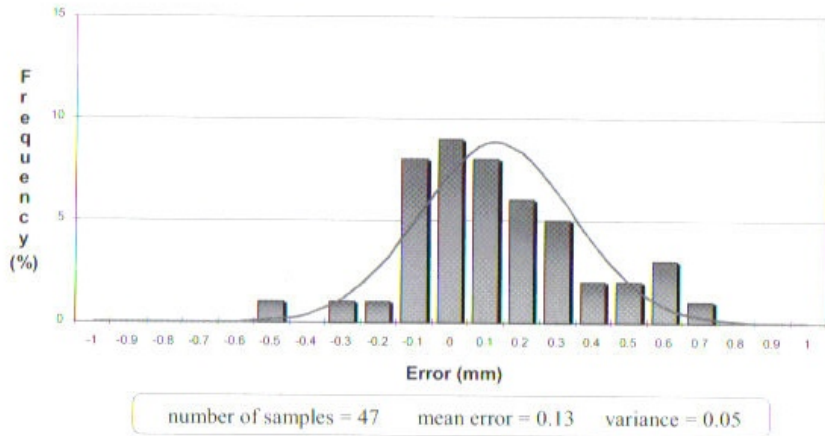
Housing Case Study

- Function - mounting precision components
 - Temps over 100°C
 - Dimensions kept within close limits
- Initial Build
 - Constructed vertically in build area (physical dimensions)
 - Downdraft was used to speed up cooling
 - Part geometry prevented downdrafting
 - Hot-spots within the part caused post-build warping of the walls

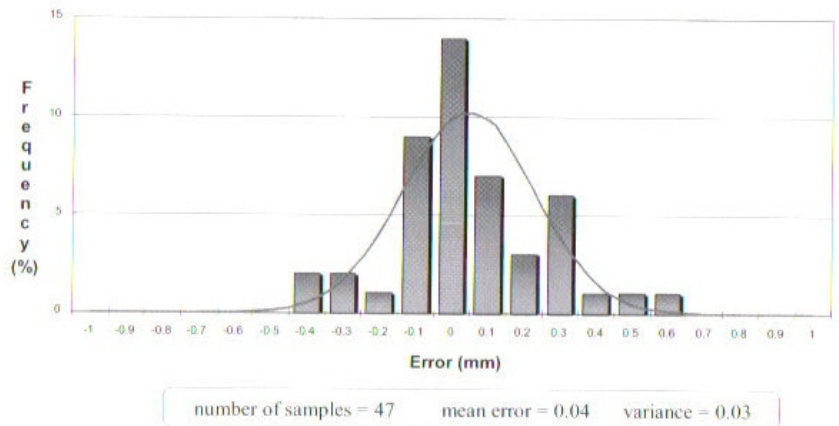


Functional Models

Housing Case Study



- 1st part suffered distortion
 - Wash-out
 - Warping of external walls (1mm variation)
- Amendments
 - Wall thickness was made uniform (2mm)
 - 2 non-functional 2mm ribs were added across the housing to stiffen it
 - Engineers experience was used to determine the quantity, position & size of ribs
 - Extra ribs added to build time
 - Ribs were located so they could be machined off after the build
- Results
 - 2nd part had improved dimensional accuracy



Rapid Prototyping Applications

Patterns for Investment & Vacuum
Casting

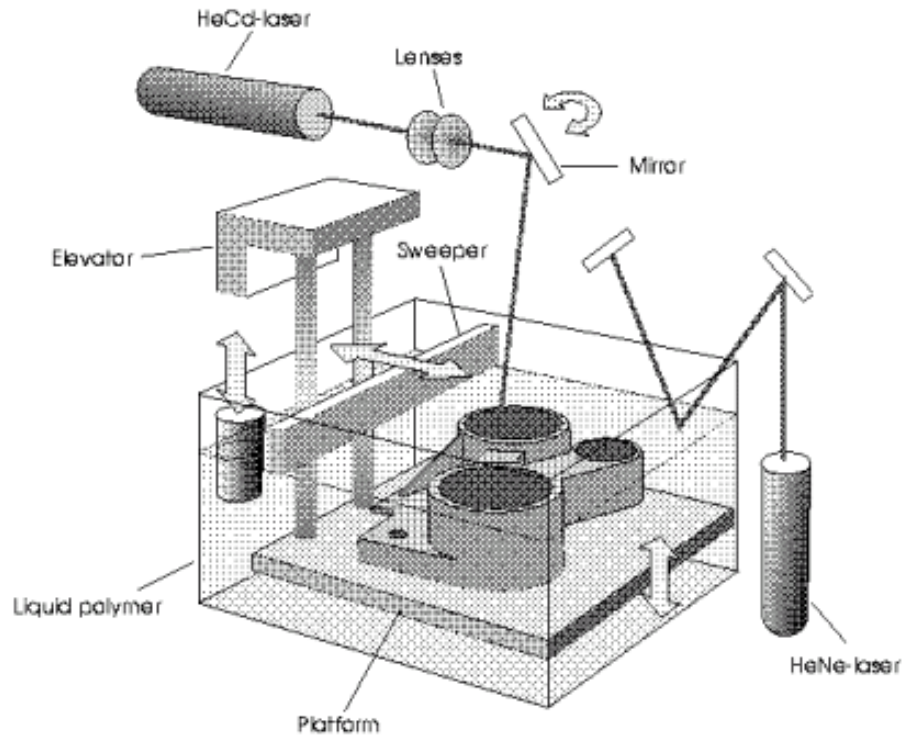
Patterns for Investment & Vacuum Casting

- RP processes used to create patterns
 - SLA
 - SLS
 - CastForm
 - TrueForm
 - acrylic based powder
 - Density ranges from 70% to 90% (build parameters)
 - Dense parts – vacuum casting patterns
 - Porous parts – Investment casting patterns
(reduced expansion /shell cracking during burn out of patterns)
 - Polished to mirror-like surface finish
 - FDM

Stereolithography (SL)

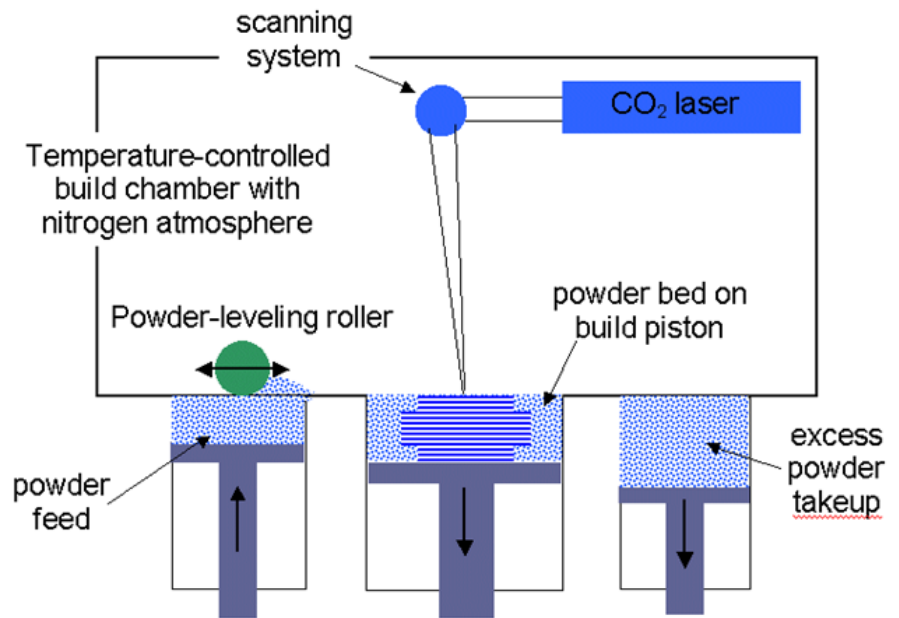
Apparatus Components

- Build platform (substrate)
- Vat (resin)
- UV Helium-Cadmium or Argon ion laser
- Mirror
- Sweep Blade



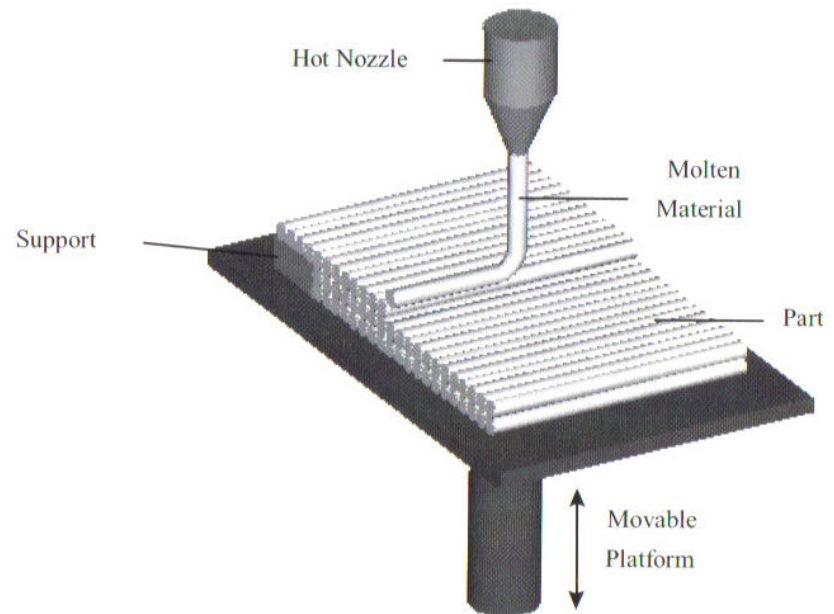
Selective Laser Sintering (SLS)

- Fine powder is heated by a CO₂ laser
- Surface tension of particles is overcome and they fuse together
- Before sintering the entire bed is heated to just below melting point
 - Minimize thermal distortion
 - Facilitates fusing to the previous layer
- Once the layer has been sintered
 - Bed is lowered
 - Powder feed is raised
 - Roller spreads powder evenly

