Prediction of Reliability Parameters and Reliability of Electric Discharge Machining by Probability Plotting

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ABSTRACT:

In electric discharge machining (EDM), predicting the reliability of electrode and tool is most important to arrive with the optimum process parameters. In this paper, the material removal rate, tool wear ratio and electrode wear rate of EDM process are plotted with weibull distribution. The shape and scale parameters of these plots are used to forecast the reliability of tool and electrode. The method of probability plotting is used for calculating the parameters of the weibull distribution. With the value of β and η, the reliability of tool and electrode is predicted at different time period. This process requires very less time, easy calculations and minimum data of MRR, TWR & EWR to find the reliability of EDM parameters. Since weibull is generalized form of distributions, it can also be applicable to find the reliability at any other kind of failure rates.

Keywords: - Weibull distribution, MRR, EDM, Reliability, probability plotting

INTRODUCTION:

With the increasing demand for new, hard, high strength, hardness, toughness, and temperature resistant material in engineering, the development and application of EDM has become increasingly important.[1] EDM has been used effectively in machining hard, high strength, and temperature resistance materials [2]. Material is removed by means of rapid and repetitive spark discharges across the gap between electrode and work piece. Since the EDM process does not involve mechanical energy, the removal rate is not affected by hardness, strength or toughness of the work piece material [3].Therefore, a comprehensive study of the effects of EDM parameters (peak current, machining voltage, pulse duration and interval time) on the machining characteristics such as electrode wear rate, material removal rate, surface roughness and etc., is of great significance and could be of necessity. The weibull distribution method which is a powerful tool for parametric design of performance characteristics is used to determine the optimal machining parameters for minimum electrode wear ratio, maximum material removal rate and minimum surface roughness in the EDM operations. [4]

The weibull distribution is a general-purpose reliability distribution used to model material strength, failure data of electronic and mechanical components, equipment or systems. Weibull distribution is a versatile distribution that can take on the characteristics of other types of distributions, based on the value of the shape parameter, *β* &scale parameter *η. [5]*

Probability plotting was originally a method of graphically estimating distribution parameter values. With the use of available failure data parametric values are calculated, the probability plot now serves as a graphical method of assessing the goodness of fit of the data to a chosen distribution. Probability plots have nonlinear scales that will essentially linearize the distribution function, and allow for assessment of whether the data set is a good fit for that particular distribution based on how close the data points come to following the straight line. The y-axis usually shows the unreliability or probability of failure, while the x-axis shows the time or ages of the units. Specific characteristics of the probability plot will change based on the type of distribution.

PROBABILITY PARAMETERS:

Distributions can have any number of parameters. The amount of data required for a proper fit increases with the number of parameters. In general, most distributions used for reliability and life data analysis, the lifetime distributions, usually are limited to a maximum of three parameters. These three parameters are usually known as the scale parameter (η), the shape parameter (β) and the location parameter (γ). Here, in this case, two parameters Weibull distribution is used, parameters being the scale & the shape.

1. Scale Parameter (η):

The scale parameter is the most common type of parameter. All distributions in this reference have a scale parameter. In the case of one-parameter distributions, the sole parameter is the scale parameter. The scale parameter defines where the bulk of the distribution lies, or how stretched out the distribution is. In the case of the normal distribution, the scale parameter is the standard deviation.

2. Shape Parameter (β):

The shape parameter, as the name implies, helps define the shape of a distribution. Some distributions, such as the exponential or normal, do not have a shape parameter since they have a predefined shape that does not change. In the case of the normal distribution, the shape is always the familiar bell shape. The effect of the shape parameter on a distribution is reflected in the shapes of the Probability Distribution Function (PDF), the reliability function and the failure rate function.

PROBABILITY PLOTTING:

The values of unreliability plotted on y-axis are calculated using Bernard median rank estimator formula which is given by

$$(\ \ ) = \frac{i - 0.3}{n + 0.4}$$

where *i* is the failure order number and *N* is the total sample size.

