1. Fuzzy Logic

1.1.Statement of the Problem

Write a computer program of hardness for sintered HSS Components using fuzzy set theory.

1.2.Background

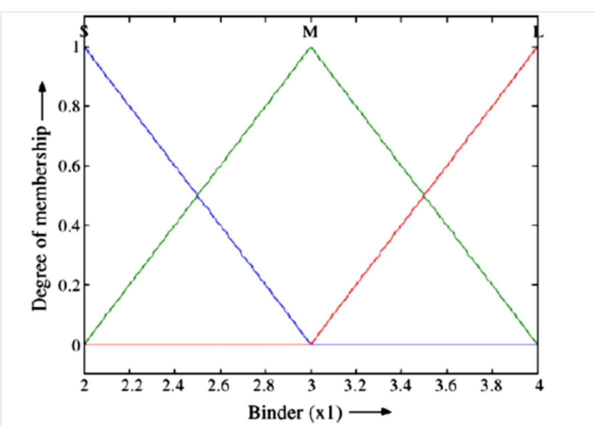
This experiment is based on work by Chatterjee *et. al* [2007]. Sintered HSS components have been produced using powder metallurgy (PM) process. Water-atomized and vacuum annealed powders of T15 HSS along with other ingredients like Zn-stearate (2%) and alumina (Al_2O_3) were used to produce the components. The percentage of alumina, sintering temperature and sintering time were considered as the controllable process parameters while the hardness of the sintered components was considered as the response variable.

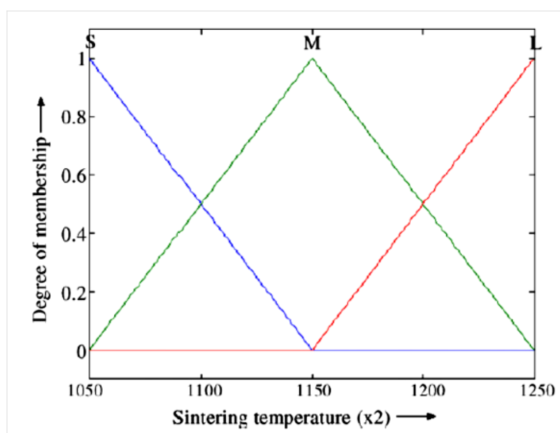
Prediction based on fuzzy set theory involves following stapes (Rajasekaran & Pai, 2013):

1. Fuzzification
2. Rule evaluation step
3. Defuzzification

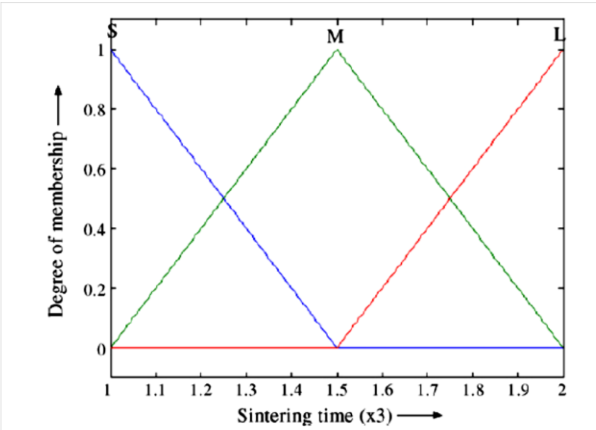
Fuzzification and Fuzzy Input steps

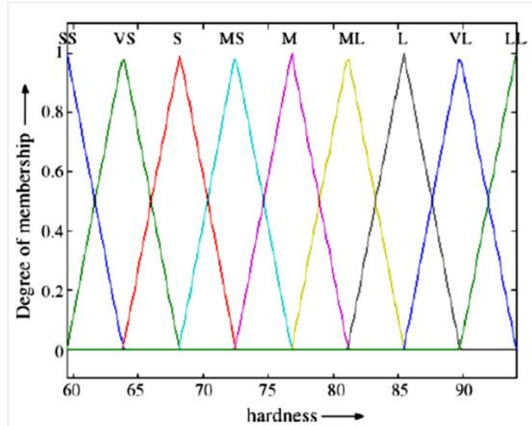
Membership functions for the input variables and output variable are given in figure 1.





(a) **(b)**





(c) **(d)**

Figure 1 Membership function for input variables: (a) binder (x1), (b) sintering Temperature (x2), (c) sintering time (x3) and (d) output variable hardness.

Rule evaluation and Fuzzy Output steps: Rules are given as follows:

Rule 1: If (x1 is S) and (x2 is S) and (x3 is S) then (hardness is M).

Rule 2: If (x1 is L) and (x2 is S) and (x3 is S) then (hardness is VS).

Rule 3: If (x1 is M) and (x2 is M) and (x3 is S) then (hardness is L).

Rule 4: If (x1 is S) and (x2 is L) and (x3 is S) then (hardness is L).