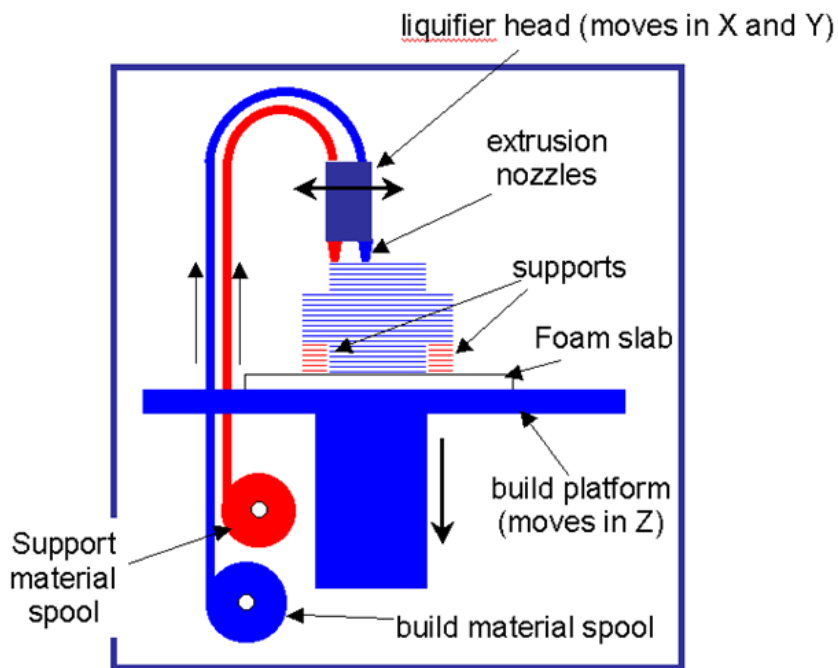


Fused Deposition Modelling (FDM)

- Movable head deposits a thread of molten material onto a substrate
- Build material is heated to 0.5° above its MP
- The material solidifies approx 0.1s after extrusion cold welding onto previous layer
- Steady nozzle speed & support structures necessary
- Newer systems use two nozzles
 - 1) Model material
 - 2) Support material
- Accuracy 375 microns

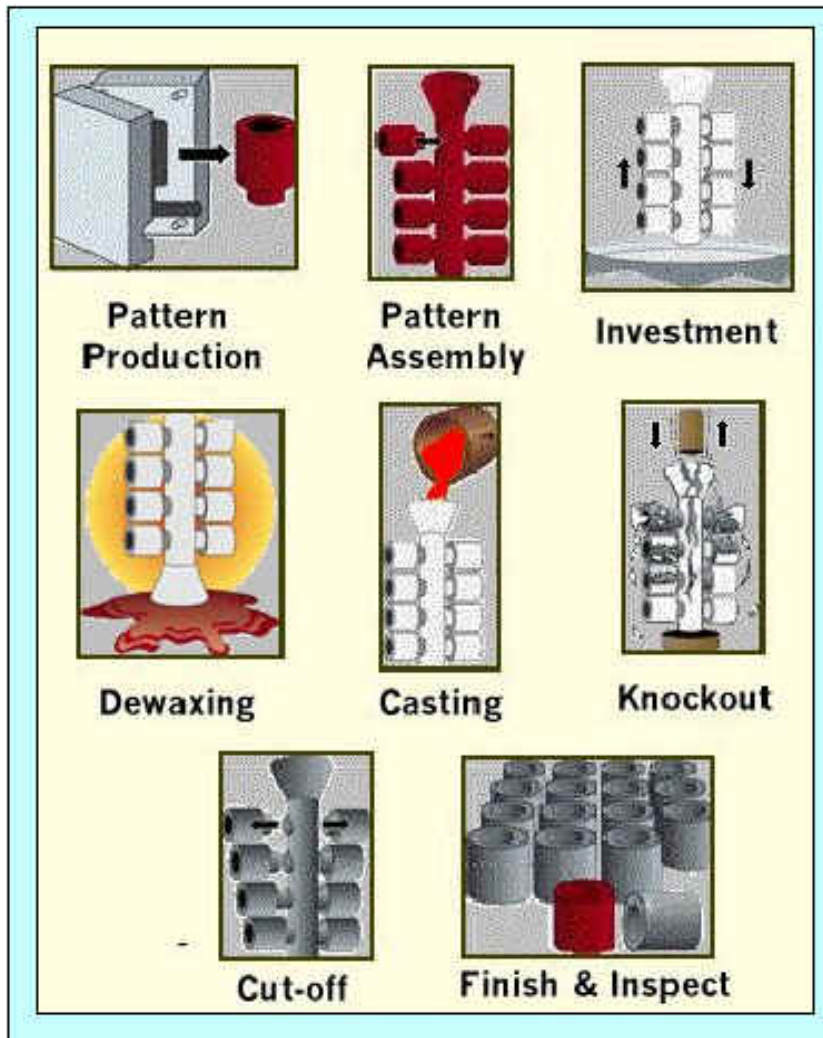


Fused Deposition Modelling (FDM)



- Advantages
 - ABS Material
 - Function testing
- Disadvantages
 - Surface finish not as good as SLS process
 - Long build times

Investment Casting Process



- Pattern Produced
- Pattern-tree assembled
- Pattern tree investment coated
- Pattern material melted out of the mould
- Molten, casting material poured into the mould
- Investment moulding material broken off the casting
- Individual castings cut off the casting tree and finished

Vacuum Casting Process

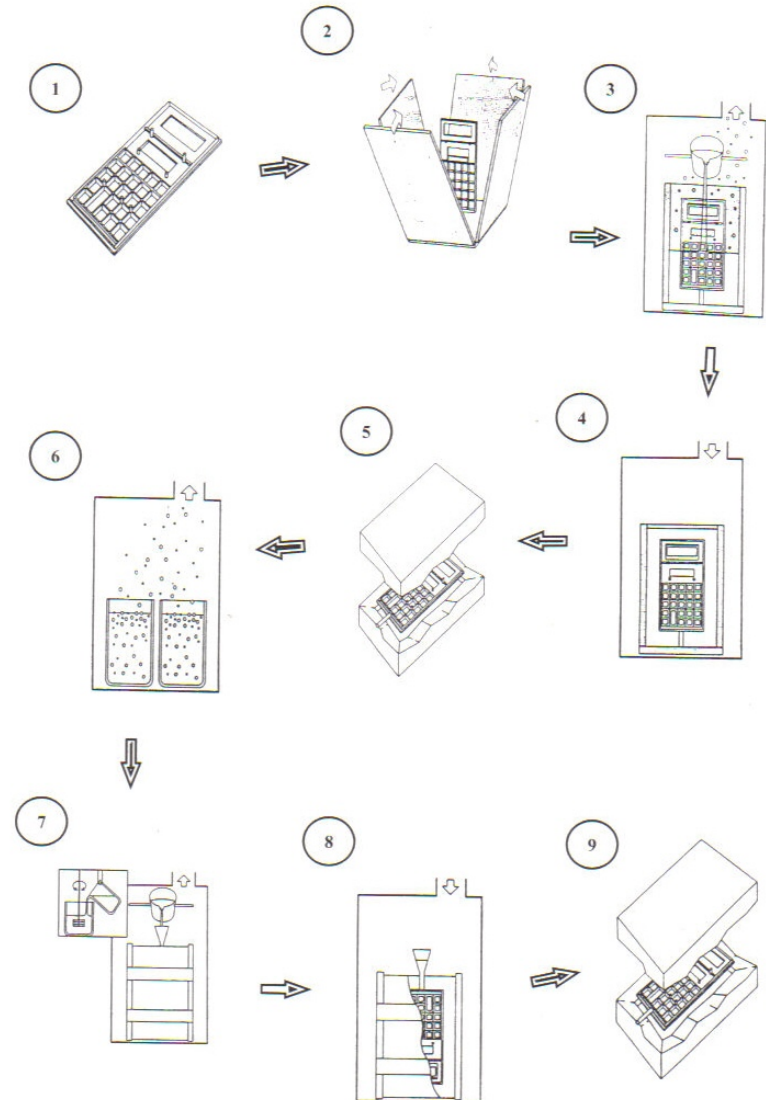


Used to create
polyurethane parts
which simulate
production materials

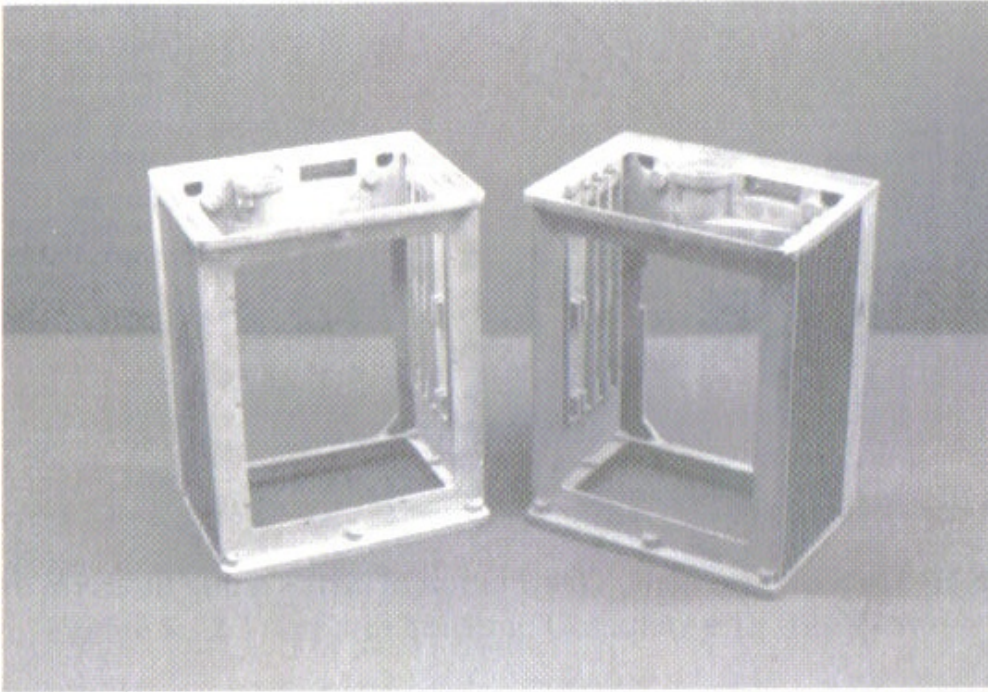
- Strength
- Toughness
- Optical Clarity
- Resistance to high / low temps

Vacuum Casting Process

1. Pattern using RP process (SLA, SLS, FDM etc.)
2. Pattern is fitted with a casting gate, set up on the parting line & then suspended in a mould casting frame
3. Once the two-part silicone-rubber is de-aerated & then mixed it is poured into the mould casting frame around the pattern
4. The mould is cured inside a heating chamber
5. The pattern is removed from the silicone mould by cutting along the parting line
6. The urethane resin is measured, dye is added for coloured components & casting funnels placed. Then the mould is closed & sealed
7. Computer controlled equipment mixes & pours the resin inside the vacuum chamber. Because this takes place in a vacuum, the mould is filled completely (no air bubbles or voids)
8. After casting the resin the mould is moved the heating chamber for 2 to 4 hrs to cure the urethane part
9. After hardening, the casting is removed from the silicone mould. The gate and risers are cut off to make an exact copy of the pattern. If required the component can be painted or plated.



