# Using 3D CAD as a tool to integrate topics across the curriculum

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Abstract

Too often CAD is taught as a subject or addressed in isolated assignments among perhaps several courses in a degree program. However it appears to be rarely used as a truly integrated design and documentation tool crossing diverse specialty disciplines within a degree program. This paper discusses how various faculty are introducing CAD as a unifying tool applicable for a variety of topics such as production design and, mechanics, engineering material, finite element analysis, mold design, enterprise CAD management and others.

As one example, first-semester students initially learn CAD techniques in a basic service course taught by the Computer Graphics department. They subsequently migrate to *Production Design and Specifications* where they polish 3D skills as they learn about fits, tolerances and other aspects of design for manufacturing and design for assembly.

In *Applied Strength of Materials* and *Experimental Mechanics,* students utilize the same CAD application to initially construct 3D models and then analyze those models using a variety of analytical techniques.

Similar to capstone experience, students later in *CAD in the Enterprise* take apply CAD knowledge to minimizing the real-world dilemma of vendors, manufacturing and customers, the components of a virtual enterprise, all using different CAD systems yet needing to communicate their CAD data among externally and internally for analysis.

Together, the described activities, including the use of the newest generation of user-friendly CAD tools has enabled a closer technical integration, a common language as it were, among the departmental students, much as MS Excel and MS Word did late in the last decade.

## I. Introduction

Historically CAD has been taught in the Purdue MET program for many years. It was first taught as an electronic drawing tool and eventually as a design tool, initially in 2D only, and as software matured, with 3D applications. Over these years a number of CAD systems have been employed and all were successful in their time in providing valuable knowledge applicable to post-graduation practitioners. However no system developed a sufficient following among the general faculty that they regularly employed CAD as a problem-solving tool for their course's technical content. Other applications such as Excel™ have become somewhat ubiquitous across the curriculum, but certainly not CAD. That will change with the availability of Alventive's IronCAD™.

After having used IronCAD™ in several courses during the Fall 2000 semester, a number of faculty decided that IronCAD™ could become the elusive MET strategic application for geometry construction applicable in any class requiring initial CAD geometry or even presentation geometry. This became evident because of several factors. Firstly it offers a very user friendly 3D modeling environment with a highly visual interface employing ‘drag-and-drop’ technology for all operations. It renders in real time, giving users instant feedback as to the success of a procedure. It allows user input of quick visual designs via the mouse, and as needed, entering exact specifications via numerical input. It offers photorealistic rendering and animation, plus it extracts highly professional looking engineering drawing from models, to ANSI, JIS or ISO standards. Built in are a full compliment of gears, bearing, fasteners and other standard parts, most in both inch and metric. From a diverse pedagogical perspective it is ideal because a full-featured student version is available for less than $200 and IronCAD™ features import/export compatibility with virtually all other major CAD systems, plus downstream applications such as finite element analysis, stereolithography, web graphics and other analysis software. For utmost flexibility, each part in IronCAD™, even in an assembly, can be either built on, or changed between, an ACIS or Parasolid graphics kernel.

With this flexibility and capability in mind, it was determined in the Fall 2000 semester that IronCAD™ should be used in Production Design & Specifications (PDS) to provide that early skills set which could then be employed in any subsequent course. The goal being to encourage IronCAD™ to become as ubiquitous among the MET student body as Excel™ is now. Since IronCAD™ features both photorealistic rendering, web graphics formats and animation, it is anticipated that students will have sufficient skills to use IronCAD™ to prepare graphic information for presentations and web projects in almost any other classes.

## II. Production Design Applications

Following a first semester introductory CAD tools course utilizing AutoCAD™, second semester students advance into MET 102, Production Design & Specifications, a core MET course. This course as its name suggests, allows students to learn industrial production design and specifications required in mechanical applications, while using an advanced 3D modeling tool. The course fulfills the two missions within the curriculum.

First and foremost it give students concrete practitioner experience using a powerful 3D CAD modeler in a design for manufacturing and a design for assembly environment. In doing so, students deal with a broad range of discipline-specific topics such as castings, weldments, machined parts, assemblies, sheet metal construction and other topics as well as an array of standards compliance requirements.

The second curricular mission for the course is to fulfill the internal requirement to equip students with the CAD expertise and presentational skills that they may be expected to apply in subsequent MET courses.

Thus beginning in the Spring 2001 semester students in MET 102 will begin using IronCAD™ as their primary CAD tool. It is then anticipated that within 3 years, the whole student body can then be expected to possess sufficient IronCAD™ expertise that they will be able to employ it in any other class as required. See figures 1 and 2 for an example of the 3D model and engineering drawing which will be the basis for the first project in MET 102. Subsequent projects become progressively more complex.

In PDS the emphasis is on both accurately modeled parts and extracting fully dimensioned and specified engineering drawing to current ANSI standards. For greater flexibility IronCAD™ also fully support ISO and JIS drawing standards as well as 1st angle and 3rd angle drawings.

IronCAD™ easily excels at the task of extracting drawings because the model and drawings are associative. From an instructional point of view s this is useful because it does allow editing of a dimensional value in the drawing, but it indicates any changed dimension by underlining them, the standard ANSI practice for displaying 'not-to-scale' dimensions. This means that a student must maintain the integrity of model and cannot take an incorrectly modeled part but 'fudge' the drawing by changing the dimensions.

