THERMAL MODELING OF OPEN DIE FORGINGS USING MICROCOMPUTER PROGRAMS

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ABSTRACT

This project was conducted as part of an NSF grant, under the direction of the Engineering Faculty Internship Program at NSF. The project allowed C.J. Van Tyne to work for nine weeks at the BethForge facilities in Bethlehem, PA. There were two major objectives to this project: 1) to develop several computer programs that would execute on a PC which would model the thermal behavior of open die forgings during heat treatment and 2) to provide an opportunity for an engineering professor to become better acquainted with the day-to-operations of BethForge. Both of these objectives were achieved during the project. This paper provides an outline of computer programs that were developed during the project.

COMPUTER PROGRAMS DEVELOPED

During the Engineering Faculty Internship, three computer programs were developed. These programs modeled several aspects of the open die forging process and heat treatment operations for open die forgings. The three computer programs are as follows:

A program to model the furnace hardening of steel rolls. The furnace cycle, quench conditions and tempering conditions can be specified by the user. The program predicts the thermal profiles at various depth locations and calculates a depth of hardness for the specified process and material.

2 A program to model the thermal changes that occur in an ingot (or forging) during heating, forging then reheating. The user can specify the heating conditions, forging conditions and reheating conditions. The program predicts the thermal profiles at various depth locations and calculates the instantaneous temperature gradient as well as the maximum temperature gradient in the piece during all three processes.

3. A program to model the heat treatment of cylindrical forgings. The user specifies the furnace cycle and the program predicts the thermal profiles at various depth locations in the forging. The program also determines the instantaneous temperature gradient as well as the maximum temperature gradient during heat treatment.

Each of the three programs is started by executing a control program. The user is presented with a series of menus where the processing conditions can be specified. The calculations are performed in a Finite Element Model (FEM) program which simultaneously displays the temperature profiles as a function of time. This display is analogous to a strip chart recording of thermocouple measurements (see Figure 1.) A detailed output file is also generated during the calculations phase of the FEM program.

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Once the FEM program is complete the user can then rerun the menu program to make changes to the processing conditions and see what effects they have on the predicted thermal profiles.

Many of the material properties and furnace convective heat transfer coefficients were based upon previous experimental work for the BethForge materials and furnaces. The programs also showed good correlation which the modeling predictions made by an mainframe program internally developed by Bethlehem Steel Corporation. There are several conditions where best estimates were made and experimental verification is still needed.

These programs run on a IBM compatible personal computer (at least a 386 with a math coprocessor and a VGA video display.) They allow easy input of information by the user and provide a clear graphical display of the results. Overall these programs provide a viable tool in gaining a better insight into the thermal treatment operations that are used for forgings and rolls.

DISTRIBUTION TO OTHER COMPANIES

These programs have been made available for use by other forging and heat treatment companies. These companies need to generate their own furnace convective heat transfer coefficients and the thermal properties for the materials they would be modeling. To date six other forging companies have requested and are using these heat treatment programs.

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Fig 1 Example screen display for the heat treatment, quenching and tempering of a hardened steel roll.