Effect of Heat Treatment Parameters such as Soaking Temperature, Time, Quench Delay and Cooling Rates on Mechanical Properties of Low Alloy Grades, Mn-Mo and Cr-Mo Steels

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Abstract— In this report, we first consider the 1m cubic block for the sake of simplicity and then we are going for the complex geometry for the shape of machines. The Prediction of mechanical properties for a particular grade of steel while applying different heat treatment conditions is the basic problem for the investigation. The project should aim at primarily the heat transfer to estimate the time-temperature history at various spatial locations in a steel component of particular grade and subsequently, predict the microstructure using existing CCT curves for the chosen grade of steel.

Key words: Wireless sensor networks, cross-layer routing, connectivity holes, geographic routing, localization error

I. INTRODUCTION

The radiation of the sun in which the planet is incessantly plunged penetrates the air, the earth, and the waters; its elements are divided, change direction in every way, and, penetrating the mass of the globe, would raise its temperature more and more, if the heat acquired were not exactly balanced by that which escapes in rays from all points of the surface and expands through the sky [5].

The great object to be affected in the boilers of these engines is, to keep a small quantity of water at an excessive temperature, by means of a small amount of fuel kept in the most active state of combustion. No contrivance can be less adapted for the attainment of this end then one or two large tubes traversing the boiler, as in the earliest locomotive engines.

The archetypical problem that any heat exchanger solves is that of getting energy from one fluid mass to another. A simple or composite wall of some kind divides the two flows and provides an element of thermal resistance between them. The steam condenses and the water is heated at the same time. In other arrangements immiscible fluid might contact each other or noncondensible gases might be bubbled through liquids [5].

The effects of heat are subject to constant laws which cannot be discovered without the aid of the mathematical analysis. The object of the theory which we are about to explain is to demonstrate these laws; it reduce all physical researches on the propagation of heat to problems of the calculus whose elements are given by experiments.

A. Rationale:

The solid object is a huge structure and cooling bath is also huge. The governing heat transfer coefficient h varies from location to location into the bath. But we assume here that h is divided into three segments like $h_0, h_I,\ h_{II}$. The individual calculation of $h_0, h_I\ h_{II}$ describe afterwards.

The heat transfer coefficient can be measured experimentally using probe with one or more thermocouples. The probe can be quenched and variation in temperature with respect to time is measured. [1, 2, 3]

Fig. 1: huge solid object

Fig. 2: Thermocouples

B. Theory Aspects of the Problem:

Consider the solid block whose initial temperature is $1000^\circ C$ i.e $T_i = 1000^\circ C$ =T(x, y, z, t=0) which is emerge in the water whose initial temperature is $20^\circ C$.

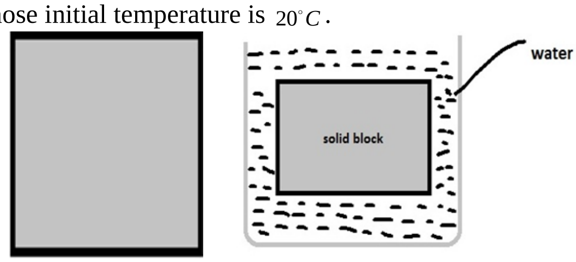


Fig. 2: (a) Theory Aspects

C. Approach:

Heat Energy Balance:
Input energy = Heat contain of the object = Heat capacity of the material X Weight of the material
Output energy = Decrease in energy of the object

1) Increasing temperature of the water (measurable)
2) Heat in the form of vapor (waste, which is not measurable) By agitation it is possible to maintain Δt of water constant

II. MATHEMATICAL MODELING

In order to formulate the mathematical model to the given problem entitle, "effect of heat treatment parameters such as soaking temperature, time, quench delay and cooling rates on mechanical properties of low alloy grades, mn-mo and cr-mo steels" we consider the following certain assumptions.

A. Assumptions:

Infinite amount of water i.e. T_∞ will be constant throughout & well stirred.

h_0, h_I h_{II} are three distinct constant values.

