IPRO 304
Improving Manufacturing Process Controls: Heat Treatment Software

Final Report

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1.0 Introduction

IPRO 304 is a 4th semester project with the company Finkl & Sons. The IPRO was created to develop an Information Tool for the Metal Industry, specifically in the area of metal Heat Treatment. Developments can be made to the current loading, heating, and tracking processes, saving companies time and money. Development of a heat treatment program requires fundamental knowledge of the heat treatment process as well as an in depth understanding of programming and software development.

1.1 Team Members

IPRO 304: Heat Treatment is composed of the following members:

Brian Murillo, Senior – Electrical Engineer

Joe Pawlak, Junior – Computer Science

Nikolay Popov, Senior – Mechanical Engineering

Nicholas Przybysz, Senior – Mechanical Engineering

Faculty Advisors consisted of:

Dr. Sheldon Mostovoy – MMAE

Professor William Maurer – INTM

2.0 Background

2.1 Heat Treatment Process

Steel is one of the most widely used metals in industry today. Steels are an iron based alloy that have a varying range of properties depending on the chemical composition as well as the methods used to process the steel. The most common addition to steel is carbon, which strengthens and hardens the steel. The carbon is added through the heat treatment process.

The majority of heat treatment done by Finkl is quenching and tempering, which is done at approximately 750 °C. At this temperature the carbon and iron atoms within the material form a solid state solutions to produce the steel. How quickly the steel is cooled depends on the composition of the steel. If the steel is rapidly cooled, known as quenching, the resulting material will be very strong and hard, but quite brittle, called Martensite. This results from small and closely packed crystals within the material. If the steel is cooled slowly, pearlite is formed, which produces a strong, hard, and tough steel. A picture of both types of steel can be seen below.
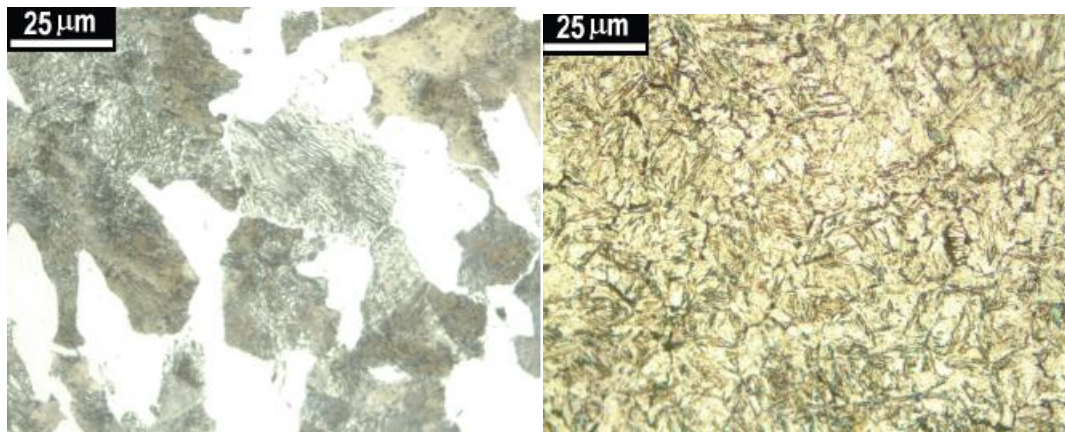

Figure 1. (Left) Pearlite steel, (right) Martensite steel

The hardness of the brittle steel can be reduced by a method called tempering, which alters the material properties of the steel and makes it more usable. The steel is heated to a temperature determined by the desired alloying content and properties after tempering. The steel is held at that temperature for a set length of time. Just like quenching, different times and temperatures of tempering will yield different properties. Tempering

for a long period of time will result in a softer and tough steel. The time it takes to temper the steel depends largely on the dimensions of the part, as larger parts take longer to reach uniform temperature due to the large thermal heat capacity. Any irregularities (odd shapes) within the part can cause irregularities within the heat treat process, and must be taken into account when the heat treat process is undergone.

2.2 Finkl & Sons Company

Finkl & Sons Company Steel is one of the worlds leading producers of forging die steels, plastic cold steels, die casting steels, and custom open-die forgings. Finkl's customers mostly consist of manufacturers building tooling for their operations or using Finkl parts within finished products. Finkl has an excellent track record and produces some of the highest quality specialized steel in the industry. Because of this reputation, Finkl has high quality standards for their products, which leads to about 7% or about 14 million pounds of their manufactured parts to be considered below quality. For the quenching and tempering process, this means that the process must be started over instead of completely scrapping the part. The failure to achieve proper heat treatment is usually due to the irregular shape and size of the steel part, as Finkl's parts range from anywhere around 500 lbs up to 100,000 lbs. There are also over a hundred different shapes that Finkl regularly produces.