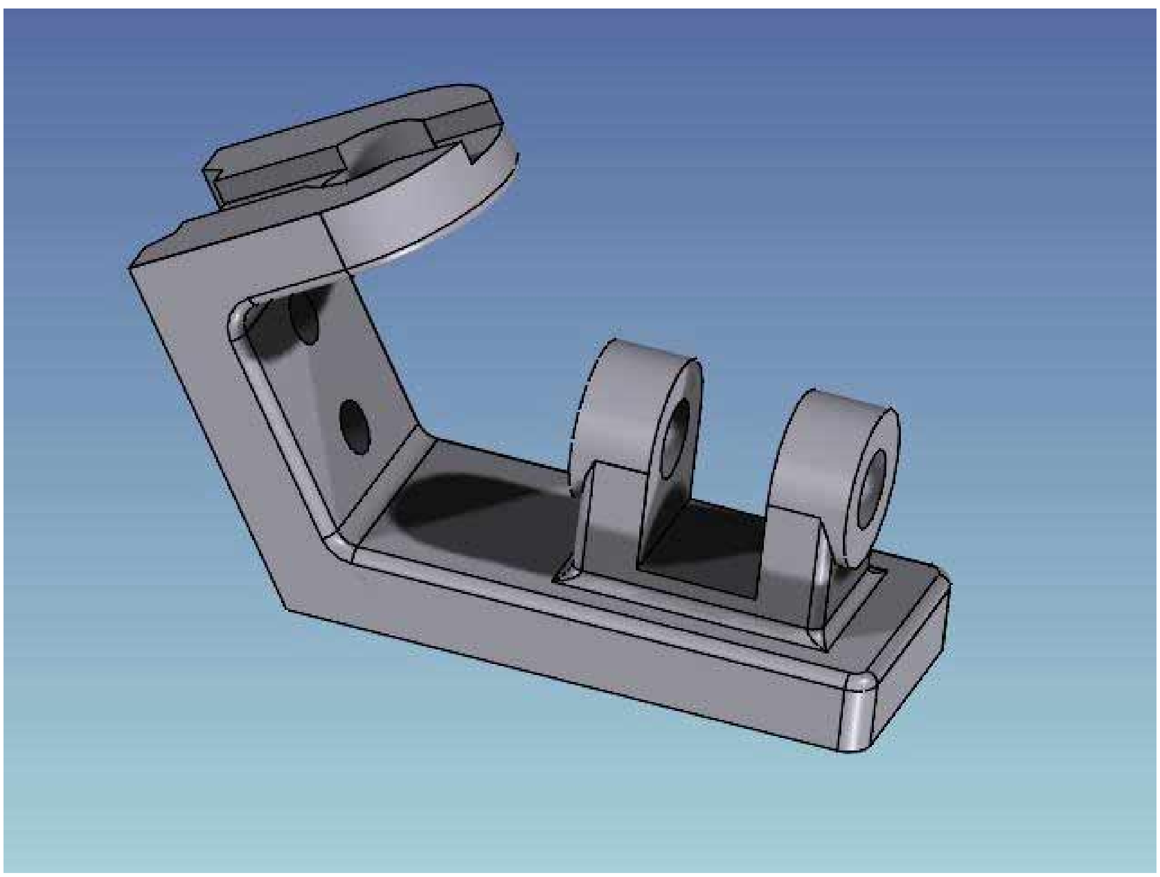

Figure 1. The first project in Production Design and Specifications.

