RPD – RAPID PRODUCT DEVELOPMENT

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1. Introduction

Rapid Product Development (RPD) defines an industrial culture that promotes the development of new products and design for production, in scales of time more abbreviated possible [FF1].

This culture uses new technologies to promote the time reduction, besides the use of 3D, CAD-CAM, Rapid Prototyping, Rapid Tooling, Simulation and the use of Administration Techniques that activate the industrial process.

The use of Rapid Product Development not only allows the industry placing in production new products in a summary scale of time, as well as they reduce significantly the costs of development of new products.

Companies all over the world consider these extremely beneficial techniques and they are ever-increasing adopting the methodologies into a growing rate. From great Multinationals to small SME, the benefits of RPD have attained immense success.

2. Keystones

The Rapid Product Development Technology improving product development efficiency in manufacturing industry has increased competence in product development across a wide front in all industry segments and created a strong background of interdisciplinary research expertise.

The latest technologies and methods for improving product development processes have been piloted and taken into use within the scope of those researches. Consequently a considerable competitive improvement has been achieved in comparison with previous processes.

While proceedings are generally intended by promoting product development, some particular researches has concentrated on examining the method corporate product development can be carried out in the most effective and productive promising method. How virtual or real prototypes of new product ideas can be conveyed into real product more quickly than before, how new products can be tested at the initial possible stage and how the commercial end products can be put on the market as rapidly and cost-effectively as possible.

The Rapid Product Development researches operate at the very crucial point by putting the results into practice, and the arrival of new products on the market has been improved and higher-quality products can be manufactured at lower cost.

The rapidity, quality, lower costs and networking, are the keystones of modern product development. Time is the most important success factor in product development today; the companies that gets their new product on market first is the one that does best. The ability of companies to network has become the most important sign of product development results.

The interdisciplinary nature of the RPD is well illustrated by the spectrum of different fields of activity of the technologies and knowledge involved from consumer goods, telecommunications and electronics, machinery and metals industry, construction, software, health care products, plant manufacturing, industrial automation and many fields of technology and process industry as well.

The RPD projects application covers the different stages of product development from identifying customer needs to testing prototypes, within the scope of the company projects, product development processes, lifecycle and environment.

Effective cooperation between industry and the research community have been achieved in many areas connected with product development and consequently the standards of research in this field have been increased. The process generated new knowledge, applied the latest technology across a broad front and produced commercial services, software and technologies for improving product development.

The effects of the results may be seen more extensively in company activities in the last ten years, since improved processes, methods and tools are taken into wider use in the development of products.

3. **Summary phases for a new product development and bringing into the market place (Figure 1)**:

a. Initial design concepts and ideas
b. Focussing on the high levels of functionality and aesthetics requirements for the various stages of testing, assembling and marketing.
c. Design created in 3D CAD and subsequently translated into 3D data.
d. Prototypes produced for form, fit and functional testing.
e. Further design modifications as required.
f. Final design, full production tooling and manufacture proceedings.
g. Product launch and release into the market place

Figure 1. Scheme RPD – Rapid Product Development [FF1]

4. **Factors contributing to Speed & Accuracy on Rapid Product Development**:

a. Understanding the Industry's pre-requisites and requirements to realize the rapid prototyping and manufacturing evolution
b. Select role and power of Rapid Prototyping or Virtual Prototyping for each product requirements.
c. Improving new developments in RP – Rapid Prototyping and RM – Rapid Manufacturing
d. Managing CAD/CAM systems to enhance accuracy and efficiency.
e. More extensive utilization of IT- Information Technology and KM- Knowledge Management to support product development
f. Introduce simulation technologies into the Rapid Product development Technologies

g. Abandoning slow, time consuming traditional product design processes by employing latest rapid prototyping and simulation solutions
h. Redefining the ideal skill set for product design manager.
i. Defining, measuring and continually improving design investments
j. Understanding and applying the latest product innovation strategies through Rapid Product Development technologies.

5. Background

Due to the requirement of improving products quality and the pressing time constraints, the essential evaluation of all feasible design alternatives with lowest cost and time is required actually for a sustainable product development.
Computer aided design; manufacturing and analysis technologies provide a valuable resource tool for the innovative design. Recent advances in technologies like reverse engineering, rapid prototyping, virtual prototyping, simulation and rapid tooling are progressively improving fast, inexpensive practices to create parts directly from computer aided design models. The promising way allowed by these technologies are giving outstanding significance to the engineering process and the impact will be revolutionary for the worldwide industries.

The experience of the experts in this area are encouraging to introduce these technologies as part of engineering modern technologies & associated equipments as well as software for Rapid Product Development in large-scale industries like automobile, aerospace, research institution like defence, space and small-scale industries and other application fields like biomedical, art and archaeology.
Traditional manufacturers need to learn and have a platform and ways to incorporate rapid prototyping technologies in the business. The manufacturers need to understand that rapid product development is definitively become established and adopt its related technologies rapidly.

6. New Activities in the Industry:

The new activities that the industrial organizations should offer are:

a. Courses of Rapid in rapid prototyping, rapid tooling, tooling making, CAD-CAM
b. Advanced apprenticeships, studies of simulation techniques and RP Decision–Support.
c. Development of new Techniques of Administration of Managerial Project – RPD–Rapid Product Development.
d. Transfer of Technology–Methods & Systems

7. RPD available commercial Services:

An extremely vast group of commercial services is now available. These include:

- Stereolithography
- Selective Laser Sintering
- Laminated Object
- Vacuum Casting s
- High Speed Machining
- Laser Engraving
- Z-Corp Model making
- Thermojet Modelling
- Sand Casting
- Direct Metal Laser Sintering of tool inserts
- Rapid Tooling
- Techniques of Injection
- Virtual Prototyping & Simulation
- Modelling & Simulation
- Processes Simulation
- Rapid Manufacturing

8. RPD Objective Proceedings

The tools for effectively and efficiently decode requirements from users or market to evolve new or enhance existing products in a globally competitive environment, involves the product design and development process with considerations for multi-disciplinary and collaborative design, as well as the adoption of information and communication and processing technologies for design, simulating, prototyping and manufacturing.

