Mid-term Progress Report

IPRO 330 – Operator Information Tool to Manage Heat Treat Furnace Parts for A.Finkl & Sons
Illinois Institute of Technology, Spring 2006

Project Objectives:

- To generate an accurate survey of temperature distribution within the furnace.
- To determine a method of stacking that provides the most uniform temperature distribution.
- To create an efficient and intuitive tracking system that allows the exact location of each part in the furnace to be recorded and catalogued for future reference.
- To put this knowledge together to create a software package that can be used to quickly and easily generate a stacking sequence that will result in a proper heat treatment for each piece in the furnace each time.
- To fulfill all IPRO requirements

Project Background:

The engineers at Finkl operating the heat treatment facility need to optimize the furnace load configurations in order to maximize the number of pieces which may be heat treated without the necessity of an additional heat treatment due to inadequate tempering.

The engineers would like to have a simple way to visualize and manipulate the loading configuration of pieces of steel inside a virtual furnace. The heat treat Foreman could then key in a furnace load number at his computer or handheld device and see a block diagram of the optimized configuration to load the furnace. The load configuration file provides electronic recordkeeping that is helpful in recalling past heat treat jobs and reviewing how the pieces were arranged inside the furnace.

This project will consist of two parts. The first part is to create a software package to represent the 3-D world inside a furnace in 2-D in order to plan the stacking of parts in a fixed space so that the heat distribution is more or less uniform over each piece in the load. This representation has to be presented to the operator visually so that he can select and manipulate graphical representations of the part shapes available from a menu of shapes. Since the operator needs this ability during the stacking operation, the program should be run on a PDA or a local PC. Possible 3-D solutions could involve defining a surface or solid model in a file, which can be generated by a CAD package (Pro/Engineer, Unigraphics, SolidEdge, etc.). This file permits verification and review of heat treatment conditions and troubleshooting and will also be used in the next step of the process to simulate the heat treatment.

In order to simulate the heat treatment process it is necessary to have real data on the time-temperature profile of parts in different configurations. These data will be obtained by thermo-coupling test blocks and running them through real heat treatments with other parts. The data will be analyzed to obtain heat transfer coefficients related to position in the furnace and load configuration.

Methodology:

The team will work closely with Finkl employees on this project throughout the semester and several trips to the Finkl plant in Chicago are planned. The team has identified the specific tasks at hand as follows:

- 3D CAD drawings of the furnaces, the loading zone, and the actual parts being treated must be generated.
- Furnace surveys must be conducted and used in conjunction with the drawings to determine ideal loading conditions.
- A basic software program must be written that can take these drawings and use them to catalogue the stacking sequence in the furnace for a given treatment cycle.
- Ultimately, this software must be adapted to allow a stacking sequence to be determined prior to loading that guarantees a proper heat treat for each item in the furnace.

The first three tasks are being tackled simultaneously, while the final item consists of a synthesis of these three tasks. All the data and information required to accomplish this is either in the team's possession now or can be found within Finkl's database. Therefore, we are confident that we will be able to accomplish all these tasks successfully and in full.

Results to date:

- The temperature distribution in an empty furnace has been successfully surveyed:

  Two team members went to Finkl and mounted 19 thermocouples inside the empty furnace. The thermocouples were distributed so as to get sample air temperatures throughout the entire furnace. Data was obtained at four different temperatures.

  The data was then analyzed in Matlab using a program written by one of the team members. Temperature distributions were plotted in 3D using several slices across the furnace. This can be seen in Figure 1. The data obtained suggest that the distribution inside the furnace is quite even and should not generally be the source of a mistreat. As such, the focus of the project has shifted from trying to correct the temperature distribution inside the furnace to generating a stacking software package for use by Finkl operators.

- CAD drawings of the furnace

  Team members went to Finkl and obtained dimensions for the furnace and for the loading zone. We used this information to generate CAD drawings and 3D models of the furnace setup. We can then reference these drawings when developing the representation of the furnace in our stacking software.

