SALD and SALVI Virtual Laboratory

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Abstract

This paper describes efforts to apply virtual manufacturing techniques to produce machine parts using Solid Freeform Fabrication (SFF). In particular, the work was done to develop a Virtual SFF Laboratory for the Selective Area Laser Deposition (SALD) and Selective Area Laser Deposition Vapor Infiltration (SALDVI) for the manufacture of machine parts and research on their characteristics, as well as for research on development of SALD and SALDVI technologies. It was the goal of the authors to supply the user with a tool to design a part, develop its three dimensional model, render it and observe its shape and dimensions. Except for research, the laboratory is intended to be used for teaching principles of design and manufacturing of machine parts, as well as for demonstrating SALD and SALVI processes to visitors. The Virtual Laboratory was developed on Silicon Graphics workstations. The Virtual Laboratory can create a multi-media, stereoscopic presentations of the SALD and SALVI processes in the Solid Freeform Fabrication Laboratory at the Institute of Material Science (IMS) at the University of Connecticut. The presentations can also be distributed through the Internet.

Introduction

Since 1983, when Myron Krueger conducted research at the University of Connecticut and introduced his concept of "artificial reality" [1], a considerable number of further investigations have been done. The term "artificial reality" is now seldom used and has given way to the term "virtual reality", though both describe projects in which potential, but as yet unrealized systems are developed. One of the first such projects was a virtual engine model created by Pratt and Whitney at the CAD&CAM and ES (Computer-Aided Design & Computer-Aided Modeling and Expert Systems) Laboratory of the University of Connecticut by Krueger and Bowley in the middle of 1980s.

Real-time virtual models, machines, and systems which visualize manufacturing processes present a promising low-cost, highly effective method for improving the quality and efficiency of manufactured durable goods. The computer models numerically and visually demonstrate the physical phenomena of a process, and allow for study and observation of the process and its behavior [2]. Manufacturing researchers and designers studying the dynamic simulation of the process are able to make modifications to the model and its parameters and observe, using the visual output devices, the impact of these modifications on any aspect of the process.

Virtual models, machines, systems, and processes are becoming useful tools in manufacturing and design research, and in the development of products. They provide the ability to investigate the properties of the part prior to building a physical model or prototype. These technologies are used in the design of machining and production processes, and in the design of finished goods. They consist of a group of recently developed techniques and approaches that allow the construction of computer models of parts along with simulation of fabrication processes. What makes this group of manufacturing technologies special is that it allows one to check production parameters before actual prototypes are manufactured.

The use of these virtual manufacturing techniques could result in great savings of both time and money. In general, virtual modeling promises shorter design cycles with more design iterations, leading to a an optimal design and better use of resources. The end goal of any virtual manufacturing is to produce a virtual model of a part, set of parts or machine that will "virtually" make the part from a database file containing the geometrical description of a physical object in terms of pre-defined geometric entities. The actual manufacturing hardware provides the physical means to machine the part, whereas virtual machining mimics the behavior of the hardware and makes the part as a computer model. Special software is employed to bridge the gap between the CAD data and the virtual manufacturing system. Such software should control various parameters, such as the rate at which the positioning system proceeds, the tool path, the thickness of the layer of the material for removal and/or length of the path, the slice length, and other factors. Virtual manufacturing provides a means for refining motion control and simplifying part manipulation for various manufacturing hardware systems. The SALD and SALDVI virtual laboratory was developed taking into consideration all of the advantages of virtual modeling.

Virtual Laboratory

Manufacturing processes, especially closed-chamber processes, are difficult to observe, to study and run for the sole purpose of design and research studies. This is an area in which the Virtual Laboratory is especially useful. It simulates the actual production environment with all its functions, i.e. designing a part, creating STL (STereo Lithography) or VRML (Virtual Reality Modeling Language) files, slicing them, converting into laser path files, and supplying the rendering parameters. This paper reports on the development of such a laboratory and its application to actual research, teaching and the demonstration of problems [3,4,5].

