Although, WEDM can machine complex and intricate components with more accuracy and precision, some unwanted surface flaws have also been observed on machined surface. Surface integrity of WEDMed surface consists of recast layer, heat affected zone, ridge lines (un-machined surface) and several micro-cracks parallel or perpendicular to the machined surface. In rough cutting operation during die manufacturing, avoiding the surface degradation is main concern in WEDM.

9.1 RECAST LAYER:
Recast layer (Hargrove and Ding, 2007) is considered as a major flaw on work (die) surface machined with WEDM as it adversely affects the die performance. Recast layer is a hard skin on the work surface formed due to the re-solidification of melted residual material which was not completely expelled during the process (Puri and Bhattacharyya, 2005). Recast layer consists of large size craters, hollow cavities and micro-cracks due to thermal residual stresses. Scanning Electron Microscopy (SEM) has been a common tool to examine EDM surfaces.

In present study, SEM micrographs have been taken to study surface characteristics of WEDMed work material. Figure 9.1 and 9.2 shows the SEM images of work surface at peak current 100 Amp, Ton 115μm, Toff 4μm and SV 30V. It can be seen from Figure 9.1 that the surface layer has been damaged due to the high heat energy, which can be distinguished by the amount of WC-grains and micro cracks. Recast layer of an average thickness 22μm was observed as shown in Figure 9.2 which cannot be ignored in a metal powder compacting die.

At high discharge energy, significant amount of melted cobalt transforms into vapour phase which on cooling gave hollow cavities (Lee and Li, 2003). These cracks have formed as a result of high thermal stresses prevailing due the rapid heating and cooling in the sparking zone. The concentration of WC grains decreases from internal surface to the top layer (or recast layer) of the surface. Recast layer consists of shallow craters of varying sizes, globules of debris formed by entrapped gases which make the surface rougher.
According to the investigations made by Lee and Li (2003), depth of recast layer and numbers of micro cracks are mostly influenced by peak current and pulse-duration.
Therefore, in present work effect of peak current and pulse-on time have been investigated on recast layer. Figure 9.3 and 9.4 shows the different size craters and crack densities which were observed at different peak current settings.

Figure 9.3 SEM image at Ip:100Amp, Ton:115mu; Toff:40mu

Figure 9.4 SEM image at Ip:80Amp, Ton:115mu, Toff:40mu
Figure 9.5 SEM image at Ton 108μm, Ip 80Amp

Figure 9.6 SEM image at Ton 115μm, Ip 80Amp
SEM images of cross section of machined surface have taken to observe the thickness of recast layer at different pulse duration (Ton) keeping peak current, pulse-off and servo voltage at constant values of 80ampere, 50μm and 30V respectively as shown in Figures 9.5 to 9.7. The average thickness of recast layer corresponding to three pulse durations i.e. Ton 108, 115 and 122μm is found as 10μm, 16μm and 22μm respectively. Therefore, thickness of recast layer increases with pulse duration. Increasing trend has also been observed in recast layer thickness with increase in peak current (Ip).

9.2 UNMACHINED AREA/RIDGE LINE:
In case of rough cutting operation in die cutting, some surface area remains unmachined as shown in Figure 9.8. In Figure 9.8, the direction of arrow shows the movement of wire electrode starting from point 0. Wire electrode completes the cutting operation when it reaches point F before reaching point, I. Therefore, a triangular shape has been generated on the die surface. This unmachined surface area is named as ridge line. The area of the unmachined surface depends mainly on discharge energy across the electrodes. Figure 9.9 shows SEM image of the top view of inside surface of the die cavity.
Figure 9.8 Representation of unmachined surface area in wire EDM

Figure 9.9 SEM image showing the top view of inside surface
Figure 9.10 SEM image at Ip 80Amp, Ton 115μ, Toff 40μ

Figure 9.11 SEM image at Ip:100Amp, Ton:115μ, Toff:40μ
Figure 9.12 SEM image at Ip: 100Amp, Ton:120mu, Toff: 30mu

Figure 9.13 SEM image at Ip:120Amp, Ton:122mu, Toff:30mu
Shape of the unmachined top surface area generally, appears in a triangular shape but it may deteriorate depending on the discharge conditions i.e. peak current and pulse duration. The increase in peak current increases the spark diameter which increases the length of ridge line. From Figure 9.10 total effective spark diameter is 296 μm which produces ridge line of nearly 148μm long. But increase in peak current and pulse-duration deteriorate the shape and length of ridge line which is mainly due to large melting and increasing recast layer as shown in Figures 9.11 to 9.13.

It is clear from SEM images 9.10 to 9.13 that the length and shape of ridge line varies with the variation in peak current (Ip) and pulse-duration (Ton). Large deteriorated ridge lines were observed with high peak current and low pulse-duration. Long pulse duration at high peak current erodes more material form work surface which may cause re-deposition of melted material because of incomplete flushing of debris out of the spark gap, resulting into deteriorated ridge line.

9.3 CONCLUSIONS:

- The recast layer and ridge line were observed on die surface using SEM images. It has been found that recast layer and ridge line exist in low thickness even at low discharge energy in rough cutting operation in WEDM.
- Recast layer thickness and length of ridge line are function of two main discharge parameters i.e. peak current (Ip) and pulse duration (Ton). Recast layer is mainly due to the incomplete flushing of the eroded carbide material out of the spark gap. Therefore, thickness of recast layer increases with increase in peak current and pulse-on time.
- Recast layer and ridge line both degrade the die performance. Due to recast layer, die surface wear out quickly when metal powder is compacted. Ridge line affects the surface quality and dimensional precision of the compacted components. Therefore, in order to improve the surface integrity of the die surface, one or more trim cutting operations are always required in WEDM process. These trim cutting operations need to be operated at low discharge energy (i.e. low peak current and low pulse-on time) with proper wire off set value.