Integration of Polymer Processing, Computer Integrated Manufacturing, and Metal Casting Processes via Rapid Prototyping

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Abstract

Facility preparation and curriculum design issues have been studied and a Stereolithography Apparatus has been purchased to be used by students of Polymer Processing, Computer Integrated Manufacturing, and Metal Casting-at "GMI Engineering& Management Institute. The apparatus was installed in January of 1996. This is being followed by six months of training in solid modeling and use of the equipment, as well as finalization of early implementation plans for the Polymer Processing and Computer Integrated Manufacturing classes in the summer and fall of 1996. These plans will begin as part design information along with mold design requirements, derived and gathered by Polymer Processing students, are fed to students of Computer Integrated Manufacturing. Upon interfacing with the Polymer students, and equipped with SLA requirements, CIM students will develop appropriate solid models for prototyping. The development of permanent molds by students of metal casting is planned for long term. Plans for the use of this apparatus in pre-college programs is also planned for, with vision toward developing small focus groups comprised of faculty, graduate students, undergraduate students, and prospective students. Young people will be exposed to modern rapid prototyping technology and how it is implemented within an actual manufacturing system. It is expected that in the future, the addition of stereolithography to GMI's Polymer Processing/Computer Integrated Manufacturing laboratories will provide current exposure to manufacturing systems engineering for GMI students and inspiration in the area of Manufacturing Systems Engineering (MSE) to young people considering further education in this field.

Introduction

Integration of curricula in polymer processing, computer integrated manufacturing, and metal casting has focused on the area of rapid prototyping. Following an extensive comparative investigation, stereolithography was selected as the best means of integrating efforts in these laboratories. Specific applications of this technique to laboratory and classroom discussion have been identified. A development plan outlining a three tier approach to adding rapid prototyping to polymer processing, CIM, and metal casting curricula within the Manufacturing Systems Engineering program at GMI Engineering & Management Institute is in place.

Facility planning and site preparation is complete and the investigators have begun training in solid modeling and use of the stereolithography apparatus. Implementation of the equipment is expected to begin in the summer of 1996.

Instrumentation Selection

The polymer processing and CIM laboratories neighbor one another within MSE facilities at GMI. This allows for physical interaction among both sets of students, and for cross-utilization of laboratory equipment. The Principal Investigators work in both laboratories, and have committed to joint efforts in curriculum development. They have attended training sessions in the area of rapid prototyping, and have investigated those techniques which would lend themselves most clearly to providing hands-on experiences to the largest fraction of GMI students. A StereoLithography Apparatus (SLA) is expected to meet all of these expectations.

Instrumentation Application

The principle behind the SLA technique first involves the development of a solid model using a Computer Aided Design (CAD) system. The solid model is exported in the tessellated STL format recognized by the SLA system. The exported model has several operations performed on it including the creation of supports for the part to be prototyped, mathematical sectioning of the part and support model using a slicing program, merging of the parts and supports, and the input of preparatory system parameters. This is followed by the build stage where the prototype is created via photopolymerization of a liquid photopolymer resin into the solid form. This polymerization is accomplished via laser curing of the polymer in three dimensions within a bath of liquid photopolymer. Development of suitable solid models requires an understanding of the support structures which must be "attached" so that the model can be suspended in a liquid medium and the part be oriented most appropriately for laser cure. An understanding of flow patterns and design requirements on the final tool is also needed. Photopolymerization must be thoroughly understood, as well as room for modification and the addition of second phases, so that appropriate materials selection can be undertaken. Finally, when the tool is to be cast, an understanding of foundry principles must be incorporated. The integration of a CIM, a polymer processing, and a foundry knowledge base can thus provide a true manufacturing process - start to finish - to students of all three disciplines.

Instrumentation Integration

The number of students per year who can potentially benefit from the addition of a stereolithography apparatus is 100 in Polymer Processing, 110 in CIM, and 25 in Metal Casting Processes. Programmed time for each of these students would be approximately 8 hours, resulting in over 2000 student-hours of programmed action with the new SLA facility.