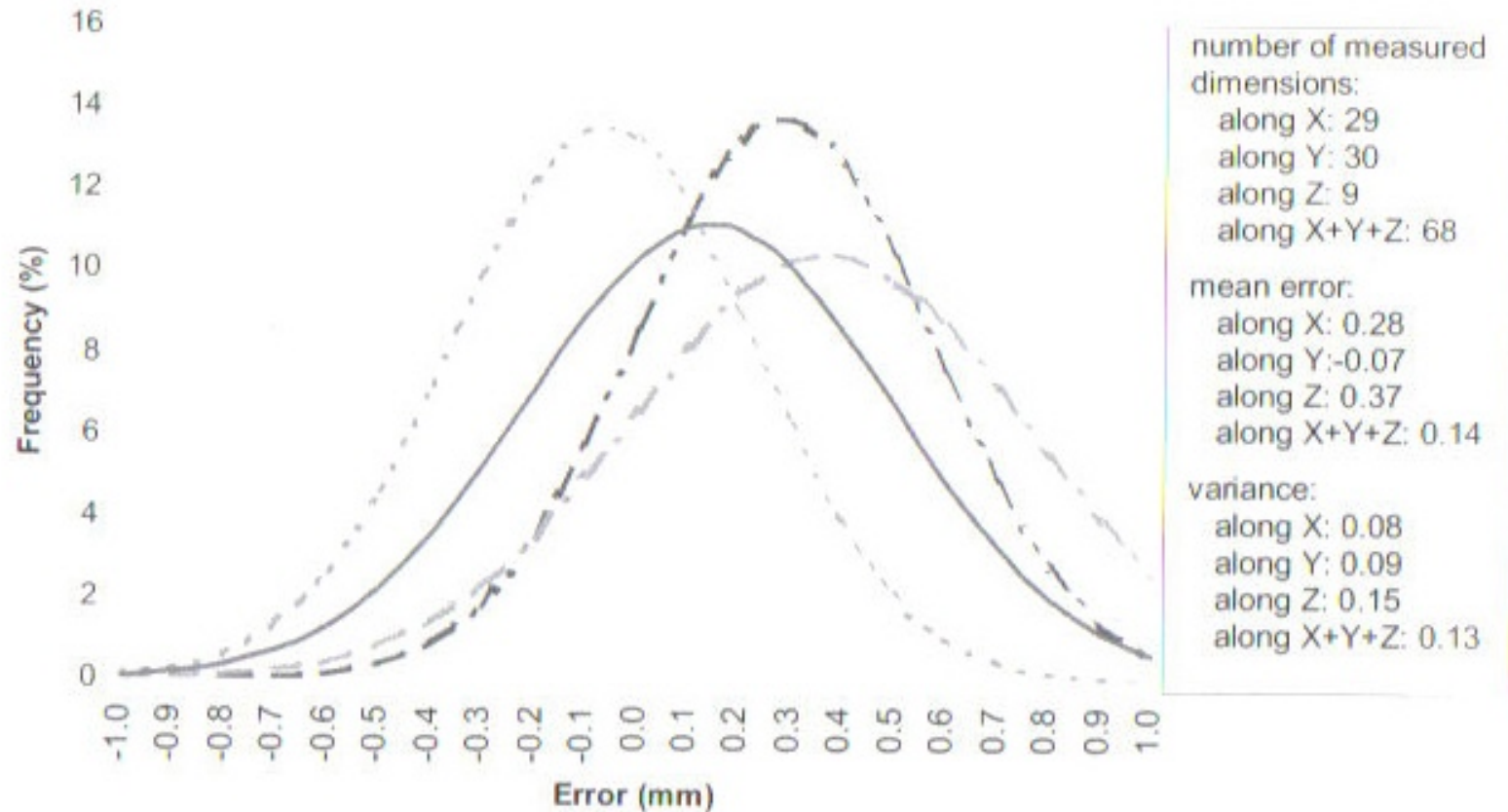
Patterns for Investment & Vacuum Casting



Aluminium Investment casting (left) TrueForm housing pattern (right)

- Aluminium Housing
(195 x 145 x 250mm)
 - Investment cast from TrueForm pattern
- Accuracy of parts is largely dependent on size
- Largest errors are found on the largest dimensions
- TrueForm component accuracy = $\pm 0.125\text{mm}$ (machine manufacturer)

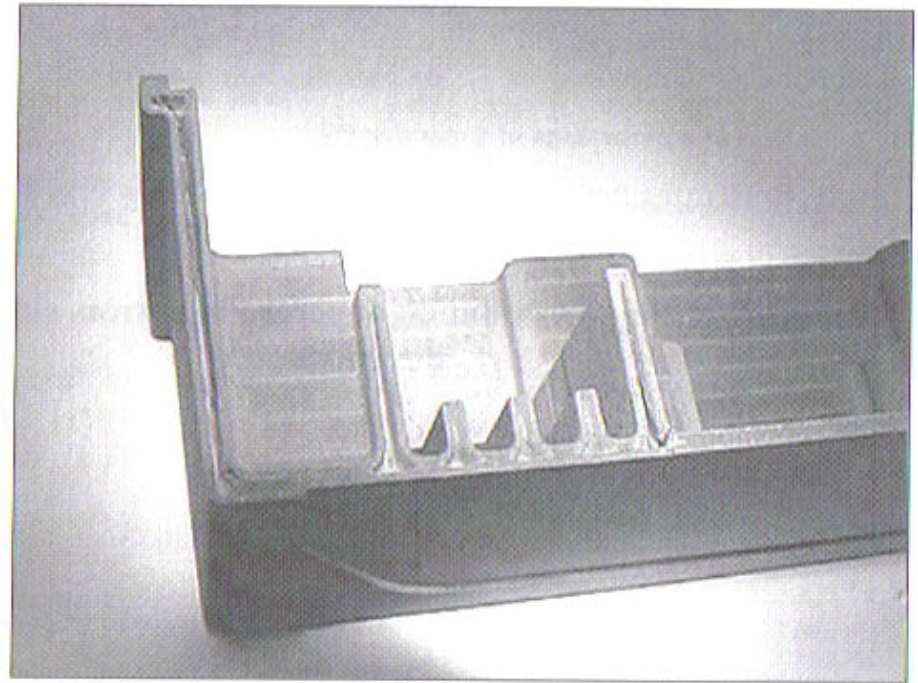
TrueForm Housing Distribution of errors along different directions



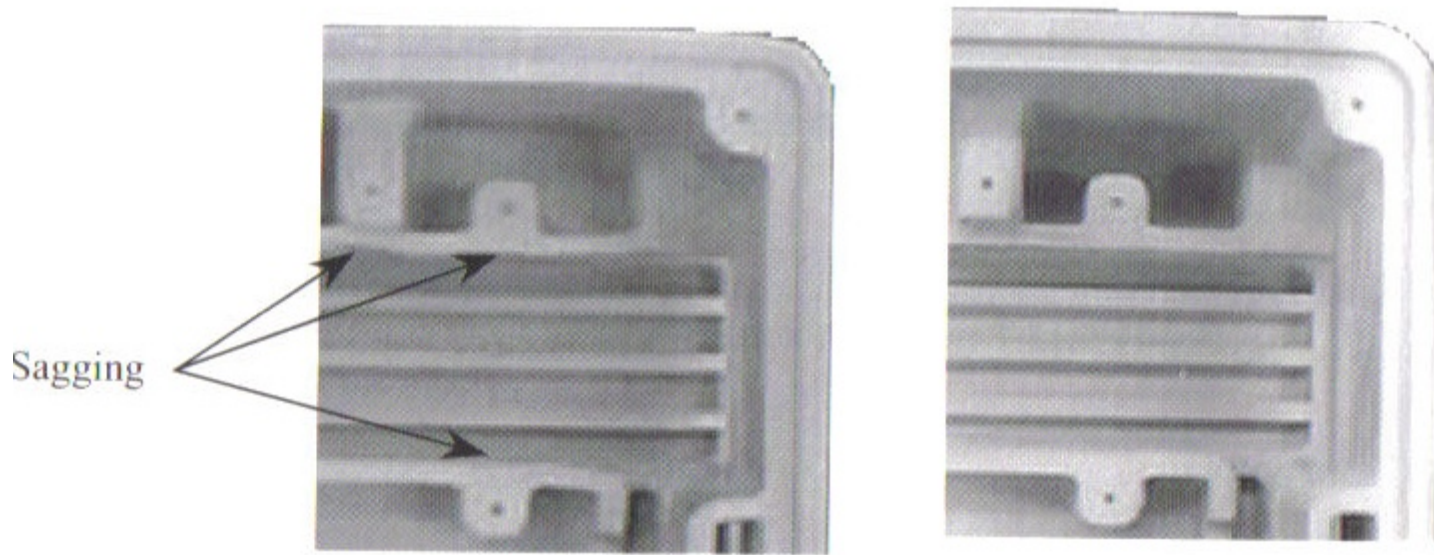
Distribution of errors of dimensions: — · · · along X · · · · · along Y - · - · - along Z ——— along X+Y+Z

Amendments to Reduce Sagging

- TrueForm behaves like an injection moulded plastic
- Thick sections are subject to sinking or sagging
- Part orientation must be used to minimise sagging – not always practicable
- Shelling of volumes can help to reduce sagging



