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Optimization of Heat Treatment Process Parameter using Taguchi and Fuggy Logic Approach in Bearing Manufacturing Industry

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Abstract *- The objective of this paper is to optimize the process parameter of heat treatment of low carbon steel by using Taguchi approach and Fuggy Logic approach. In bearing industry, when shell of bearing is heat treated then shell has not optimum hardness due to unsuitable process parameter such as carburizing temperature, carbon potential, holding time and quenching time. So, our sole aim is to obtain optimizing condition of different parameter in order to get sufficient hardness of low carbon steel as per requirement. Taguchi and Fuggy logic approach both are optimizing software. In this paper, we also analyze the obtained process parameter by both techniques*.

Keyword: Taguchi, *Fuzzy, Carburizing, Carbon potential.*

1.INTRODUCTION:

Steels are iron-carbon alloys that may contain appreciable concentrations of other alloying elements; there are thousands of alloys that have different compositions and heat treatment. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0wt%. Some of the more common steels are classified according to carbon concentration-low-carbon, medium-carbon, and high-carbon types. There is also subclass of each exists within each group according to the concentration of other alloying elements. Plain carbon steels have only residual concentration of impurities other than carbon and a little amount of manganese. For alloy steel, more alloying elements are intentionally added in specific concentrations.

Low-Carbon steel:

Low carbon steel is produced in greatest quantities. These generally contains less than about 0.25 wt% C and are unresponsive to heat treatment intended to form martensite; strengthening is accomplished by cold work. microstructure consists of ferrite and pearlite constituents. So these alloys are relatively soft and weak but have outstanding ductility and toughness and also they are machineable, wieldable, and, of all steels, are the least expensive to produce.

Medium carbon steel:

The medium carbon steel have carbon concentrations between about 0.2 and 0.60wt%. These alloys may be heat treated by austenizing, quenching, and then tempering to improve their mechanical properties. The plain medium carbon steels have low hardenabilities and can be successfully heat treated only in very thin sections and very rapid quenching rates. This heat treated alloys are stronger than low carbon steels, but a sacrifice of ductility and toughness.

High Carbon steel:

The High carbon steel contains carbon between 0.60 and 1.4wt%. These are hardest , strongest and yet least ductile of carbon steels. It is especially wear resistant and capable of holding a sharp cutting edge. These steels are used as cutting tools and dies for forming and shaping material as well as in knives, razors, hacksaw blades, springs, and high strength wire.

Heat treatment :

The heat treatment in metal are carried out first by heating the metal and then cooling the caustic soda solution ,water ,oil and air. The heat treatment in material is to improve soften the metal, to change the grain size, to modify structure of material to relieve the internal stress set up in the material.

The various heat treatment process are

- Hardening
- Tempering
- Annealing
- Normalising
- Carburizing

Hardening:- The process of hardening consists of heating the metal to a temperature of 30^0c to 50^0c above the upper critical point for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steels. Metal is held at this particular temperature for a considerable time and then quenched(cooled slowly)in a suitable cooling medium. The main objective of hardening in the material are to increase the hardness of metal so that it can resist wear, to enable it to cut other metals.

Tempering:- The tempering process consists of reheating the hardened steel to some particular temperature below the lower critical temperature ,followed by any desired rate of cooling. The tempering in material is done for the following reasons.(a) To reduce brittleness of the hardened steel and this to increase ductility.(b) to remove internal stress caused by rapid cooling of steel(c) To make steel tough to resist shock and fatigue.

Annealing:- Annealing is the process of heating the steel 30^0c-50^0c above the upper critical temperature for hypo eutectoid steels and for hyper-eutectoid steels, by the same temperature above the lower critical temperature. It is held at this temperature for some time and then cooled slowly in the furnace. The annealing in materials are carried out for reduce hardness, improve mach inability, relieve internal stress, refine grain size.