Part Design

For the purpose of rendering using SALD and SALDVI systems, the parts are designed using a software package called I-DEAS [6,7]. I-DEAS Master Series is an advanced Computer Aided Design (CAD) software package that allows users to create very complex and detailed geometries. I-DEAS was used to design parts to be created in a three dimensional space (Figure 1). A special procedure is used for creating a three dimensional model in I-DEAS Master Series and converting that model into an STL file format so the model can be used in Solid Freeform Fabrication (SFF). A VRML format was also examined and it was discovered that format has some advantages in useful in sending files through the Internet [8]. After the geometry of the parts is described, the parts are displayed on the screen in a simulated three dimensional image.

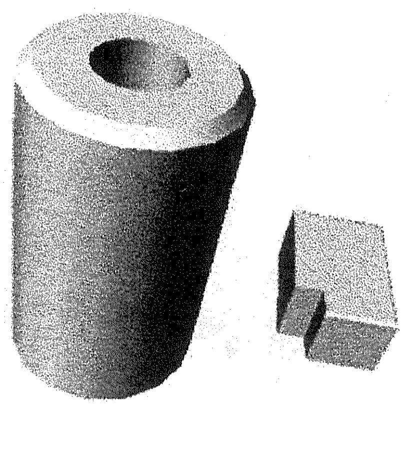


Figure 1. A shaft and a block designed for rendering using SALDVI.

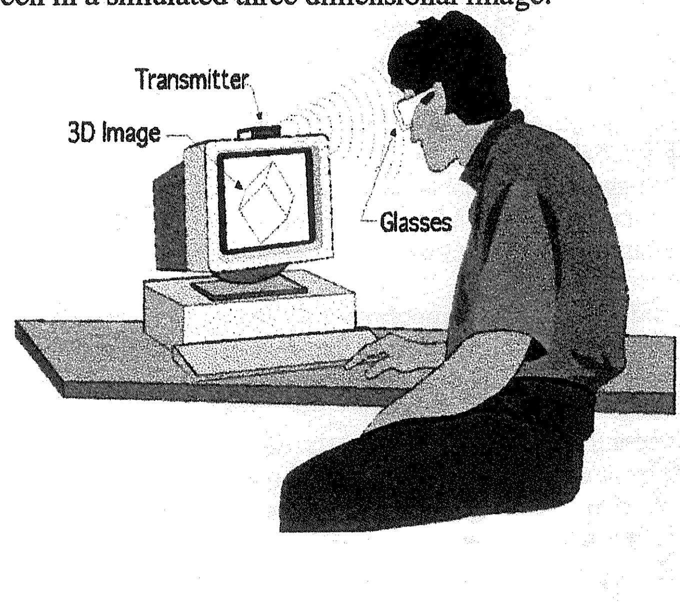


Figure 2. A part examining session using CrystalEyes™ stereo view system [10].

Inventor and Stereoview

It has been proven that objects created in I-DEAS can be readily transferred into Inventor for animation and stereo viewing. This creates an invaluable visualization tool, not only for the researcher, engineer and technician, but also for the people who want to learn more about SFF processes. Inventor is a useful tool for visualizing 3D objects either created in the Inventor program using basic 3D shapes, or complex geometries imported from other programs. Once a model has been brought into Inventor, it can be animated and textured using some basic commands. If a more robust animation sequence is needed, C++ can be used to call various Inventor libraries. Inventor is a good visualization tool because it directly supports the use of stereo viewing. Stereo viewing is a system that incorporates the use of a special set of glasses with LCD lenses. The lenses act like shutters, opening and closing many times a second, the left and right lens alternate shutter cycles, such that only one eye sees the computer screen at any instant in time. Mounted on the computer monitor is an emitter box that sends an infrared signal to the glasses, this signal synchronizes the lenses of the glasses with the images on the screen. The computer screen cycles through two different views of a model in sync with the glasses, resulting in the left eye seeing one view of a model and the right eye seeing another. The images in the left and right eye are combined in the brain and the illusion of a 3D image is created (Figure 2).

Object Examining

Once an object was created in I-DEAS, as in the case under discussion here where a model of the SFF laboratory in IMS was created, it was converted to an Inventor file format and brought into Inventor. Each component of the model was created separately and brought together in the I-DEAS assembly module, this allowed the objects to be manipulated independently, as separate "children" in Inventor. If the different components were constructed in the same drawing and saved as one part, it would exist as one object in Inventor, and the different components could not be manipulated individually.

