SOLID MODELING IN ENGINEERING

To help understand the concept of solid modeling, it is necessary to know that it is an important tool in the engineering process. Also, it is important to know how solid modeling actually applies to product design.

Design for Manufacturing

This is the process of designing parts, components or products for ease of manufacturing with the end goal of making better products at lower costs. This is done by simplifying, optimizing and refining the product design.

Five principles are critical during design for manufacturing. These are:

1. Manufacturing Process.
2. Design Process.
3. Material Selection.
4. Environment where the product will be used.
5. Compliance/Testing – to meet with safety and quality standards.

Ideally, after "design for manufacturing", tooling is then carried out. In addition, properly-executed "design for manufacturing" needs to include all the stakeholders, that is: engineers, designers, contract manufacturer, mold-builder and material supplier.

The intent of this "cross-functional" process is to *challenge* the design — to look at the design at all levels, namely:

Component level;

sub-system level;

system level; and,

holistic levels.

This will ensure that the design is optimized and does not have unnecessary cost embedded in it.

What is Solid Modeling?

Solid Modeling is the computer modeling of 3D solid objects. The objective of Solid Modeling is to ensure that every surface is geometrically correct. It requires the CAD software to simulate the object from within and outside.

A 3D model is essentially made up of vertices, which come together to form a mesh and act as the core of the 3D model. Each point on the model can be manipulated to change the shape. By using coordinate data, the software identifies the location of each vertical and horizontal point, all relative to a reference point.

The most common way to begin making a 3D model is to start with a basic shape – a cube, box, sphere, or whatever you think is best suited. From your starter shape, you can start moulding and refining it into what you desire.

The use of solid modeling techniques allows for the automation process of several difficult engineering calculations that are carried out as a part of the design process. Simulation, planning, and verification of processes such as machining and assembly were one of the main catalysts for the development of solid modeling.

Generally speaking, computers have changed product design and manufacturing methods. Not only are products designed using applications such as computer-aided design (CAD) and solid modelling, but much of the manufacturing is

automated in contemporary industrial facilities. Solid modelling augments the process of manufacturing by:

- **Constructing;**
- **Analyzing; and,**
- **Testing a product design.**

This is done in the computer and helps in facilitation of the manufacture of the product using rapid prototyping.

Solid modelling is the process of digitally creating a 3d design using CAD software. There are 2 primary forms of 3d modelling, solid and surface. Surface usually for visual purposes and solid for real world fabrication and computer simulations.

Difference between 2d & 3d CAD

2d is just a flat drawing which include the x, y axis. 3d is a solid three-dimensional object which includes the x, y & z axis.

2d drawings can communicate a design sufficiently to a user, however if one wants to produce the CAD design using computer controlled production machinery then he or she would need 3d drawing.

Advantages of Solid Modeling

Solid modeling is one of the most important applications of the CAD software and it has become increasingly to-date. The solid modeling CAD software helps the designer to see the designed object as if it were the real manufactured product. It can be seen from various angles or directions (and in various views). This helps the

designer to be sure that the object looks exactly as the he or she wanted it to be. It also gives additional vision to the designer as to what more changes can be done in the object.

Solid modeling is a **tool that enables the design engineer to facilitate the design process more easily. Solid Geometric Modeling is a relatively new form of Computer Aided Engineering.** It can facilitate:

- **interference checking;**
- **visualization and visibility studies;**
- **Packaging; etc.**

By employing this tool in the early concept phase of design, many potential problems can be eliminated. This solid model can be refined to include more detail as the final design is determined. The model can then be passed to a CAD/CAM system for generation of drawings or Numerical Control tapes (that are coded to facilitate manufacturing processes), or to a Finite Element Pre-processing program where a finite element model can be built based on the geometry already created.

Use of Solid Modeling in design will ensure:

- Ease of interpretation with multiview perspectives.
- Acceleration of the engineering design process.
- Simulation of real-life conditions like stress or force loading.
- Processes will be cheaper and faster than building a physical model.
- Saving of time and development costs
- Easy use with visual aids when presenting or selling design ideas.
- Direct use for CAM manufacture like 3d printing or CNC allowing mass and volumetric analysis. For example weight, center of mass, volume and inertia.