Because size, shape, and tyupe of steel are the main parameters that influence the heat treatment process, there is a specific and limited combination of parts that can be heat treated at one time at Finkl. Many large furnaces, as seen in the picture below, treat the

parts and can only hold a limited number of parts at one time. The foremen at Finkl make the most of the limited space by expertly arranging and stacking parts within the furnace so that as many parts can be treated as possible while still meeting quality standards. When the parts are loaded into the furnaces, via crane, then are placed and their position is recorded on a piece of paper by the foreman. The only information on this piece of paper is the part number and where the part approximately is in relation to the front or back of the furnace. After the heat treat process, this piece of paper is filed away. As a result, when a part does not complete the heat treatment process and meet Finkl's high standards, it is often difficult to tell why the part did not treat properly. The way the Finkl foremen visually creat the work-order database and part layout makes for a process that is inefficient, slow, and poor at tracking the parts.

2.3 Previous IPRO Work

As this the IPRO's 4th semester working with Finkl, there have been numerous other versions of the heat treatment program. These programs were successful in illustrating shapes within a digital furnace. These programs were capable of part manipulation , translation and rotation, within the furnace. While these programs did make it possible to replace the hand drawn slips, they had some inherent problems.

Previous versions of the program were made using obscure developmental software that was not easy to upgrade and was not compatible with Finkl's database. Early versions of the program lacked solid modeling, and just represented the parts as very basic shapes. More recent versions of the software have included a part code library with shapes modeled in Pro Engineer that can be imported into the program. Another major problem with the previous semesters work was the lack of commenting in the program code. With new students working with unfamiliar software, the lack of comments on previous work made it impossible to decipher what parts of the code did what and made the software incredibly difficult to work with and upgrade.

3.0 Purpose

The purpose of this IPRO is to create a tool that Finkl & Sons Company can use daily that will replace the current paper system they have, increase efficiency, and provide reliable tracking of previous parts throughout the heat treatment process. The ability to save in scrap or retreated metal as well as track and analyze part placement has the ability to save Finkl a substantial amount of time and money. In order for the solution to function at an be useful in the long run, it is necessary to make the program compatible with industry standards and components.

3.1 Project Goals

IPRO 304 has a set of long term goals that have been in place since the beginning of the IPRO. Some of these goals have been met, while others have been changed. Below is a list of the goals of IPRO 304.

The software must:
- Visually display an accurate representation of the parts within the furnace
- Function with Finkl's work order database
- Utilize file formats used by popular CAD packages such as Pro E or UGS
- Capable of accepting upgrades developed by future IPRO teams
    - o Migration to handheld devices for foremen
    - o Thermodynamic modeling and optimization
- Have an easy user interface

3.2 Semester Goals

Due to the fact that there is only one semester to work on the project, and that a majority of the members of the team will be graduating, a few goals were focused on from the list of project goals mentioned above.

Goal 1:

A major goal if this semesters IPRO was to revamp the previous version of the Heat Treat program as the code left for the IPRO was uncommented and hard to follow. The team would work on creating an easy to follow and well commented program code that could easily be modified by future IPRO groups

Goal 2:

Integrate the program with Finkl's work order database so that if a foreman wishes to pull up a previous load he can enter the work order number and visually see where each part was in the furnace. This will also pave the way an optimization function of the program that will allow the foreman to enter the parts that are going to be treated in the furnace and have the program automatically arrange the parts so that the best heat treatment can be achieved.

3.3 Original Project Plan

The team spend a good portion of time initially in contact with Finkl to learn exactly what Finkl wanted from the program. These meetings with Finkl ranged of actually going over to the Finkl plant and seeing the current process to sitting down and having discussions with Finkl's IT group. Below is a rough weekly schedule that was made in the beginning of the semester.

Week:
1. 1/22-1-25
2. 1/28-2/1
3. 2/4-2/8
   -Meet with Finkl
4. 2/11-2/15
   -Draft of project plan
   -Continue looking at old code
   - Meet with Dr. Hu
5. 2/18-2/22
   - Final project plan due
6. 2/25-2/29
   -Begin working on remaining shape codes
7. 3/3-3/7
   -Midterm Report Draft 1
   -Possibly begin coding new program
8. 3/10-3/14
   -Midterm Report Due
      -Current progress
      -Preliminary Analysis
      -Proposed Solutions
      -Testing Draft
9. 3/17-3/21
   -Code testing
10. 3/24-3/28
    -Code Testing
11. 3/31-4/4
    -Modification of code to better suit Finkl's needs

12. 4/7-4/11
    -Meet with Finkl to establish we have given them something they can use
13. 4/14-4/18
    -Finish compiling final code
14. 4/21-4-25
    -Prepare for IPRO Day
15. 4/28-5/2
    -IPRO Day Presentations
    -Final Deliverables
16. 5/5-5/9
    - Final written report due
17. 5/9-5/13
    -Debriefing meeting
    -Post brief with Finkl

4.0 Research Methodology

Our initial research involved finding out what had been done in previous semesters, and what still had to be done this semester. First we reviewed previous reports and documentation produced by previous IPROs, and then we met with Dr. Hu to discuss previous and future progress. After we finally got access to last semester's source code, we compiled the program to see what worked. We then reviewed the source code to see what groundwork was started, and had not been worked on yet. After we figured out what had to be done this semester, we begin to research the HOOPS and ACIS documentation to become familiar with their proprietary functions.