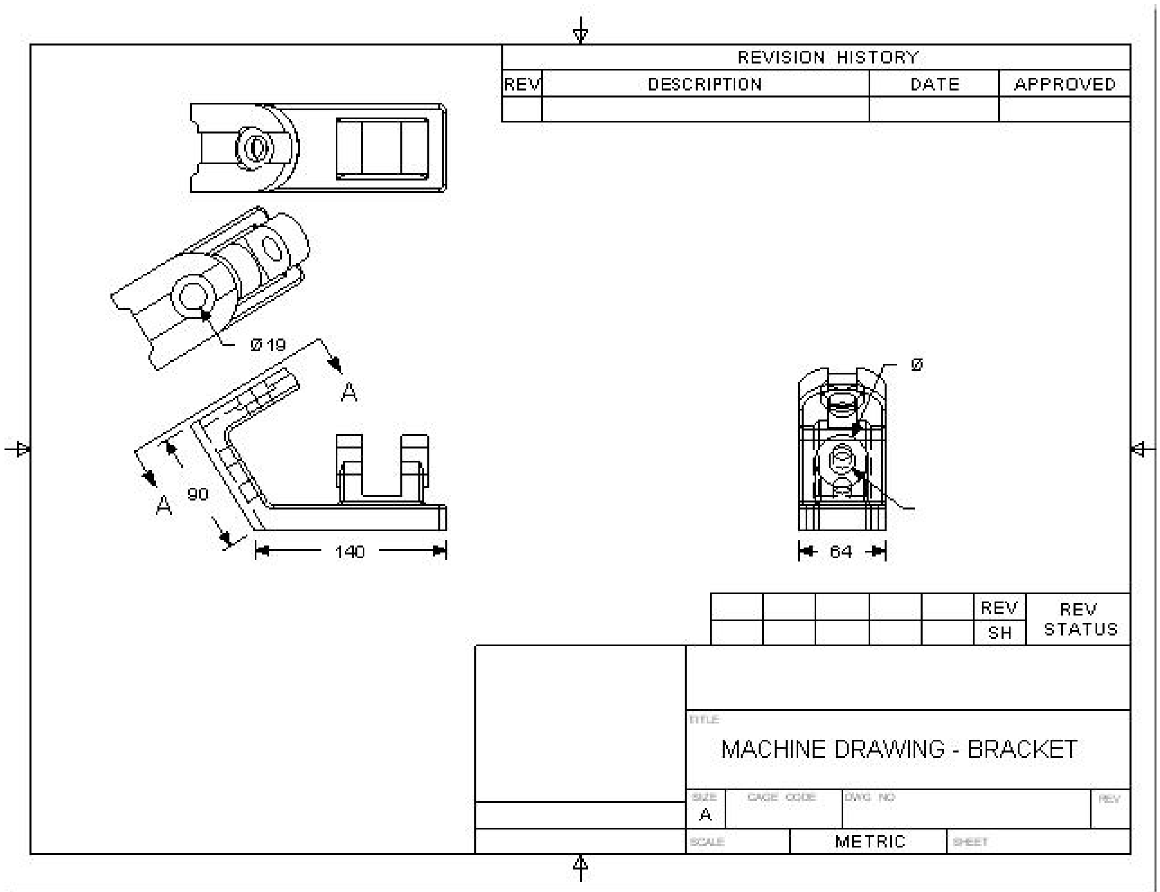


Figure 2. To-be-completed engineering drawing generated from the model in Figure 1.

Initially students learn the basic operation of the system via three projects then migrate to more complex models. The first introductory project involve taking a design for a discrete part such as that that shown in Figure 1 and reverse-engineer the model from a finished machine drawing state (finished sizes as required for in-service use) to the casting stage with added machine allowances and the fillets & rounds necessary for green sand casting. From the modified model they produce an engineering drawing similar the partially completed engineering drawing shown in Figure 2.

In the second project they employ the built-in ASTM stock materials (hot rolled and cold rolled L angles, flats, Ts, Us, C channels, pipes, S beams, etc.) to build a multi-part fixture and on the extracted drawing, specify the welding symbology necessary to build it. See Figure 3. In the third and last introductory project, students model a complexly formed sheet metal box using the standard sheet metal tools in IronCAD™ and then generate the drawing in the form of a dimensioned unfolded flat pattern.

After introductory phase, students model and generate drawings for a 10-15 part assembly/detail set featuring castings, machined parts, standard fasteners and sheet metal parts. They complete the semester by extensively modifying the assembly via a series of ECOs (engineering change orders). Among others tasks, to fulfill the requirements of these ECOs, students do calculations for gears sets, fits, tolerances, dimensional stack-ups and GD&T.

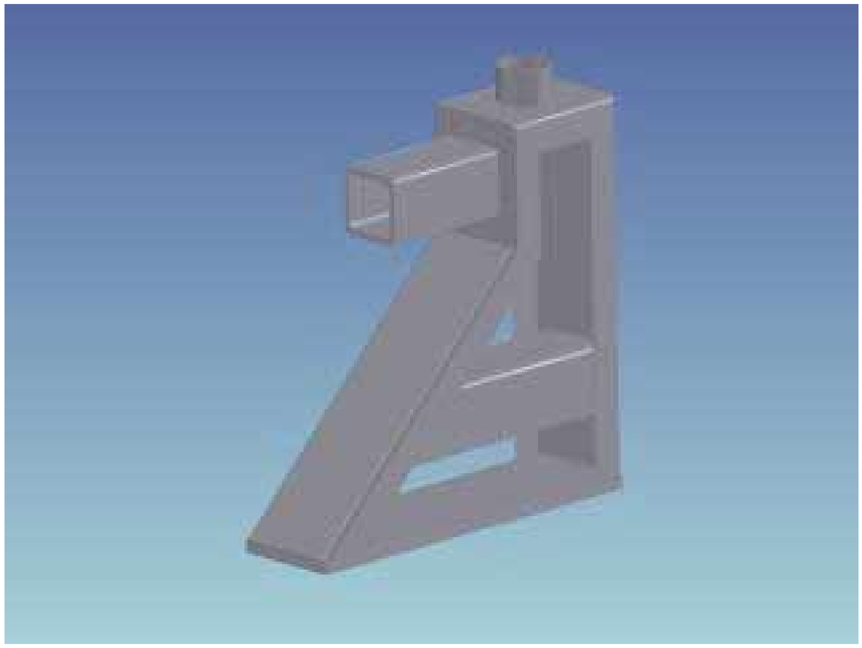

Figure 3. Model built of ASTM standard material for specifying welding symbology.

Taken together, these projects prepare students to function both as users of engineering drawing industrially and as necessary preparers and modifiers of 3D model geometry, plus employ any of the above skills in subsequent classes.

Notwithstanding, should students anticipate the need for more extensive CAD exposure, they take MET 302, CAD in the Enterprise, an elective course design to give them experience in a broader multiple-CAD environment. The scenario in MET 302 is built on the premise that a company, its vendors and customers might all use different CAD systems and yet must integrate their CAD data across the virtual enterprise. In solving these problems, students also gain valuable experience in the use of CATIA™, Pro-Engineer™ and other CAD systems, as well as IronCAD™.

