2006-949: PROGRAM SYNERGY: ENGINEERING LABS USING FOUNDRY RESOURCES

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Program Synergy: Engineering Labs Using Foundry Resources

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Abstract
Materials programs have followed trends in cost reduction by closing foundries and other expensive facilities. They have also oriented curricula to popular topics such as composites and MEMS. When partnered with other disciplines, materials curricula are even further pressured to effectively match resources to that discipline's vision.

At the Central Washington University, Cast Metals is part of the Industrial Technology Program, and has some shared courses with Mechanical Engineering Technology (MET). With support from the Foundry Educational Foundation, and a majority of students from the MET Program, the foundry is a small but viable resource. In an attempt to utilize this resource more, it was decided to use the foundry to support MET labs. On example is the use of SOLIDCast™ in a Heat Transfer lab.

The MET Program has outcomes which stress conceptual and applied knowledge and skills. Experiments exist that guide students through predictions and experimental verification of simple transient heat conduction. Numerical analysis enables a greater depth and realism in this process. Instead of a prediction of temperature at a point, gradients can be discussed, illustrated and applied. At a cost of a few hundred dollars per year, a basic solidification tool can support a core MET course. Students showed great interest in the software, and the use of the software increased. This addressed specific program outcomes. Lab reports (the most relevant evidence) had greater scope as measured by a created metric. An added benefit was an increased use of the foundry and interaction between the programs.

Introduction
Motivations for developing alternative resources fall into two categories. First, there is never enough money to satisfy typical requests for support. Second, there may be resources next door that can be used with improved awareness and cooperation. As a subject of interest, the MET Program has a Heat Transfer course that has various associated laboratories. As discussed by Feisel and Rosa, engineering laboratories support education 'of nature that goes beyond mere theory"[1]. Our Heat Transfer laboratory concerns a comparison of analytical prediction of the cooling of a slab of metal, and experimental data that is determined in the lab exercise. Historically, only the lab only included these two components. With the advent of various numerical methods, it is appropriate to include an associated numerical prediction. However,

these software programs are generally expensive. It was noticed that the foundry program had software that might be adapted to support the heat transfer lab. A standard numerical analysis program was also accessed for comparison.

This paper queries the worth of including numerical analysis as an addition to the existing lab. First, the existing lab process was reviewed. Then, COSMOSWorks™ [2] was applied to predict behavior. Then the foundry software, SOLIDCast™ [3], was applied. A review of the student work and outcomes was addressed to evaluate the impact of numerical analysis on the program and course outcomes.

The 'Slab' Heat Transfer Laboratory Description:
The MET316 Heat Transfer course has numerous labs of which one is called the 'Slab Lab'. This lab addresses the prediction of temperature over time of a slab that is cooled from boiling to freezing water[4]. Analytical prediction is accomplished via a 'lumped system analysis' outlined in the text by Cengel[5]. It uses the Biot Number for applicability (successfully in that $Bi=0.034<0.1$). This results in an equation of temperature over time (using various related parameters). The resulting expression follows: $[T(t)-T\alpha]/[Ti-T\alpha]=e^{(-bt)}$. Assumptions limit the use of the equation, in that no cross-section through the slab is possible. But it is easily handled using a spreadsheet and produces an appropriate predictive curve.

Experimental data was acquired with a FLUKE Hydra Datalogger and three thermocouples. The placement of the sensors is shown in the laboratory handout. The slab is stabilized in boiling water and then plunged into the ice bath. Most of the temperature reduction occurs in the first half minute.

The 'Modified Slab' Heat Transfer Lab:
We were able to apply two computer modeling techniques to the Slab Lab. The first technique utilizes a commercial package that offers many options for structural, fluid, thermal and other applications. It is rather expensive (thousands of dollars). In this instance, it is embedded in a solid modeler for model generation.

The other program is a solidification program that is rather inexpensive (hundreds of dollars) that was in-place supporting the Foundry Educational Foundation Program. Though not specifically targeting generic heat transfer problems, it was managed to apply to the slab lab.

COSMOSWorks™ modeling of the Slab:
The main problem to addressed was: Can the heat transfer experiment be modeled using the thermal capabilities of COSMOSWorks™? The following scenario was used:

The blocks were first drawn in SolidWorks™ [6] 2003 3D modeling software. Then create the mesh in COSMOSWorks. Next, the material was selected. Finally, a 'scenario' was run. Once the scenario was completed, a plot of the results was displayed in the viewing area. In this experiment, we were interested in the temperature distribution throughout the interior of the block. The 'view port' displayed a sectioned view of the temperature distribution. The location of each section could be adjusted to display temperature distribution from any location. From the ‘dialog box’, the location and orientation of each sectional plane could be manipulated. To select specific points in the slab, the ‘probe’ function was used. Clicking various points along the section records the temperature and coordinates into a chart that appears when the command is active. By picking points along a straight line, the data was saved into a spreadsheet to produce useful plots. Temperature data can be displayed at t = 0.5s going through the width of the steel block as shown in the figure below:

