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ANALYSIS OF MICRO CRACKS AND MICRO HARDNESS IN WHITE LAYER FORMATION ON MACHINED SURFACES IN EDM PROCESS

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In spite of huge advancement in Die-sinking EDM process and noticeable enhancement in surface integrity subsequent to machining, but this phenomenon is unavoidable and some technical issues stay unsolved in the region of surface integrity while machining of metals. Micro crack formation in the white layer zone in EDM leads to damage the quality of machined surface. This paper furnishes a quantitative investigation of micro-crack formation, in terms of crack width and orientation of micro cracks formed in white layer zone. The impact of processing conditions like peak current (I_p) and pulse on-duration (T_{on}) on crack formation is examined by utilizing the perceptions of scanning electron microscope (SEM). In this work Microhardness is measured at different zones that is deposited layer, heat effected zone (HAZ) and base metal. The hardness value of the recast layer (9.175Gpa) is significantly larger than that of the base metal (3.115Gpa) of M_2 die steel.
***Keywords*:** peak current (I_p), pulse on-duration (T_{on}), Micro cracks and hardness, White layer formation.

1. Introduction:

Die-sinking Electrical discharge machining is a thermal method that uses spark discharges to electrode, electrically conductive materials. A formed electrode defines the area during which spark erosion can occur, therefore deciding the form of ensuing cavity or hole within the workpiece. Since Die-sinking EDM become advanced, a great deal theoretical and experimental work has been completed to identify the primary process involved. It is now one of the basic techniques utilized in die manufacturing, and has true accuracy and precision without a direct contact between tool and work throughout machining. In spite of enormous progress on this technique and marked improvement in surface integrity after machining, some technical troubles continue to be unsolved. Much of the cases, as in tools, die, and aviation parts manufacturing, extreme pressure and thermal loads are experienced. To keep away from conceivable disappointments emerging from the surface imperfections of Die-sinking EDMed parts, it is imperative that there ought to be a sufficient comprehension of the nature and degree of surface damage granted under different machining conditions [1]. In most engineering material the formation of recast layer and the surface cracks while machining through Die-sinking EDM observed. The extreme heat created and connected with each discharge amid machining results in neighbourhood serious temperature gradients in the machined surface on discontinuance of the discharge, the surface layers cool rapidly and build up a tensile stress that is frequently adequate to deliver cracks in the machined surfaces. As many cases, the cracks terminate inside the recast layer. Be that as it may, if they enter similar to the parent material, a noteworthy decrease in the fatigue strength, abrasive resistance, and corrosion resistance is observed [2]. Thus, the Die-sinking EDM process is for the most part pursued by some type of post preparing treatment to expel the recast layer with the end goal that the mechanical respectability of the machined segment can be checked. Anyway this treatment procedure reaches out to manufacturing procedure as well as expands its expense. Therefore, it will be it is attractive to distinguish the processing conditions which eliminate the formation of recast layer with the end goal that the requirement for post treatment can be wiped out and improve the mechanical properties of the machined part [3]. The present investigation underlines to connect the higher order influences of major Die-sinking EDM parameters like peak current (I_p), and pulse-on duration (T_{on}) with various viewpoints of surface integrity like white layer thickness (WLT) and surface crack width while machining M_2 die steel. In this work Micro-hardness is estimated at various zones that is deposited layer, heat affected zone and base metal.

2. Experimental procedure:

A die-sinking EDM (Model T-3822, make Electronica machine tools Ltd., India) shown in Fig. 2.1 is used for the study. This machine has different current settings with a peak capacity of 12 A maximum. It can be run in both polarities. It has up to 520 μs.

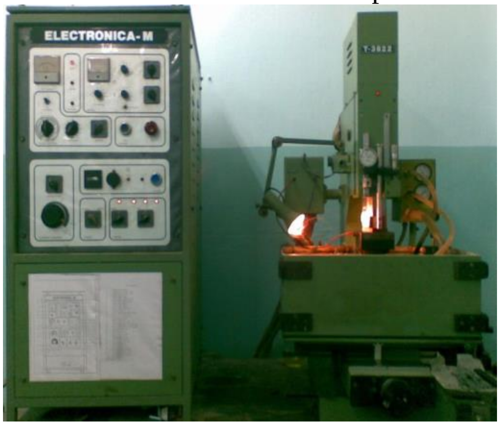


Fig. 2.1 EDM Experimentation setup

Specifications:
Maximum work piece height: 125 mm
Maximum work piece weight: 80 kg
Longitudinal travel (X – axis): 200 mm
Transverse travel (Y – axis): 125 mm
Least count of hand wheel graduations with vernier scale: 0.02 mm
Maximum table quill distance: 340 mm
Minimum table quill distance: 190 mm
Work tank dimensions: 600 X 350 X 240 mm
Travel of the quill: 150 mm
Marching current maximum (A): 12
Open gap output voltage (V): 135 ± 5 %
Pulse duration: 2 μs to 520 μs

