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FUZZY RELIABILITY EVALUATION OF WEAVING MACHINE IN TEXTILE INDUSTRY

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ABSTRACT

Reliability has vital significance to engineers and designers in Industry. Reliability is a measure of the probability that an item will perform smoothly. In this paper application of fault tree in the industrial systems using trapezoidal intuitionistic fuzzy numbers is presented. The failure rate of weaving machine and the reliability of the system are discussed. Also the concept of trapezoidal intuitionistic fuzzy fault tree analysis is used to find the numerical values.

Keywords: *Fuzzy numbers, Trapezoidal Intuitionistic Fuzzy Number, Fuzzy failure, Fuzzy fault tree, Industrial revolution, Weaving mechanism.*

1. INTRODUCTION

Reliability analysis is based on the probabilities and uncertainity detection of failure data to modify the stability. The concept of fuzzy number approach has been used in the reliability evaluation by L. A Zadeh [26]. Intuitionistic fuzzy sets are being studied and used in different fields of science. Among the research works on these sets we can mention Atanassov [1-4], Atanassov and Gargov [5], Ban [6], Buhaesku [7, 8], Deschrijver and Kerre [13], D. Stoyanova [22], Szmidt and Kacprzyk [23], Burillo etal [9]. They proposed definition of Intuitionistic Fuzzy Number (IFN) and studied perturbations of IFN, their properties and the correlation between these numbers. Mitchell [18] considered the problem of ranking a set of intuitionistic fuzzy numbers to define a fuzzy rank and a characteristic vagueness factor for each intuitionistic fuzzy number. Arithmetic operations of IFN are also evaluated.

Fault tree analysis is the commonly used failure analysis technique in all major fields of reliability in engineering [25]. In conventional method reliability of the system is characterized in perspective of probability procedures. But it becomes unfeasible to assess precise probabilities due to presence of inaccuracy and uncertainity in data and information [20]. Singer [21] discussed a fuzzy set approach to fault tree and reliability analysis. Chen [11] presented a method for analyzing the fuzzy system reliability using fuzzy number arithmetic operations. Cheng and D.L Mon [12] used interval of confidence for analyzing the fuzzy system reliability. Verma [24] considered the dynamic reliability evaluation of the deteriorating system using the concept of probist reliability as a triangular intuitionistic fuzzy number. Reliability of a system using trapezoidal intuitionistic fuzzy number is explained by G.S Mahapatra and B.S Mahapatra [15]. Also G.S. Mahapatra and T.K Roy [16] presented that the reliability evaluation using triangular intuitionistic fuzzy number. Ranking method of trapezoidal intuitionistic fuzzy numbers was presented by S. Rezvani[19]. Application of Intuitionistic Fuzzy Equations on Reliability Evaluation was done by G. M. Rosario [14].

The present study deals with the fault tree analysis in the industrial wing and explain the reliability analysis of Weaving Machine in the textile wing using Trapezoidal Intuitionistic Fuzzy Number (TrIFN).

2. WEAVING MECHANISM

The industrial revolution changed the nature of work. The commencement of the industrial revolution is closely linked in fact to a small number of innovations made in the second half of the 18th century. Many innovations introduced in

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the Textile Industry. Similar technology was subsequently applied to spinning worsted yarn for various textiles and flax for linen. Textile Industry has become highly dependent on very complex distributed system for yarn production and as well as for cloth production. Expansion of man-made systems and industrial automation is an outcome of interaction between market-pull and technology-push. Industrial automation has a long historical revolutionary expedition starting with the advent of machines driven by windmills in the Dutch Zaanstreek in the 17th century. Greater automation in the spinning and pattern weaving Industry via production streets popularized by Ford in the early 20th century to semi-automatically managed energy production and distribution systems [25]. A loom is a device used to weave cloth. The basic purpose of any loom is to hold the wrap threads under uniform tension to facilitate the interweaving of the weft threads. In weaving, the wrap is the set of lengthwise yarns through which the weft is woven. There are different types of weaving machines. There are many factors affecting the smooth functioning of the weaving machines. In this paper we use Fault Tree Analysis to find the failure rate and reliability of the system.

3. SOME BASIC DEFINITIONS

Definition 1-Intuitionistic fuzzy set

Let X be a set, an intuitionistic fuzzy set (IFS)$\breve{A}$in X is of the form $\breve{A} = \{< x, \mu_{\breve{A}}(x), v_{\breve{A}}(x) >: x \in X\}$, where $\mu_{\breve{A}}(x): X \to [0,1]$ and $V_{\breve{A}}(x): X \to [0,1]$ define the degree of membership function and degree of non-membership function respectively, of the element $x \in X$ to the set $\breve{A}$, which is a subset of X.

