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An Interdependence Relation to Support Case-based Reasoning Solution for an Industrial Application

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ABSTRACT

One of the major issues required to be dealt with the case-based reasoning (CBR) is the challenge to meet to maintain and control the correctness and accuracy of the results expected to be produced against the proposed algorithm and methodology for the candidate CBR system. This paper introduces a computational model with the assistance of the concept of Regression fitting within the mathematical and simulated model proposed through the Case Based Reasoning for predicting the case hardening process parameters of steel to be maintained within the furnace of steel hardening unit.

The paper is mainly focused towards the derivation of the interrelationship between the alloying percentage of the elements within a steel of any kind and the hardness contribution corresponding to each element. Few of the Plasma Nitriding Engineering considerations are also briefed within the paper.

General Terms
Process parameters, intelligent system, regression fitting.

Keywords
Case Based Reasoning, Plasma Ion Nitriding (PIN), Soft PIN System (SPIN), Case Hardening

1. INTRODUCTION
Case-based reasoning (CBR) proposes an intelligent-system to increase the efficiency and reduce cost in various industrial applications [5]. [6], [7], [8]. In this problem too, CBR proposes an efficient system for steel hardening system by significantly automating the prediction of the values of the process parameters, temperature, time and gas composition, involved in the process of case hardening of the steel in the PIN System [4], [8].

The exploration of the solution of the problem of predicting the PIN process parameter values has revealed the conclusion that some relation is required to be obtained for the process parameter to support the prediction process. Here, with the help of the intervention of the metallurgy science, a relation between the percentage of the alloying elements of the steel viz. Carbon, Manganese, Chromium, Nickel, Tungsten, Molybdenum, Vanadium, Silicon and Phosphorus and the hardness contribution by each of them in steel of any kind, is depicted for the purpose of the prediction of the process parameters.

The Plasma Engineering considerations relevant to the proposed model is presented in the ensuing sections. The review and formulation of the problem is discussed in section 2. Plasma Nitriding considerations are discussed in section 3. The presentation of interrelationship model is described in the section 4 with the conclusion and future scope in section 5.

Here, we proceed further with the expectation that the mathematical formulation of the targeted relation along with the predestined theoretical backdrop could help in refining the preferred outcomes and hence contribute for the maturity of the competent CBR based Soft PIN system with efficacy.

2. REVIEW OF THE PROBLEM - SOLUTION FOR THE PIN PROCESS
All The PIN process problem includes the requirement of the automation of the prediction of the process parameters associated with steel hardening process for a new steel material in the PIN system. The prediction methodology involves the application of the case-based reasoning approach on the already available information of around 23 grade steels, considered as cases to determine the values of the parameters viz. temperature, time and gas compositions for a new steel case [4]. Thus, the collaboration of the Case based reasoning with the PIN process, suggests the values of unknown parameters in a steel hardening process, based on the solutions of similar past problems [4], [8]. The case based reasoning is a four-step process consisting Retrieve, Reuse, Revise and Retain processes. Here, the solution formulation steps could be traced as follows:

- *Retrieve*-The steel cases relevant to the unknown new steel case for finding process parameter are retrieved with the process parameter values.
- *Reuse*-The cases are matched and then mapped with the solutions of the best fit available retrieved cases of steel with the new steel case.
- *Revise*-The resultant process parameters are tested or simulated in the real world and revised for accuracy.
- *Retain*-The solution after appropriate adaptation is expected to give the good results, thus the new steel case is stored as a new case with the predicted values of the parameters.

While tracing the Revision step of the CBR methodology [3], [8] we met the requirement of determining some relation, which could help in finding the dependency of the hardening parameters on the percentage of alloying of the elements. This relation could be influenced by the impact of the alloying percentages of the individual elements in any kind of the steel. Here, the interdependency of elements and hardenability of the steel is obtained through regression fitting technique and resulted in the form of polynomial equations.

2. PLASMA NITRIDING ENGINEERING DELIBERATIONS
Steels are widely used in a large number of industries due to their favorable physical and mechanical properties. Also this

could not be declined that the industrial world could not survive without this class of material. Some specific treatments help in improving the desired properties of this class of material. To increase the surface hardness as well as the wear resistance of the steels, Plasma Nitriding Process is found to be an effective and efficient surface treatment[1].

The Plasma nitriding process produces a hard outer casing on the steel material being nitrided. Here, the hardness achieved on the surface decreases with depth until the core hardness is reached. The elements forming nitride are the key factors that control the hardness and the case depth of the steel material. For few sampled steel materials, the effectiveness and influence of the surface treatments to increase the surface hardness of the steel was observed through experiments and notified that the nitriding temperature influences the hardness of the layers.

As we know that the alloying of steels is must to gain additional properties like hardenability, corrosion resistance, machinability, increase in electrical and magnetic properties etc., but here, we emphasize more on hardenability of the steel and thus we explored more on the relation between hardness of the steel material and the effect of alloying of the elements on it. Figure 1 presents the comparative effect of the alloying elements on the hardness of alloy steels.