The values of MRR, TWR & EWR are plotted on x-axis which is given as failure data.

Because Weibull distribution is used, it's cumulative density function (cdf) is considered. The cdf for Weibull distribution is given by

$$F(T) = 1 - e^{-(\ )}$$

So at T= η

$$F(T) = 1 - e^{-\left(\frac{\eta}{\eta}\right)^{\beta}}$$

$$= 1 - e^{(-1)^{\beta}}$$

$$= 0.632$$

$$= 63.2\%$$

The value of T= η for the corresponding unreliability value of 63.2%

I. EFFECT OF MATERIAL REMOVAL RATE ON RELIABILITY:

The failure data collected is

(i)	1	2	3	4	5	6	7	8	9	10	11
MRR (mg/min)	8.312	16.302	23.672	28.036	32.549	35.678	38.321	43.256	45.213	47.564	52.369

The Graph plots obtained for MRR of EDM from Weibull++ V7

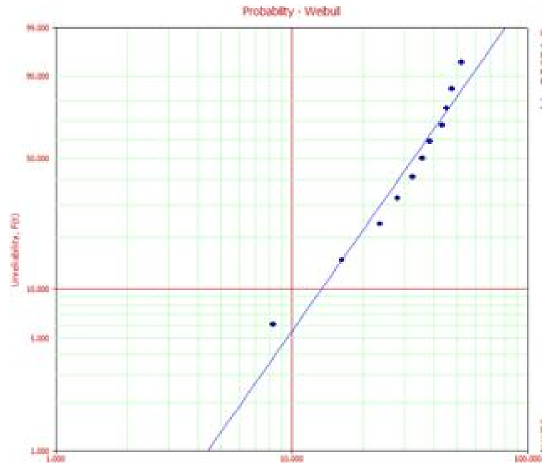

Fig 1-Unreliability vs MRR

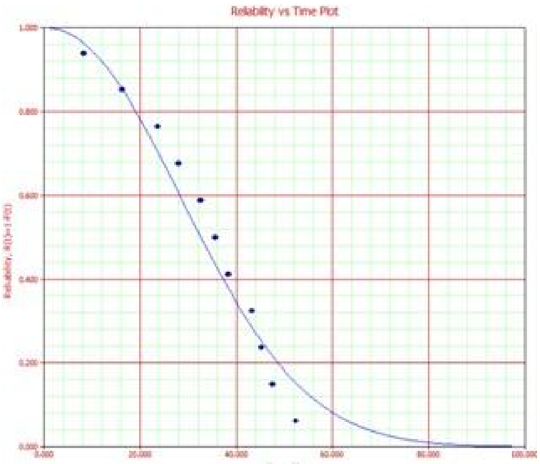

Fig 2- Reliabilty plot

Fig 3- Unreliability plot

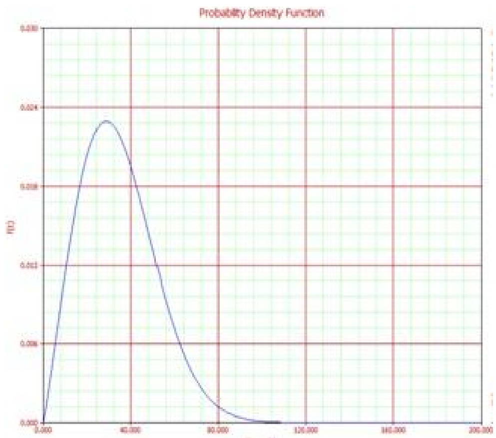

Fig 4 - pdf plot

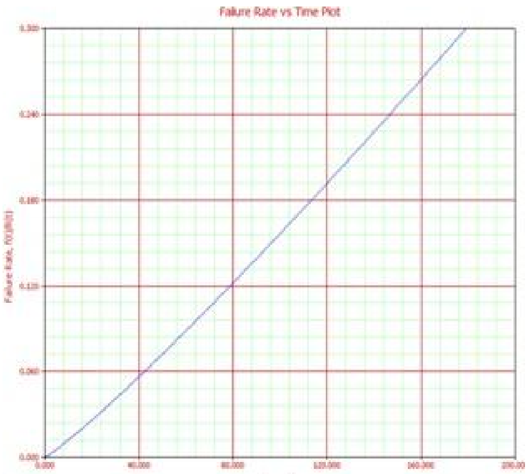

Fig 5- Failure plot

The Weibull parameters β & η are obtained from graph are 2.1160 & 38.8368 respectively. So the reliability of tool is calculated for t (i.e.at for any MRR)= 25 mg/min is given by

$$R(T) = e^{-\left(\frac{25}{38.8368}\right)^{2.1160}}$$

$$= 0.6745$$

$$= 67.45\%$$

II. EFFECT OF TOOLWEAR RATE ON RELIABILITY:

The failure data collected is

(i)	1	2	3	4	5	6	7	8	9	10	11
TWR (mg/min)	1.302	2.565	5.523	6.678	7.712	12.864	16.349	19.838	28.984	33.382	46.230