RPD Structure - Phases involve identification of market opportunity, key concepts, methodologies for detail design and prototype making. Techniques and Tools to Facilitate and Shorten Product Design and Development; Emerging Trends according:

8.1 Product Design Planning

a. Identify Market Opportunities
b. Evaluate and Prioritise Projects
c. Allocate Resources and Plan Timing
d. Comprehensive Pre-project Planning

8.2 Product Requirements Identification

a. Define the Product Requirements Scope
b. Gather and Infer Data
c. Management Requirements
d. Establish Worth
e. Permanent Development Improvement

8.3 Product Architecture

a. Translate and Realize Functional Requirements
b. Determine Types of Product Architecture
c. According to Impacts – Market and Environment

8.4 Product Specifications

a. Establish Target Specifications
b. Refine Specifications
c. Functional Analysis
d. Review on the Results and the Process

8.5 Design for Manufacturing

a. Preliminary Project Estimates
b. Factored Project Estimates
c. Detailed Project Estimates
d. Address Manufacturability Issues Early in the Design Cycle
e. Identify Costly Aspects of Design
f. Iterate Process to Improve Design and Reduce Costs

8.6 Concept Generation/Selection

a. Concept Selection Matrix
b. Rate and Rank Concepts
c. Combine and Improve
d. Select Best Concept
e. Review the Process

8.7 Computer Aided Product Design

a. Shape Design & Styling
b. Product Design and Functional Evaluations and Manufacturing Planning
c. Product Lifecycle Management
d. Internet-facilitated Collaborative Product Design

8.8 Industrial Design

a. Design Visualization and Communication Methods
b. Form Design Basics
c. Functional Analysis
d. Ergonomics Principles

8.9 Prototyping and Modelling

a. Determining Prototypes Functions
b. Principles and Types of Prototypes According to product design
c. According Prototyping Technologies
d. Virtual Prototyping
e. Modelling and Simulation

8.10 Tooling

a. RT – Rapid Tooling
b. Full Production Tooling

8.11 Product Development Economics

a. Product Economics
b. Cost and Schedule Variance Analyses and Reports
c. Net Present Value
d. Sensitivity and Trade-off
e. Analysis for Development

8.12 Product Manufacturing

a. Manufacturing Process
b. Contractors and Suppliers Assessment and Recommendation
c. Safety, Training, Operation and Equipment Manuals

8.13 Knowledge Management Applications

a. Developing KM applications
b. Using the proceedings applied in the product development and introduction of a Rapid Product Development KM system

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9 Rapid Manufacturing (RM)

Rapid Manufacturing is a new area of manufacturing developed from a family of technologies known by a broad term including the use of (RP) rapid prototyping, (RT) rapid tooling, and the direct use of layer manufacturing technologies to produce final products rapidly.

RM processes have previously produced the achievement of equally improving products and reducing their development time; resulting in the development of the Rapid Tooling technologies, which improved its own processes implementing Rapid Prototyping techniques. Rapid Manufacturing technology allows manufacturers to create products without tools, furthermore enables previously impossible geometries to be made. It is economically realistic to use existing commercial Rapid Prototyping systems to manufacture series parts in quantities of up to 25,000 and tailored parts in quantities from one-off to hundreds of thousands. This kind of manufacturing can be extremely cost-effective and the process is significantly more flexible than conventional manufacturing. Rapid Manufacturing is an innovative Industrial Revolution for the digital era that provides excellent advances in the manufacturing industry in emerging research and development in product design and materials science, as well as in manufacturing engineering, CAD/CAM and manufacturing process.

9.1 Rapid Manufacturing process & materials development

Rapid Manufacturing uses technologies originally developed for Rapid Prototyping. Existing RP technologies are far from ideal, as the processes have not been developed or optimised for production manufacture.

New research projects are developing dedicated Rapid Manufacturing technologies using a range of new and emerging materials.

9.2 Design for Rapid Manufacture

Researches are implementing new design protocols and working methodologies to increase the maximum benefit of part production using layer-wise manufacturing.

One of the most important emerging technologies that will drive the future manufacturing is rapid Manufacturing (RM). Using Additive Layer Manufacturing technologies such as Laser Sintering, Laser Consolidation and even Stereolithography and manufacture end-use component parts straight from 3D CAD-to-part represents the most important principle of RM.

Tooling elimination is another of most notable advantages of RM. Eliminating the constraints of tooling, RM provides manufacturers the ability to produce cost-effective lots of one-off parts, and multiple product design iterations at no additional cost. RM has now become a typical manufacturing process for some polymer and metal-based components, being cost effective the manufacture of tens of thousands of polymer parts.

Due to RM uses layer logic manufacturing, components can be manufactured with no split lines, or with complex internal and re-entrant features reducing manufacturing and assembly costs.

Significant time and costs can be saved when compared to traditional manufacturing.

9.3 Management of Rapid Manufacturing

The advent of Rapid Manufacturing will generate deep transformation on existing supply chains. The transfer and manipulation of electronic data will characterize manufacture and no longer constrained by the availability and location of tooling.

RM also comprises the quick fabrication of the tools required for mass production, such as specially shaped moulds, dies, and jigs. Many different layer-manufacturing processes have been developed, using an increasing range of materials. The parts produced have progressively increasing size and durability, as the quality has improved.

Layer manufacturing is being used frequently to fabricate the parts both for production tools and functional prototypes. The application of layer manufacturing to make the components used in production is designed by Rapid Tooling (RT), which has been largely employed for injection moulding, investment casting, and mould casting processes.