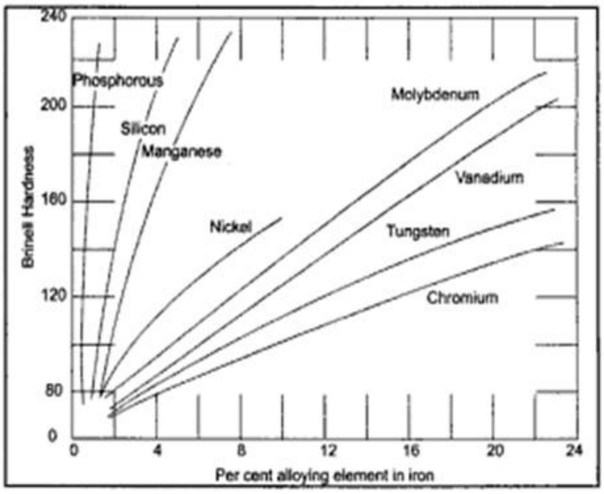
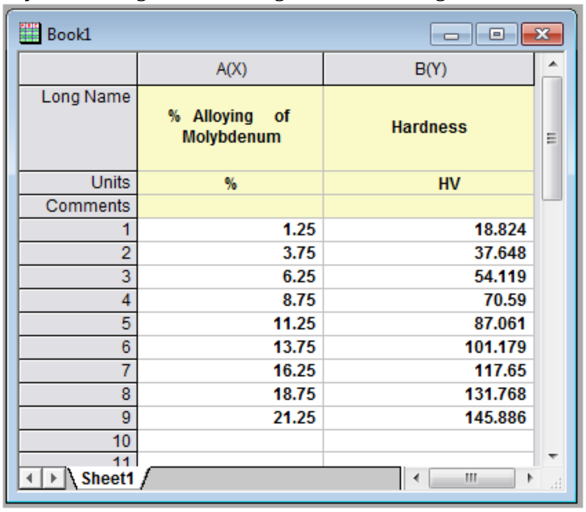


Figure 1 Effect of Alloying elements on the probable hardness of alloy steels

Here, it can be seen that the effect of each alloying element is different on the hardness contribution, which increases with the increase in the percentage composition of the elements [2].

3. AN INTERDEPENDENCE RELATION TO SUPPORT CBR SOLUTION

The impact of the alloying percentages of individual elements in steel or the contribution of the percentage composition of element in the hardnenability property of the steel is explored with the help of the software, OriginPro8. This software is basically for managing data, and creating, exploring and organizing analysis results and graphs. It also offers analysis tools for Statistics, 3D Fitting, Image Processing, and Signal Processing. With the help of the figure 1, we could find the data points, (A(X), B(Y)) for all the alloying elements of the steel for which the variation in the hardness of steel with respect to the change in the alloying percentages is given. Here, A(X) is the value of alloying percentage of an element and B(Y) is the value of the hardness w.r.t. A(X). For example, on considering the percentage composition of Molybdenum as A(X) and its corresponding hardness values as B(Y), the data points depicted for the purpose of the Polynomial Regression Fitting are shown in figure 2.


Book1

	A(X)	B(Y)
Long Name	% Alloying of Molybdenum	Hardness
Units	%	HV
Comments		
1	1.25	18.824
2	3.75	37.648
3	6.25	54.119
4	8.75	70.59
5	11.25	87.061
6	13.75	101.179
7	16.25	117.65
8	18.75	131.768
9	21.25	145.886
10		
11		

Sheet1

Figure 2 Data points depicted for the Polynomial Regression Fitting

Polynomial regression fits the depicted data set to the following model:

$$Y= B_0 + B_1 x^1 + B_2 x^2 + B_3 x^3 + \dots\dots\dots\dots + B_k x^k + \epsilon$$

Where, βi are the coefficients and ε is the error term. The error term represents the unexpected or unexplained variation in the dependent variable. Here, it is assumed that the mean of the random variable ε is equal to zero.

As the consequence of Polynomial regression fitting the values of the coefficients βi and ε is obtained as shown in figure4.

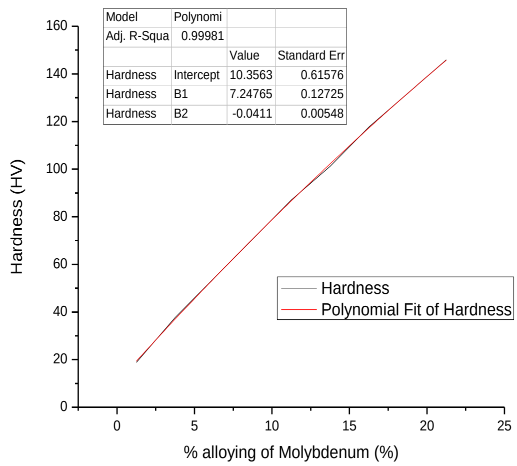


Figure 4 Polynomial Regression fitting for Molybdenum and its hardness contribution

This result gives the equation which depicts the relation between hardness and percentage alloying of the Molybdenum as:

$$Y=10.35638 + 7.24765\ x + (-0.04115)\ x^2 + \text{Error}$$

where, Y= Hardness value in HV and x = Percentage of Molybdenum

Similarly polynomial equations for all the alloying elements of the steel could be obtained. By considering Y_1, Y_2, Y_3, Y_4 , ……., Y_n, as the hardness values for all the constituent elements, these values could be obtained with respect to all the constituent elements in one steel type. The variation in the value of hardness of a steel Y_{steel} could be seen in terms of percentage variation in the constituent alloying elements through the relation:

$$\mathbf{Y_{steel} = Y_1 + Y_2 + Y_3, + Y_4 + \ldots\ldots + Y_n}$$

This relation thus helps in calculating the hardness contribution by all the constituent alloying elements and thus additionally supports in predicting the process parameters of the steel hardening system through CBR [4], [8].

4. CONCLUSION AND FUTURE SCOPE

Here, we have presented a mathematical simulated model for the purpose of the solution of the parameter prediction of a new steel case through CBR approach. Future Scope under this research may include the following tasks:

1) Analysis and testing of the model is proposed next for its successful implementation.
2) To explore further an advanced relationship model, that could depict the impact of the alloying percentage of the elements after their integration within the steel.
3) To find interrelationship model for the process parameters: temperature, time and gas composition.
4) To find other process parameters like pressure, voltage and current required in the PIN system.

5. ACKNOWLEDGMENTS

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