Normalising.-The process of normalising consists of heating the steel 30^0c-50^0c above its upper critical temperature for hypo-eutectoid steels or Acme line for hyper-eutectoid steels. It is held at this temperature for about fifteen minutes and then allowed to cool down in still air. The main objective of normalising are to refine the grain structure of the steel, to improve machinability to remove strains cause by cold working processes.

Carburizing:-Carburization is also a heat treatment process in which steel or iron absorbs carbon when the metal is heated in the presence of a carbon -bearing material, such as charcoal or carbon monoxide. This causes harder will be metal. The affected area can vary in carbon content must depend on the amount of time and temperature,. The main purpose of carburizing is done in material for increased surface hardness, wear resistance, fatigue/tensile strengths and increased surface carbon content.

2.TAGUCHI METHOD:

In traditional experimental design procedures, a large number of experimental works have to be carried out when the number of process parameters increases. This problem is solved by the Taguchi method, which uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is the saving of effort in conducting experiments, saving experimental time, reducing the cost and discovering significant factors quickly. Taguchi's robust design method is a powerful tool for the design of a high-quality system. In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value(standard deviation, SD) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to the SD. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available, depending on the type of characteristic; lower the better (LB), nominal the best (NB) or higher the better (HB).

The S/N ratio for the higher-the-better criterion is given by Taguchi

$$\frac{\mathrm{S}}{\mathrm{N}} = -10 \log_{10}\left[\frac{1}{n}\sum\frac{1}{y^2}\right]$$

where 'y' is the observed data and 'n' is the number of observations.

The S/N ratio for the lower-the-better criterion is given by Taguchi as:

$$\frac{\mathrm{S}}{\mathrm{N}} = -10\log_{10}\left[\frac{\sum y^2}{n}\right]$$

where 'y' is the observed data and 'n' is the number of observations.

3.FUZZY EXPERT SYSTEM:

A fuzzy rule based system consist of four parts:

- Knowledge base
- Fuzzifier
- Inference engine
- Defuzzifier

A block diagram representing these four function is given in this continuation

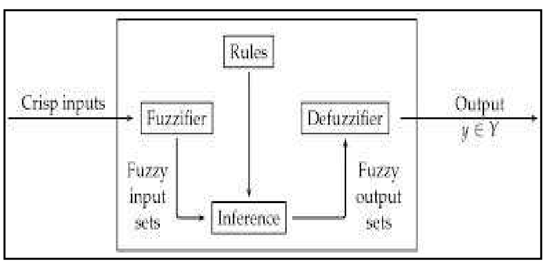

Fig-1: A block diagram of fuzzy Logic System Fuzzifier

The real world input to the fuzzy system is applied to the fuzzier. In fuzzy literature, this input is called crisp input since it contains precise information about the specific information about the parameter. The fuzzifier convert this precise quantity in the form of imprecise quantity like large medium high etc. with a degree of belongingness to it. Typically the value range from 0 to 1

- Knowledge base:

The main part of the fuzzy system is the knowledge base in which both rule base and database are jointly referred. The database defines the membership functions of the fuzzy sets used in the fuzzy rules whereas rule base contains a number of fuzzy IF then rule.

- Inference engine:

The inference system or the decision making input performs the inference operation on the rules. It handles the way in which the rule are combined.

- Defuzzifier:

The output generated by the inference block is always fuzzy in nature. Areal world system will always require the output of the fuzzy system to the crisp or in the form of real world input. The job of the defuzzifier is to receive the fuzzy input and provide real world output. In operation, it works opposite to the input block. In general, two most popular fuzzy inference system are available: Mamdani fuzzy model and sugeno fuzzy model. The selection depends on the fuzzy reasoning and formulation of fuzzy IF-THEN rules. Mamdani fuzzy model is based on the collection of IF-THEN rules with both fuzzy antecedent and consequent predicts. The benefit of this model is that the rule base is generally provided by an expert and hence to a certain degree it is translucent to explain and study. Because of easiness, Mamdani model is still most commonly used technique for solving many real world problem. The first step in system modeling was the identification of input and output variable called the system variables. In the selection procedure, the inputs and outputs are taken in form of linguistic format. A linguistic variable is a variable whose values are words or sentences in natural or man- made languages. Linguistic values are expressed in the form of fuzzy sets. A fuzzy set is usually defined by its membership functions. In general triangular or trapezoidal membership function are used to the crisp inputs because of their simplicity and high computational efficiency.