No radiation heat transfer

Basic of convective heat transfer coefficient is to consider the "stagnant layer" adjacent to the wall.

If stagnant layer get disturb, heat transfer coefficient must be different.

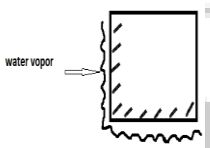
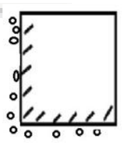
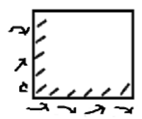
PHASE – I LEIDENFROST EFFECT	PHASE – II NUCLEAR BOILING	PHASE – III LIQUID – SOLID HEAT TRANSFER
when solid block is emerged into the water tank then vapor blanket starts forming	Water vapor starts forming and breaking	vapor layer disappears and starts mixing with the water and forced convection starts
		
h_0	h_I	h_{II}

Table 1: Different Phases

$$h = \begin{cases} h_0 & T > T_{LF} \\ h_I & T_{LF} > T > T_B \\ h_{II} & T_B > T \end{cases}$$

Fig. 3: 1m Cubic block

B. Modeling:

Consider the solid block as shown in Fig. 1 whose initial temperature is $1000^\circ C$ i.e. $T_i = 1000^\circ C$ =T(x, y, z, t=0) which is immersed in the water whose initial temperature is $20^\circ C$. (First Leiden frost /vapor region – until about 800 deg c. explains) At $100^\circ C$ the evaporation stops i.e. vapor blanket disappears and the solid block comes in direct contact with water.

C. Finite Element Method for 1-D Method:

The governing equation for this same problem is in energy equation for conduction is given by

$$\rho C_p(T) = \frac{\partial T}{\partial t} - \nabla.K(T)\nabla T = 0 \quad \text{-------------- [1]}$$

Where $C_p(T)$ = Specific Heat, $K(T)$ = Thermal conductivity

The boundary condition are given in the terms of heat flux as $-K\bar{n}.\nabla T|_\Omega = \dot{q}$, where $\dot{q} = h(T_s - T_\infty)$ and $T_s : T|_\Omega$

Mathematically, the combined heat transfer coefficient is given by combination of Heaviside function as

h= h_0 * H ($T-T_{LF}$) + H (T_{LF}-T) * (h_I.H($T-T_B$) + h_{II} * H (T_B-T))

T_{LF} = Leiden frost transition (700 deg c)

Where T_B = Boiling 100 deg c

T_{LF} = Temperature at surface

D. Mat Lab Code:

For the solution of Eq. (1) we use finite deference method by developing our own code by MATLAB as

```
%heat1Dexplicit.m
% Solves the 1D heat equation with an explicit finite difference scheme
clear all; close all
%Physical parameters
L = 1; % Length of modelled domain [m]
Twater = 20; % Temperature of magma [C]
Tinit = 1000; % Temperature of country rock [C]
kappa =1e-5; % Thermal diffusivity of rock [m2/s]
W = 5; % Width of dike [m]
% Numerical parameters
nx = 50; % Number of grid points in x-direction
nt = 1000; % Number of time steps to compute
dx = L/(nx-1); % Spacing of grid
x = -L/2:dx:L/2;% Grid
tfinal=220*60;
dt = tfinal/nt; % Time step [s]
% Setup initial temperature profile
%T = ones(size(x))*Trock;
%T(find(abs(x)<=W/2)) = Tmagma;
T = ones(size(x))*Tinit;
T(1)=Twater;
T(nx)=Twater;
time = 0;
for n=1:nt % Time step loop
   % Compute new temperature
   Tnew = zeros(1,nx);
   for i=2:nx-1
Tnew(i) = T(i)+kappa*dt*(T(i+1)-2*T(i)+T(i-1))/(dx*dx);
   end
   % Set boundary conditions
   Tnew(1) = T(1);
   Tnew(nx) = T(nx);
   % Update temperature and time
   T = Tnew;
   time = time+dt;
   % Plot solution
   figure(1)
   plot(x,Tnew);
   xlabel('x [m]');
   ylabel('Temperature [^oC]');
```

```
    n
    drawnow
end
```