For every element of $x \in X, 0 \le \mu_{\breve{A}}(x) + v_{\breve{A}}(x) \le 1$.

Definition 2-(α, β) – cut

A set of (α, β) – cut, generated by an intuitionistic fuzzy set $\breve{A}$, where $(\alpha, \beta) \in [0,1]$ are fixed numbers such that $\alpha + \beta \le 1$ is defined as $\breve{A}_{\alpha,\beta} = \{(x, \mu_{\breve{A}}(x), V_{\breve{A}}(x)): x \in X, \mu_{\breve{A}}(x) \ge \alpha, V_{\breve{A}}(x) \le \beta, \alpha, \beta \in [0,1]\}$.$\breve{A}_{\alpha,\beta}$ is defined as the crisp set of elements x which belongs to $\breve{A}$ atleast to the degree α and which does not belong to $\breve{A}$ atmost to the degree β.

Definition 3-Intuitionistic Fuzzy Number

An Intuitionistic Fuzzy number$\breve{A}$ is

1) An intuitionistic fuzzy sub set of the real line
2) Normal ie, there is any $x_0 \in R$ such that $\mu_{\breve{A}}(x_0) = 1$ $[so\ V_{\breve{A}}(x_0) = 0]$
3) Convex for the membership function $\mu_{\breve{A}}(x)$
   ie, $\mu_{\breve{A}}(\lambda x_1 + (1-\lambda)x_2) \ge \min(\mu_{\breve{A}}(x_1), \mu_{\breve{A}}(x_2))\ x_1, x_2 \in R, \lambda \in [0,1]$
4) Concave for non-membership function $V_{\breve{A}}(x)$
   ie, $V_{\breve{A}}(\lambda x_1 + (1-\lambda)x_2) \le \max(V_{\breve{A}}(x_1), V_{\breve{A}}(x_2))\ x_1, x_2 \in R, \lambda \in [0,1$

Definition 4-Trapezoidal Intuitionistic Fuzzy Number (TrIFN)

A Trapezoidal intuitionistic fuzzy number $\breve{A}$ is an intuitionistic fuzzy number in R with membership function and non-membership function as follows

$$\mu_{\breve{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} & for\ a_1 \le x \le a_2 \\ 1 & for a_2 \le x \le a_3 \\ \frac{a_4-x}{a_4-a_3} & for a_3 \le x \le a_4 \\ 0 & otherwise \end{cases} \quad \text{and} \quad V_{\breve{A}}(x) = \begin{cases} \frac{a_2-x}{a_2-a_1'} & for\ a_1' \le x \le a_2 \\ 0 & for a_2 \le x \le a_3 \\ \frac{x-a_3}{a_4'-a_3} & for a_3 \le x \le a_4' \\ 1 & otherwise \end{cases}$$

where $a_1' \le a_1 \le a_2 \le a_3 \le a_4 \le a_4'$ and trapezoidal intuitionistic fuzzy number is denoted by

$\breve{A}_{TrIFN} = (a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4')$

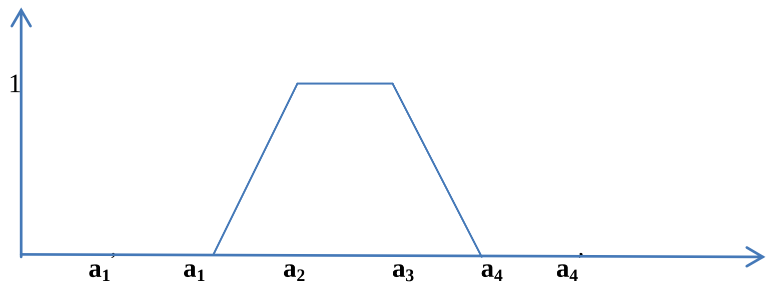

Figure-1: Membership function of TrIFN

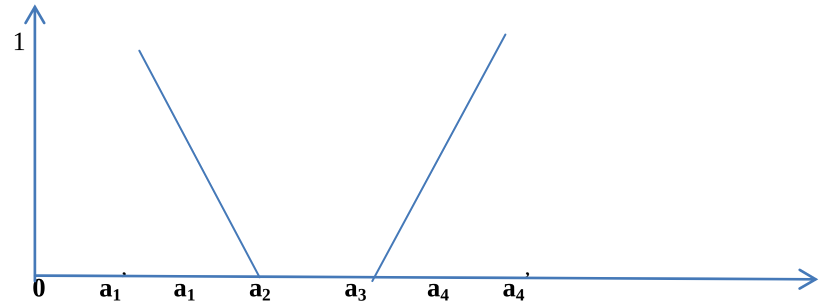

Figure-2: Non-membership function of TrIFN

Arithmetic operations on trapezoidal intuitionistic fuzzy number:

Let $\breve{A} = (a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4')$ and $\breve{B} = (b_1, b_2, b_3, b_4; b_1', b_2, b_3, b_4')$ be two trapezoidal intuitionistic fuzzy numbers.

1) Addition: $\breve{A} \oplus \breve{B} = (a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4') + (b_1, b_2, b_3, b_4; b_1', b_2, b_3, b_4')$
$= (a_1 + b_1,\ a_2 + b_2,\ a_3 + b_3,\ a_4 + b_4;\ a_1' + b_1',\ a_2 + b_2,\ a_3 + b_3, a_4' + b_4')$
2) Multitiplication: $\breve{A} \otimes \breve{B} = (a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4') \times (b_1, b_2, b_3, b_4; b_1', b_2, b_3, b_4')$
$= (a_1 b_1,\ a_2 b_2,\ a_3 b_3,\ a_4 b_4;\ a_1' b_1',\ a_2 b_2,\ a_3 b_3,\ a_4' b_4')$
3) $k\breve{A} = k(a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4')$
$= (ka_1, ka_2, ka_3, ka_4; ka_1', ka_2, ka_3, ka_4')$

Here, k is any positive real n umber.

Also $1 - \breve{A} = 1 - (a_1, a_2, a_3, a_4; a_1', a_2, a_3, a_4')$
$= (1 - a_1, 1 - a_2, 1 - a_3, 1 - a_4; 1 - a_1', 1 - a_2, 1 - a_3, 1 - a_4')$

4. IMPRECISE RELIABILITY OF SERIES AND PARALLEL SYSTEM USING TRAPEZOIDAL INTUITIONISTIC FUZZY NUMBER

4.1 Series System

Cosider a series system consisting of n-components. The intuitionistic fuzzy reliability $\breve{R_S}$ of the series system shown below can be evaluated by using the expression as follows

$$\breve{R_S} = \breve{R}_1 \otimes \breve{R}_2 \otimes \breve{R}_3 \otimes \ldots\ldots\ldots\ldots \otimes \breve{R}_n$$

Consider $\breve{R}_1, \breve{R}_2, \breve{R}_3 \ldots\ldots\ldots \breve{R}_n$ are trapezoidal intuitionistic fuzzy number then, $\breve{R_S}$ is also a trapezoidal intuitionistic fuzzy number by arithmetic operations.

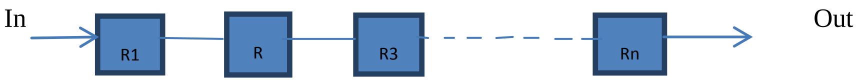

Figure-3

4.2 Parallel System

Consider a parallel system consisting of n-components. The fuzzy reliability $\breve{R}_P$ of the parallel system can be calculated by using the expression as follows

$$\breve{R_P} = 1 \ominus \left(\prod_{j=1}^{n} 1 \ominus \breve{R_j}\right)$$

$\breve{R_P} = 1 \ominus [(1 \ominus \breve{R}_1) \otimes (1 \ominus \breve{R}_2) \ldots\ldots\ldots \otimes (1 \ominus \breve{R}_n)]$. Here $\breve{R_P}$ is also a trapezoidal intuitionistic fuzzy number.