Rule 5: If (x1 is L) and (x2 is L) and (x3 is S) then (hardness is L).

Rule 6: If (x1 is M) and (x2 is S) and (x3 is M) then (hardness is SS).

Rule 7: If (x1 is S) and (x2 is M) and (x3 is M) then (hardness is LL).

Rule 8: If (x1 is M) and (x2 is M) and (x3 is M) then (hardness is VL).

Rule 9: If (x1 is L) and (x2 is M) and (x3 is M) then (hardness is ML).

Rule 10: If (x1 is M) and (x2 is L) and (x3 is M) then (hardness is LL).

Rule 11: If (x1 is S) and (x2 is S) and (x3 is L) then (hardness is ML).

Rule 12: If (x1 is L) and (x2 is S) and (x3 is L) then (hardness is S).

Rule 13: If (x1 is M) and (x2 is M) and (x3 is L) then (hardness is VL).

Rule 14: If (x1 is S) and (x2 is L) and (x3 is L) then (hardness is ML).

Rule 15: If (x1 is L) and (x2 is L) and (x3 is L) then (hardness is L).

Figure 2 shows all the fifteen rules along with the ranges of independent (x1, x2 and x3) and response (hardness) variables. The red vertical lines denote the values of independent variables for which the output of the response variable has been estimated. In this example, values of binder percentage (x1), sintering temperature (x2) and sintering time (x3) are 3.4%, 1200 ◦C and 1.85 h, respectively.

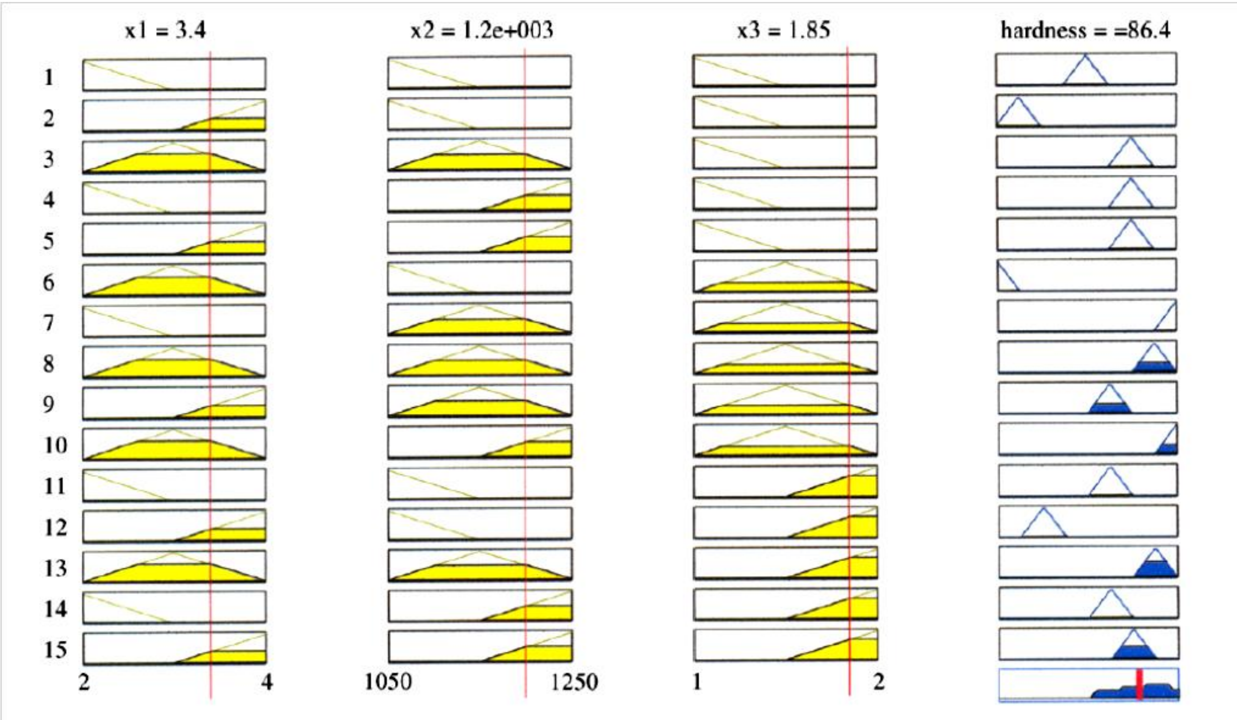


Figure 2 Fuzzy rule-based sample estimate of response

For a specific case i.e. rule number 8, details are given in figure 3.