Amendments to Reduce Sagging



- Shelled ribs and features reduce weight and thus the effect of sagging
- If a larger SLS machine was used to build the housing, the part could have been oriented horizontally in the build area
- Once the components were shelled at key areas, the castings were fully satisfactory as any deviations were corrected as key features were machine finished after casting
- True form patterns are cost effective up to 50 parts of a complex design are required

Rapid Prototyping Applications

Medical Models

Medical Models

- RP technologies are employed within the medical engineering in the following areas
 - Operation Planning
 - Surgery Rehearsal
 - Training
 - Prosthesis Design

Medical Models

Operation Planning

- Real size RP models of patients pathologic regions.
- Surgeons can more easily understand physical problems
- Surgeons can gain a better insight into operations to be performed
- RP models can assist in the communication of proposed surgical procedures to patients

Medical Models

Surgery Rehearsal

- RP models can be used to mock-up a complex, rare or ground braking surgical procedure
- The same techniques & tools can be used as would be used in the real surgery
- Such rehearsals can lead to changes in surgical procedures & significantly reduce risk to patients

Medical Models Training

- RP specimens of unusual medical deformities can be built
- The RP parts can be used to facilitate the training of medical staff training to become surgeons & radiologists
- Such models can also be employed in student examinations

Medical Models

Prosthesis Design

- RP models can be used to create master patterns
- Casting techniques can then be employed to create prostheses from bio-compatible materials
- Implants created in this way can be produced much more accurately than when using conventional techniques

Steps for building RP models of anatomical structures

1. Data acquisition with medical equipment
2. Generation of STL files from the scan data
3. Building RP models from the generated STL files

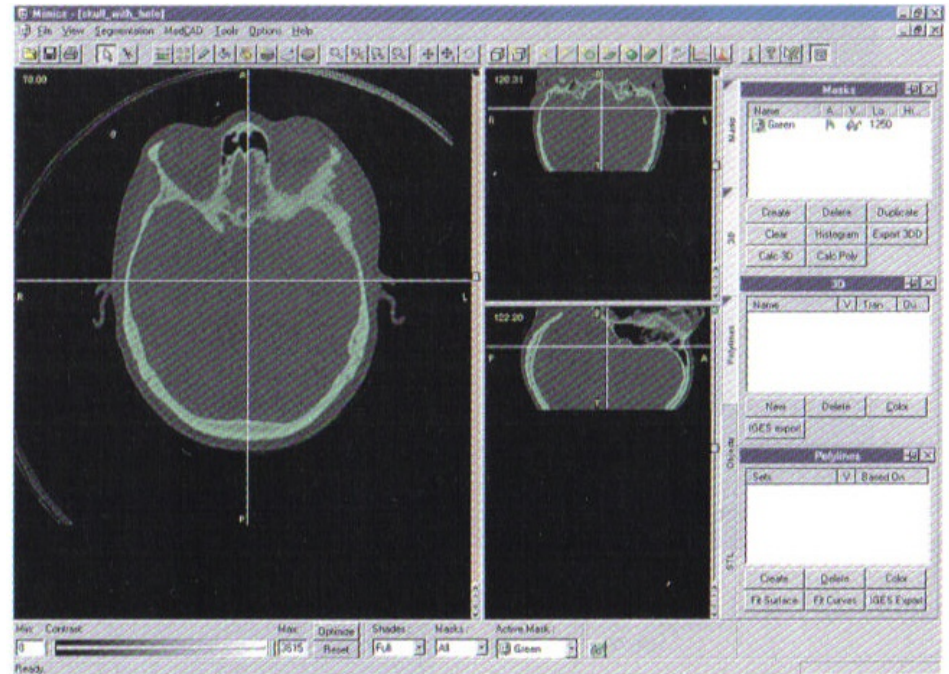
Data acquisition with medical equipment



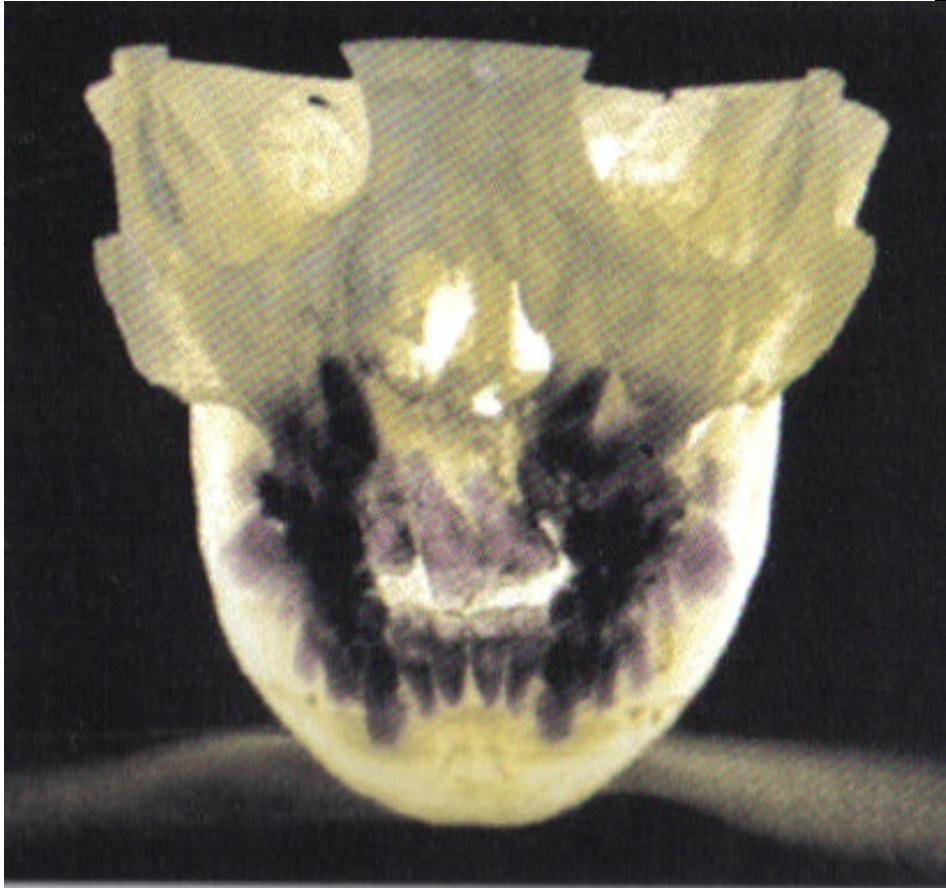
- Data acquisition with medical equipment
 - Conventional 3D medical scanners (CT Scans, MRI Scans, 3D Ultrasound)
 - Capture images of particular anatomic structure

Generation of STL files from scan data

- Interactive software tools are used to segment the scanned images and generate STL files
- MIMICS allows user to control & correct the segmentation of scanned images
- The segmentation volume is defined by all pixels with grey value higher than a predefined threshold value
- This technique can be employed for segmentation of CT or MRI images



Building RP Models from the generated STL files



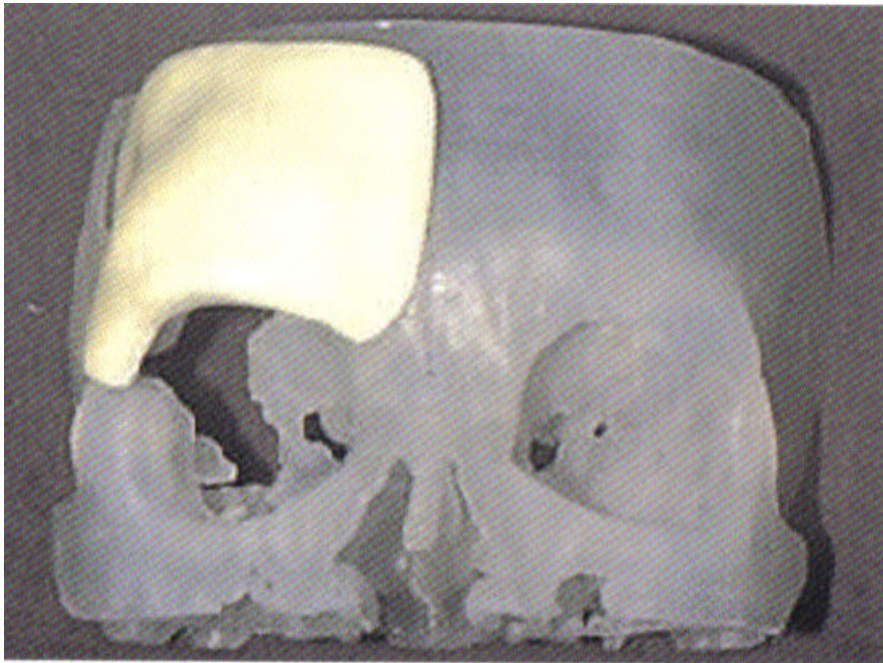
Any RP technology can be employed for building medical models

In addition to general-purpose RP materials, special medical materials have been developed for medical applications

- SLS – fine Nylon Medical Grade (MG)
 - Autoclave
- SLA – Stereocol
 - Accuracy
 - UV laser colouring