I-DEAS also supports an additional feature that allows three-dimensional models to be exported in the Inventor format. Inventor files can also be created using an additional application that takes STL or IGES files and translates them into Inventor format. The SGI (Silicon Graphics, Inc.) Irix 6.2 operating system has a built in command that converts STL files into Inventor files. This command is: STLtoINV <filename.stl> <filename.iv>.

Stereo viewing is used for part examination. First, I-DEAS Master Series [6,7] is used to create complex parts. Once created in I-DEAS, the models are converted into Inventor [9,11] and an Inventor file format is generated. Inventor is used to add realistic features to the image of the part designed and is capable of constructing basic three-dimensional geometries. It also fully exploits the stereo-viewing capability by adding sound and animation to the model. The part can be viewed and animated in stereo view (Figure 2). Stereo viewing is a very powerful visualization tool in design. It makes three-dimensional objects appear as if they were suspended before the computer screen, giving the viewer a sense of a true three-dimensional structure from a flat, two-dimensional computer screen. This presents users with a better three-dimensional representation of a modeled object's behavior, so that features and functions can be examined in detail.

The work was conducted using Silicon Graphics Indigo Extreme work stations equipped with Inventor, GL library, C compilers and stereo view systems. The installation of stereo view glasses using a CrystalEyes™ [10] stereo view system allows the viewing of the entire system in three dimensional space. This system will be improved with some C++ programming routines under study that promise to make the animation sequences more robust.

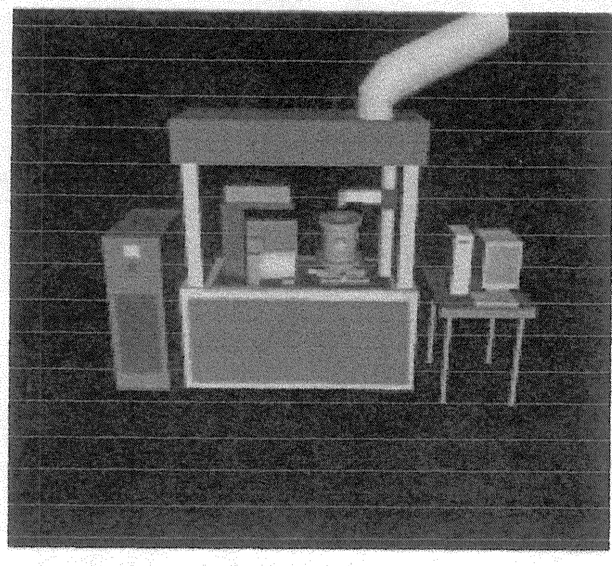


Figure 3. A general view of SALD and SALDVI rendering system.

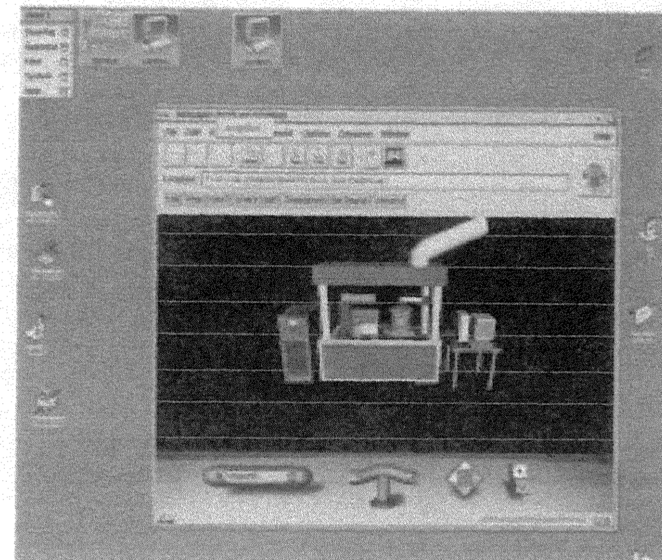


Figure 4. A SALD and SALDVI rendering system - view on the World Wide Web.