III. Mechanics Course Applications

Mechanics applications of IronCAD™ is a means to have students quickly create geometry that can be modified as design, analysis, and test feedback dictates. In a sophomore-level mechanics course at Purdue University, this capability was demonstrated to the students immediately after their experimental mechanics lab on Photoelasticity. Several of the students modeled the geometry on their own, but in Fall 2000 it was not required. DesignSTAR™ requires a parasolid format, which IronCAD easily provides. Figure 4 shows the geometry of a typical photoelastic test specimen prior to exporting into a format that can be imported into DesignSTAR™.

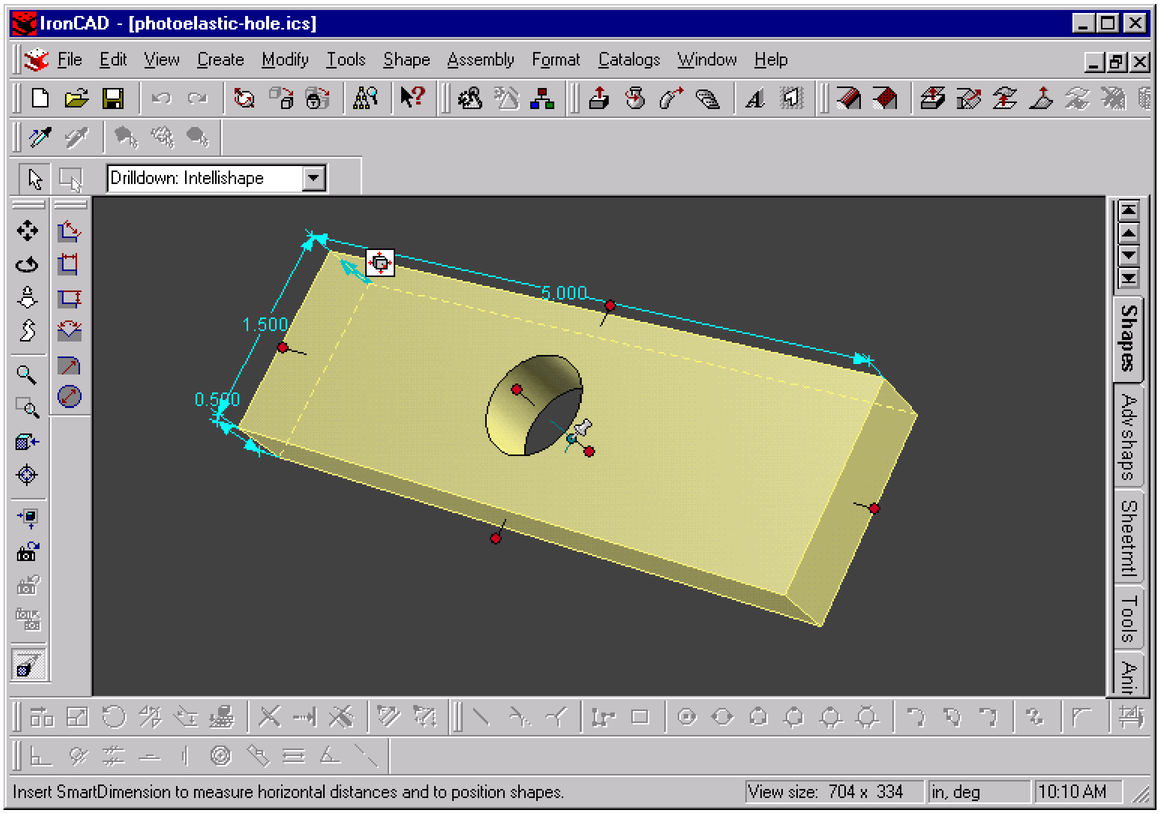


Figure 4: Photoelastic specimen geometry modeled with IronCAD™

Once the geometry was imported into COSMOS/DesignSTAR™, a study was created that established the material properties, restraints, and loading prior to mesh creation. Subsequent to mesh creation, the FEA model was run with the resulting Von Mises stress plot shown below in figure 5. Plots of displacement, strain, and deformation are also available as outputs for visualization, subsequent analysis, and/or presentation.