Medical Application of RP Case Study

Anatromics, 2000, Queensland Australia

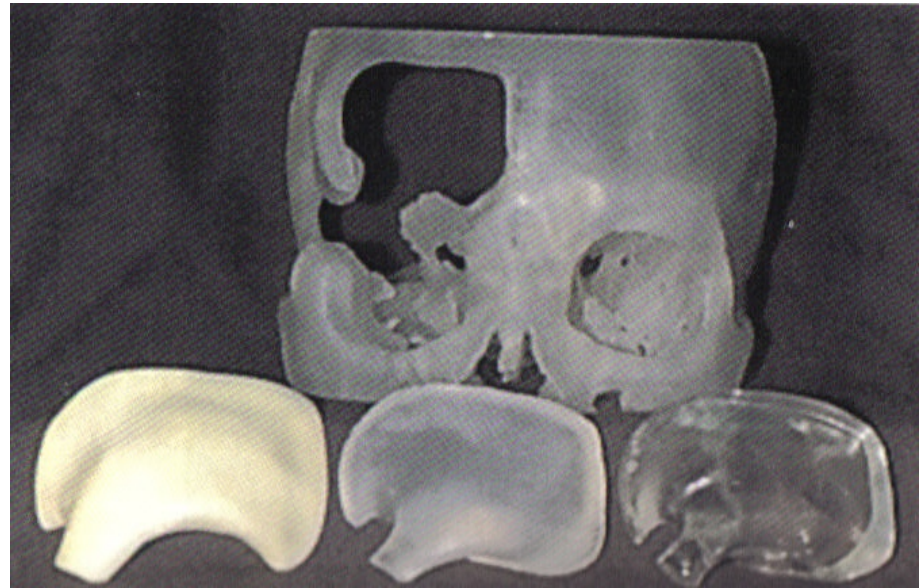


- Two SLA models built for patient suffering carcinoma of the right superior orbital margin & the adjacent frontal bone
- **Model 1** was used to
 - plan the resection of the cancerous bone
 - Act as an operational reference & as patient consent tool
- The SLA model was cut using the same tools used for resectioning the bone
- A resectioned template was created in plastic following the surgeons desired resection line
- The fabricated template was then placed over the model to check the match with the surgeons resection line

Medical Application of RP Case Study

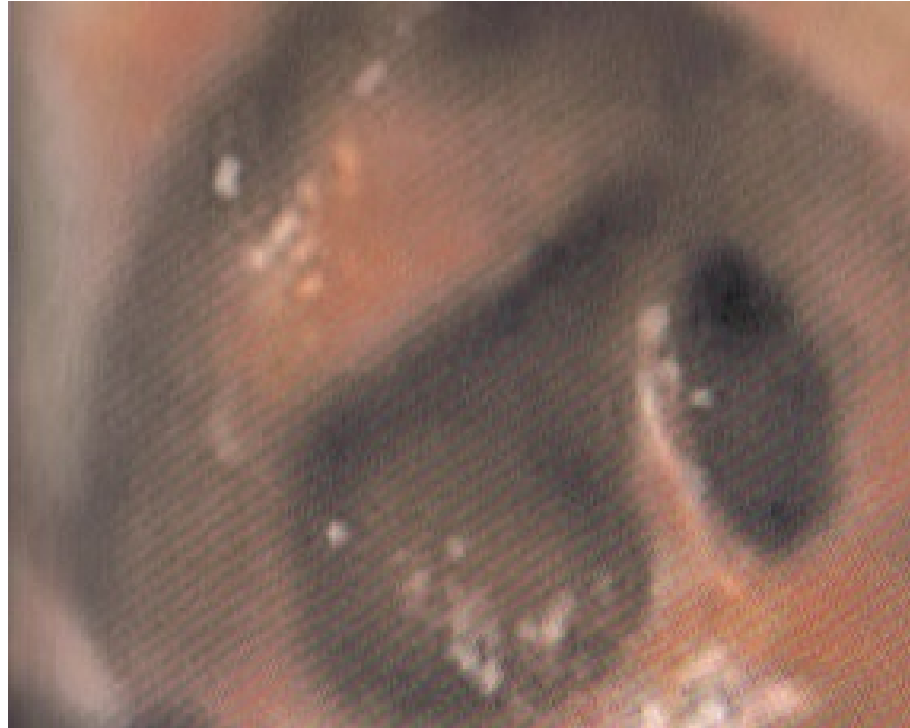
Anatromics, 2000, Queensland Australia

- **Model 2** was used to construct a custom acrylic implant
- The unaffected left superior orbital margin was mirrored across to assist the design of the implant
- The resection template & the custom implant were then prepared for the operation by gas sterilisation
- The template was used to mark the resection line, the bone was cut away & the custom implant was inserted into the deficit
- The operation was a complete success. The surgeon was fully satisfied with the quality & cost of utilising RP models



Medical Application of RP Case Study

Obturator Prosthesis, Materialise, 2000



- A hole resulted from the irradiation of a tumour in the mouth cavity
- This hole has to be filled by an implant to allow the patient to breathe and eat normally

Medical Application of RP Case Study

Obturator Prosthesis, Materialise, 2000



- The soft tissue surrounding the cavity was modelled by CT scanning
- This model was used to design a tool for direct moulding of the implant

Medical Application of RP Case Study

Obturator Prosthesis, Materialise, 2000



- A silicone implant was moulded from the tool

Medical Application of RP Case Study

Obturator Prosthesis, Materialise, 2000



- Without surgery, the deformable silicon prosthesis was implanted
- Magnets were used to fix the prosthesis to a hard dental implant

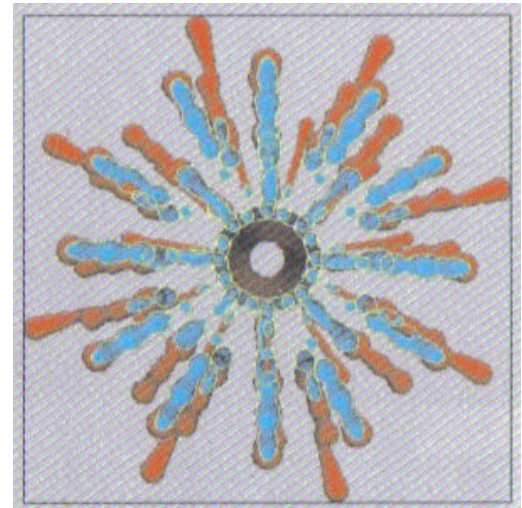
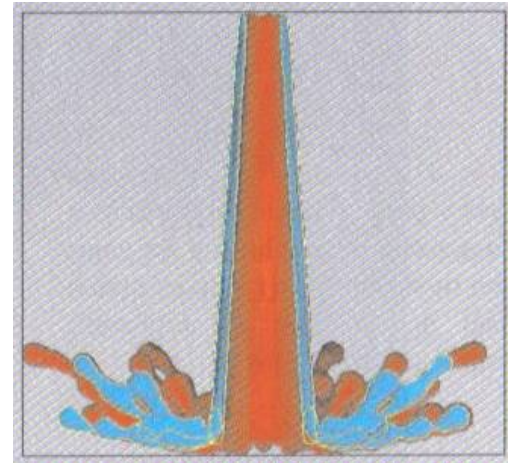
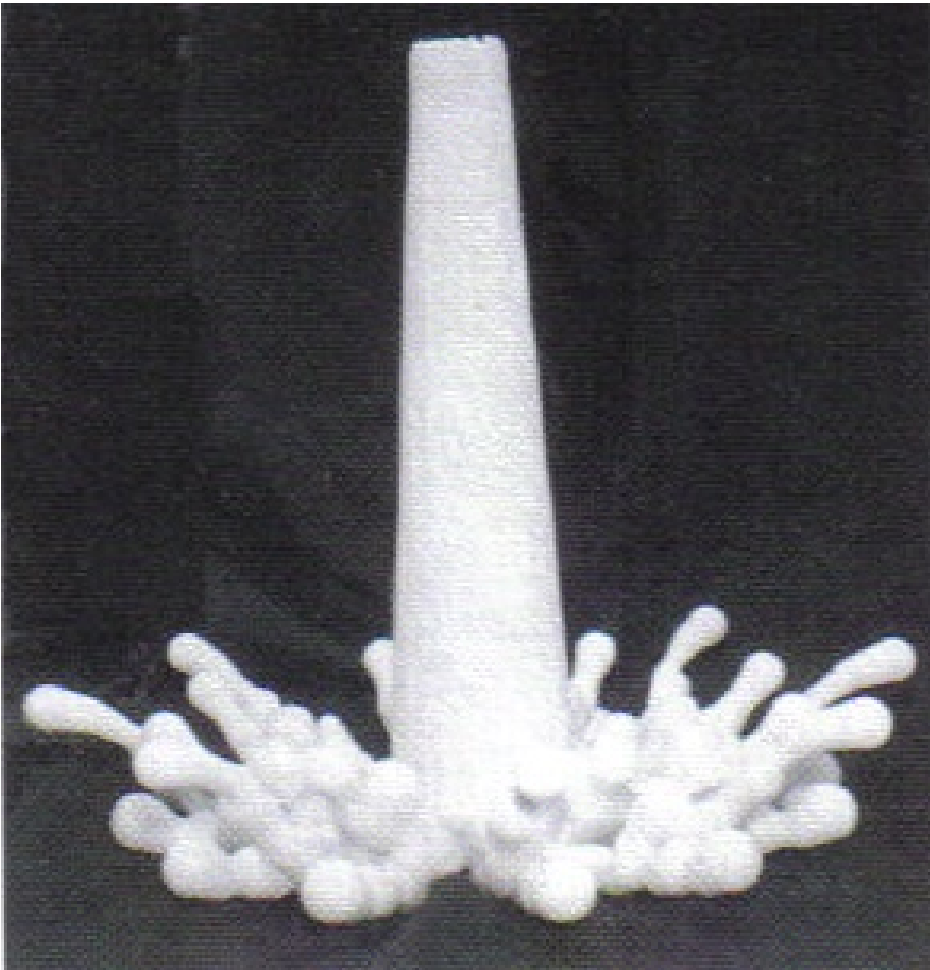
Rapid Prototyping Applications