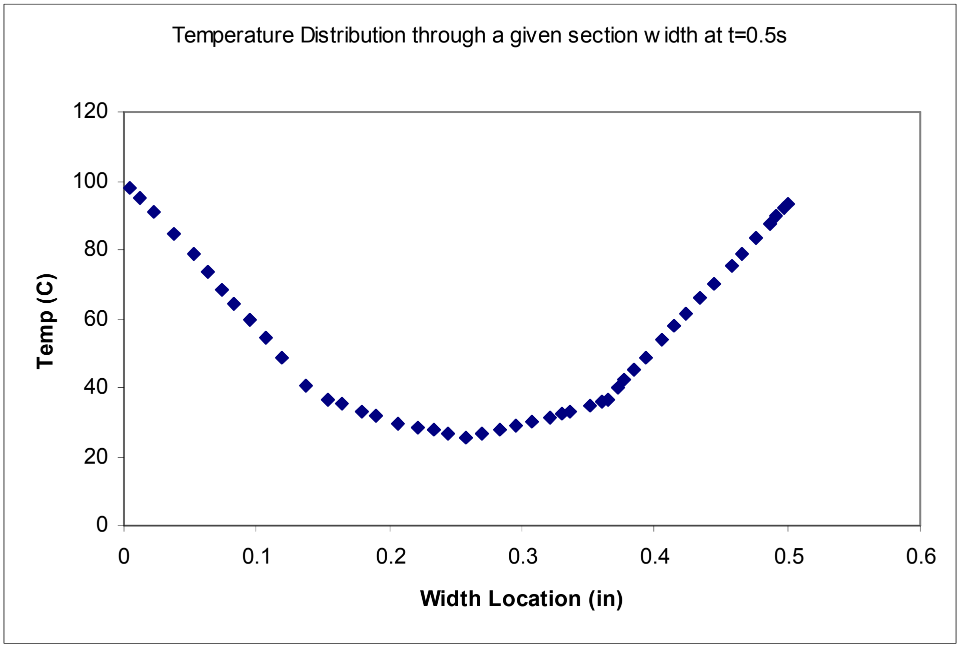

Figure 1: Temperature profile using data exported to MS Excel™.

Temperature could also be logged versus time for a given location. In this example, the center of the steel block was used for the location of data collection. For both the heating and cooling scenario, plots of nodal temperature distribution for each time segment were formed. The figure below displays temperature versus time for the center of the slab:

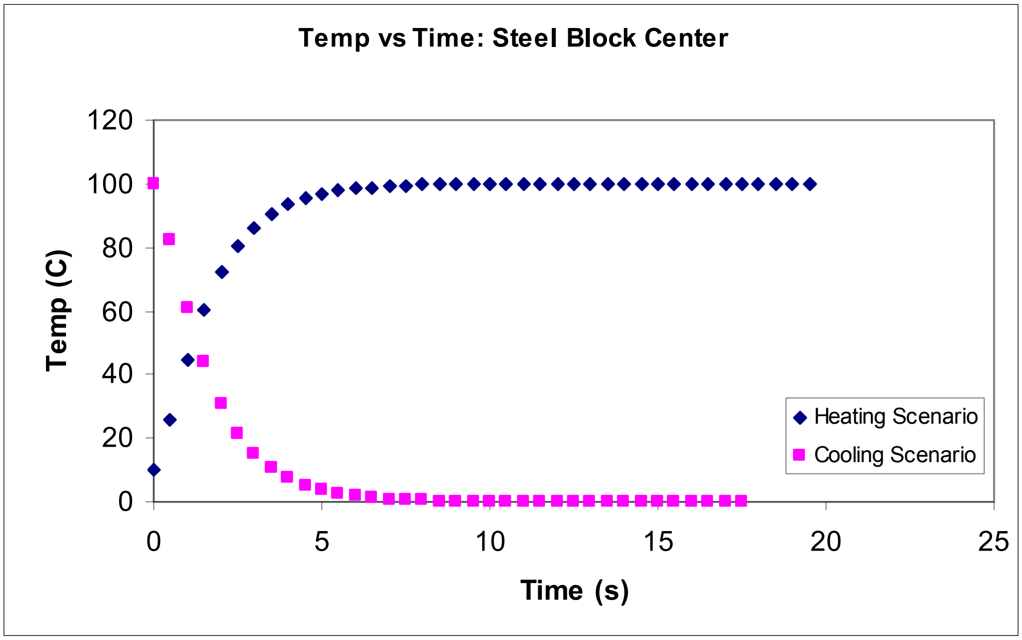

Figure 2: Data for the center of the steel block.