The targets of present experimental analysis have been finished in different parametric combinations, for deriving most effective parametric aggregate. The work material was typical Die Steel (M2-hardened and annealed) with composition 0.85% C, 6.25% W, 4% Cr, 5% Mo, 2% V and rest Fe and of each work sample is 12mm×12mm×12mm at ambient temperature. To investigate diverse EDM process parameters on white layer average thickness along with surface crack width and subsequent measurement of micro hardness at different Heat affected zones (HAZ).

A EDM tool diameter of ϕ6mm is selected for drilling a blind hole of 2mm depth on Die Steel work samples with Copper electrode for the present experimental studies in combination with Die steel work piece. Castrol oil (ILO CUT-400) was chosen as dielectric with its specific properties like dielectric quality, high flash point, and low viscosity.

Variable pulsed DC power supply was utilized for experimentation. The impacts of peak current and pulse-on duration were verified through the trial experimentations with variable peak current and pulse-on duration from 1 to 12A and 2 to 520 μs, respectively, during experimentation by keeping the remaining machining parameters constant. The levels of peak currents (I_p) were set at 3, 3.5, 5, 6.5 and 7A while that of pulse-on durations (T_{on}) were set at 42, 104, 252, 400 and 462μs for various experiments [6,7].

The work sample is cleaned with acetone and the average white layer thickness is measured by using optical micrographs for each sample at 500× magnification. Finally the surface crack widths of work samples are observed by using SEM micrographs for different peak currents at pulse-on duration (462μs).

Prepared Copper electrode, work holding device and sectional view of machined work sample are shown in Fig.2.2, 2.3 and 2.4 respectively.

Fig. 2.2 Copper electrode

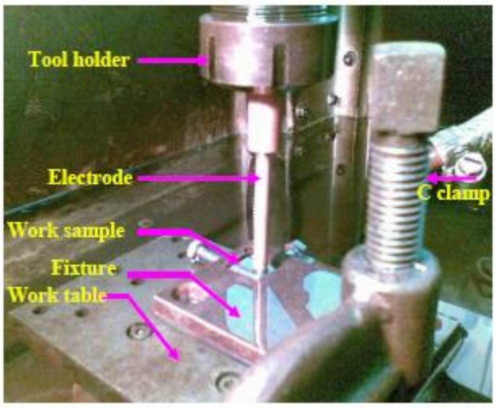


Fig. 2.3 Work holding setup

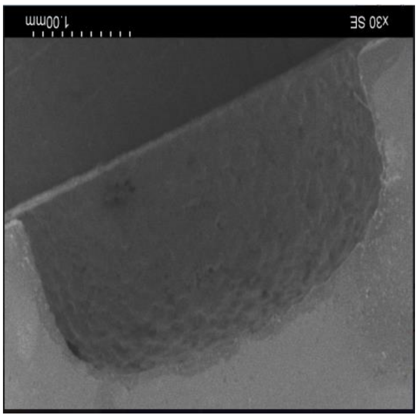


Fig. 2.4 Sectional view of workpiece

3. Design of experiments:

The principal goal in the use of experimental design is to provide most and accurate information in the results, alongside the maximum efficient use of existing information. Here experiments were planned on the basis of the experimental design method. A 2^k factorial, where k is the number of variables, with central composite-second-order rotable design, was utilized to enhance of dependability of results and to reduce the set of experimentation without loss of accuracy. The predominant objective of the factorial experiments consists of studying the connection among the response as a dependent variable and the parameter levels. This method facilitates to better apprehend how the change in the levels of application of a collection of parameters impacts the response. An aggregate of the levels of the parameter, which cause positive efficient response, can also be located through this methodology. Here we think about the consequence of the impacts of pulse-on duration (T_{on}), Peak current (I_p) on the White Layer Thickness (WLT) and surface crack width. A 2^K factorial with central composite-second order rotatable design (CCRD) is used (in this case k = 2). This consist of $n_c = 2^k = 4$ corner points at +1 level, $n_a = 2^k = 4$ axial points at $\gamma = +1.414$, and a centre point at zero level repeated five times (n_o) to estimate the pure error. The axial points are picked such that they allow rotability which ensures that the variance of the model prediction is constant at all points equidistant from the design centre [4].