- Ease of export into large variety of file formats depending on its purpose.

Note also that solid modelling is usually parametric - meaning that size and detail changes in design can be made easily retrospectively, extremely useful for flexible design iteration.

Representation

Solid modelling produces a three-dimensional model of a design in the computer, and contemporary computers easily render the models to create lifelike images of the design. These three-dimensional images and models make it easier for laypeople, such as manufacturing facility's client, to understand the design, in comparison with traditional orthographic projections, such as elevations, sections and plans.

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Properties

Solid modelling applications provide material and dimensional properties for the designed elements. For example, a solid model of a can of soda can provides the mass, dimensions, volume, density, center of mass of the can as well as the structural properties of the aluminium can. These properties help the manufacturer determine the most efficient form of the design.

Testing

Because solid modelling provides material, dimensional and structural properties of a design, the product can be tested with loads and other environmental factors in the computer before the costly manufacturing process. For example, a bottle of detergent can undergo a test to ensure it will not break if dropped on a hard surface, or that the handle is located in the right position to pour liquid detergent into a washing machine.

3D Printing and Prototyping

Solid modelling applications can export three-dimensional formats, such as stereolithography files, to produce the model using rapid prototyping machines, such as three-dimensional printers and computer numerically controlled (CNC) machines. Rapid prototyping provides quick production of designs to test in reality before the production of expensive moulds and mechanisation.

A solid model of an object is a more complete representation than its surface (or wireframe) model. It provides more topological information, tools that used analysis of "shape", in addition to the geometrical information which helps to represent the solid unambiguously.

Solid modeling is the most advanced method of geometric modeling in three dimensions. It is the representation of the solid parts of the object on the computer. Solid Modeling is **the computer modeling of 3D solid objects**.

The objective of Solid Modeling is to ensure that every surface is geometrically correct. It is considered the most complex aspect to master in computer-aided design (CAD) because it requires the CAD software to simulate the object from

within and outside. **Solid modeling** is a consistent set of principles for mathematical and computer modeling of three-dimensional ***solids***. Solid modeling is distinguished from related areas of ***geometric modeling*** and ***computer graphics***, as ***3D modeling***, by its emphasis on physical fidelity. Together, the principles of geometric and solid modeling form the foundation of ***3D-computer-aided design*** and in general support **the creation, exchange, visualization, animation, interrogation, and annotation of digital models of physical objects.**

Application of Solid Models

1. Graphics:

This is for generating drawings, surface and solid models.

2. Design

This is for mass property calculation, interference analysis, finite element modeling, kinematics and mechanism analysis, animation, etc.

3. Manufacturing

This is for tool path generation and verification, process planning, dimension inspection, tolerance and surface finish.

4. Component Assembly

This is used in various application to robotics and flexible manufacturing. It involves:

- **Assembly planning;**
- **Kinematics and dynamics driven by solid models;**

- **Vision algorithm; etc.**

Process of Making the Solid Models

The typical geometric model is made up of wire frames that show the object in the form of wires. This wire frame structure can be two dimensional, two and half dimensional or three dimensional. Providing surface representation to the wire three dimensional views of geometric models makes the object appear solid on the computer screen and this is what is called as solid modeling.

Note:

The term **"wire frame"** comes from designers using ***metal wire*** to represent the three-dimensional shape of solid objects.

To make the solid models one has to first make the wire frame model of the object and convert it into 3D view. Thereafter the surfaces are added to the 3D wire model to convert it into 3D solid model. For creating the solid models one needs to have special CAD software that can create solid models. One of the most popular CAD software for solid modeling is SolidWorks. A number of other CAD software like AutoCAD and others also have features of creating the solid models.

Applications of Solid Modeling

Solid modeling is used for:

- **creating solid models of machine parts;**
- **buildings;**
- **electric circuits, etc.**

The solid modeling software are being used for a large variety of applications, here are some of them:

1) **Engineering**: The engineering design professionals use solid modeling to see how the designed product will actually look like at the initial stage of conception.

   The architects and civil engineers use it to use the layout of the designed building.