9.4 Advantages and Disadvantages

Fundamental advantages and disadvantages of rapid prototyping and/or simulation on rapid manufacture (RM):

We should balance the benefits of RM against current significant limitations. Unless there are imminent needs for a specific advantage that RM provides, the balance frequently favours a conventional approach. However, with technical problems solved in a lot of fronts the balance leans more frequently in favour of RM. Although it should be recognized the rapid prototyping can be a rapid solution for the industrial development of a product and production tools, or to test the design, mechanism or marketing. However per times it should be opted for the virtual prototyping, where a wide range of products can be studied and verified with reduced costs, and/or simulation or advanced simulation where components can be evaluated, and simulated in every conditions, including materials and processes.

9.5 Rapid Manufacturing (RM) & Standard Manufacturing

The production speed compared to standard industrial methods is slower. For some estimates, existent methods of mass production are faster 10 to 1,000 times. The finishing and precision as well cannot attain the same level of the conventional technology. Secondary operations are also requested, as removal of supports and manual finishing. In a production situation where multiple parts are manufactured, it can add secondary operations and origin addition of time. There are still current limitations of dimensions of pieces that are more restrictive than in the standard methods.

However these processes are incomparable for the production of small series, as in the case of tools for health care, dental, the one-off products industry, small line products, tailored products, etc.

9.5.1 Materials

Addictive production offers the potential of using multiples material as well as to control the located intermediate geometry - and micro-structure of a piece. This means that can be improved the functionality of a part in ways that were previously impossible with existent industrial methods. Materials can be selected designed for the mechanical properties, thermal, optical or others, and then they can even be deposited precisely just to certain point physically, improving or changing those properties besides the capacity of the own inherent material. On the other hand, the reality today is that the key word is " potential ". There will be a long time before the choice of materials available for RM–Rapid Manufacture should be really remotely comparable for the available ones in standard industrial technologies. There is about of some dozens of materials of RP/RM commercially available today, understanding all the classes of materials as plastics, metals and ceramic. In contrast, a database of selection of existent plastics lists more than 40,000 active graduations exclusively in plastics. Materials recycled compounds can be difficultly or impossible of using.

9.5.2 Elimination of Tooling

CAD-CAM drives all the addictive production directly into processes, while turning theoretically possible to avoid completely the tooling use. In practice, it cannot still be possible frequently because processes and materials limitations of one type or other, but the technology of complementary rapid tooling can present a beneficial commitment. However, when possible, the complete elimination of tooling applications results in enormous savings of time and money. It turns possible to manufacture parts and products in small amounts, or using materials and design parameters that could be inconceivable.

9.5.3 Reduced costs

The ability to manufacture products more economically appears from several connections in the RM process chain: One of the larger savings, as mentioned, it is the elimination of the tooling needs. Additional savings appear from the reduction or to zero inventory demands, and eventually it can be expected that also appears of the ability to manufacture completes operational assemblies.
The establishment of distributed manufacture is simplified once tooling and inventory demands are eliminated. Parts and products can be manufactured in the use point and in the requested exact amount. For instance, parts can be manufactured at the place of the final assembly line, or in a substitution of part of the local distribution, or in a ship at the sea or in an external space. It will only be necessary to inventory the materials requested instead of many parts or sub-assemblies, or even the own final product.

10 Rapid Prototyping (RP)

Rapid Prototyping is the most common name given to a compound of related technologies that are used to manufacture physical objects directly from data sources of CAD. These methods are only in processes, they add and they unite materials in layers to form objects.
Such systems are also known by the names: addictive production, three-dimensional impression, production of solid free form (SFF - Solid freeform) and production in layers (layered manufacturing). The addictive technologies now offer advantages in a lot of applications compared to methods of production classic subtractive as machining or lathing:

- Objects can be formed with any geometric complexity without the need of having elaborated adjustments of machines or final assembly;
- Systems of rapid prototyping reduce the construction of complex objects to a manageable process, direct, and relatively rapid.

This resulted in the large employment by engineers as a way to reduce time of manufacture, better to specify and to communicate the product design, and to produce rapid tooling to manufacture those products.

10.1 Rapid Prototyping is not a solution to all problems of production of pieces or parts.

It should be observed that the technology CNC is economical, widely understood and available, offers wide material selection and excellent precision. However, whatever the demand involves producing a part or same object geometry moderately complex, and rapid execution – RP usually has enormous advantages. Examining extreme cases and determining which of technologies to apply, CNC or RP is relatively simple. For many other less extreme cases the line of crossing selection is hazier, it changes the whole time, and it depends on several pondered weights, factors case-dependent. Even whether the precision of rapid prototyping is not usually perfect as CNC, it is still adapted for an extensive range of applications and precisions requirements.

10.2 Materials used in rapid prototyping are still limited and dependent of the chosen method.

The range and available properties are growing rapidly. Numerous plastics, ceramic, metals that vary from stainless steel to titanium, and paper wood-type are available. Anyway, numerous secondary processes are available to convert patterns done in a rapid prototyping process into final materials or mould tools. *Geometric freedom* **-** Essentially all the addictive production technologies (addition of materials) provide the ability for production with limitless geometric freedom. It is the most important advantage over the subtractive methods and main reason of their existence. Geometric freedom still understands several limitations of the current technologies.

10.3 Stereolithography (SLA) is a free form fabrication technology, the first Rapid Prototyping process, was developed in 1986. It is a layered manufacturing method that utilizes a photo-curable liquid resin in combination with an ultraviolet laser. A storage bin of photosensitive resin contains a platform that can moving vertically. The construction part under is supported by the platform that moves downward by a layer thickness --typically about 0.05 mm to 0.25 inches-- for each layer. When the ultraviolet laser beam hits the liquid it hardens a small amount of resin under the beam point A laser beam “draws” the shape from CAD design of each layer and solidifies the photosensitive resin.
Stereolithography was developed by 3D Systems. Due to its accuracy and surface finish, it has become the most popular of the rapid prototyping methods.