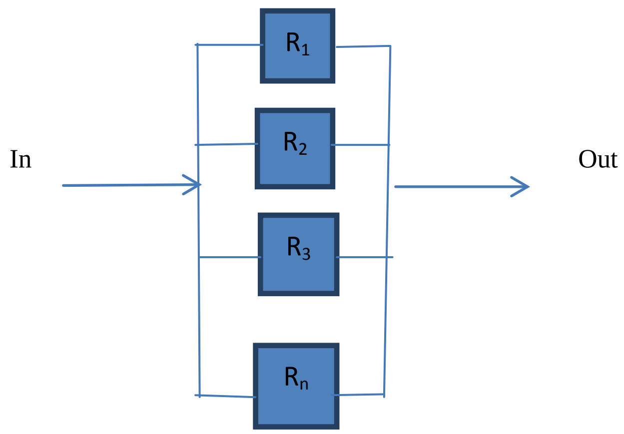

Figure-4

5. FUZZY FAULT TREE ANALYSIS

Fuzzy Fault Tree is a very effective tool to predict probability of hazards, resulting from sequences and combinations of faults and failure events. It is a logical and graphical description of various combinations of failure events. To depict a fault tree, first we determine the hazards and then look for the events causing this hazard. Causes of failure of weaving machine are shown in the following fuzzy fault tree.

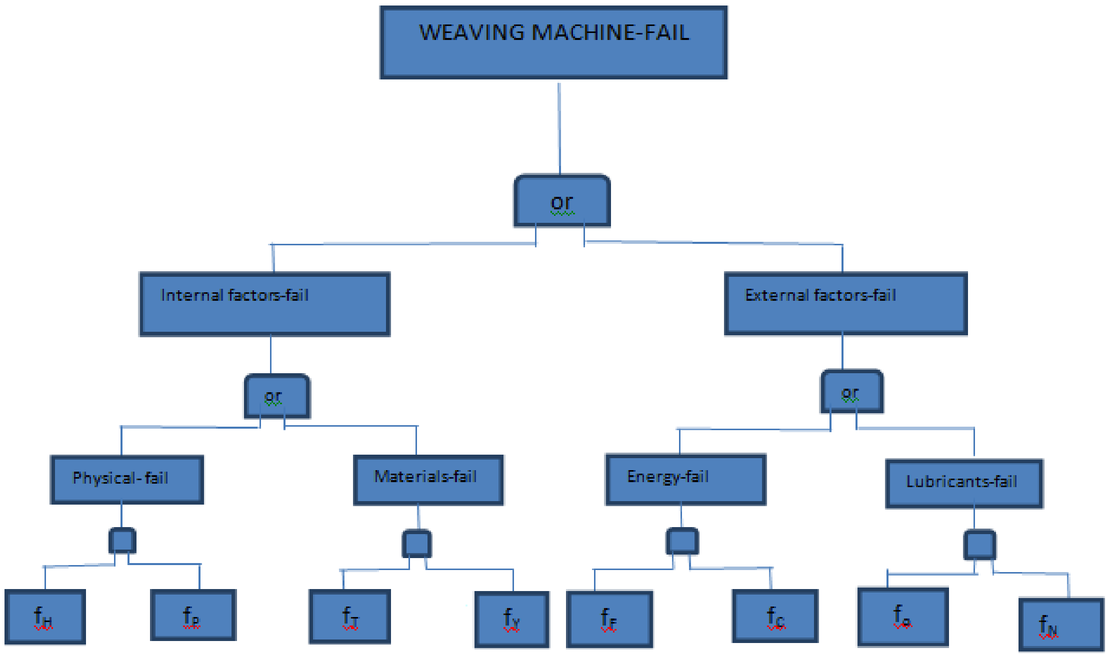

Figure-5 Fault tree of failure of weaving machine

Here,

$\widetilde{f}_{WM}$ failure of weaving machine
$\widetilde{f}_{IF}$ failure of internal factors
$\widetilde{f}_{EF}$ failure of external factors
$\widetilde{f}_{PS}$ failure of physical stabilities
$\widetilde{f}_{RM}$ failure of row materials
$\widetilde{f}_{WE}$ failure of working energy
$\widetilde{f}_{FO}$ failure of flow of lubricants oil
$\widetilde{f}_{N}$ failure due to nozzles blocked

$\breve{f}_H$ failure of controlled humidity
$\breve{f}_P$ failure of balanced pressure
$\breve{f}_T$ failure of quality of the thread
$\breve{f}_Y$ failure of continuous filament yarn
$\breve{f}_F$ failure of availability of the fuel
$\breve{f}_C$ failure of the balanced current flow
$\breve{f}_O$ failure of shortage of lubricants oil

The intuitionistic fuzzy failure of **weaving machine** can be calculated when the failures of the occurrence of basic fault events are known. Failure of **weaving machine** $\widetilde{f}_{WM}$ and reliability of the system can be evaluated by using the following steps:

STEP-1:

$\widetilde{f_{PS}} = 1 \ominus (1 \ominus \widetilde{f_H})(1 - \widetilde{f_P})$
$\widetilde{f_{RM}} = 1 \ominus (1 \ominus \widetilde{f_T})(1 - \widetilde{f_Y})$
$\widetilde{f_{WE}} = 1 \ominus (1 \ominus \widetilde{f_F})(1 - \widetilde{f_C})$
$\widetilde{f_{FO}} = 1 \ominus (1 \ominus \widetilde{f_O})(1 - \widetilde{f_N})$

STEP-2:

$\widetilde{f_{IF}} = 1 \ominus (1 \ominus \widetilde{f_{PS}})(1 - \widetilde{f_{RM}})$
$\widetilde{f_{EF}} = 1 \ominus (1 \ominus \widetilde{f_{WE}})(1 - \widetilde{f_{FO}})$

STEP-3:

$\widetilde{f_{WM}} = 1 \ominus (1 \ominus \widetilde{f_{IF}})(1 - \widetilde{f_{EF}})$

Here, $\widetilde{f_{WM}}$ is evaluated using the above steps. Let the failure rates be represented as Trapezoidal intuitionistic fuzzy numbers.

STEP-4:

The probability of the sum of the failure rate and the success rate is always 1.

So the probability of success rate of the machine = 1-P(failure).

Probability of the success of the working of the machine is the reliability of the system.

Therefore,
Reliability of the system= $1 - \widetilde{f_{WM}}$

6. NUMERICAL ANALYSIS OF FAILURE OF WEAVING MACHINE USING TRAPEZOIDAL INTUITIONISTIC FUZZY NUMBER

Let us consider the following values which represent the failure rates of components as trapezoidal intuitionistic fuzzy number.

$\widetilde{f_H} = (0.2,0.25,0.3,0.4\,;0.1,0.25,0.3,0.5)$
$\widetilde{f_P} = (0.1,0.2,0.3,0.4\,;0.08,0.2,0.3,0.5)$
$\widetilde{f_T} = (0.3,0.4,0.5,0.6\,;0.2,0.4,0.5,0.7)$
$\widetilde{f_Y} = (0.2,0.4,0.6,0.7\,;0.1,0.4,0.6,0.75)$
$\widetilde{f_F} = (0.3,0.45,0.5,0.7\,;0.2,0.45,0.5,0.8)$
$\widetilde{f_C} = (0.4,0.5,0.6,0.7\,;0.3,0.5,0.6,0.8)$
$\widetilde{f_O} = (0.5,0.6,0.7,0.8\,;0.4,0.6,0.7,0.9)$
$\widetilde{f_N} = (0.5,0.7,0.75,0.8\,;0.3,0.7,0.75,0.9)$

Using the Arithmetic operations on Trapezoidal Intuitionistic Fuzzy Number the following results are obtained:

Step-1:

$\widetilde{f_{PS}} = (0.28,0.4,0.51,0.64\,;0.172,0.4,0.51,0.75)$
$\widetilde{f_{RM}} = (0.44,0.64,0.8,0.88\,;0.28,0.64,0.8,0.25)$
$\widetilde{f_{WE}} = (0.58,0.725,0.8,0.91\,;0.44,0.725,0.8,0.96)$
$\widetilde{f_{FO}} = (0.75,0.88,0.925,0.96\,;0.58,0.88,0.925,0.99)$

Step-2:

$\widetilde{f_{IF}} = (0.5968,0.784,0.902,0.9568\,;0.40384,0.784,0.902,0.4375)$
$\widetilde{f_{EF}} = (0.895,0.967,0.985,0.9964\,;0.7648,0.967,0.985,0.9996)$

Step-3: Failure rate of weaving machine which is also a TrIFN is given by

$\widetilde{f_{WM}} = (0.993952,0.992872,0.99853,0.99984448\,;0.859783,0.992872,0.99853,0.999775)$

Step-4: Therefore
Reliability of the system= $1 - \widetilde{f_{WM}}$
Also it can be concluded that the failure of weaving machine in the industrial sector is about an interval [0.992872,0.99853] with tolerance level of acceptance [0.993952,0.99984448] and tolerance level of rejection [0.859783,0.999775]

7. CONCLUSION

In this paper, the arithmetic operations of trapezoidal intuitionistic fuzzy number based on the (α, β)-cut method is used. We have discussed the failure rate and reliability of weaving machine. Intuitionistic fuzzy fault tree is efficient and simple to implement for computing the failure of the system of all fields of engineering and sciences and also to compute the reliability of the system.

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