- Researched different visualization software☹

  We are currently discussing the possibility of using commercial programs to do the visualization in our stacking software. The two programs we are researching are the 1) AnCAD MATFOR GUI system and the 2) OpenInventor program. These programs give developers a higher level way to build the interface, though the actual coding still has to be done either using original code or selecting from options built into the software. The general specifications are outlined below:

Visualization Software – AnCAD **MATFOR® GUI System**

A. http://www.ancad.com/overview.html#overviewmenu
B. Must get license from this company – are in contact already
C. Capabilities:
   1. Can see actual geometry of the furnace and structure – brick, steel, etc.
   2. Can change parameters such as material, size, position, can also add menus file, output
   3. Can operate using manual options in the program
   4. Can do animations
   5. Ability to use Matlab kernels we have written and develop them into Fortran or C/C++, and compile using the program.
D. On website, has module to convert Matlab code into Fortran or C++
   1. http://www.ancad.com/codeconverter.php

Visualization Software - OpenInventor

A. http://oss.sgi.com/projects/inventor/
B. Free 15 day trial for academic institutions
   1. Open source – might be an issue for Finkl
   2. Can perhaps look into a non-open source version.
C. Capabilities:
   1. Can build 3D solid models – does it already have collision detect?
   2. Has built in sets of objects such as cubes, polygons, text,
   3. Can change materials
   4. Has cameras, lights, trackballs, handle boxes, 3D viewers, and editors
   5. Windows system, but platform independent

- Wrote an alpha build of the stacking software

  In the first attempt at developing the Stacking Software, we used C# and the .NET Framework. C# combines the power of C/C++ and the productivity of Visual Basic and greatly reduced development time. It seemed like a good idea to develop our graphical application using C# and SharpGL (an OpenGL library for

.NET). However, after only a few days into development, we faced problem which could not be easily solved with the standard OpenGL Library. The outer axes of the furnace had to be marked with graphical text representing X Y and Z axes. For this to work properly, the axes had to be mapped on the outer boundaries of the furnace. After discussing this problem with Dr.Hu, it was decided that we will have to use VTK (Visualization Toolkit) to render all furnace data and the outer axes. VTK provides a great framework for rendering polygons and volumes, however, in order to use it the software had to be written in C++. Taking into consideration the tools and flexibility offered by VTK, we made the switch from C# to C++.

- Compiled literature on heat treatment:
  To better understand the problem at hand, the team has gathered background information on the theory and application of steel heat treatments. Such references are requisite to making qualified claims concerning the possible sources of mistreat. The most comprehensive sources for this particular project are <u>Physical Metallurgy Principles</u> (Reed-Hill and Abbaschian, PWS Publishing Company, 1994) and <u>Mechanical Metallurgy</u> (Dieter, McGraw-Hill, 1986). The team has now moved on to collecting information more specific to the tempering process.

Remaining Objectives:

- More specific information concerning Finkl's heat treatment processes:
  In order to determine the causes of mistreats, information concerning the alloy composition, hardness specification, and applied heat treatment for any parts that fail to meet specification must be collected. Additionally, temper charts, nominal chemistry, and other characteristic information for each type of alloy treated must be obtained.

- A survey of a loaded furnace must be conducted:
  Although the temperature distribution within the furnace when empty was found to be nearly even, the distribution in a loaded furnace could be quite different. As such, the team has resolved to conduct another furnace survey on a loaded furnace.

- Continue software development
  The software package is constantly being reviewed and refined. The team will continue to test new versions in addition to their existing responsibilities.

Images and Appendix:

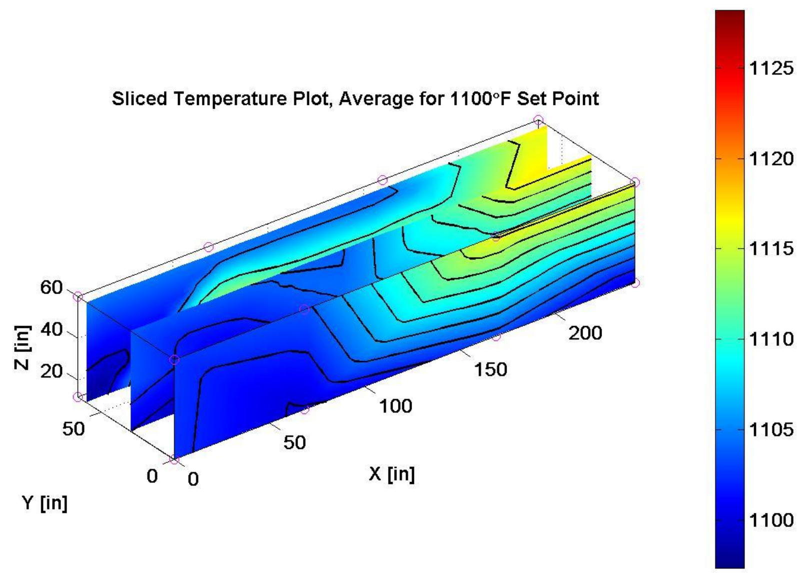

Figure 1: Temperature distribution for 1100 F nominal temperature.

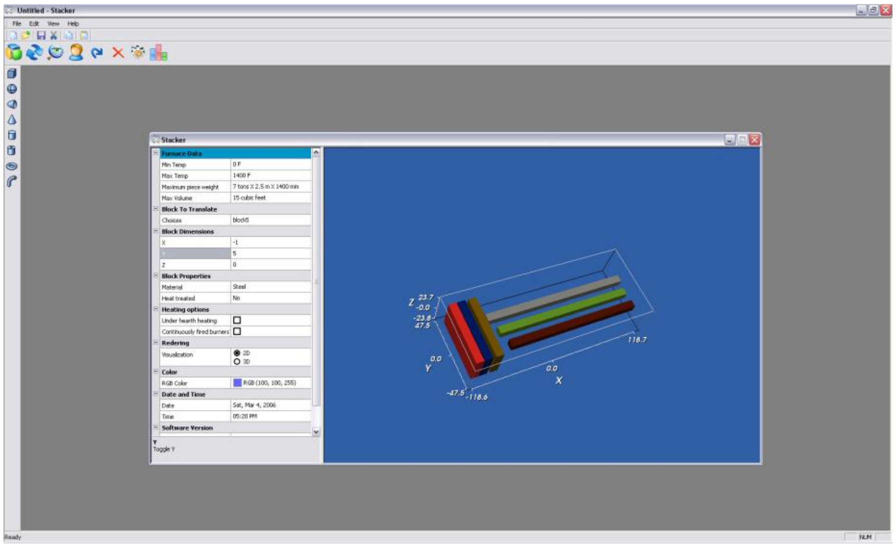

Figure 2: Typical workspace in the current build of Stacker

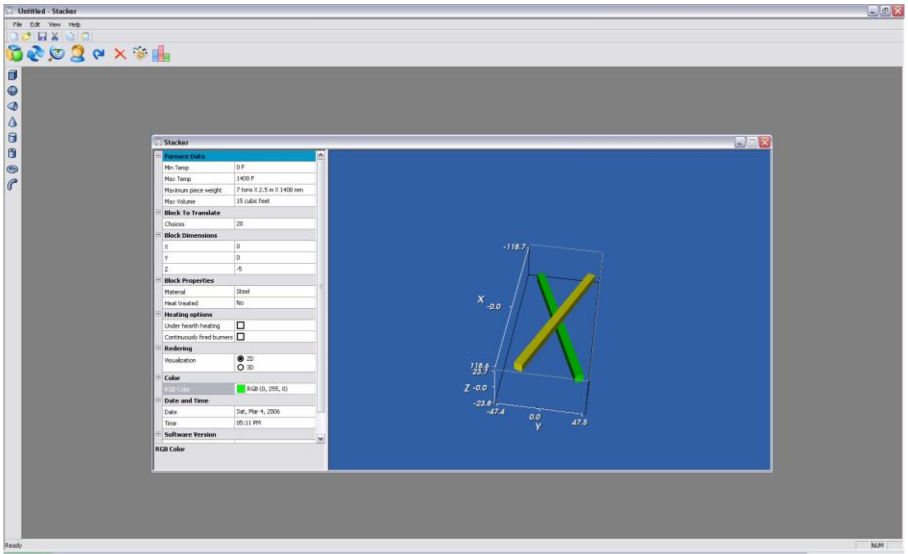

Figure 3: Stacker is capable of laying objects at any angle.