2) Entertainment industry: The animation industry has been using solid modeling to create various characters and the movies out of them.

3) Medical industry: Modern imaging scanners are being used to create the solid models of the internal parts of the body. This helps the doctors to visualize specific tissues of the body, designing various medical devices etc.

Beyond the drawing

There is more to solid modeling, a cornerstone of computer-aided design, than meets the eye. Beyond the drawing, a solid model offers details that enable computer analysis and rapid prototyping like 3D printing and CNC machining.

Since Solid Modeling is the computer modeling of 3D solid objects, the objective in the simulation process is to ensure that every surface of the object modeled is geometrically correct.

Solid Modeling therefore requires that the CAD software should be able to simulate the object from within and outside. This is critical as it enables designers

to obtain provide cutaways of the design, such as an engine and its components. Figs. 1 and 2 illustrates this.

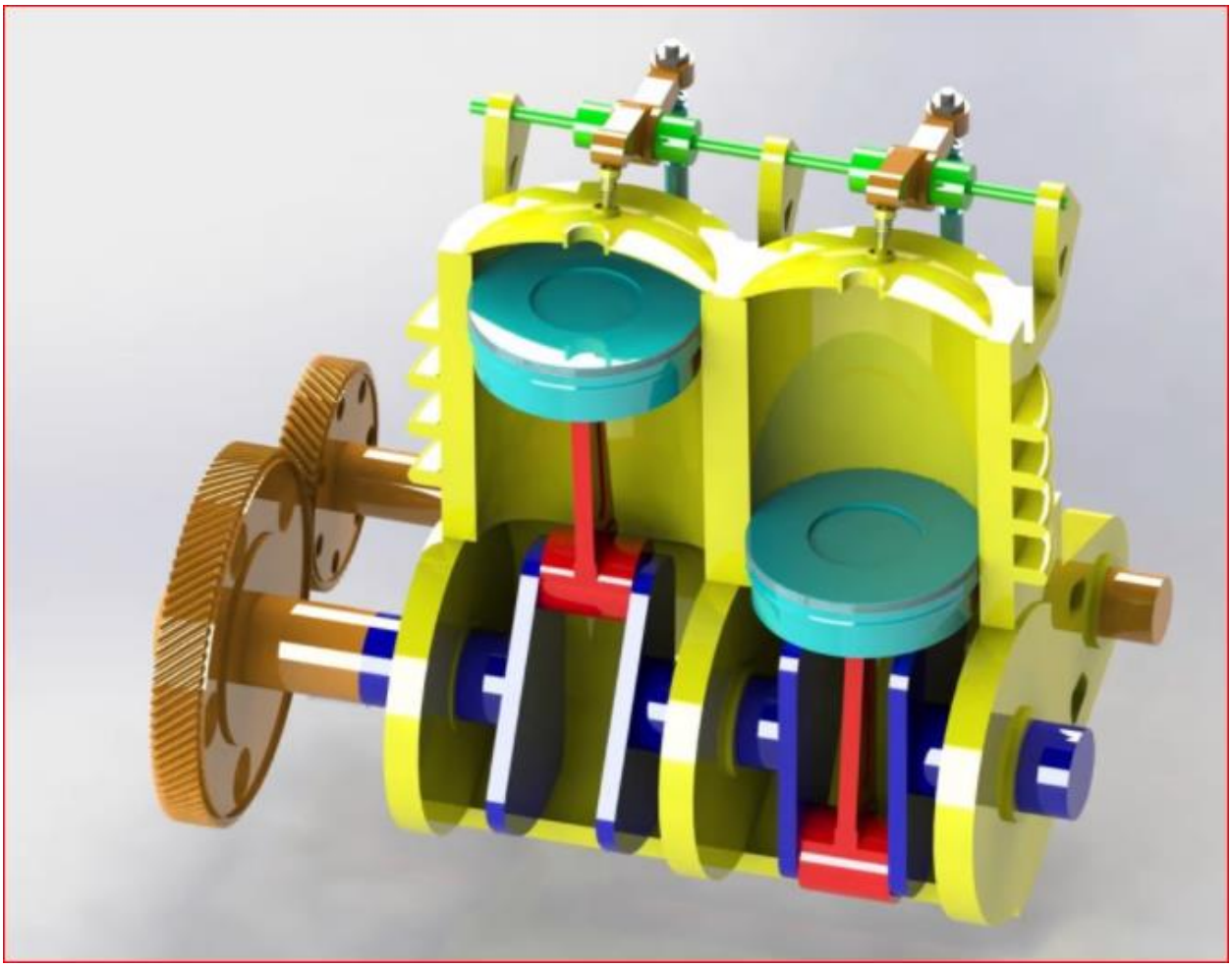

Fig. 1: A solid model of twin-piston engine.

Note:

CNC stands for Computerized Numerical Control. It is a computerized manufacturing process in which pre-programmed software and code controls the movement of production equipment. CNC machining controls a range of complex machinery, such as grinders, lathes, and turning mills, all of which are used to cut, shape, and create different parts and prototypes.

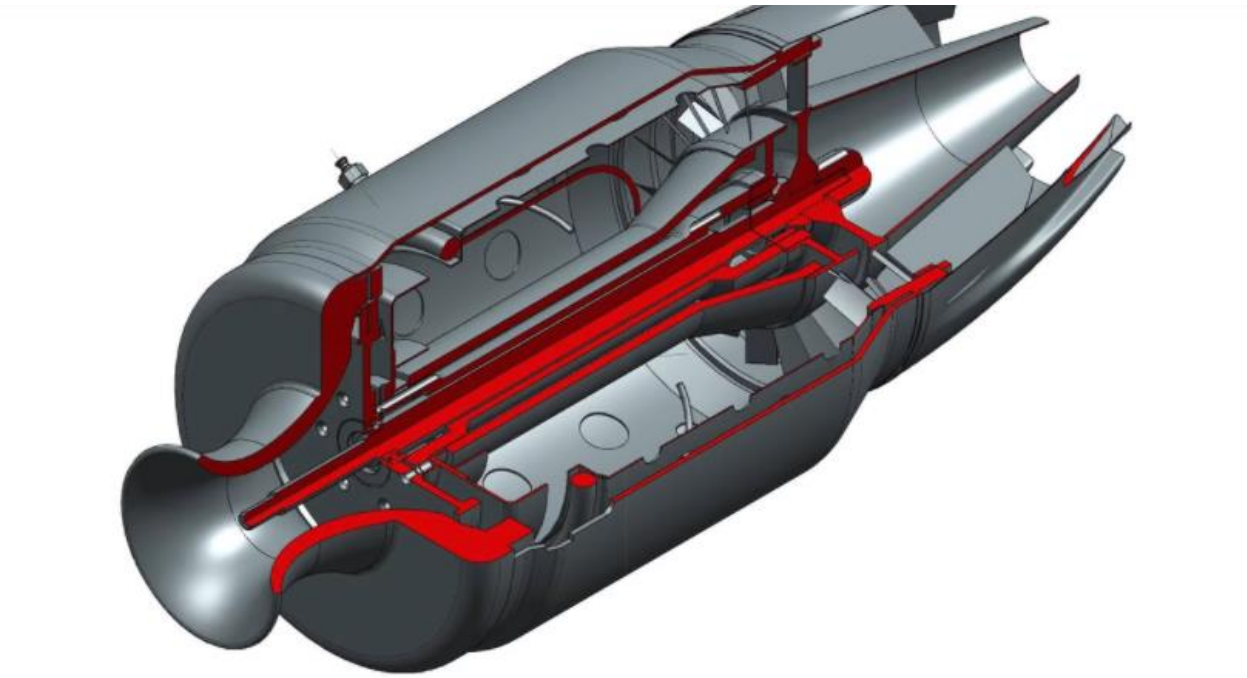

Fig. 2: A solid model of jet engine.

On paper or in 2D CAD, a designer creates drawings of different views of an object. They imagine how the front, side and plan views work together to describe the actual three-dimensional object.

However, solid modeling transforms that 2D designer's understanding into a 3D electronic representation. The resulting object has,

- **a volume;**
- **a boundary surface;**
- **holes; and, even hidden voids.**