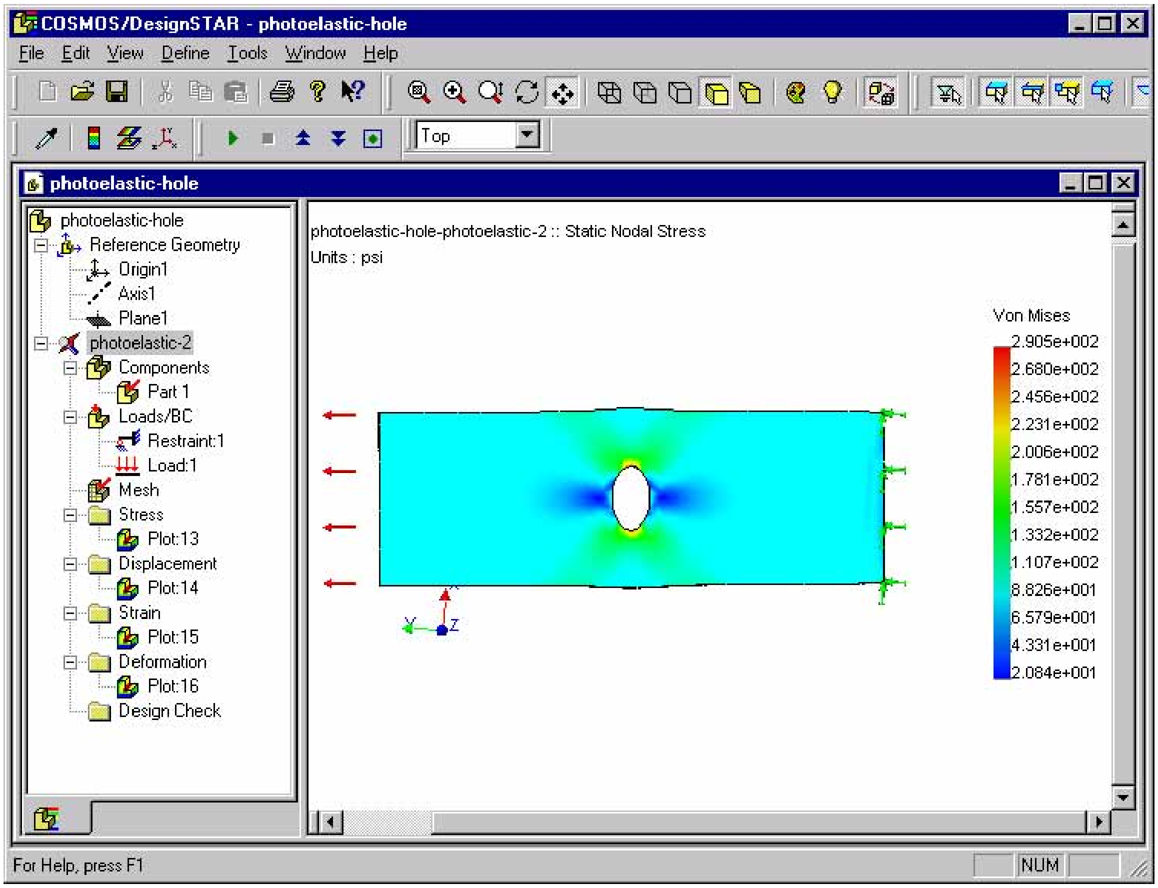


Figure 5: COSMOS/DesignSTAR™ Finite Element Analysis von Mises Stress Results

During the corresponding laboratory on Photoelasticity, the students loaded an actual test specimen and correlated the color bands observed with the calibrated stress levels in the part. A digital video was taken of this loading sequence and put onto the course website to support lab write-up. One frame of this digital video is shown below in figure 6.