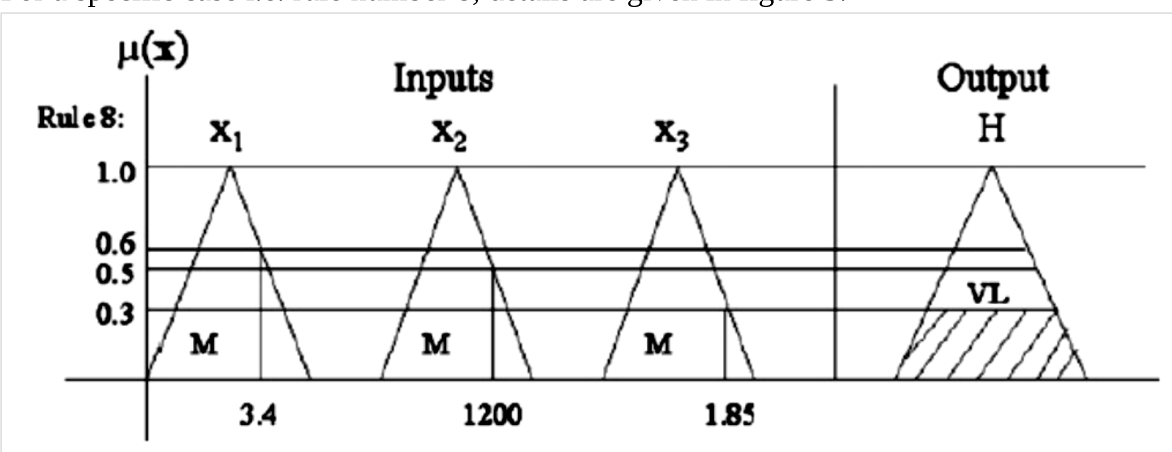


Figure 3 Output of rule 8 for input x = [3.4, 1200, 1.85].

Defuzzification and Crisp Output steps

Figure 4 shows the aggregation of all the fuzzy outputs due to simultaneous firings of rules 8, 9, 10, 13 and 15. The fuzzy output of each rule is aggregated and the centroid of the aggregated area is estimated using Eq. (1) that gives the crisp output of the response (hardness).

$$\hat{y}_i = \frac{\sum_{\mu \in B_i} y \cdot \tau_i(y)}{\sum_{\mu \in B_i} \tau_i(y)}, \tag{1}$$

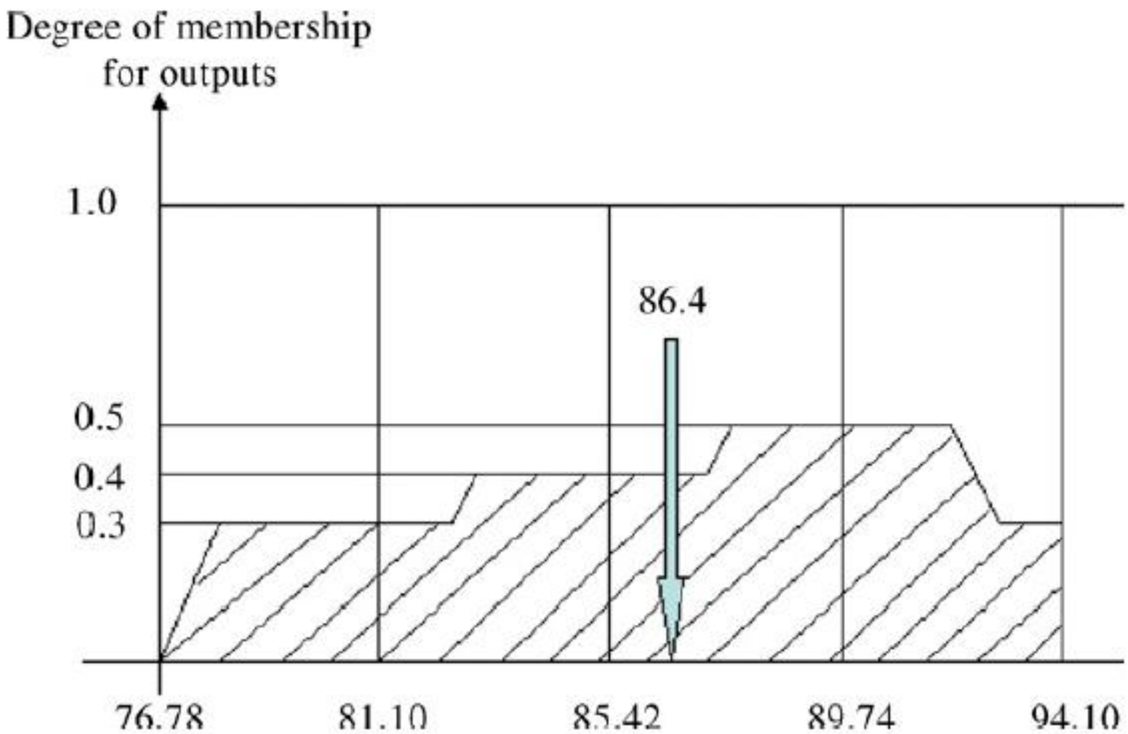


Figure 4 Fuzzy output for simultaneous firing of rules 8, 9, 10, 13 and 15 for input x = [3.4, 1200, 1.85].

References

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