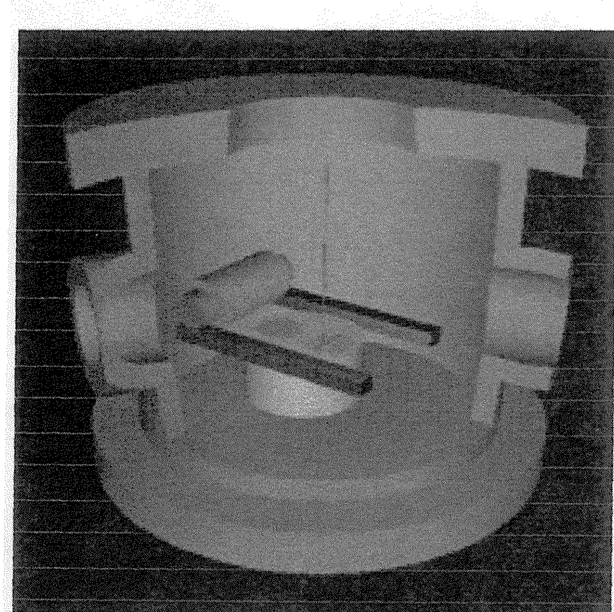
Part Rendering

Once part is designed using I-DEAS Master Series, special procedures are used to create a three dimensional model and convert it into STL file format. This file is sliced and a special file to drive the laser is created. Once this is done, the model can be used for SALD and SALDVI rendering. The virtual laboratory is equipped to render parts [3], as well as to simulate joining [4] SiC tubes. All of this is available in the virtual session.

Once a model is created in I-DEAS, it can be easily exported into a STL format. The .stl or stereolithography format is an ASCII or binary file used in the interchange between CAD systems and the rapid prototyping machines. It lists the triangular surfaces that describe a computer-generated solid model. This is the standard input format for most rapid prototyping machines.
From this STL file, the object is then processed into a set of coordinates that can then be sent to a laser scanning system for Solid Freeform Fabrication (SFF).

Virtual Laboratory Session

The Virtual Laboratory session can be conducted in In situ or remote modes. The In situ mode takes place in the SFF Laboratory of IMS, where there are SGI systems at the disposal of the users. The SALD and SALDVI system is displayed on the screen (Figure 3). To tour the laboratory in the remote mode, users can use Netscape to navigate through the system (Figures 4, 5, 6). In this mode, the user can visit two operations. In operation one, a shaft (Figure 1, 5, 6) is rendered. In operation two, the process of joining two pieces of silicon-carbide tube via SALD can be witnessed and studied. The pieces of tube joined by the SALD process are shown as a finished product in Figure 8. Figure 10 is a magnified image of this finished product. The virtual process of joining two pieces of tube via SALD is shown in Figures 9 a,b,c. An added bonus of the virtual laboratory is that the user can "virtually" enter rendering chambers during part generation (Figures 3 and 4) or during the joining operation (Figures 5 and 6). This is impossible to do in the real-world operation.