The triangular membership function as described the concept of fuzzy reasoning is described briefly based on the two input one output fuzzy logic unit. The fuzzy rule base consists of a group of IF THEN control rules with the two inputs, x1 and x2, and one output y, i.e.-

Rule 1: if X1 is A1 and X2 is B1 then y is C1
Rule 2: if X1 is A2 and X2 is B2 then y is C2
else________________
Rule n: if X1 is An and X2 is Bn then y is Cn.

Ai, Bi, and Ci are fuzzy subsets defined by the corresponding membership functions, i.e., mAi, mBi and mCi.

Finally, a defuzzification method, called the center-of gravity method, is adapted here to transform the fuzzy interface output μC0 into a non-fuzzy value yo, i.e.

$$y_0 = \frac{\sum y.\mu co(y)}{\sum \mu co(y)}$$

In this paper, the non-fuzzy value y0 is called an MRPI. Based on the above discussion, the larger is the MRPI, the better is the performance characteristic.

The shell bearing has following parts:
1. Cage

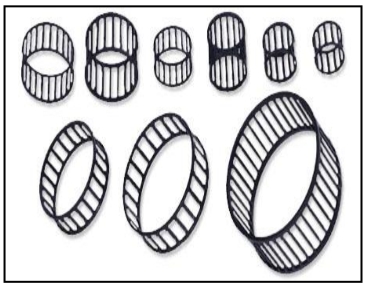

Fig-2: Cage

2. Shell

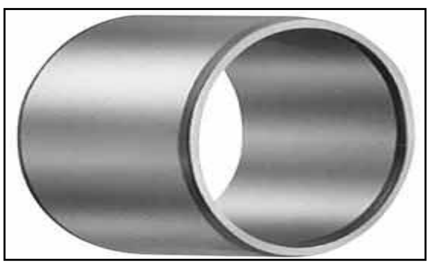

Fig-3 : Shell

3. Needle

Fig-4: Needle

4. Shell Bearing:

Fig-5: Final Product (Shell Bearing)

<u>Composition of low carbon steel which is used for producing shell of Bearings</u>:
carbon(C): 0.14 -0.20 %
Manganese(Mn): 0.60-0.90 %
Iron(Fe): 98.81-99.26 %
Phosphorous(P):0.03 %
Sulphur(S):0.025 %
Chromium(Cr): 1.3-1.6 %

4.OPTIMIZATION BY TAGUCHI APPROACH:

The process variables were noted as holding time, carbon potential, carburizing temperature and quenching time which affect the hardness and these were selected for the Taguchi design method. A L9 (3^4) orthogonal array design was implemented for experimentation the bearing sample chosen.
The objective is to obtain optimize hardness so that larger -the-better will be our criterion.

Nine observations were conducted by varying all these four parameters, the details of parameter are given below:

Table: 1: Process Parameter specifications:

S. No.	Parameters	Notations	Unit	Value with Range
1	Holding Time	HT	min	40-50
2	Carbon Potential	CP	m^3/kg	1.05-1.35
3	Carburizing Temperature	CT	^0C	860-900
4	Quenching Time	QT	min	4-6

The results of the L9 Orthogonal array of gas carburizing process parameters are given below:

Table 2: Taguchi method

S.N.	HT	CP	CT	QT	HVN	S/N Ratio
1	40	1.1	860	4	780	57.8419
2	40	1.2	875	5	810	58.1697
3	40	1.3	890	6	795	58.0073
4	45	1.1	875	6	845	58.5371
5	45	1.2	890	4	830	58.3816
6	45	1.3	860	5	865	58.7403
7	50	1.1	890	5	850	58.5884
8	50	1.2	860	6	895	59.0365
9	50	1.3	875	4	840	58.4856

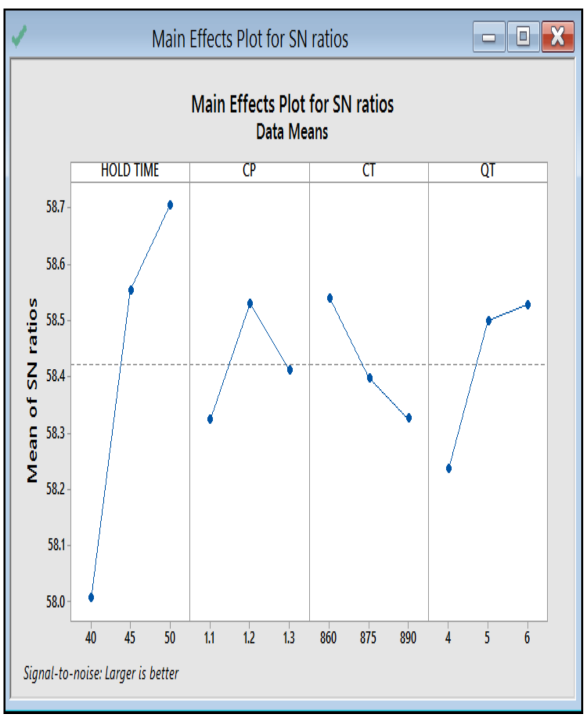

Fig-6: Main effects plot for S/N ratio.

The objective is to obtain optimize hardness so that larger -the-better. So that the optimize process parameters are

Holding Time(HT)= 50 min.
Carbon Potential(CP)=1.2 m^3/kg
Carburizing Temperature(CT)=860 ^0C
Quenching Time(QT)=6 min.

5.OPTIMIZATION BY FUZZY LOGIC APPROACH:

Table 3: Fuzzy Rule Table:

S/N Ratio of HVN	Multi performance character Index(MPCI)
Low	Low
Nominal	Nominal
High	High

Table 4: fuzzy Logic Table:

S/N Ratio of HVN	Multi performance character Index(MPCI)
57.8419	0.461
58.1697	0.5
58.0073	0.5
58.5371	0.5
58.3816	0.5
58.7403	0.524
58.5884	0.527
59.0365	**0.575**
58.4856	0.5

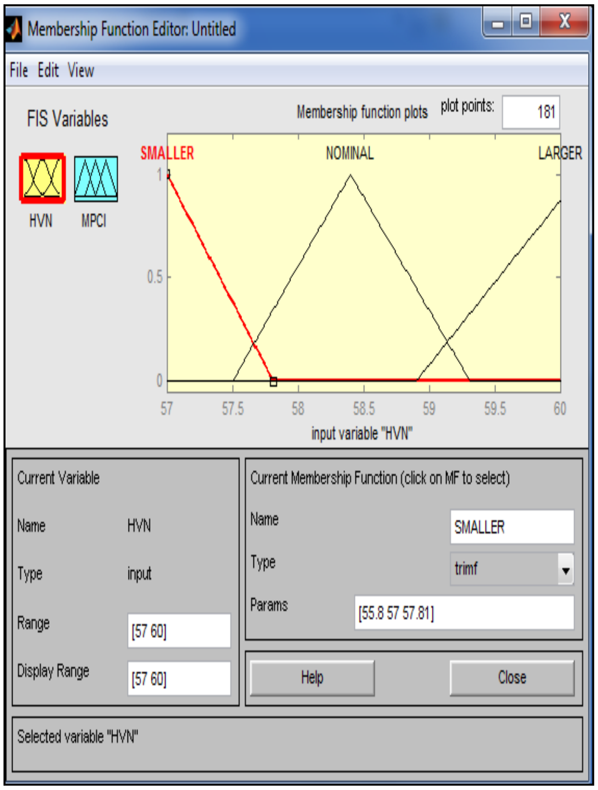

Fig-7: Membership Function of HVN.