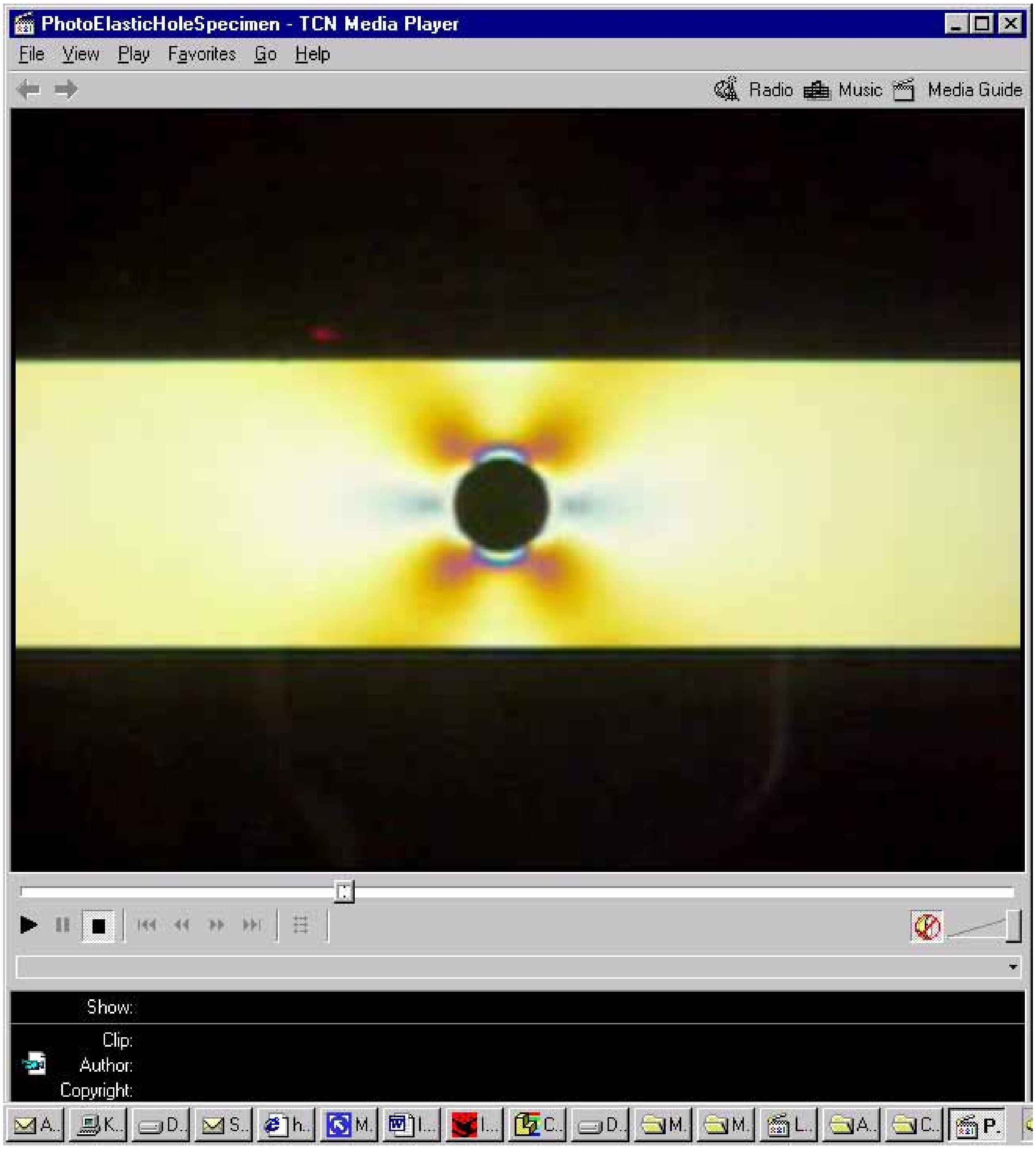


Figure 6: Experimental photoelastic specimen under test loading

The assembly capability of IronCAD™ provides the students an opportunity to quickly assemble and render visualizations of complex mechanisms. Figure 7 shows a truss assembly with multiple links and hardware. The hardware toolbox of IronCAD™ allows students to learn about a wide variety of fastener types and quickly insert a selected fastener into an assembly, where fits and clearances can be checked. In the figure, a thread length problem is clearly highlighted through the rapid visualization capabilities of IronCAD™.

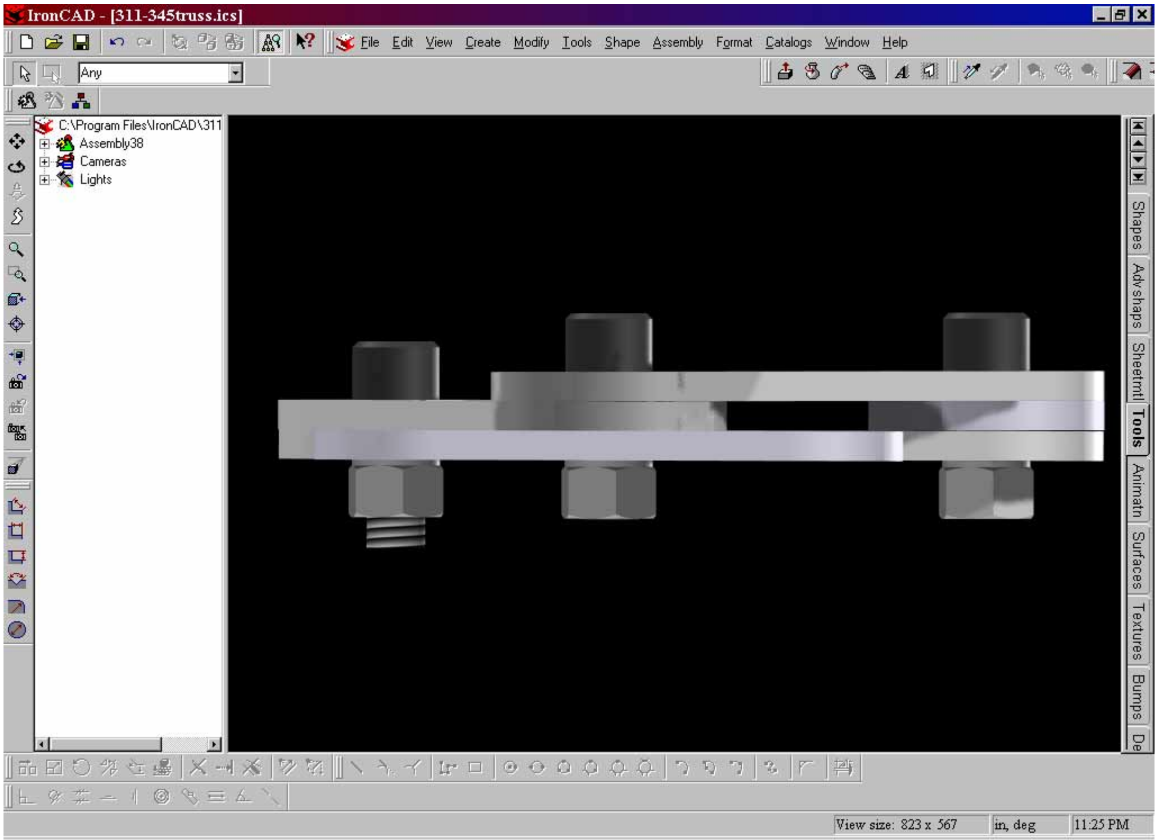


Figure 7: Rendered assembly using IronCAD™ highlights thread length problem

Future plans include utilizing IronCAD™ and DesignSTAR™ as vehicles to supplement homework problems and laboratory write-ups in the mechanics area, specifically MET 211, Applied Strength of Materials and MET 311, Experimental Mechanics. Major goals for MET 211 students are to work through the tutorials on IronCAD™ and DesignSTAR™ in the first portion of the semester after lecture demonstrations and then assign various homework problems and laboratory write-ups to include IronCAD™ modeling and DesignSTAR™ studies. Major goals for MET 311 are to also have the students work through the tutorials to come up to speed on the programs and address some sizable projects using both software packages. It is anticipated that the students will first design truss members using IronCAD™ for use in fabricating various bridge configurations that can be tested photoelastically. Students in a MET materials class, MET 342, will utilized the exported geometry and provide fabrication of pour molds and part fabrication. The individual truss links will be assembled within IronCAD™ into configurations that will be designed by the various teams to meet given design parameters. These assemblies will then be imported into DesignSTAR™ after the parasolid format is exported from IronCAD™, where finite element analysis (FEA) studies can be performed. Comparison of the "hand" analysis, FEA analysis, photoelastic test, and strain gage test results will provide a thorough grounding in mechanics principals and ample opportunity for team presentation visuals. This type of design-analysis-test-presentation activity will be replicated for the other laboratory and homework problems in the mechanics courses in the future.