Tier One: -Polymer Processing Applications Using SLA

1. A fundamental understanding of the chemistry behind photopolymerization will assist polymer processing students in understanding why only certain polymers can be selected for this technique. Development of modified resins or resins containing reinforcements can extend from this knowledge -base. This will allow for the development of working prototypes, capable of sustaining higher thermal and mechanical stresses.
2. Lectures focusing on part design (and therefor mold design) will lead directly into the design of prototype tooling and the development of a set of design criteria to be sent to the CIM students. Consideration of final material make-up and structural integrity of the part to be manufactured - and the processing technique to be applied once tooling is complete will be required of all students. This will provide a sympathy and understanding for the pre-process requirements of polymer part manufacture.

Tier Two: Computer Integrated Manufacturing Applications Using SLA

1. Central to CIM education at GMI is the integration of product design, manufacturing process design, and production planning otherwise known as concurrent engineering. The Concurrent Engineering Design process is driven by input from all personnel that are impacted by a product over its lifecycle. This mindset will be encouraged in interfacing with polymer processing students for the development of product definition data and design requirements (such as such things as flow patterns structural requirements) for parts of interest. CIM students will then further the design process by developing surface and solid models using MASTERCAM® and UNIGRAPHICS® respectively. CIM students will be required to take general part design and process information and generate a working model for manufacture. The results of their work will not remain on paper, however, and a prototype tool will be created using their recommendations .
2. Refinement of techniques will lead to the required rotation of solid models in space such that fewer support structures are required. As support structures can be eliminated, post machining of tooling or parts can be eliminated. Insight into these techniques will be gained by CIM students as well.
3. Once a valid prototype has been created, an examination of the extent of curing within the photopolymerized part will be undertaken, and a measurement of post-cure distortion will be made jointly by members of the CIM lab and the polymer processing lab. Feed-back from this evaluation will result in recommendations for (a) modified part or tool design or (b) modified laser pattern curing of part.
4. The usage of the SLA system will allow CIM students working in concurrent engineering design teams to thoroughly examine and functionally test multiple design alternatives because the time to prototype will be reduced by several orders of magnitude. This iterative process of product visualization, verification, and optimization is consistent with current best practices in industry and will constitute an invaluable learning experience.

Tier Three: Metal Casting Applications Using SLA

1. Equipped with an understanding of what is achievable in casting of metals, and knowledgeable of the requirements for suitable flow within a cast part, foundry students will provide design input to CIM students as solid models are being developed.
2. Once a prototype has been created and evaluated using SLA, the prototype will be delivered to the foundry for creation of a permanent mold. A working interface between the CIM and polymer processing labs and the foundry will be developed and GMI students will manage a manufacturing process spanning these three laboratories.

Conclusion

Stereolithography will allow the study of the planning, design, prototyping, and manufacture of a product by students of polymer processing, computer integrated manufacturing, and metal casting. The boundaries between these areas within the Manufacturing Systems Engineering curriculum will be made transparent as all students" follow a product from concept to completion. The selection of stereolithography as a means to this end is ideal, for this technology brings with it many areas of future study and research - from the investigation of the effects of various curing conditions of prototype integrity, to the study of the effects of solid model orientation on support mechanisms. A three tier approach, outlining specific problems to be addressed has been detailed, and more extensive independent study projects with undergraduates are likely. Initial implementation of this equipment is planned for this summer, with full use expected by the end of 1996.

Biography

Dr. Laura L. Sullivan is an Assistant Professor of Manufacturing Systems Engineering at GMI Engineering & Management Institute, where she has taught Engineering Materials, Advanced Engineering Materials, Polymer Processing, and Polymer Properties. Her research interests extend from polymeric materials and processing to biomaterials. She has conducted research at Baylor College of Medicine in Houston, Texas and currently collaborates with the Urology Research Laboratory at William Beaumont Hospital in Royal Oak, Michigan.

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