Table:1 Actual and corresponding coded values for each parameter

PARAMETERS	CODED VALUE AT DIFFERENT LEVELS				
	1	2	3	4	5
	− 1.414	−1	0	+1	+1.414
Pulse on duration (T_{on}) µS	42	104	252	400	462
Peak current (I_p) A	3.0	3.5	5.0	6.5	7.0

Replicates of the test at the centre are very vital as they provide an unbiased estimate of the experimental errors. The precision of the predicted surface does no longer rely on the orientation of design with respect to the true response surface or the course of the search for optimum conditions. This entails total of 13 experimental observations. The values of coded and actual value of each parameter used in this work are listed in the table (1). The experimental matrix that was adopted here in the coded form is shown in table (2). The coded number for variables used in table (1) and table (2) are obtained from the following transformation equation:

X_i = (Chosen parametric values – Central rank value) / (Incremental parametric value)

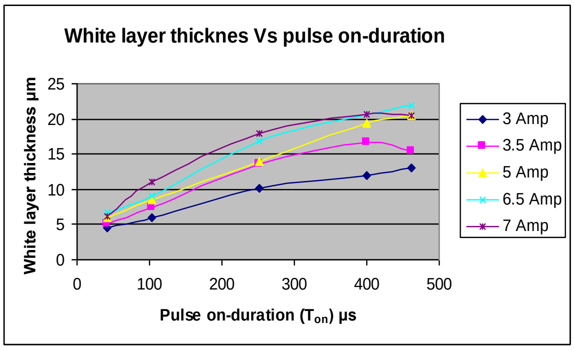
Table:2 Experimental results for training of the models based on CCD

Expt No.	Coded variables		machining parameters		WLT (µm)
	X_1	X_2	Pulse on time (T_{on}) µs	Peak current (I_p) A	
1	-1	-1	104	3.5	7.41
2	1	-1	400	3.5	16.6
3	-1	1	104	6.5	9.13
4	1	1	400	6.5	20.6
5	-1.414	0	42	5	5.95
6	1.414	0	462	5	20.39
7	0	-1.414	252	3	10.1
8	0	1.414	252	7	17.91
9	0	0	252	5	13.98
10	0	0	252	5	9.51
11	0	0	252	5	12.47
12	0	0	252	5	11.21
13	0	0	252	5	10.6

4. Experimental results and discussions:

(i) Effect of pulse on duration (T_{on}) and peak current (I_p) on White layer thickness

The variation of white layer thickness different peak current is shown in Fig 4.1. It is seen that the WLT increases as the pulse-on duration (T_{on}) increases. The higher pulse-on duration permits the electro-discharge energy to enter further into the material, as a result the thickness of the molten metal builds, which don't escape by the deficient detonating pressure of the dielectric. This is at last outcomes in greater white layer thickness [5].



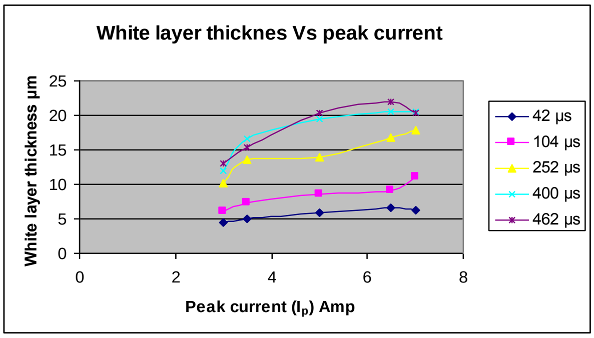
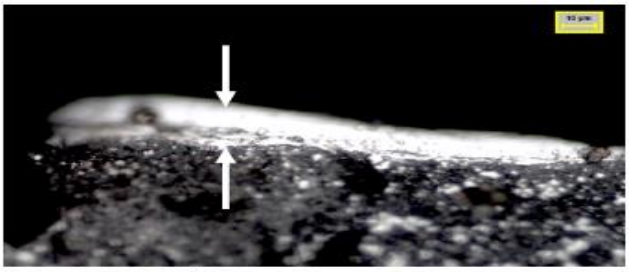