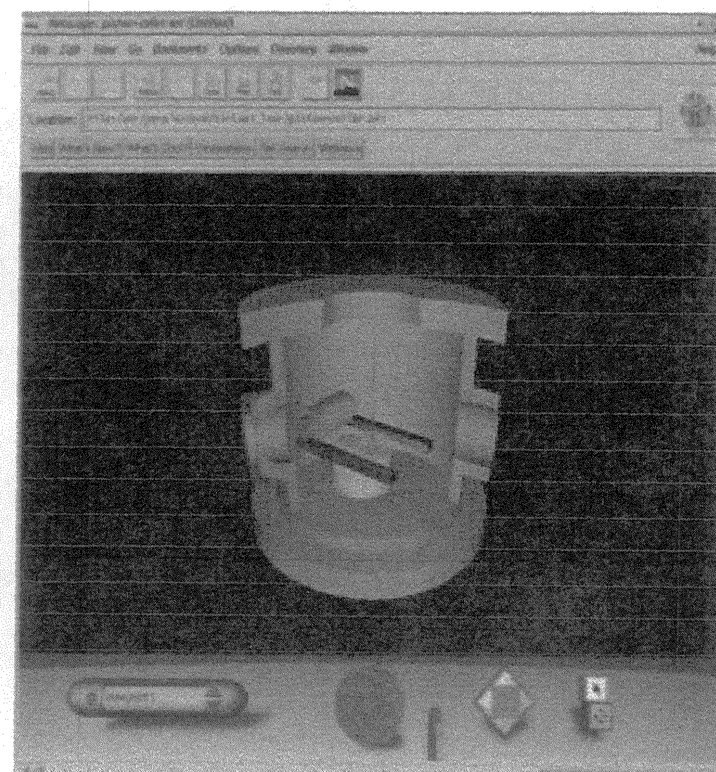


Figure 5. A SALDVI rendering chamber with the powder feeding mechanism and the part support.

Figure 6. A SALDVI rendering Chamber with the powder feeding. View on the World Wide Web.

Internet Session

The virtual laboratory can be visited on Internet [12,13] where the user can operate it through the WWW. After coming to the IMS page and entering the lab page, a greeting screen appears (Figure 11). The remote mode is enabled automatically and the user can enjoy his/ her visit to the laboratory (Figures 3 to 10). The virtual laboratory is also accessible by the World Wide Web where projects can be examined. It has been used successfully in teaching, design, and technology presentations.

Possible Future Development

At this time, the Virtual Laboratory can be used only to examine designs and processes previously created. In future developments, we anticipate adding the ability to create a part virtually in real time, the ability to examine the part, and the ability to render the part using the SALDVI process. Also, more investigation is being done to study the C++ programming language aspects, so that all the objects in the project will fit together into a single flowing presentation. C++ will also help to make the animation better and add more realism to the process. Future work is suggested to improve the part design and fabrication animation. More features may also be added to the presentation capabilities.

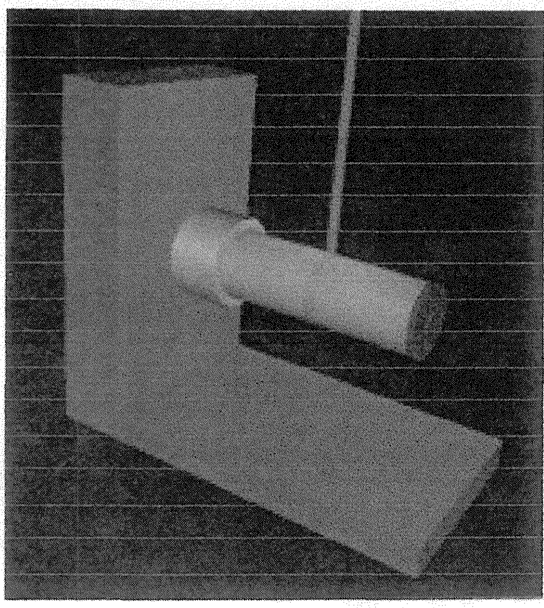


Figure 7. Two pieces of silicon - carbide tube SALD joining process.