The Graph plots obtained for TWR of EDM from Weibull++ V7

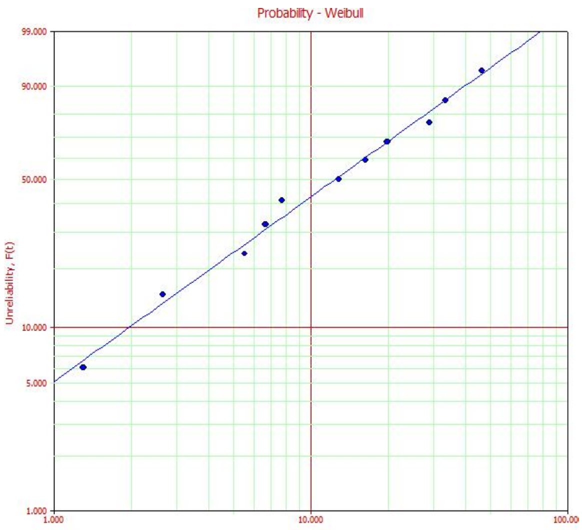

Fig 6-Unreliability vs TWR

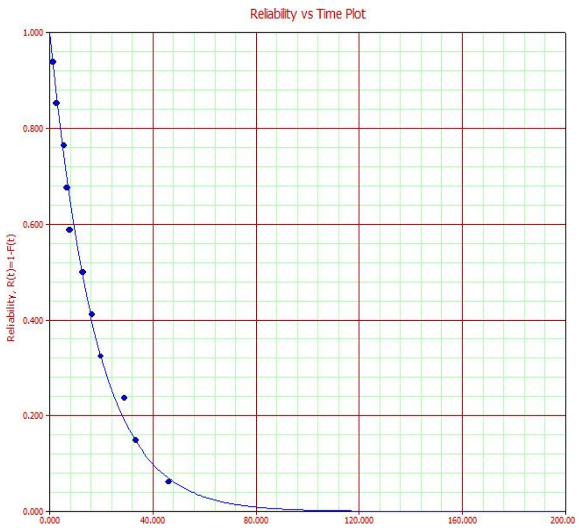

Fig 7- Reliabilty plot

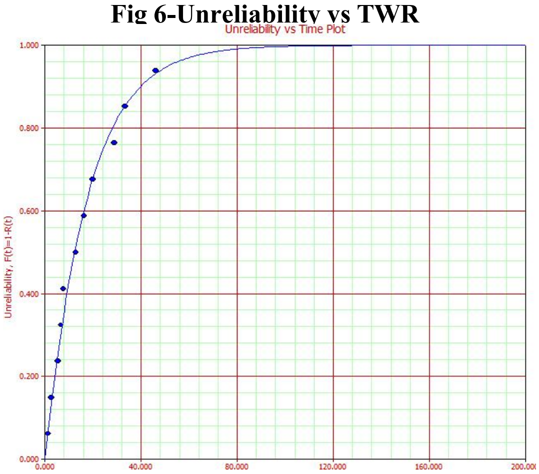

Fig 8- Unreliability plot

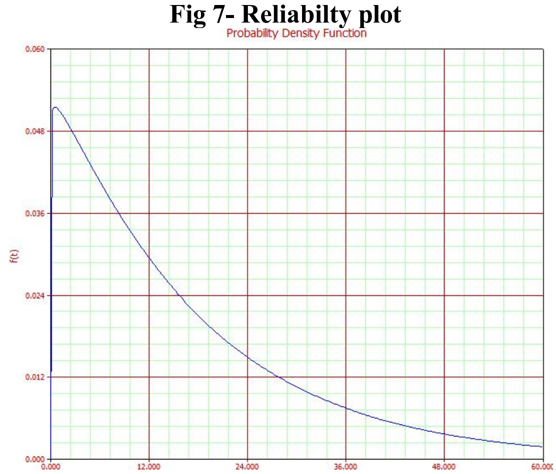

Fig 9 - pdf plot

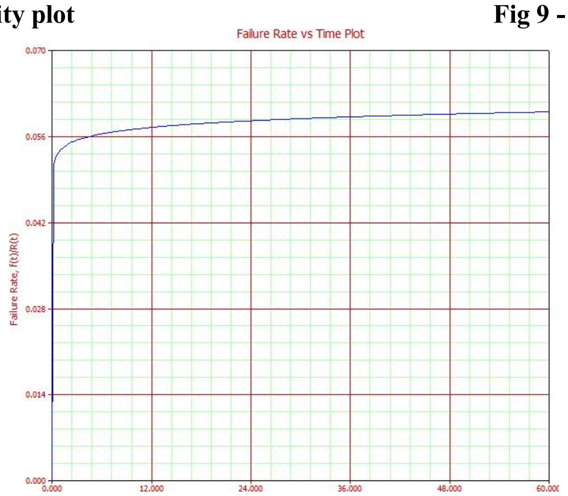

Fig 10- Failure plot

The Weibull parameters β & η are obtained from graph are 0.9755 & 18.9341 respectively, so the reliability of tool is calculated for t (i.e. for any TWR)= 25 mg/min is given by

$$R(T) = e^{-(\frac{\ }{\eta})}$$

$$(\ ) = {}^{-(\frac{25}{18.9341})^{0.97550}}$$

= 0.2695

= 26.95 %

III. EFFECT OF ELECTRODE WEAR RATIO ON RELIABILITY:

The failure data collected is

(i)	1	2	3	4	5	6	7	8	9	10	11
EWR (mg/min)	3.76	5.47	9.98	10.61	11.18	12.76	13.69	14.41	17.86	19.12	35.61