Using COSMOSWorks in this matter has limitations. The first plot produced from the data represents only one increment in time. This means that the entire process of producing the plot then probing for data must be done for each time increment for a given location. This process becomes both time consuming and is susceptible to human error.

SOLIDCast™ models the Slab:
The solidification program used was SOLIDCast™. It is typically used to predict the behavior of castings as they are poured. Since it is externally supported, it is an asset that is unique in academic environment.

To model the slab lab, the slab was generated in the program as a mold cavity. Properties that emulate water were created for the mold material. The 'pour' material was acquired from the AFS (American Foundry Society) material database. Maximum and minimum temperatures were monitored, though there were other ways to place temperature sensors in the slab. Data was collected and routed to a spreadsheet.

Results/Discussion
The technical/engineering part of this study is interesting in itself. The plot below shows all of the forms of data generated for the lab (Figure 3).

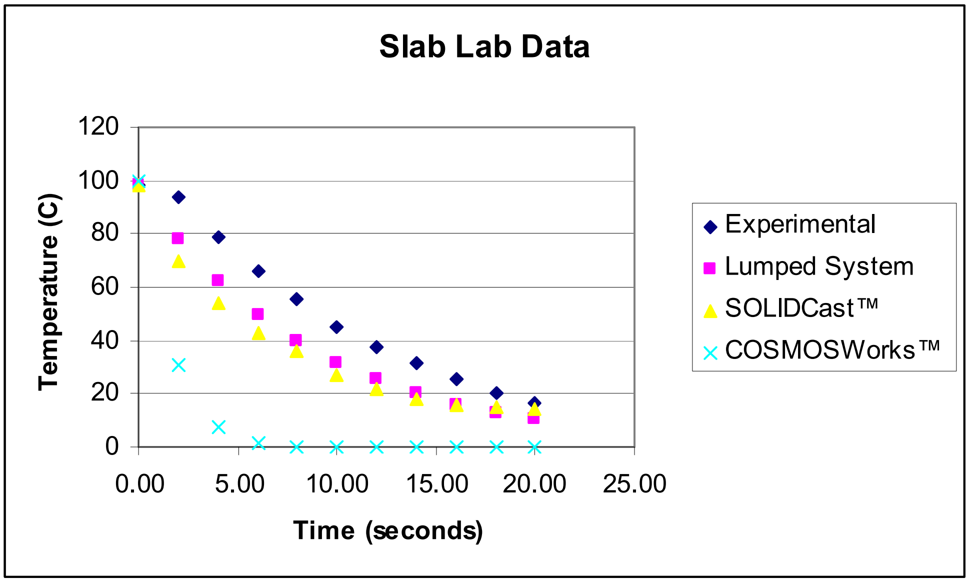

Figure 3 Slab Lab Data

The results show more similarity between the experimental data and the analytical predictions than either of the numerical approaches. This is instructive in its own right (e.g. don't believe the pretty pictures until they are validated). The lab instructs the student to discuss the data, trends, limits etc. This graph alone carries enough information to support a substantive discussion.

The MET program outcomes identify skills that are of both predictive and experimental nature. The original lab compared experimental with analytical temperature predictions. However, students will most likely be asked to use numerical methods in the workplace. The addition of numerical predictive methods into an MET heat transfer lab supports ABET outcome (a) [7] as well as internal program and course outcomes.

Comparison of traditional vs. modified lab experiences:
The students' discussion content were reviewed from the previous year's work ('05) to the current year's work ('06). To provide quantitative feedback, and following the descriptions of Olds, Moskal and Miller, an 'observational' assessment method was used[8]. Specifically, a simple metric was used to assess the student's ability to apply experimental, analytical and numerical skills to the heat transfer experiment (Table 1, below).

SCORE	Evidence of Exp., Analytical and Numerical Skills	'05 scr/10stds	'06 scr/14 stds
0	No discussion or results found	0 students	TBD
1	Experimental and Analytical data shown	2 students	TBD
2	Exp. and Analytical data with relevant discussion	13 students	TBD
3	Exp., Analytical and Numerical data shown	0 students	TBD
4	All data shown with relevant discussion	0 students	TBD

Though it is not indicative of the impact of various types of numerical analysis on the student's performance, the data suggest that it's a reasonable way to approach meeting the outcome if for no other reason than no other choice exists for past performance. The MET program has not generated all of the metrics needed to support current accreditation needs, so this study supports a number of efforts.

Conclusions

The application of available software met a portion of the predictive needs in this specific lab, and the related MET program outcomes. Students were able to include and demonstrate modeling skills that were not available previously. The MET program was able to utilize existing 'extra-program' numerical analysis tools to satisfy outcomes.

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