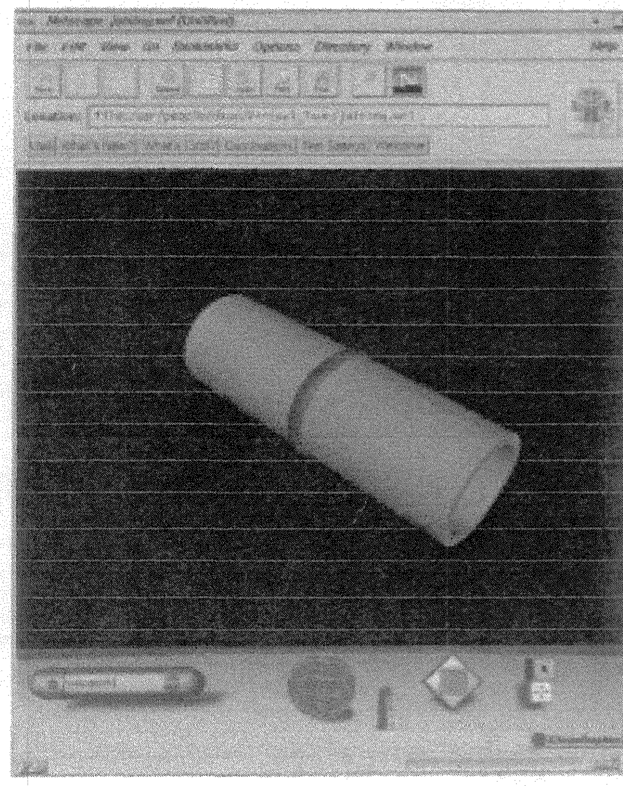
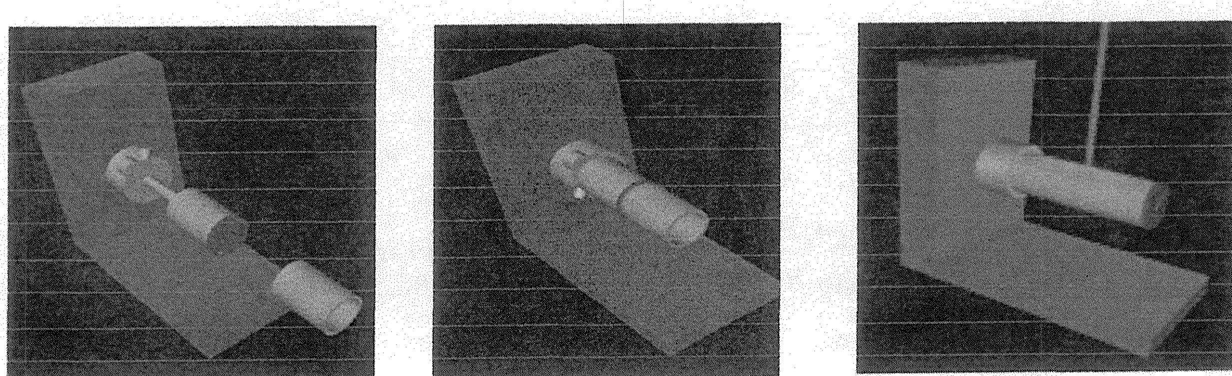


Figure 8. Two pieces of silicon - carbide tube joined by SALD. View on the WWW.



a) b) c)

Figure 9. Three frames from the virtual SALD Operation.
a)Two separate pieces, b)The pieces are brought together, c) The pieces are joined.

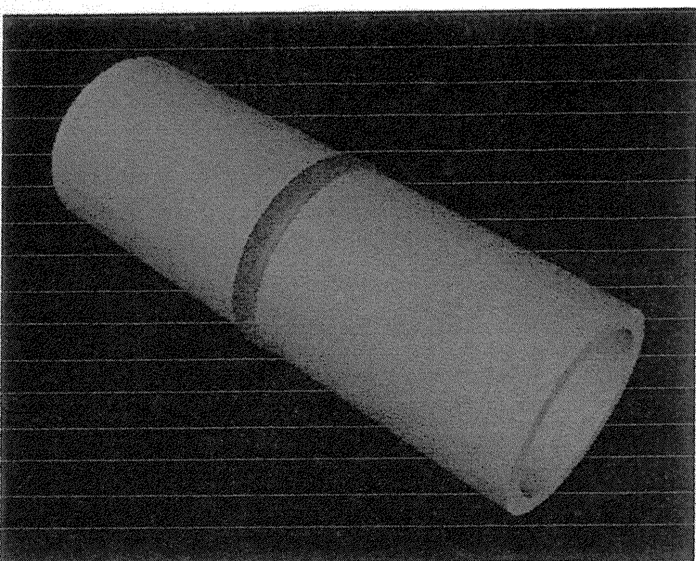


Figure 10. Two pieces of silicon - carbide Tube joined by SALD.

Figure 11. A welcome screen on Internet [12,13].

Concluding Remarks

This work is still in progress, and at this stage, the user can only study the rendering of the parts that have already been programmed. It is extremely useful for case studies and for presentations to the research team, students and visitors. The virtual laboratory is also accessible by the World Wide Web where its products can be examined and contributions to the general knowledge of SALD and SALDVI processes can be found. It has been used successfully in teaching, design, and technology presentations.

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