The Graph plots obtained for EWR of EDM from Weibull++ V7

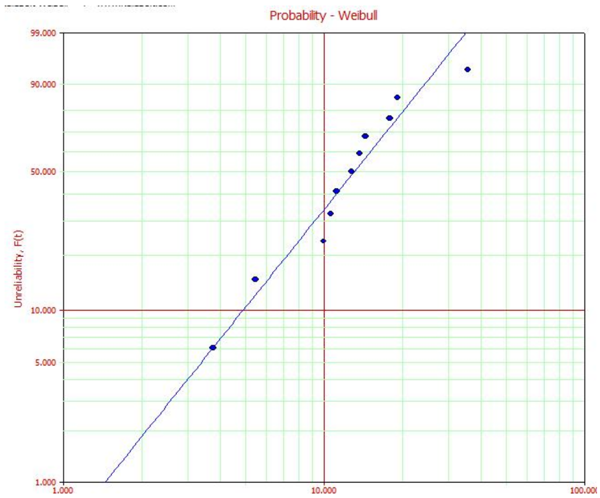

Fig 11-Unreliability vs EWR

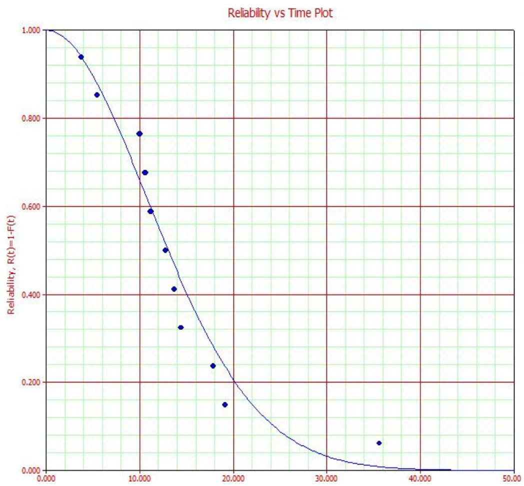

Fig 12- Reliabilty plot

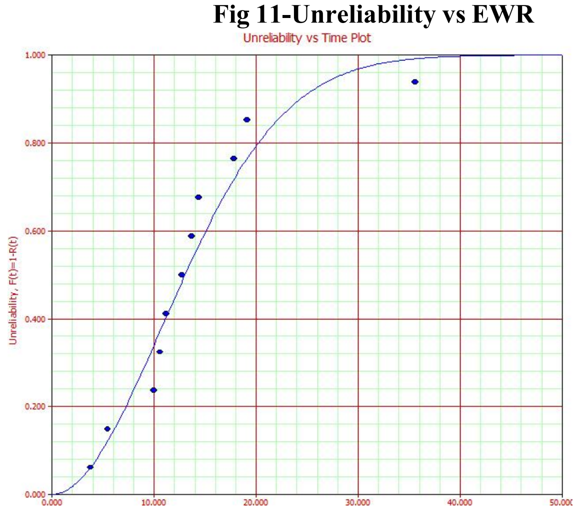

Fig 13- Unreliability plot

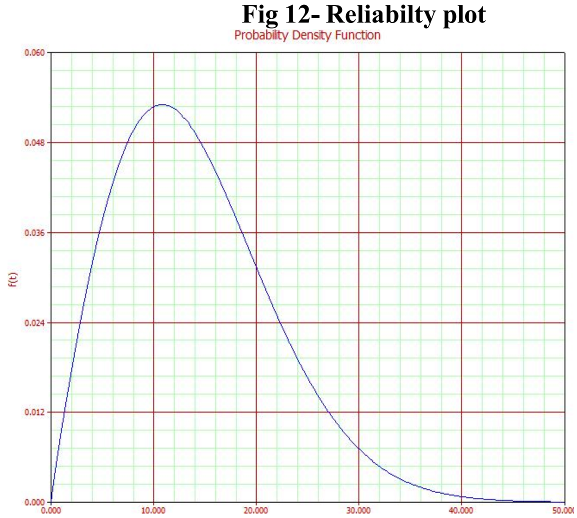

Fig 14 - pdf plot

Fig 15- Failure plot

The Weibull parameters β & η are obtained from graph are 1.9264 & 15.7853 respectively, so the reliability of electrode is calculated for t= 25 is given by

$$(\;) = {}^{-(\overline{\;})}$$

$$R(T) = e^{-\left(\frac{25}{15.7853}\right)^{1.9264}}$$

= 0.088495

= 08.8495%

Conclusion: -

From the above plots it is concluded that the reliability of tool can be calculated at any given instant with minimum failure data.

With the use of weibull distribution in probability plotting reliability parameter are calculated easily and reliability is obtained using these parameters.

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