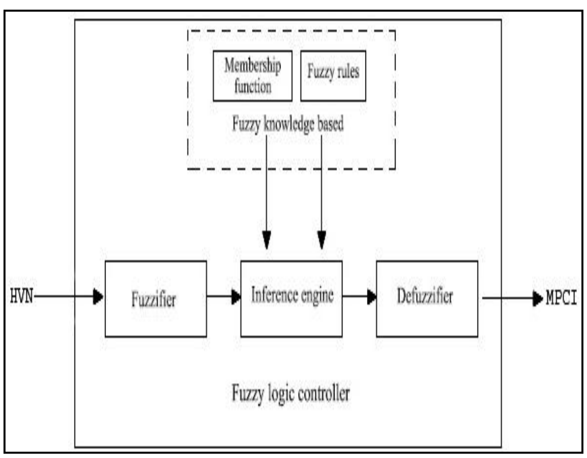

Fig-8: Fuzzy Logic controller

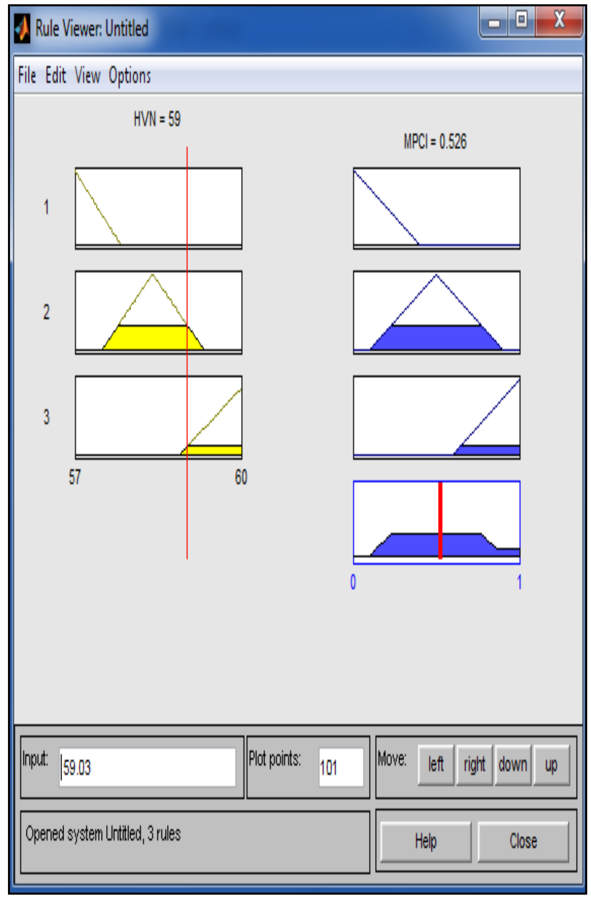

Fig-9: Multi performance character Index.

The higher value of MPCI is 0.527 corresponding to S/N ratio of HVN is 59.0365. So that
The optimize process parameters are
Holding Time(HT)= 50 min.
Carbon Potential(CP)=1.2 m^3/kg
Carburizing Temperature(CT)=860 ^{0}C
Quenching Time(QT)=6 min.

6. CONCLUSION:

By applying two method of optimization and these are Taguchi approach and Fuzzy logic approach and we observe that for obtaining optimize value of hardness, the process parameter in optimized condition will be

Holding Time(HT)= 50 min.
Carbon Potential(CP)=1.2 m^3/kg
Carburizing Temperature(CT)=860 ^{0}C
Quenching Time(QT)=6 min.

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8. BIOGRAPHIES:

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