The Correlations between Rate of Tool Erosion and Black Layer formation during Electro-Discharge Machining

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# TOOL WEAR RATE AND BLACK LAYER

Electro-Discharge Machining is a technique where the electrode machines the required contour over the work by the spark erosion facilitated by dielectric medium. The spark heat removes the material while the dielectric flushes off the detritus from the spark gap. During sparking, a black layer sticks to the tool surface that may impact the efficacy of machining.

The blackness on the tool is due to the relocation of carbon through the dielectric [2,5,8]. It results due to correspondence of machine variables with its outcome and it modifies the tool’s thermal conduction [1]. This phenomenon occurs at high temperature and it resists tool wear [3].

Other than carbon, the black layer also contains Fe, Cr, V and Mo [2,5]. Its major component is carbon which releases through the dielectric [4]. The thickness of this layer is between 15 to 20 micro-meter that attaches quickly on the tool surface [4]. Temperature distribution also has influence on the formation of carbon layer over tool surface [4].

The black layer formed during machining is a brittle and exerts influence over tool’s thermal conduction [5]. The discharge energy dominates the thickness of black layer [6]. Higher duty factor also leads to formation of black layer while it disappears at a lower level of duty factor [7]. This hinders the machining of work material [9]. The dielectric pyrolysis lays a fine black carbon skin over the tool’s surface [10].



# Figure 1 Black Layer over the Tool’s surface

# Table 1 ANOVA analysis of 2FI model of Tool Wear Rate

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| --- |
| **Experiment Specifications** |
| Work Material | AISI 4340 |
| Tool Material | Copper-Tungsten |
| Dielectric | Kerosene |
| Selected Process Parameters | Current, On Duration, Voltage, Duty Factor |

The above table 1 shows the experimental specifications considered for assessing the results.

* + 1. **Black Layer Formation**

When the electrons travel from tool because of developed suitable voltage between the tool and work, the spark initiates due to ionization and de-ionization of dielectric medium. A temperature of about 10000°C is generated. Owing to the thermal decay of dielectric medium at elevated temperature developed due to high discharge energy, a thin black film deposition is observed on the tool surface.

Subsequently due to the thermal decomposition, the carbon progresses in the direction of the tool and cover its surface in form of a layer. This layer resists the positive ions that strikes the surface of the tool resulting in lower rate of tool erosion.

# Table 2 ANOVA analysis of the 2FI model of Tool Wear Rate



The duty factor exerts much influence on tool erosion. It is also detected as crucial factor as per ANOVA in table 2. It can be observed from scanning electron microscopy images in figure 2 (a), 2 (b) and 3 that the elevated duty factor results in higher occurrence of the black layer. The TWR of 0.05124 mm3/min at Ip = 4A, Ton = 25µsec, V = 90V and τ = 0.8 is minimum. It depicts that the higher value of τ will lead to more resistance to the positive ions impinging the tool surface thus contributing minimum TWR.

 

1. **(b)**

# Figure 2 Electron Microscopic and Spectroscopic images

#  (a) Sample 1 (Ip-4A, Ton-15µsec, V-90V, τ-0.6)

# (b) Sample 11(Ip-4A, Ton-25µsec, V-90V, τ-0.8)

From the EDX images, black layer majorly constitutes carbon, silicon, oxygen and iron. The thermal decomposition of dielectric results in carbon deposition while the other elements account their deposition through the workpiece. The oxygen present results due to the oxidation.



# Figure 3 Electron Microscopic and Spectroscopic image of Sample 20 (Ip-7A, Ton-30µsec, V-105V, τ-0.7)

# 1.2 Effects of black layer over tool erosion

From the previous section we could say that the composition detected in the black layer constitutes other elements along with carbon. These elements are Silicon (Si), Iron (Fe) and Oxygen as identified by EDX analysis. The presence of iron (Fe) and silicon (Si) is due to their migration from the work surface.

The presence of oxygen indicates the oxidation that is caused while machining the work. The elevated duty factor results in higher occurrence of the black layer. The duty factor was most dominating parameter for the development of black layer. It depicts that the higher value of τ will lead to more resistance to the positive ions impinging the tool surface thus contributing minimum TWR.

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