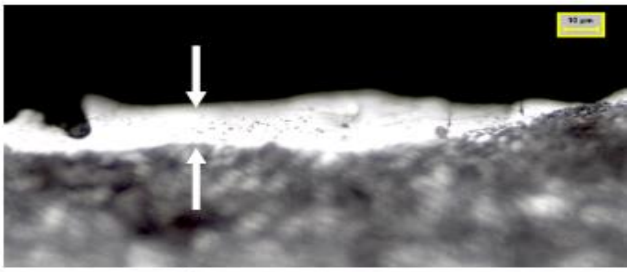
Fig. 4.1 Effect of pulse on duration and peak current on white layer thickness

The effect of peak current on white layer thickness is shown in Fig. 4.1. From the plot, it is observed that the average white layer thickness directly proportional to peak current and heat energy transferred in to specimen. This molten material solidified up to the recast layer under cooling effect and depth also formed as per the volume of liquid metal.

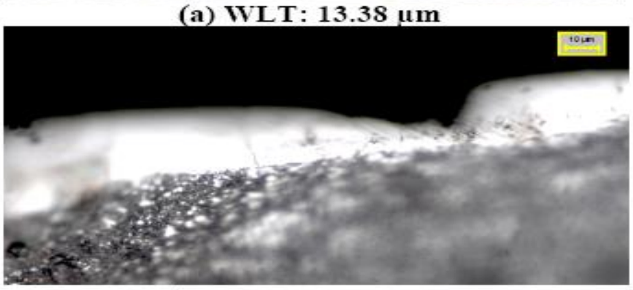
Fig. 4.2 shown the parametric combination of 3A/462µs, 3.5A/462µs, 5A/462µs, 6.5A/462µs, and 7A/462µs (**I_p / T_{on}**) and reveals the proportionality of average white layer thickness with peak current.



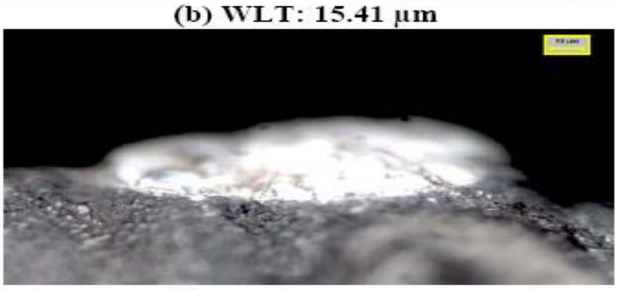
(a) WLT: 13.38 µm



(b) WLT: 15.41 µm



(c) WLT: 22.04 µm



(d) WLT: 29.32 µm

(e) WLT: 33.63 µm

Fig. 4.2 Optical micrographs of white layer at (a) 3A/462µs (b) 3.5A/462µs (c) 5A/462µs (d) 6.5A/462µs (e) 7A/462µs (I_p/T_{on})

(ii) Effect of machining parameters on surface crack width:

Among the surface imperfections, cracking is the most critical since it prompts a decrease in the material resistance, fatigue and corrosion especially under tensile loading conditions. The Fig.4.3 shows quantify the crack width varies with changes in peak current at constant pulse on duration. It is observed that the surface crack width increases with increasing of peak current for a constant pulse on duration. At the value of peak current that is 3Amp, the cracks width is very low and the low values of peak current that is 7Amp, the cracks width is high.