E. Numerical / Abstract Results:

From this MATLAB program got the following results:

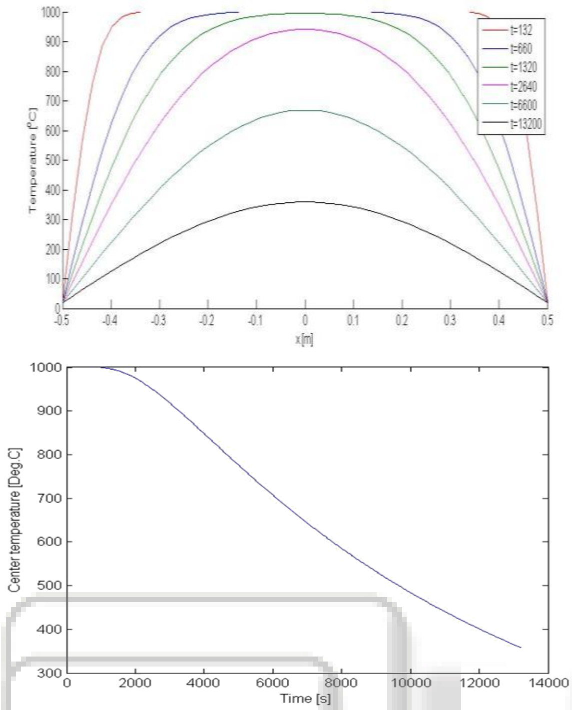


Fig. 4: Graphs generated by MATLAB coding of FDM

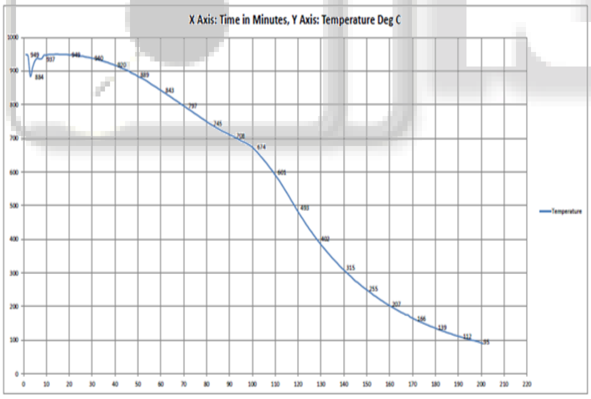


Fig. 5: Graph by practical data

F. The Second Approach We Can Show here by taking the Spherical Ball:

Consider a spherical steel ball of radius R. Assuming the ball is cooled uniformly from the entire outer surface. Assume also that all the parameters are constant. Then we have the heat equation

$$\frac{\partial T}{\partial t} = \kappa \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial T}{\partial r}\right)$$

Where $\kappa = k/(C_p\,\rho)$; K = 52 (W/mK); Cp = 465 (J/kg K) ;ρ= 7800 (kg/m^3)

Solve the above equation with

R = 0.5(m).

Initial condition: $T(0, r) = t_i = 1000$,

Boundary condition: *T(t, R)* is given.

Exponential decay of the surface temperature:

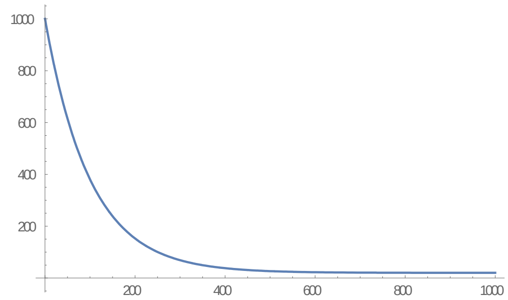


Fig. 6: Graph by practical data

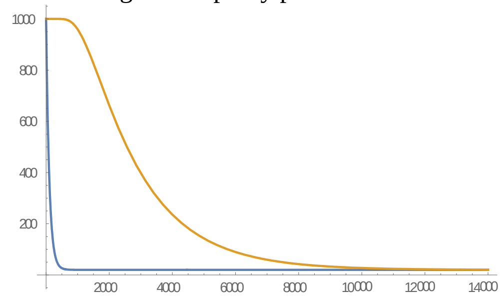


Fig. 7: Graph by practical data

To guess the cooling time

Three phases:

1) The film boiling or vapor blanket stage. cooling rate is relatively slow.
2) The nucleate boiling stage: strong convection, high rate transfer from the ball to the water.
3) The convection stage: the cooling rate is slow and is determined mainly be the rate of convection and the viscosity of the water.

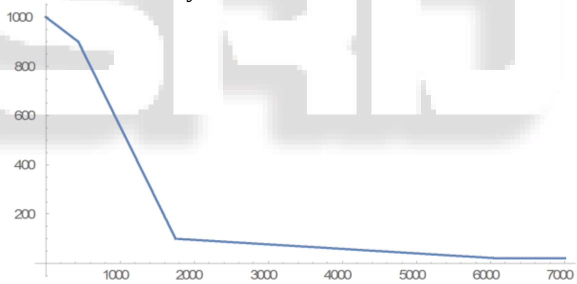


Fig. 8: Graph by practical data

Boundary condition *T(t,R)*

Time: (s)

Temperature: (^{o}C)

Linearly decreasing:

Time 0 to 7000/16 = 437.5(s): decrease from 1000 to 900;

Time 437.5 to 1750: decrease from 900 to 100;

Time 1750 to 6125: decrease from 100 to 20;

Then keep constant at 20 degree.

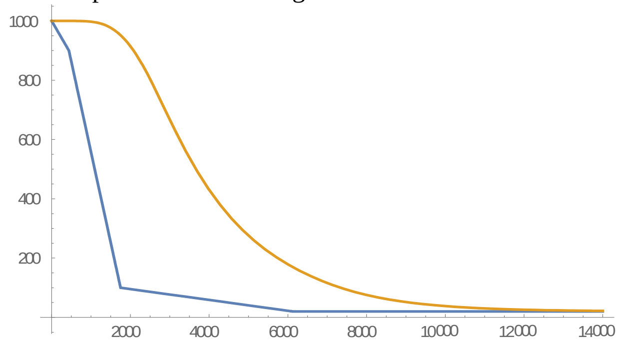


Fig. 9: Yellow line is the temperature at the center of the ball.

III. PRACTICAL ASPECTS

- Type of water
- Quantity of water
- Thermal conductivity of water
- Thermal conductivity of material
- Way of insert the object into the medium
- Number of stirrer
- Use of heat carrier if possible
- Breaking of water vapor blanket by some mechanism
- Agitation by stirrer
- Agitation of the object
- Number of variables for heat transfer coefficient
- Type of the surface (smooth or rough)

IV. CONCLUSION / SUGGESTION TO INDUSTRY

- Main effect in the boundary heat transfer is the transition between Leiden frost region and boiling phase
- Including a more detailed HTC correlation and temperature dependent properties is numerically no problem
- Easy to solve the temperature field
- Further experiments can assist in development of case specific HTC correlations
- Solve for 1 – dimensional problem and further we can investigate for higher dimension
- Solve for cube, further we can take complex geometry

REFERENCES

[1] Bates CE, Totten GE, Clinton NA (1993) Handbook of Quenchants and Quenching Technology, ASM International Material Park, Ohio, USA
[2] Heat Treating Proceedings of the 19th conference, ASM International Materials Park, Ohio, USA, pp284-291
[3] 4th International Conference on Quenching and Control of Distortion, ASM International, Materials Park, Ohio, USA 2003
[4] George E. Totten, Maurice A.H. Howes, Steel Heat Treatment Handbook
[5] John H .Lienhard IV and John H .Lienhard V, 4th edition. A Heat Transfer Textbook