10.4 Selective Laser Sintering (SLS) - A layer manufacturing technology in which the layers are formed by using a laser to bond the surface of a layer of powder material in the desired shape. Selective Laser Sintering (SLS) is a free-form fabrication technology developed by the 3D Systems. It is a layered manufacturing method that creates solid, three-dimensional objects by fusing powdered materials with a CO2 laser. A thin layer of powder material is laid down and the laser “draws” on the layer, sintering together the particles hit by the laser. The layer is then downward by a layer thickness and a new layer of powder is placed on top. This process is repeated layer per layer until the part is complete.
The advantages of SLS over Stereolithography (SLA) involve mainly material properties, as SLA process is limited to photosensitive resins that are typically fragile.

A great variety of materials can approximate the properties of thermoplastics such as polycarbonate, nylon, or glass-filled nylon are available for the SLS process. Meanwhile the smoother surface of an SLA part typically wins over SLS when an appearance model is required.
A SLS type machine consists of two powder magazines on each side of the work area. One roller moves powder over from one magazine to the other magazine crossing over the work area. The laser then draws the CAD file out the layer. The work platform moves down one layer by the specific thickness and the roller then moves to the opposite side. The process repeats until the part is finished.
Normally the surface of a SLS part is powdery, due to the base material whose particles are fused together without complete melting.

10.5 The LOM Process – Laminated object manufacturing (LOM) is a rapid prototyping process where a part is built sequentially from layers of paper. Successive layers of heat bonded sheet material form the model using typically paper. A laser system controlled by a sliced CAD data is used to cuts the perimeter of each slice in the sheet material. A heated roller will apply the next sheet layer, and waste material around the slice is left in place to support the next layer of the model.
Applying a laser to cut the profiles of the model cross-section on paper, plastics, and meshed or metallic material the system accomplishes a low cost process. A feed roll supplies a tape bonded to the previous layer melting a plastic coating to the bottom side of the paper.
One of the most important problems of LOM is the process of hot pressing. The purpose of hot pressing is binding the current layer to the built part. The speed of hot pressing must match with the power of heating up. If the of hot-pressing movement is too fast, the binding between layers the layer will not be rigid; while if the movement is too slow, the layer will be over-heated and the hot stress of will affect the shape of object. Another question is focused onto attain the cutting speed and the power of laser beam.
The LOM process is very advantageous in many aspects. First, because the laser beam only cut the outline of shape, this process can decrease process times than other RP. It is the most efficient process in all kinds of RP process. Secondly, the LOM process can manufacture very complicated object. The complicacy of the LOM object is less limited than the FDM (Fused Deposition Modelling) object because there is no need of support material in the LOM process; low material cost is also an advantage of this process.

10.6 3D Printing Process – is an innovative process, which uses a multi jet modelling head to apply a thermo polymer material in three dimensions. The completed CAD solid model is transferred to a STL data file, ready for the shape process. Parts are produced by the print head consisting of multiple jets that build the model layer by layer. If the part is larger than the head work space, the build platform will reposition within the Y-axis such that the process may continue.

The final model has appearance similar to that produced with Rapid Technologies such as Stereolithography, Laminated Object Manufacture and Laser Sintering, or meaning a stair stepped appearance. Duplicating freeform shapes within discrete layers creates these undesirable effects. Constructing models of thinner layers reduce the stair stepping effect, but thicker layers may still be acceptable within concept modelling.

Most of the models built using the 3D printer method are weak and can easily be damaged and deformed. In this case infiltrating with wax can strengthen these models, and adding ink to the initially transparent wax can produce parts that have a variety of colours.

Support structures are required to hold temporary the part before it is finished. Some types of rapid prints require post-processing, moreover for design reliability or aesthetic appearance. Making the part more attractive for presentational purposes the characteristic post-processing finishing involves sanding or painting.

10.7 Investment casting also known as the lost wax process is one of the oldest manufacturing processes. Complexes shapes can be made with high accuracy. Hard to machine or manufacture metals are indicate for this process. It can be used to make parts that have complex shapes cannot be produced by normal manufacturing techniques, such as turbine blades, parts that have to withstand high temperatures. Using a computer solid model master a wax pattern is made using a stereolithography or similar model prototyping.

Making a pattern using wax or some other material that can be melted away, makes the mould. Dipping a wax pattern in refractory slurry, a skin forms wrapping the wax pattern. As soon as this is dried and the process of dipping in the slurry and drying is repeated until a robust thickness is attained. Following the entire pattern is placed in an oven and the wax is melted away leading to a mould that can be filled with the molten metal. Because the mould is formed around a one-piece pattern, (which does not have to be pulled out from the mould as in a traditional sand casting process, very intricate parts and undercuts can be made. Materials as Aluminium alloys, Bronzes, tool steels, stainless steels, Stellite, Hastelloys, and precious metals can be cast in the moulds. Due to close tolerances that can be achieved parts made with investment castings often do not require any further machining.

10.8 Metal Spray & Electroplating - Metal Spray tooling and electroplating can be used for parts that are to be constructed using plastic production processes, being important resource in Rapid Tooling. This process applies a zinc/aluminium alloy with an arc spray to a pattern or model. The pattern or model can be a stereolithography part or a model made from wood, composite, plastic or metal. The alloy is sprayed over the pattern to a shell thickness from .060-inches to 0.125-inches as required. As soon ass it hardens into the desired shape and adheres to the pattern, the sprayed metal shell is then reinforced with high-treat aluminium-filled epoxy resin or caster aluminium or low melt metal alloy.