5.0 Assignments

Individual Assignments

Name	Major	Individual Role
Bryan Murillo	Electrical Engineering	Programming
Joseph Pawlak	Computer Science	Team Leader/Programming
Nikolay Popov	Mechanical Engineering	3D Modeling
Nicholas Przybysz	Mechanical Engineering	3D Modeling

The roles in the team have stayed the same since the midterm report. Joseph Pawlak is the team leader since the first team leader left the IPRO at the beginning of the semester.

There are two sub-teams. First sub-team consists of Joseph Pawlak and Bryan Murillo and it deals with programming aspect of the project. The team was responsible for writing the code for the needed functions of the program and implementing them and creating the interface of the heat treatment software. Also after the last meeting with Finkl this sub-team has done work to integrating the program with Finkl's database. Bryan Murillo was assigned the task of creating the group's poster for IPRO day.

The second sub-team consists of Nikolay Popov and Nicholas Przybysz and it deals with modeling the 3D shapes that are going to be read by the software. The team has completed the 3d models of all possible shapes that can be inputted in the furnace based on Finkl's shape codes. Also the team has to create any additional models and tables with models specifications, which the software needs to be inputted. This sub-team was also assigned work on the project deliverables.

The team as a whole has had to meet with Finkl representatives twice since last report and discuss the work being done and get feedback from Finkl. A formal presentation of the progress was prepared and presented by Joseph Pawlak and Nikolay Popov.

6.0 Obstacles

Some of the obstacles we were faced with were getting access to previous semesters' work and reviewing what had been completed. The source code was not documented, and none of our group members were familiar with the HOOPS and ACIS frameworks. This forced us into a slow start, but we were able to study the framework documentation and become intimate with the entire program, not just the parts that were newly implemented.

We were also faced with the obstacle of integrating Finkl's part database with our program. We overcame this obstacle by providing a separate program that Finkl can integrate into their existing software and provide our application with the necessary information.

One of our group members also dropped the IPRO after the first several weeks. He assumed a leadership position, but quickly dropped the course without informing us.

7.0 Results

This semester's IPRO was able to advance upon the work of previous IPROs and provide our sponsor company with additional functionality. We were able to integrate Finkl's work order database with our program, expand the shapecode library, and provide functionality to manipulate parts inside the virtual furnace.

Future IPROs will have to rely on the requirements of Finkl to determine what future functionality is needed. Current requests from Finkl would require future IPROs to develop a version of the software to be used on a hand-held device, and to determine optimal placement of parts based on past loads.

The licensing cost for the HOOPS and ACIS framework starts at $36000/year. This is a large amount of money, and future IPROs will have to research alternative products that do not have such a large price tag.

8.0 Recommendations

Based on the progress that was done this semester there are several logical follow ups for future work. A working program was created, but it hasn't been tested in real conditions to determine its usefulness, ease of use and robustness. So a next step would be to work with Finkl's management to validate and if need it be improve the functionality of the program. Since the program is to be used by workers at the heat treatment site at Finkl it should be tested with them to gather feedback on ease of use of the interface and if needed improve on that aspect also. If the program is going to be continued by another IPRO it is advisable to start by researching for cheap development packages, because the current one requires an expensive license for Finkl to pay every year if it is to be used. Also based on Finkl's feedback the program requires additional functionality in order to fit better with their needs. Future work could be done on scaling parts automatically based on dimensions of existing Finkl database, providing different camera views and the navigation of the parts. In the last presentation at Finkl, some feedback was received regarding changing their shapecode system at some point in the future, so work would have to be done to adapt the program to the other system.

9.0 References and Resources

- A. Finkl and Sons Management

- Dr. Zhi-Yong Hu

- Programming Microsoft Visual C++

  Authors – David J. Kruglinski, George Shepherd, Scot Wingo

- "Switching to other view in a doc-view application"
  http://www.vckbase.com/english/code/doc_view/switching_views.shtml.htm

- "Interprocess Communication Between .NET and MFC Using WM_COPYDATA"
  http://www.codeproject.com/KB/threads/InterprocessCommunicator.aspx

- 3D ACIS Modeler

  http://www.spatial.com/products/acis.html

- Hoops 3D

  http://www.spatial.com/products/hoops.html

  http://developer.techsoft3d.com/documentation/index.html

- Microsoft .NET Framework Version 2

  http://www.microsoft.com/downloads/details.aspx?FamilyID=0856EACB-4362-4B0D-8EDD-AAB15C5E04F5&displaylang=en

- Visual Studio

  http://msdn.microsoft.com/en-us/vstudio/products/default.aspx

- Pro/Engineer

  http://www.tristar.com/software/proengineer.asp?gclid=CM-zpP3MhpMCFSH0IgodJxmlSw

10. Acknowledgments

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    o 3D ACIS Modeler

    o HOOPS 3D

- Advisors

    o Professor William Maurer (INTM)

    o Professor Sheldon Mostovoy (MMAE)

- Consultants

    o Professor Dr. Zhi-Yong Hu (MMAE)