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Additionally, optimization will be introduced to the process, allowing students at the sophomore and junior level to utilize the optimization solver within DesignSTAR™, the generic solver within Excel, and a genetic algorithm (GA) solver within Excel. This capability to iterate part geometry and/or material to address single objectives such as to minimize weight or to equalize stress distributions. Where multiple, simultaneous objectives exist, such as to minimize weight and equalize stress distributions, the GA solver will be introduced and utilized.

IV. Graduate Metal-Casting Design Course Applications

IronCAD™ software is used as CAD design software for the graduate course "Optimization of Metalcasting Design" because it allows easy generation of 3D solid models. In addition, it exports models in a number of formats that can be imported in other software packages that are used in this course. This course deals with design of castings and their optimization with respect to structural integrity and manufacturability. The nature of the course is such that frequent changes of a part's shape are common and students should focus on the structural and manufacturability analysis, whereas learning CAD software should be minimized as much as possible. The experience with this software proved to be very good; namely, students became quite proficient in fundamentals of the software within three two-hour lab periods. Within this time period the students were able to generate fairly complex geometries, such as the one shown in Figure 8.

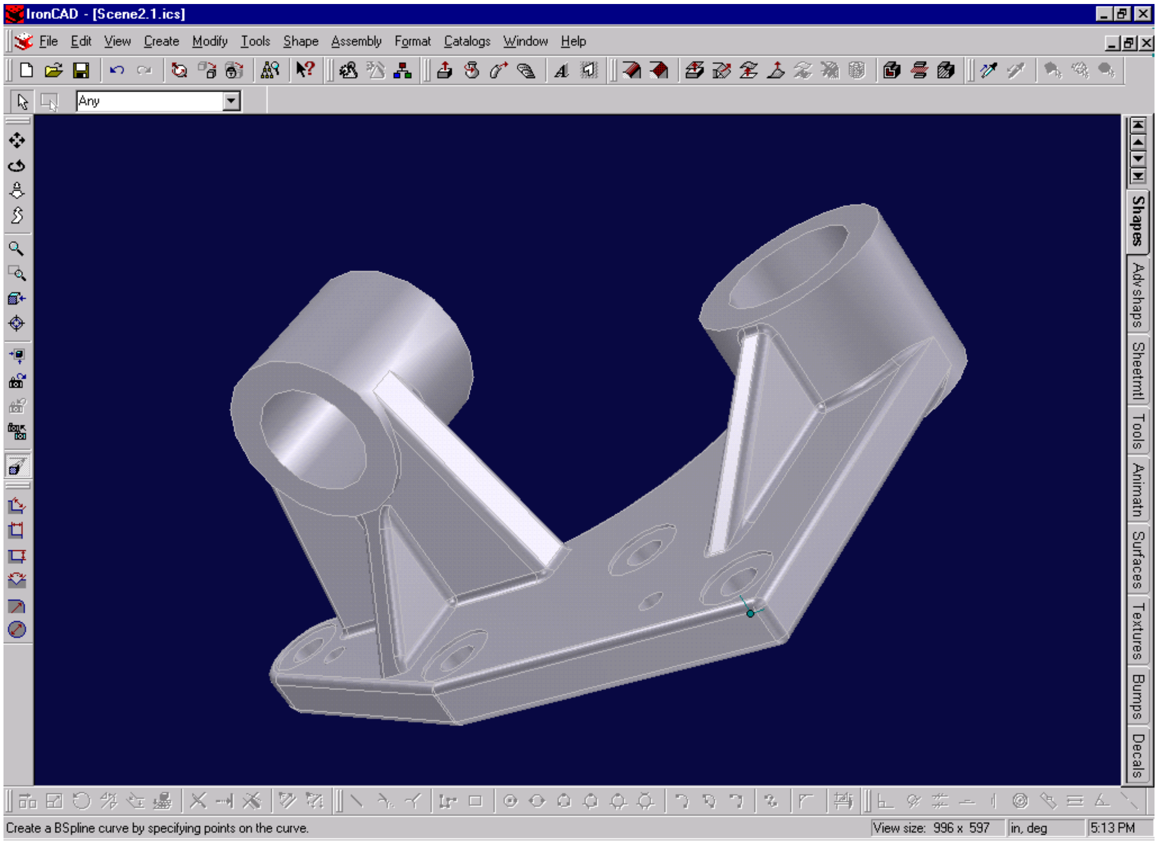


Figure 8: Example geometry modeled with IronCAD™.

In addition, IronCAD™ comes with a fairly large library of predefined geometries, which makes design process easier by allowing user to simply pick-drag-drop desired geometry. It also allows user to generate his/her own library of solid elements, which is very useful feature for design of metalcastings, since there is a number of geometries that are common to many casting designs (e.g. gates, risers, etc.). An example of simple plate casting with attached gating system is shown in Figure 8. Although many castings are significantly different, the flasks that are used for molding are standardized and gating and risering system can easily be scaled in IronCAD™ to fit any flask configuration.