The finished mould can produce parts from virtually any production material, from polypropylene to glass-filled polycarbonate. The longevity of the tool is process dependent. Low-pressure operations such as casting, blow moulding or rim will yield more parts than the higher pressure applications. Turnaround time for producing a sprayed tool from Rapid Prototype Pattern is between ten days to three weeks depending on complexity of the tool.

Types and Quantities of Parts Made:

- Polyurethane 300 to 20,000
- Polyurea 300 to 20,000
- Epoxy 100 to 600
- Investment Wax Patterns 500 to 10,000
- Low Melt Metal Alloys 100 to 1,500
- Polyurethane Foam 2,000 to 20,000
- Silicone Rubber 10,000+
- Injection Moulding 10 to 1,000
- Rim Moulding 1,000 to 15,000
- Blow Moulding 300 to 500
- Vacuum Forming 5,000 to 100,000

10.9 CNC Milling Technologies - CNC RP milling machines commanded by special CAM software allows producing Rapid Prototype to Rapid tooling. Computer Numerical Control (CNC) in some aspects is related to a tool or model manufacturing, in which a cutting machine such as a lathe or milling machine is controlled by computer to cut a specified shape, often with many different steps and cutting tool changes. The fabrication process builds the part systematically by cutting material, with a high precision and finishing.

CNC cutting and milling has been in use for a longer period than RP and are relatively common in manufacturing. Driven by CAD data there are ranges of applications for cutting, hole punching, milling, engraving, etc. and a number of different technologies, which are used. The best advantages of CNC are its accuracy and speed.

The accuracy of CNC cutting means that elements can fit high precision and apart from cutting, CNC can be used for milling, drilling, tapping, bending, welding, grinding, etc and many industrial items are fabricated or assembled from components at the end of a CNC process.

10.10 Laser Machining - Laser machining represents a revolution. Before being limited to profiling work where depth of cut was unimportant, depth can now be controlled opening many new opportunities both in the production of components and in tool making. The laser can machine virtually any material and once calibrated, establishing possibilities with ceramics and other previously impossible to machine materials. Presenting the "tool" diameter of 0.1mm or less, the laser can attain restrict areas and create detail that milling could never reach.

As the "tool" does not wear, providing always-optimal cutting performance even pre-hardened steel or tungsten carbide, is vaporised as the laser traverses the surface. Similar to many RP systems working in layers, except that the layers are down to one micron thick, a cavity or section is created by material removal.

10.11 Fused Deposition Modelling (FDM) - The FDM technology involves heating a filament of thermoplastic polymer unwound from a coil and provides material to an extrusion nozzle. The heated nozzle melts the plastic and flow the melted plastic to be twisted on and off. The nozzle is mounted into a mechanical device, which can be controlled in both horizontal and vertical directions by a computer CAD data file. The system is sheltered within a compartment, which is held at a temperature just below the plastic melting point. Each layer is formed of extruded plastic deposed by the nozzle moving over the table in the required geometry. The plastic consolidate instantly after being sprayed from the nozzle and attach to the previous layer.

The machines range from fast concept modellers to slower, high-precision machines. The materials include polyester, polycarbonate, ABS, elastomers, and investment casting wax.

11 Rapid Tooling: Introduction

The term Rapid Tooling (RT) it is used to describe a process that uses typically a standards of Rapid Prototyping (RP) as a pattern to create a rapid mould or to use Rapid Prototyping process to manufacture a tool directly for a limited volume of parts.

Principal characteristics of RT:

- Time to manufacture tool much shorter than in a conventional tooling. Typically, around 20% of the conventional tooling.
- The cost of Tooling is very inferior that for a conventional tooling. The Cost can be below fifty percent of the cost of conventional tooling.
- Useful life of the tool is considerably smaller than for a conventional tool.
- Tolerances are larger than in a conventional tool.

The field of RT is expanding quickly and information on many of the new methodologies is still in evolution.

Rapid Tooling is a means of transferring non-functional models constructed from the range of rapid techniques into a functional prototype part.

This is normally carried out using a casting process, such as investment casting. It would typically use expendable rapid prototype models, particularly those made by the LOM or SLA or QuickCast processes.

Development and manufacture of products using the rapid prototyping route can be achieved effectively, saving time and eliminating costs associated with traditional manufacturing methods.

Rapid Tooling can utilise rapid models in two ways, as a master for the production of casting moulds or as a sacrificial pattern for one casting. At this stage of the manufacturing process the rapid model becomes less significant than the next step, the development of tooling. Tools need to be manufactured to specification and must be durable enough to last a certain time period.

12 Virtual Prototyping

Deliver more complex products with increased quality in shorter development cycles is effectively the main target of manufacturers. Traditional test-based development processes is no longer an option for engineering the performance of mechanical designs mainly where RP is too much expensive and complex as vehicles. Virtual prototype is the only valid alternative for evaluating functional performance attributes using Virtual Prototypes. A virtual engineering motion simulation application enables engineers to effectively analyse and optimise real-life performance of mechanical systems, before expensive and time-consuming real prototypes and physical testing.

Today Virtual Prototyping solutions are used by leading manufacturers like Airbus, Boeing, Renault, Ford, Audi, BMW, Seat and Skoda. Virtual Prototyping represents a keystone in their strategy as it delivers a highly attractive business argument. The investment in a Virtual Prototyping solution stands for costs that is in most cases already covered by the first replaced prototype but, of course, can be affect for future purposes at minimal variable cost. Virtual prototyping solution transforms product development into a competitive distinctive approach.

12.1 Improving product quality and reliability

Engineers seek to ensure that the dynamic performance of their mechanical systems will correspond to the project target and specifications. They research the multiple components interact and move as planned under the influence of real-life conditions, such as gravity and frictional forces. Virtual prototyping is the right answer, mainly for vehicles, aerospace, multi-components dynamic equipments, at last all product design with high costs development, and prototyping investment.