Artworks

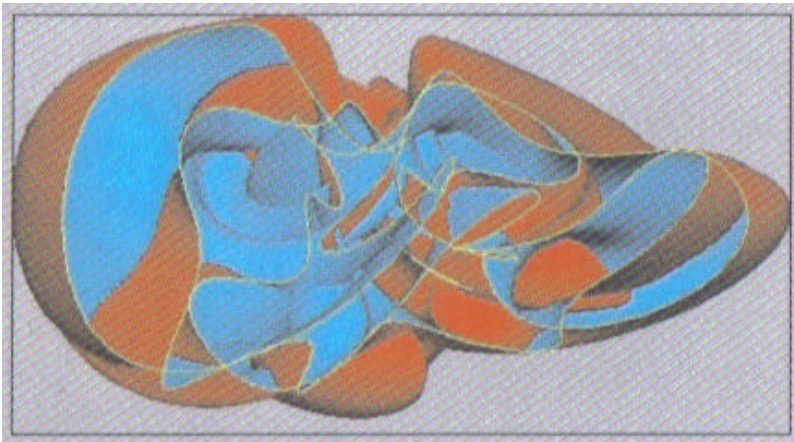
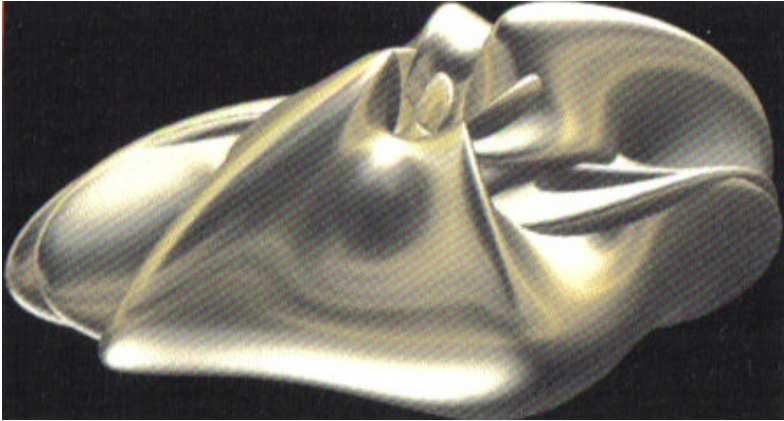
Artworks

- A growing application area for RP technologies is in art & design
- Initial high costs made RP prohibitive & put limitations on size of models
- The advent of concept modellers has made the use of RP for art more cost effective
- Accuracy and materials available make concept modellers more than adequate for the majority of art applications

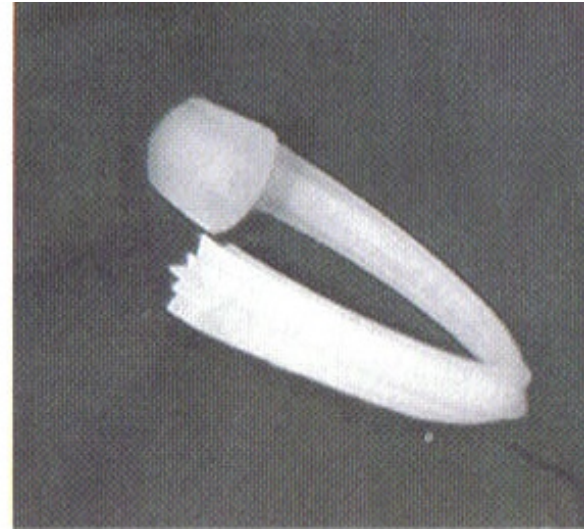
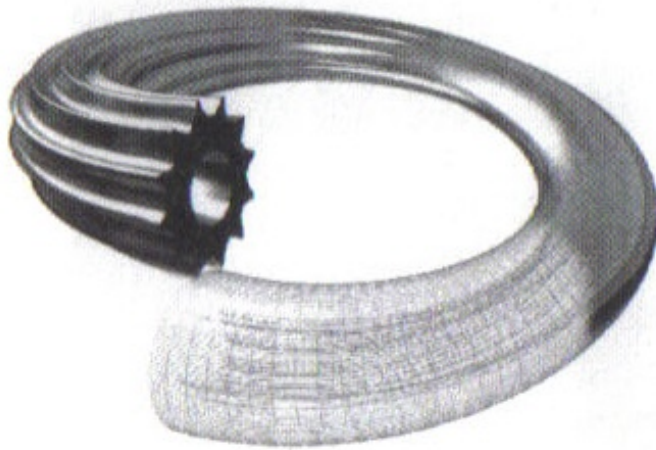
Artwork created by M Harris, CALM, 1998



Cybersculpture by K , CALM, 1998

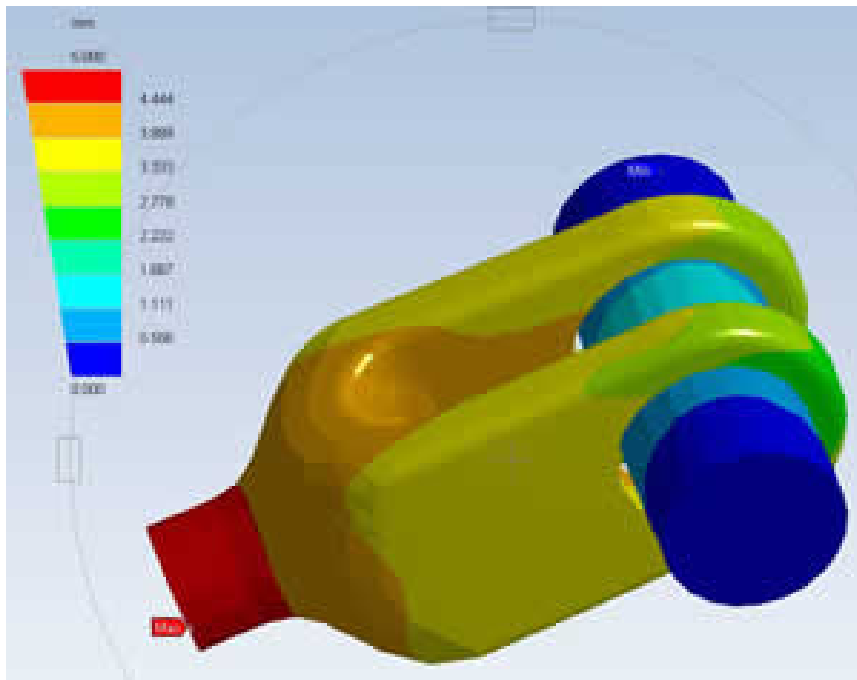


Bracelet by M. Woolner & T. Cook, CALM, 1998



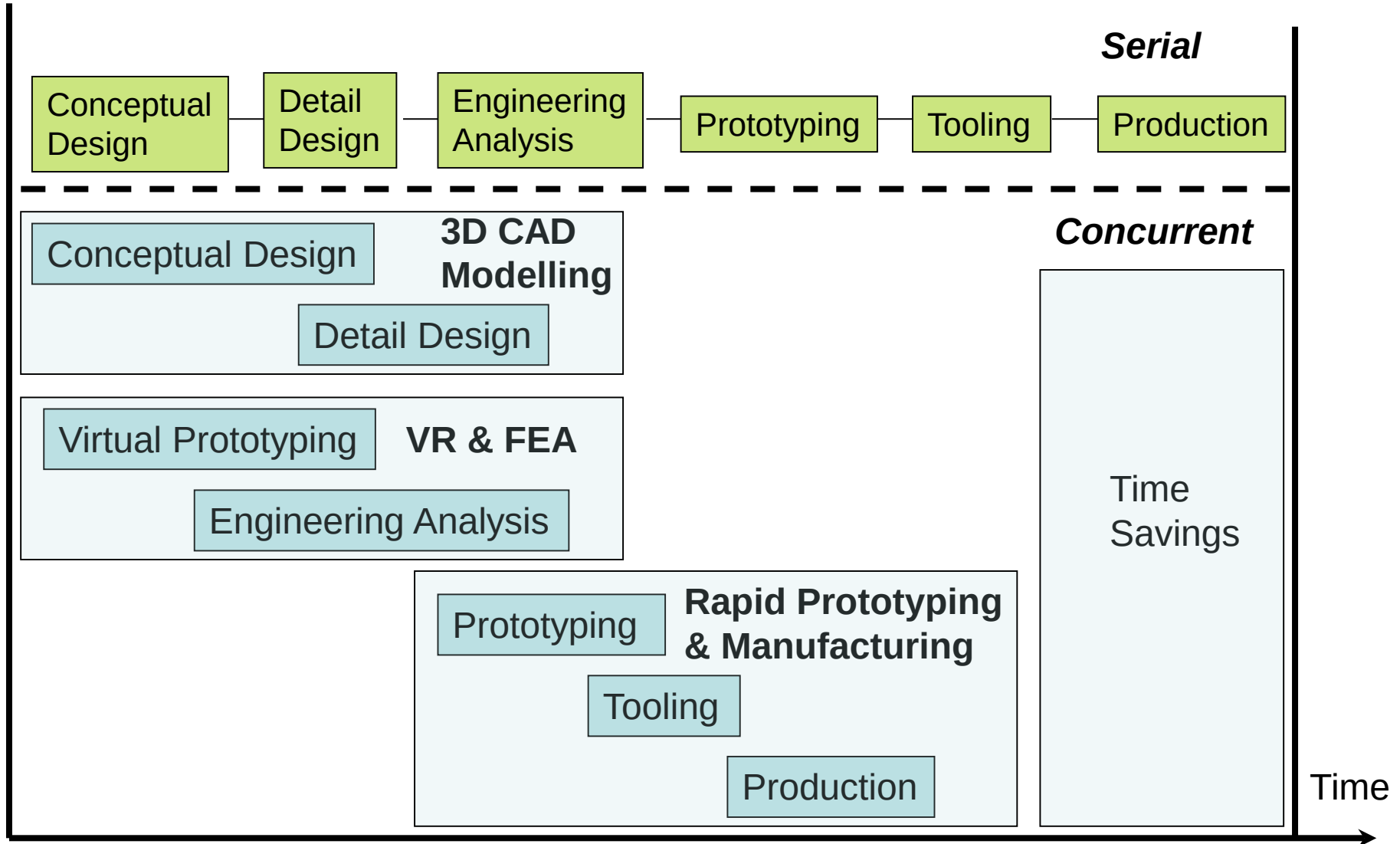
- Complex extrusion could not be manufactured using conventional manufacturing methods
- Extrusion starts with an internal star section on one end and progressively changes into star shaped external section at the other end

Engineering Analysis Models



- CAE analysis is an integral part of TCT/TCE
- Various software tools exist – mainly based on FEA
- Accurate FEA models for complex engineering components can require a significant amount of time, effort & expertise

Time Compression Engineering (TCE)



