Prediction Model for Hardness of Quenched Steels in Varying Concentrations of Polyacrylamide Aqueous Solution

S. Jyothirmai, I. Aparna devi*, I. Sudhakar and R. Ramesh
Centre for Intelligent Manufacturing Automation, Department of Mechanical Engineering, MVGR College of Engineering, Vizianagaram-535005, INDIA

Abstract

The importance of various form of heat treatment operations done on medium carbon steels in order to overcome the problems that may arise in making a wrong choice of these steel materials or faulty heat treatment operations which may give rise to serious disruption in terms of human safety, higher cost and untimely failure of the machine components is of great concern. The mechanical properties such as ductility, toughness, strength, hardness and tensile strength can easily be modified by heat treating the medium carbon steel to suit a particular design purpose. In the present experimentation, specimens were produced from medium carbon steels of two grades i.e., EN19(without Nickel) and EN24(with Nickel) and were subjected to one of heat treatment processes i.e., hardening following with polymer quenching in different concentrations to understand the effect of Nickel on hardness. Nickel increases the Austenizing zone area, thereby a needle like fine grain structure is obtained, which is very hard. Hence Nickel plays a pivotal role as an alloying element. Thus the hardness values are tabulated, and with the help of these values, a prediction model is developed using Matlab based on Support Vector Machine (SVM). In order to estimate hardness value at any condition within the conducted domain, the basis for development SVM model has been obtained by the data base comprising of set of input values(Temperature, Metalgrade, concentration) and output data (hardness).Finally the graphs were plotted and the results were examined and was found out that the hardness for EN24(with Ni) grade of steel was more when compared to EN19(without Ni) grade and also SVM prediction model has been very useful in determining the intermediate conditions.

Keywords: Hardness, Support Vector Machine, Quenching.

1. INTRODUCTION

Polymer quenchants are the most versatile, stable, and consistent performers among aqueous quenchants. In the present scenario, polymer quenchants are being used increasingly in the heat treating industry. One reason for this increase in use is the continual engineering advancements that facilitate their replacement of quench oils and also water. For these reasons, these products have seen dramatic growth in use during the past sixty years. The first widely used polymer quenchant was polyvinyl alcohol (PVA), but it is no longer commonly used in the U. S. because of regulatory concerns. Currently, there are several proprietary polymers available in the marketplace, but the most commonly used formulations are polyalkylene glycols (PAGs), polyvinyl pyrolidines (PVPs), and polysodium acrylates (PSAs). Today, PAGs are the most commonly used polymer quenchant in the united states. Polymer quenchants can be formulated to provide quenching power ranging from that similar to fast quenching oils to that greater than water. PAG quenchants have shown significant market penetration, replacing fast and medium speed quenching oils for a range of steels and part geometries.

2. REVIEW OF LITERATURE

Basak and chakroborty [1] developed Cr-Mn-Cu white cast iron to improve erosive and corrosive wear resistance by adding Cu in Cr-Mn iron. Kuma and Gupta [2] studied the abrasive wear behaviour of Cr. Steel to improve abrasive wear resistance.

Raman and Rajagopalan [3] conducted heat treatment process for aircraft alloys using polymer based quenchants. George [4] used polymer quenchants for induction heat treating to control distortion and cracking of steel. Małgorzata and Wojciech [5] uses aqueous polymer quenchants for hardening of carbonitrated parts. Lu and Winnik [6] have done their research on luminescent oxygen sensors.

* Corresponding Author. aparnaimandi@gmail.com

3. EXPERIMENTAL WORK

3.1 Selection of Base Metal and Quenching Medium

The objective of this work is to present an approach for simultaneously handling data from various heat treatment processes with different ranges of input values yet producing similar hardness on the specimen. A conventional regression approach will not be able to predict the output accurately. To develop such an approach, a set of experiments were conducted given the available facilities and range of operating conditions as described below. The process parameters that were focused upon in the present work are temperature, material, type of heat treatment process. Polymer as quenching mediums on medium carbon steels of two grades i.e. EN24, EN19 as shown in Fig. 1 were carried out using muffle furnace. For all of these operations, the hardness was measured using a Rockwell's hardness testing machine for varying values of temperature, material, type of heat treatment process. The main reasons to select these type of steels is that these two grades of steels are similar in nickel composition. After heat treatment the specimens are subjected to quenching.