Virtual Prototyping and simulation can attain actually all required accuracy, and on time to positively impact the development process resulting in best solutions that can be easily re-scaled to support the various stages of the entire development process. The most important is that these solutions evaluate the dynamic motion performance in connection of all system requirements, including reliability, robustness, functionality and operation.

12.2 The following examples introduce two main representative advanced axis of Research & Development in Rapid Product Development through virtual prototyping and simulation:

- LMS International NV
- DLR Institute of robotic and mechatronic

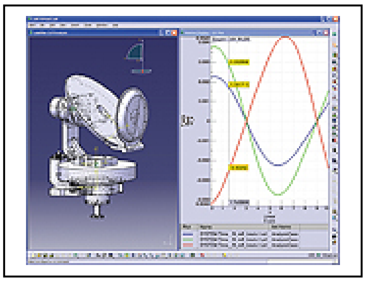
12.3 LMS International NV is the State-of-Art company in Virtual Prototyping and Simulation, offering besides advanced services, the LMS Virtual.Lab (presented below) integrated software for virtual prototype simulation.
LMS Company [LM1] is the recognized leader in virtual prototype simulation for critical performance disciplines such as structural integrity and safety, vehicle dynamics, comfort and sound quality, fatigue and durability. Our integrated solutions enable engineers to accurately simulate and refine mechanical design long before prototype testing.

LMS provides an unrivalled suite of physical-prototype testing and analysis solutions for durability, noise and vibration engineering. The LMS offering ranges from large-scale laboratory systems to compact and highly portable instruments. LMS Engineering Services works with customers to solve their most critical problems, optimise their development processes, or co-develop their products. Its unique combination of process know-how, and engineering experience turns attribute engineering into a strategic competitive advantage.

12.4 Virtual Prototype Simulation

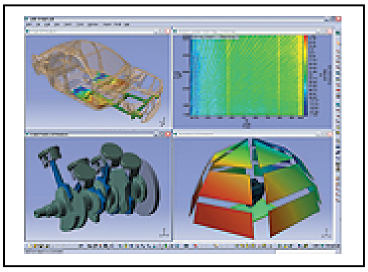
LMS Virtual.Lab - The Integrated Environment for Functional Performance Engineering - LMS Virtual.Lab offers an integrated software suite to simulate the performance of mechanical systems in terms of structural integrity, noise and vibration, durability, system dynamics, ride and handling as well as other attributes. LMS Virtual.Lab covers all the critical process steps and required technologies to perform an end-to-end assessment of a design in each of these key disciplines, long before committing to expensive tooling and physical prototype testing. Using LMS Virtual.Lab, engineering teams can quickly and effectively analyse a multitude of design options, and drive major design choices from the perspective of key performance attributes. LMS Virtual.Lab is based on CAA V5, the open middleware for PLM from Dassault Systèmes.

12.4.1 LMS Virtual.Lab



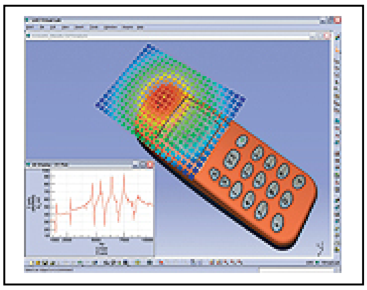
LMS Virtual.Lab eliminates much of the non value-added time from the typical engineering process. It is open to the leading CAD systems - CATIA, I-DEAS, UniGraphics and ProENGINEER. It removes the barriers between CAD, CAE and Test. It allows engineers to re-use models rather than rebuilding them for each application.

12.4.2 LMS Virtual.Lab Desktop



The LMS Virtual.Lab Desktop provides the common environment for functional performance engineering. Users have seamless access to models and data of leading CAD and CAE codes as well as to Test data. It also offers a complete visualization environment for geometry, functional performance engineering data, time and frequency functions etc...

12.4.3 LMS Virtual.Lab Acoustics

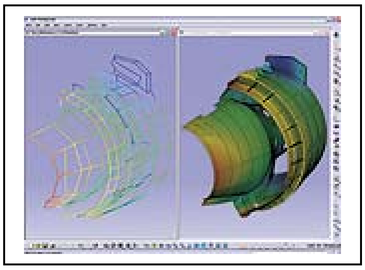


LMS Virtual.Lab Acoustics offers an integrated solution to minimize the radiated noise or to optimise the sound quality of new designs before prototype testing. Convenient modelling capabilities combined with patented solver technologies and easy-to-interpret visualization tools speed up simulation process drastically.

12.4.4 LMS Virtual.Lab Noise and Vibration

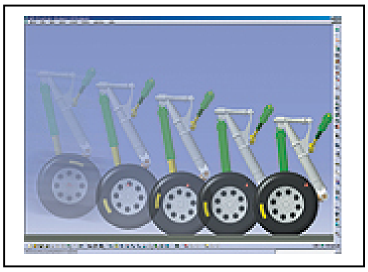
LMS Virtual.Lab Noise and Vibration performs unmatched noise and vibration analyses on the level of a full vehicle or aircraft. It accelerates the building of full-system models, and boosts the speed of simulation runs. It allows pinpointing the root cause of noise and vibration problems. It assesses a design variant within minutes, and quickly explores multiple options.

12.4.5 LMS Virtual.Lab Correlation



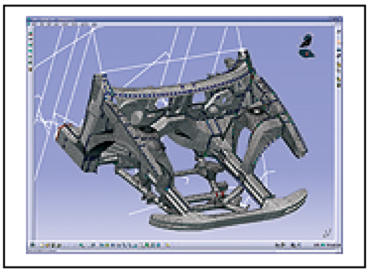
Correlating structural characteristics - Although static physical tests serve many design purposes, models used for vibro-acoustic simulations usually require systematic test-based validation of dynamic properties. LMS Virtual.Lab Correlation assists in the correlation with physical test results and in the preparation of structural tests.