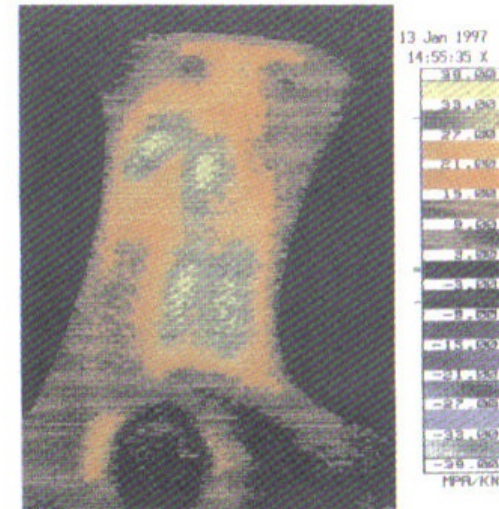
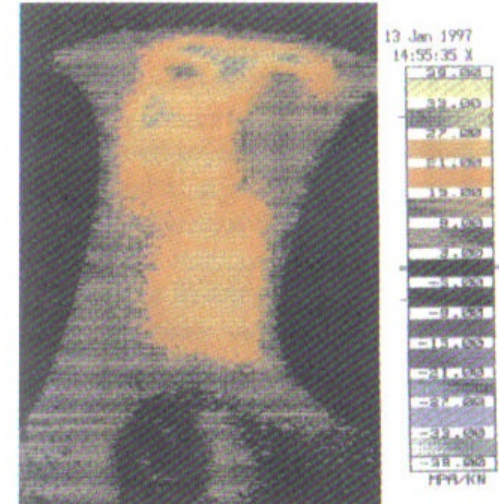
Visualisation of Flow Patterns

- SLA models were used to optimise the cross-flow jacket of a V6 high-performance racing engine
- 60 sensors were installed in the model to monitor local flow temperature & pressure conditions
- Coolant flow patterns were visualised by accurately injecting very small air bubbles
- The flow patterns were recorded by a high-speed video
- The data allowed critical sections to be redesigned and SLA models of the modified components were produced & re-tested
- Each design iteration took one week
- The accuracy & surface quality of the SLA models are more than adequate to reproduce complex flow behaviours

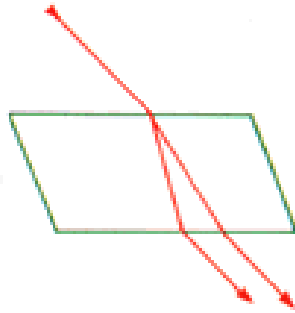
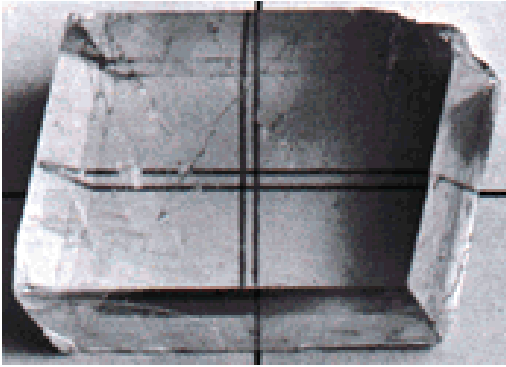


Thermo Elastic Tension Analysis (THESA)

- RP models of real parts are used on test rigs for structural analysis
- The effect of a particular load on the temperature patterns is analysed using thermal imaging
- Here an SLS model built in glass-filled Nylon is utilised to optimise the design of a highly loaded rim of a sports car
- Initially a rim was RP from a number of different materials to find the optimal material for the THESA investigation
- Results showed that temp patterns for the glass-filled Nylon were very similar to those obtained from cast metal parts



Photoelastic Stress Analysis

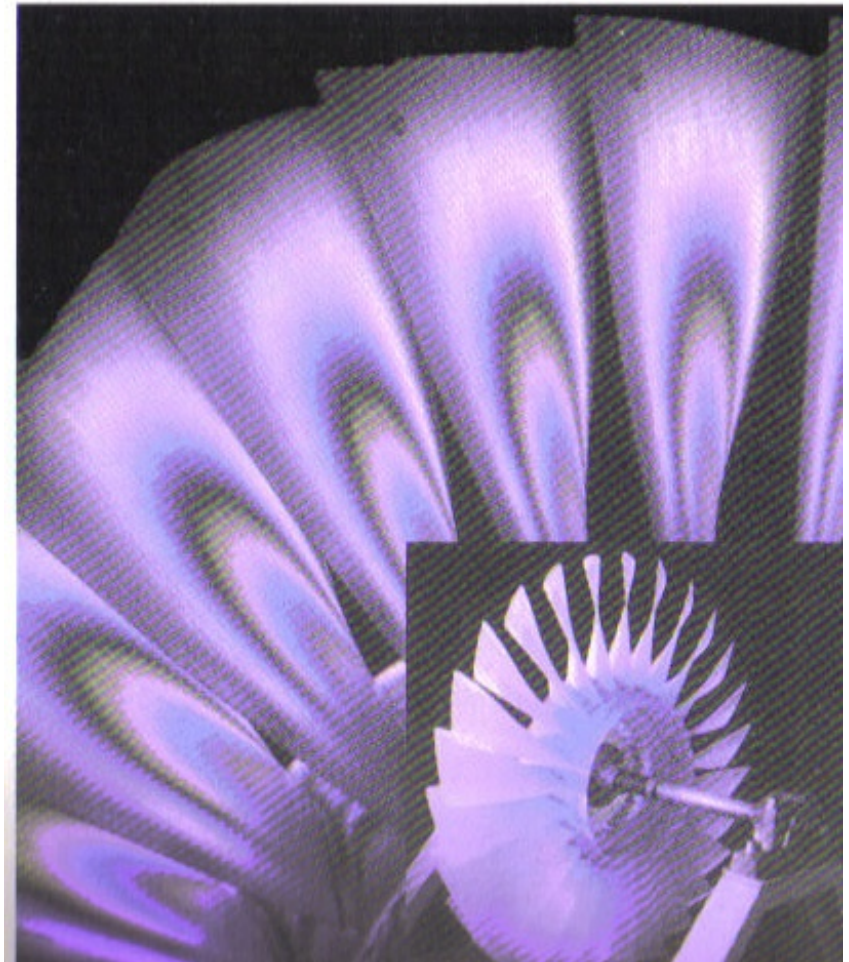


- Used to determine the stresses & strains within physical parts under specific conditions
- Based on temporary birefringence of a transparent material subjected to specific load

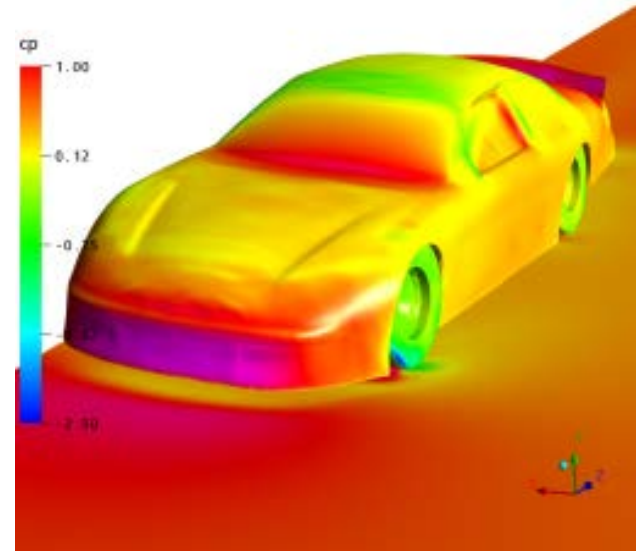
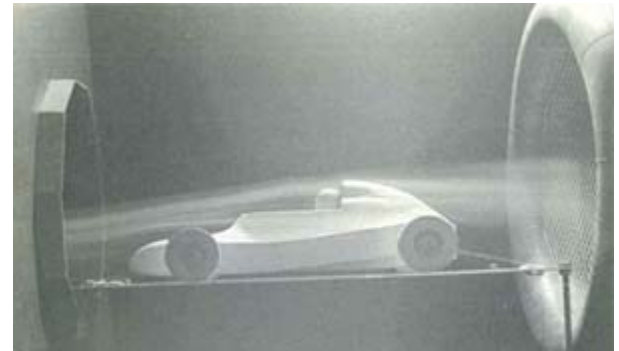
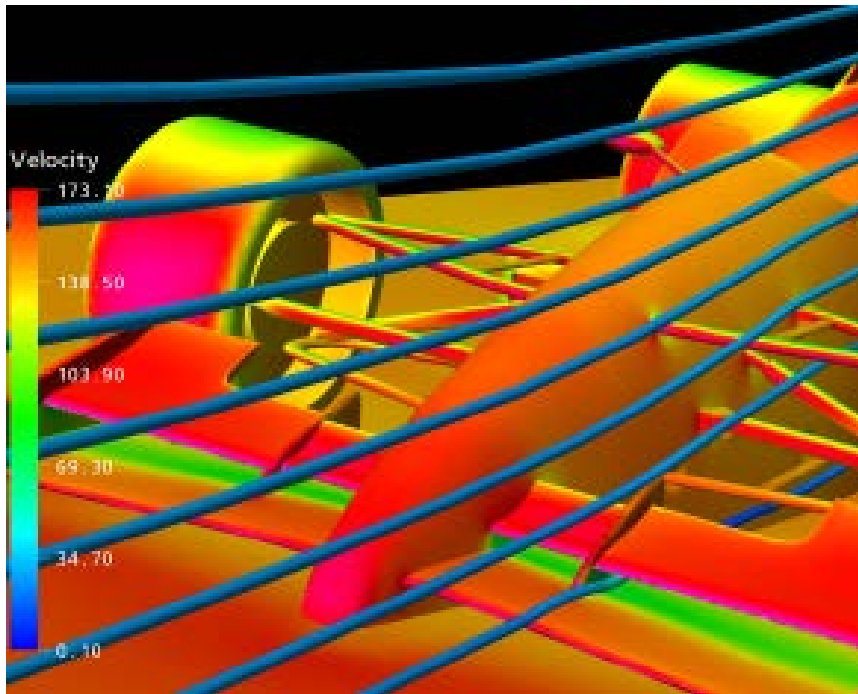