Figure. 1. EN19 & EN24 grades of steel specimens

3.2 Generation of Database

This section illustrates the generation of database for the SVM perdition model by conducting experiments on each EN19 and EN24 alloy steels under the Rockwell's hardness machine to obtain the initial hardness values. The Rockwell hardness scale is based on indentation hardness of a material. After the initial hardness test the heat treatment process has been carried for EN19 and En24 alloy steels by performing heating operations at 10 different temperatures in the range of 500°c to 950°c, in the intervals of 50 each. After heating the specimens in the muffle furnace they are subjected to polymer quenching using soluble oil with water in 1:10 ratio at different temperatures ranging from 500°c to 950°c with an interval of 50°c. The heat treated EN19 and EN24 alloy steels under different heat treatment processes are as shown in the Fig. 2.

Figure 2. Polymer quenched specimens after heat treatment

After heat treatment processes the specimens are tested for hardness measurement and the corresponding sample hardness data values are shown in Table 1.

Table 1: Hardness values at different temperatures for different polymer concentrations

TEMP ^{0}C	EN24	EN19	EN24-H	EN19-H	EN24-H	EN19-H	EN24-H	EN19-H	EN24-H	EN19-H
	Pure polymer solution		30ml water in Pure polymer solution		60ml water in Pure polymer solution		90ml water in Pure polymer solution		120ml water in Pure polymer solution	
500	11	22	26	10	33	32	48	48	42	41
600	13	20	14	10	12	13	32	44	22	18
650	47	10	49	27	54	28	55	31	51	21
700	80	80	84	61	83	76	85	84	83	79
750	53	62	43	50	48	55	54	59	50	46
800	51	52	42	46	50	43	52	55	36	44
850	44	48	34	27	40	48	51	45	34	43
900	19	56	29	48	39	53	46	78	16	68
950	14	20	21	23	35	27	69	42	33	28

3.3 Results and Analysis

After heat treating the EN19 and EN24 steels in the furnace at different temperatures, followed by quenching in a polymer solution, graphs plotted as shown in Fig.3 between hardness and temperatures of the above mentioned grades of steels for different concentrations of polymer solution.

4. HARDNESS PREDICTION MODEL

4.1 Proposed Methodology

The primary objective of this paper is to propose an approach that can handle data for four processes simultaneously, predict the hardness. In addition, The development of a prediction model to estimate hardness under given operating conditions for EN19 and EN24 steels using different heat treatment processes. SVM based approach using Matlab has been adopted herein. A pilot set of experiments were conducted given the available facilities and range of operating conditions. In order to simultaneously handle data related to four processes, SVM regression which predicts hardness given process parameters as input is adopted.

4.2 Hardness Prediction

In this ection, various results obtained in the present investigation are outlined and discussed to arrive at a suitable conclusion. In particular, the hardness values for EN-19 and EN-24 grades of steels were determined by quenching them in polymer solutions of different concentrations and were finally analysed through different graphs and later a prediction model(SVM)had been developed.

5. PREDITION MODEL VALIDATION

In the case of EN 24 alloy steel, it can be observed that SVM predicted values and the values obtained through experimentation are fairly close. Out of 25 values given as test values as shown in Table 2, 14 values have an error less than 1, 8 values have an error slightly greater than 1 and 3 points have an error value around 3. An error of 1 to 2 is considered to be negligible in industries especially because the overall hardness is itself of the order of 40 to 50. In the present work, the hardness values being so close and their range being less, this variation appears to be a major deviation especially when plotted in Fig. 7.

6. CONCLUSION

The hardness values increases for EN-24 grade of steel when compared to EN-19 grade of steel increases because the presence of Nickel as an Austenitic stabilizer increases the Austenitic zone area, there by a needle like fine grain structure is obtained, which is very hard. There is a tremendous change (increase) in the hardness value at (700-800) ^{o} c, as it is the critical temperature for heat treated steels in Austenizing zone and beyond the above temperature range, the hardness decreases as the grain size (coarse) increases. It was also observed that, on increasing the concentration of water in polymer solution, there is a controlled heat dissipation, thereby reducing the cooling time and increasing the hardness.

7. REFERENCES

[1] Basak and chakroborty , "*Corrosive wear behaviour of Cr-Mn-Cu white cast irons in sand in sand water slurry*", *Elsevier*, Volume 143, Issue 2, Page no:203-220,1991.

[2] Kuma and Gupta project report on ," *The abrasive wear behaviour of mild, medium carbon, leaf and high carbon, low Cr. Steel by means of a dry stand rubber wheel abrasion apparatus*", NIT Rourkela,2009.

[3] Raman, PS and Rajagopalan, on "*Heat treatment of aircraft alloys upon using polymer based quenchants*", Project Report, NAL, Banglore, 1989.

Note: Full details of the paper are available in the soft copy of the proceedings