12.4.6 LMS Virtual.Lab Motion



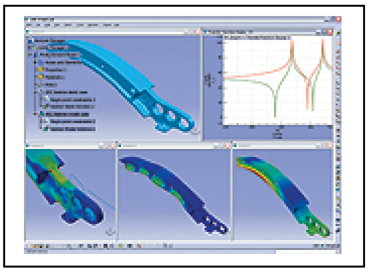
LMS Virtual.Lab Motion offers a complete and integrated solution to simulate realistic motion and loads of mechanical systems. It allows engineers to quickly analyse and optimise the real-world behaviour of their mechanical design and to guarantee that their design performs as expected, before signing off on a physical test.

12.4.7 LMS Virtual.Lab Durability



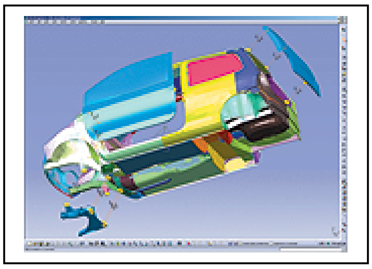
LMS Virtual.Lab Durability allows engineers to predict the fatigue hotspots and corresponding fatigue life of components and systems. It combines dynamic component loads with stress results automatically derived from structural FE-meshes and fatigue material parameters. Dedicated durability post-processing allow engineers to quickly assess multiple design alternatives.

12.4.8 LMS Virtual.Lab Structures



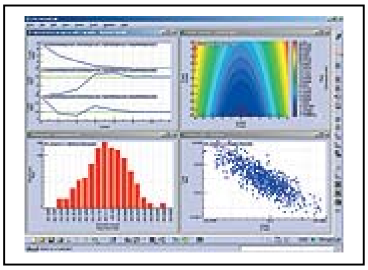
LMS Virtual.Lab provides ABAQUS, ANSYS, CATIA CAE and MSC.NASTRAN users an active, associative link between Virtual.Lab and their structural FE (Finite Element) solver for linear and non-linear structural analyses. Virtual.Lab transparently accesses the modelling and results data, and makes the structural solver an integral part of the Virtual.Lab simulation process.

12.4.9 LMS Virtual.Lab Modeling and Assembly



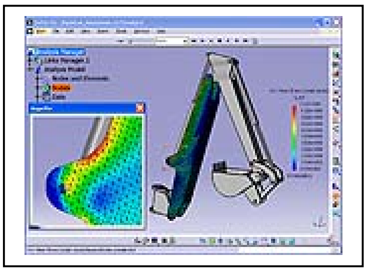
Building and assembling attribute-specific simulation models is key to accurate virtual performance simulation. LMS Virtual.Lab therefore includes all the necessary mesh editing, modeling and assembly capabilities to quickly derive attribute-specific virtual models from CAD geometries or FE models.

12.4.10 LMS Virtual.Lab Optimization



LMS Virtual.Lab provides a set of powerful capabilities for single and multi-attribute optimisation. Through Design of Experiments (DOE) and Response Surface Modeling (RSM) techniques, engineers quickly detect all the possible design options that meet their requirements.

12.4.11 LMS Virtual.Lab Designer



LMS Virtual.Lab Designer, a CATIA V5 add-on software suite, provides users direct access to dedicated simulation solutions for system dynamics, acoustics, fatigue-life and durability. It also delivers mesh-based design capabilities that allow designers and analysts to quickly modify FE simulation models and to efficiently analyse multiple design variants. [LM1]

13 DLR Institute of robotic and mechatronic

The DLR Institute of robotic and mechatronic [DLR1] of Professor Gerd Hirzinger ranks Europe-wide among the largest and most successful of its kind. Based on the institute's software and hardware developments leading German manufacturers of industrial robots could substantially increase their competitiveness. Its intention, however, is currently focused on space: What sounds for a non-expert like material from a science fiction novel, starts in DLR to become reality. In some years it is planned to send robots developed in Oberpfaffenhofen into space, which can do the job of astronauts. It has in particular been started thinking about the construction of a "robonaut" that by its own efforts can cover thousands of kilometers thus making it possible to also reach and repair faraway satellites. DLR succeeded in getting the breakthrough in the field of robotics during the D-2-shuttle mission in 1993. From the earth, the scientists operated the "rotex" robotic arm so precisely that it succeeded in capturing a freely suspended object. "We have demonstrated for the first time that many things can also be done from the ground", says the director of the institute Professor Gerd Hirzinger. Also on the earth the institute is doing pioneering work. Hirzinger's team is currently developing robotic arm systems allowing the surgeons to perform major operations only with a minor cut. The most successful product so far put on the market by this DLR institute is the "space mouse" originally developed for the "rotex" robotic arm. It is the most successful European computer peripheral item already sold in quantities exceeding 100,000.

13.1 Aeronautics Research

Dynamics and control in aeronautics is a key area of research and application within the department Control Design Engineering. DLR are specialists in multi-disciplinary design of flight control laws, as well as in development of multi-disciplinary models for aircraft flight dynamics and aircraft on-board systems. DLR applies, and continuously improves, an integrated flight control laws design process that is supported by methods and tools developed in our department. DLR further performs modelling and model integration of on-board aircraft systems, aiming at reduction of peak power loads and overall power consumption by systems on-board the aircraft.

13.2 Flight Dynamic and Control

Flight control laws (FCLs) form the core of the aircraft electronic flight control system (EFCS) software. So-called "primary flight control laws" provide all functions to control the aircraft flight dynamics, either manually or automatically. Secondary control laws provide add-on functionality such as active damping of airframe structural dynamics, and active reduction of loads on the airframe during manoeuvring or turbulence and gusts.