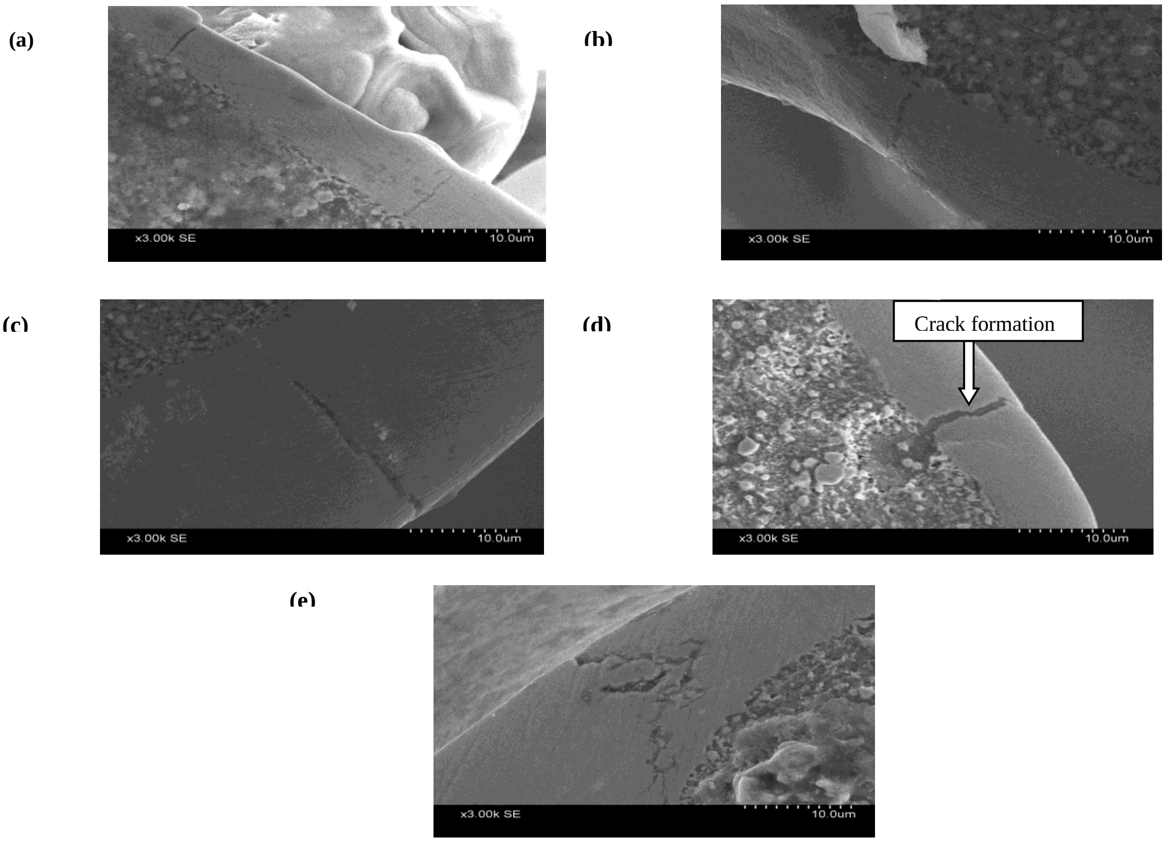


Fig.4.3 SEM Micrographs of surface cracks at (a) 3A/462µs (b) 3.5A/462µs (c) 5A/462µs (d) 6.5A/462µs (e) 7A/462µs (I_p/T_{on})

(iii) Microhardness:

Microhardness is measured at different zones are deposited layer, heat effected zone (HAZ) and base metal as shown in Fig. 4.4. The hardness value of the recast layer is significantly larger than that of the base metal of M_2 die steel. Hardness value of the deposited layer is 9.175Gpa, at the junction of deposited layer and HAZ hardness value is 7.577Gpa, and at the base metal it is 3.115Gpa respectively.

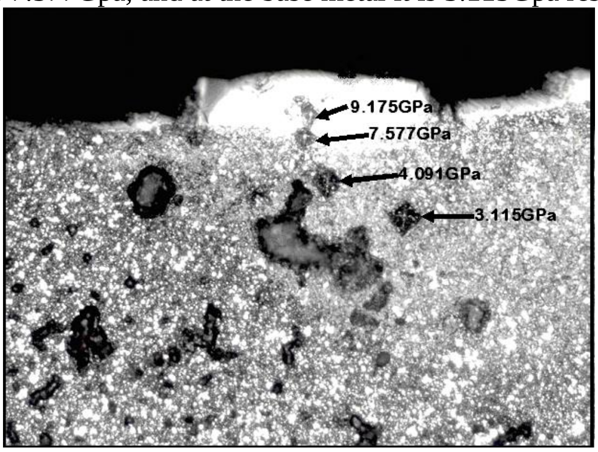


Fig. 4.4 Microhardness at different zones of the transverse section

5. Conclusions:

- It is seen from the parametric investigation that as the T_{on} and I_p increases, average white layer thickness increases.
- The surface crack width proportional to peak current for a constant pulse on duration.
- Recast layer has more hardness compared to base metal M_2 die steel.

6. References:

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