Photoelastic Stress Analysis

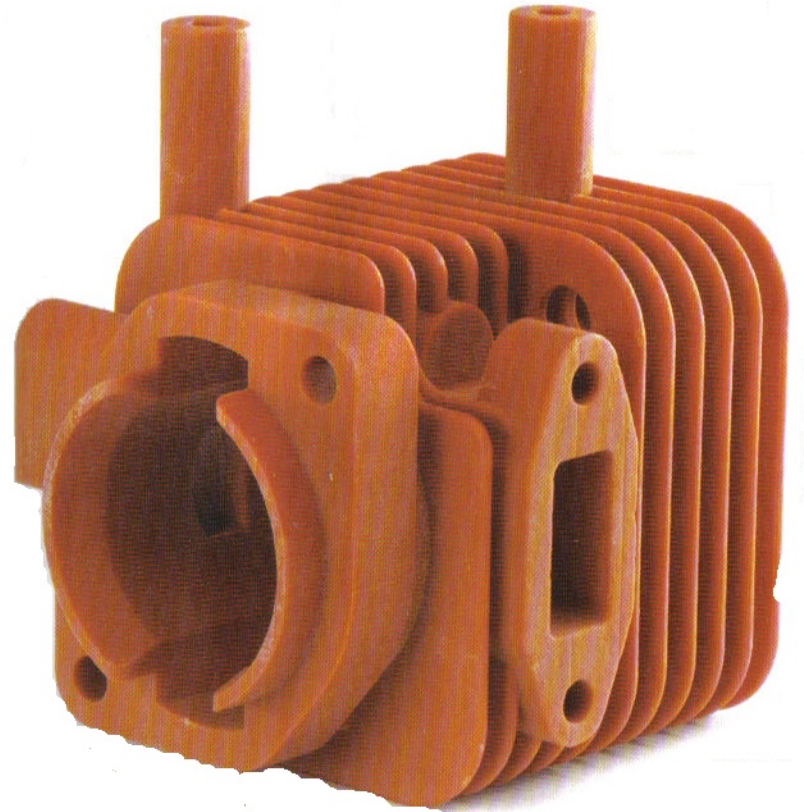
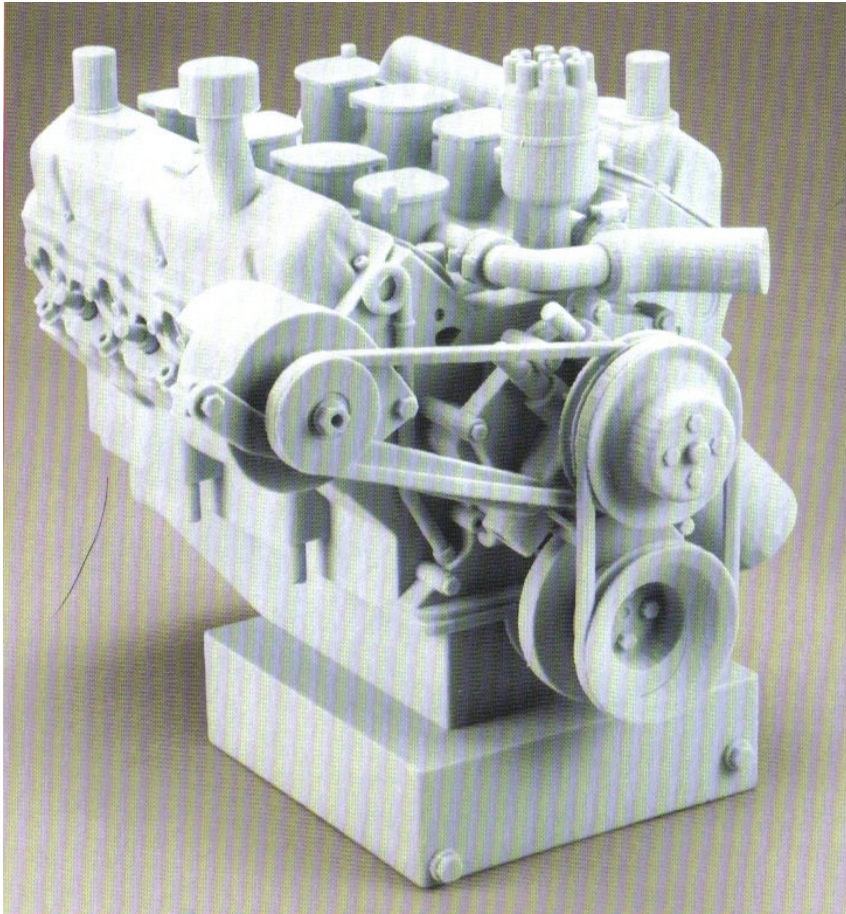
- SLA models exhibit the required birefringence that can be illustrated by irradiating the test samples with polarised white light & monochromatic light
- Results can be transferred to metal parts by applying fundamental similarity laws
- This allows predictions to be made regarding the stress distributions quickly and at low cost
- Freezing of the stresses & strains can be achieved by raising the temp above glass transition temp then allowing to cool



Fabrication of Models for Wind Tunnel Tests



Z Printer 310 Plus



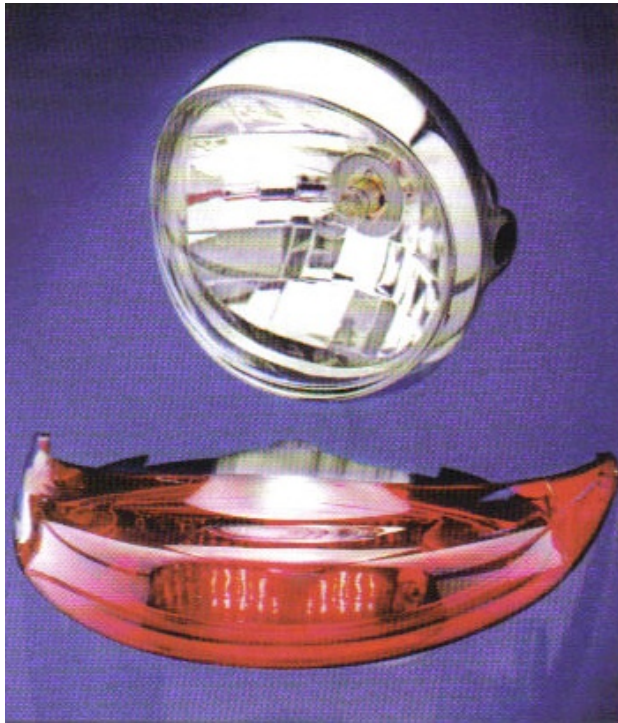
Clear Prototypes

Paragon: clear examples

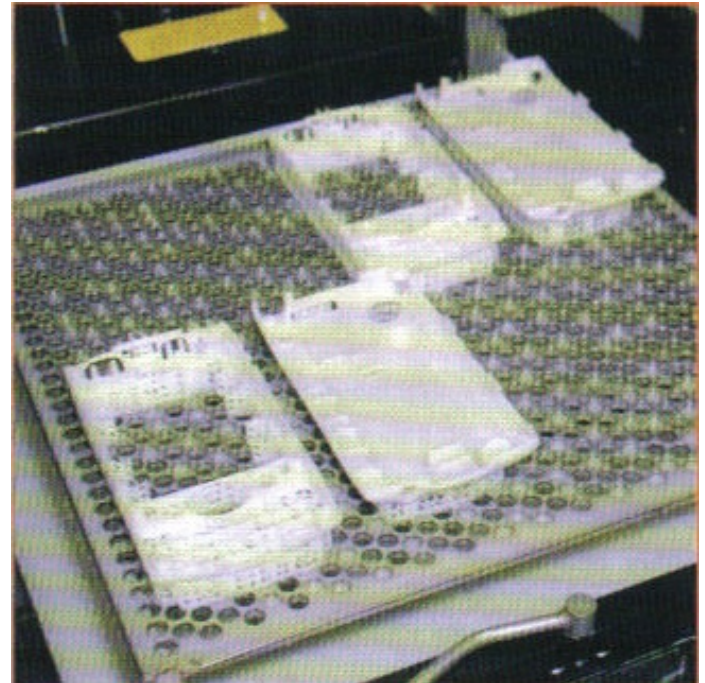
- ✓ Clear and tinted lenses for cars and motorbikes, which also included chrome finished reflectors and surrounds.
- ✓ Coloured beacons for emergency vehicles, with intricate prism detail on both the internal and external surfaces.
- ✓ Clear LED light guides for use in electronic enclosures.
- ✓ Tinted "smoke effect" infra red lenses for remote control devices.
- ✓ Clear containers for point of sale and transparent coloured baskets for outdoor products.



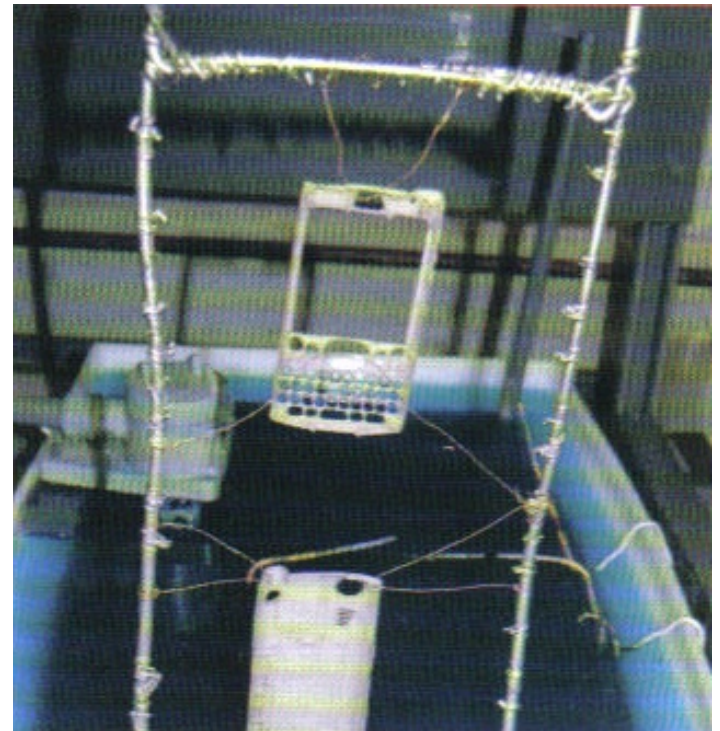
Clear Prototypes



SLARMOR



SLARMOR



SLARMOR