13.3 Aircraft modelling and simulation

The development of aircraft flight dynamics models of appropriate fidelity is a key aspect of the flight control law design process. These models must allow all relevant multi-disciplinary design criteria (e.g. handling qualities, structural loads) to be computed efficiently and with sufficient accuracy.

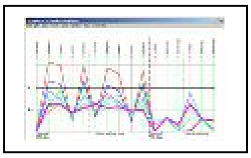
13.4 The modelling approach

The basic modelling philosophy is to construct aircraft models around a backbone describing the non-linear equations of motion of a (possibly flexible) flight vehicle with respect to the (rotating) earth.

13.5 Flight dynamics and control

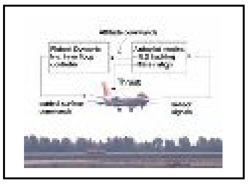
Flight control laws (FCLs) form the core of the aircraft electronic flight control system (EFCS) software. So-called "primary flight control laws" provide all functions to control the aircraft flight dynamics, either manually or automatically. Secondary control laws provide add-on functionality such as active damping of airframe structural dynamics, and active reduction of loads on the airframe during manoeuvring or turbulence and gusts. With aircraft performance being pushed more and more towards its physical limits, there is a growing need for an integrated design approach. DLR develops modelling and design tools that are able to cope with the resulting increasing complexity of the FCL design task.

13.6 The flight control laws design process



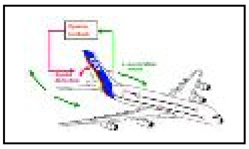
DLR proposes and applies a structured design process for flight control laws. This process is based on object-oriented modelling technology, advanced and/or classical controller synthesis methods, multi-objective parameter synthesis, and efficient analysis methods for performance and robustness assessment. The process supports handling of complex controller structures, addressing of the full envelope of aircraft loading and operating conditions, handling of large amounts of multi-disciplinary design criteria, and handling of various types of uncertainty and parameter variation.

13.7 Primary flight control laws design



DLR applies design process and tools to develop manual and automatic control laws, both for civil transport as well as highly manoeuvrable military aircraft. Recent examples are manual control laws for the thrust-vectored X-31A aircraft, and automatic landing control laws for DLR's experimental aircraft ATTAS.

13.8 Secondary flight control laws design



Over the past years a close and successful cooperation with Airbus Germany has been established for development of control laws for active loads alleviation and comfort improvement. DLR expertise in design process technology, multi-objective optimisation, and multi-disciplinary model integration has been an important contributing factor in this cooperation. In the frame of the EU-funded project AWIATOR DLR develops gust estimation and gust load alleviation systems.

13.9 Multi-disciplinary aircraft modelling and simulation

Flight control law design requires the availability of accurate aircraft dynamics models that allow all types of numerical criteria of interest to be evaluated. To this end, DLR develops models by integration of agreed-on model components and data from all involved engineering disciplines (e.g. flight mechanics, aeroelastics, actuation systems). DLR has developed a flight-dynamics library based on the multi-physics modelling language Modelica. Besides control design, the models may be used in real time simulation, for example in our interactive desktop simulation tools. [DLR1]

14 Simulation

The presents unequalled multi-engineering capacities and new and revolutionaries modelling solutions and simulation turn possible to simulate the dynamic behaviour and complex interactions among systems of many engineering fields, as mechanic, electric, thermodynamic, hydraulic, tire, thermal and control of systems. This means that the users of simulators can build models more integrated and they might have resulted of simulations that best describe the reality.

14.1 Adapt flexible and open Simulation Methods

The simulation atmosphere is completely open offering means in that the users are free to create the own libraries of models or to modify the libraries of ready models to equip the users better, in the development of models and simulation needs. The flexibility of simulators created a versatile tool that is perfectly adapted to model and to simulate new design alternative and technologies.

14.2 Methods and Tools in Dynamics and Control

Advanced design processes are model-based and problems of control of laws (physics or behaviour) of design they are also frequently by nature many different and you multi-discipline, and frequently contradictory design demands have to be accomplished simultaneously.

Problems of control design connected to critical processes in aerospace and robotics demands methods attended by efficient computer and safe tools.

The simulations for computer aid in the approach for the following basic techniques:

- Modelling to multi-discipline and simulation
- Law control and evaluation of Optimisation-based design
- Non-linear controller's synthesis
- Linear system techniques.

15 Rapid Product Development

Faster to Market: The New Best Practices - Ten years ago time to market new vehicles industry designs were from 60 months to now 18 to 24 months.

Better management focus, better concurrent engineering practices and standards for design, virtual prototype and validation. Better collaboration and information technologies, simulation, Knowledge Management across development teams, both within and beyond the corporate.

Better tools as advances in solids modelling, computer-aided engineering systems, project management tools, product data management software applications. Managing the creation, propagation and storage of data, these tools ensured wide engineering and work language that dramatically compressed cycle times for development.

The radical change in manufacturing starting from Rapid Manufacturing (RM) is based on completely new additive manufacturing techniques that produce fully functional parts directly from a 3D CAD model without the use of tooling. This offers the potential to change the paradigm of manufacturing, service and distribution with opportunities for producing highly complex and customised products.

Rapid product Development introduces now a wide range of tools and technologies, which involves evaluation and advanced expertise to obtain the best results for each industrial chain. Meanwhile no industry in worldwide market will continue indifferent to the new approaches in Product Development due to the interaction amid the diverse potential actions and results.

The revolutionary processes, and promising new technologies are changing completely the profile of design and manufacturing, involving as never before Research & Development, Technologies Transfer, and computer science applications.

16 References

[FF1] – Factory of Factories Portal - http://www.factoryoffatories.com

[LM1] - The Articles and Images are courtesy of © LMS International NV - http://www.lmsintl.com/

[DLR1] - (c) Institute of Robotics and Mechatronics, German Aerospace Center / DLR Oberpfaffenhofen