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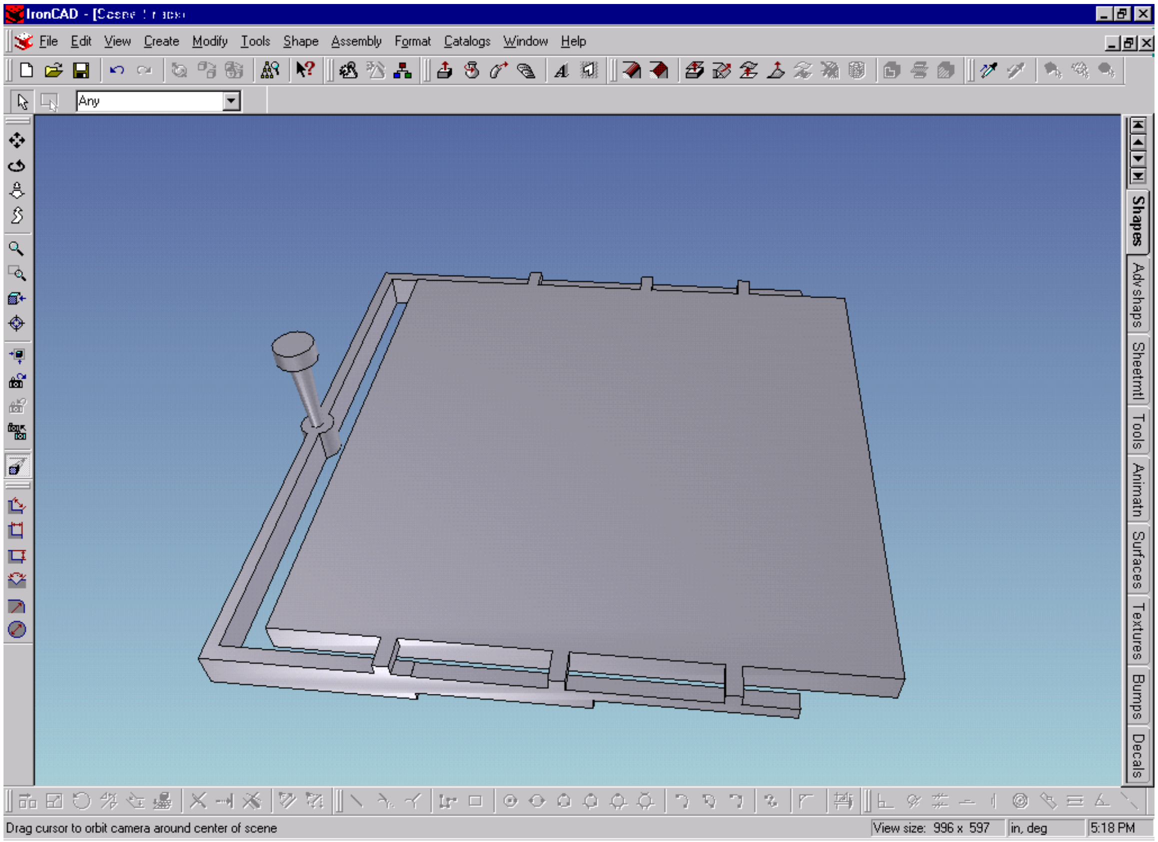


Figure 9: Plate casting with gating system.

The other software packages used in this design course are COSMOS/M-DesignSTAR module and MagmaSoft(TM). DesignSTAR is used for stress analysis, while MagmaSoft(TM) is used to simulate casting process (mold filling, solidification, residual stresses etc.). DesignSTAR accepts solid models in the ACIS format, while MagmaSoft(TM) accepts models in the STL format. IronCAD has the capability to export 3D solid models in both of these formats. In addition, the other two software packages are very sophisticated with respect to their numerical simulation capabilities, but they are quite limited with respect to their design capabilities, and using more sophisticated CAD package is quite beneficial. In addition, these two software packages do not generate solid models that can be easily interchanged. Thus, IronCAD is a very good tool that can serve as a design basis for other structural and manufacturability software packages.

V. Conclusions

The Spring 2001 semester will be a milestone for the MET at Purdue. We will have begun this collaborative effort to integrate a CAD package across the curriculum. If the project is successful over the 3 years, it can only enhance the technical expertise of already outstanding graduates as they become practitioners for the 21$^{st}$ century.

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### BRUCE A HARDING

Harding is a Professor of Mechanical Engineering Technology and an ASEE Fellow. He teaches manufacturing design and specifications related courses emphasizing manufacturability, design for assembly and other quality issues. In 1983 he pioneered the first undergraduate CAD instruction at Purdue. His current specialty is implementation of geometric dimensioning and tolerancing standards. Presently he is a member of the ASME main committee overseeing American National Standards for CAD and engineering drawings, and chairs the ISO technical committee writing the worldwide versions of CAD and engineering drawing standards.

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Szaroletta is an Assistant Professor of Mechanical Engineering Technology at Purdue University where he presently teaches solid mechanics courses. He is a member of ASEE and ASME. He has 18 years industry experience in engineering and project management positions, with 12 awarded U.S. patents, and 6 years university teaching experience. He received his B.S. Degree in Mechanical Engineering from University of Michigan, Ann Arbor in 1977, M.S. Degree in Engineering (Product Design) from Stanford University, and an Applied Mathematical Sciences Degree (Computer Science) from University of Georgia. His current applied research interests are product design, experimental mechanics, lab automation, and optimal design using genetic algorithms.

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