# Investigation of Machining Characteristics of High Carbon High Chromium Tool Steel by using Wire EDM

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*Abstract:* - Wire-cut electrical discharge machining is one of non conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This paper presents the effect of various WEDM process parameters such as wire speed, wire tension on different process response parameters such as material removal rate (MMR), surface roughness (Ra), wire wear ratio (WWR). This paper also reviews optimization methods applied by researchers and finally outlines the recommendations and future trends in WEDM research.

*Key-words:* - Wire cut EDM machining process, High carbon high chromium, Tool steel, Work piece, and Air gap.

## 1 Introduction

Electric Discharge Machining (EDM) is a non-conventional metal removal process used for machining of very hard materials like ceramics, super alloys and composite matrix for manufacturing very complex shapes which are not possible by conventional machining process [1].

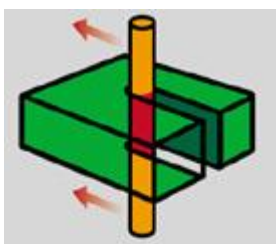

**Figure 1:** Wire Cutting Model

## 2 Electric Discharge Machining (EDM) Setup

The setup of EDM includes a power supply source, a dielectric medium, a work piece which is electrically conductive and an electrode which act as tool. Work piece is connected to the positive terminal and tool to the negative terminal of the power supply thus the work piece become anode and tool become cathode .This is done so because it has been observed that if both the electrodes are made of the same material, the electrode connected to the positive terminal generally eroded at faster rate, for this work piece is made anode. Work piece and electrode are separated by a small gap called spark gap [2]. The spark gap usually varies from .0055mm to .05mm. To maintain this predetermined spark gap a servo control unit is used. This system correctly locates the tool in relation to the work piece surface, maintain constant gap throughout the operation and sense changes in the gap conditions [3].

When a circuit voltage of 50V to 450V is applied through dielectric medium across gap between tool and work piece, the electric path build up along the path of the least resistance causing the breakdown of the dielectric fluid and formation of the spark due to the spark gap. The sparks are directly impinge on the work piece surface. It only takes a few microseconds to complete the cycle and spark discharges hit the work piece (anode) with considerable force and velocity resulting in the development of the very high temperature of the range 10,000°C on the spot [4].

This temperature is high enough to vaporize and melt a very small amount of the material from the work piece and flushed away by dielectric fluid. The spark frequency is normally is in the range 200-50000 Hz and this is high enough to remove a considerable amount of the material from the work piece [6].

**Machine Details:**
Series: VQ 100F
X/Y axes: 1000*600mm
U/V axes: 120-12mm
Z axis: 310mm
Maximum Work piece 1500*1000*305 mm

**Machining Parameters:**
1. Pulse on time.
2. Pulse off time.
3. Arc gap.

**Selection of work piece:**
In this experiment Mild steel plates of size 100*100*6 mm, 100*100*8 mm, 100*100*10 mm are chosen as a work piece material.

**Selection of tool material:**
The tool used is brass wire with 0.25 mm nominal diameter due to its high tensile strength, conductivity, vaporization temperature and hardness.

**Dielectric reservoirs pump and circulation system:**
Dielectric reservoirs and pump are used to circulate the EDM oil for every run of the experiment and also used the filter the wire EDM oil.

**Power generation and control unit:**
The power supply control the amount of energy consumed. First it has a time control function which controls the length of time that current flows during each pulse; this s called ""on time." Then it is control the amount of current allowed to flow during each pulse. These pulses are of very short duration and are measured in microseconds. There is a handy rule of thumb to determine the amount of current a particular size of wire should use: for an efficient metal removal rate. A low current level for large electrode will extend overall machine time unnecessarily. Conversely, too heavy a current load can damage the work piece. The control unit control the all function of the machining for example of Ton, IP, duty cycle, putting values and maintain the work piece the tool gap [5].

**Working tank with work holding device:**
In wire EDM de mineralized water kept in the working tank and is used during the process of machining.

**The tool holder:**
The tool holder holds the tool during the process of machining.

## 3 Results and Discussion

### 3.1 Speed vs. Time:

As per graphs 1-3 (Figure 2, 3, 4) and tables 1-3

- There is a decrease in Time with increase in speed for 6mm.
- There is a decrease in Time with increase in speed for 8mm.
- There is a decrease in Time with increase in speed for 10mm.

TABLE 1
SPEED VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Speed | Time (min) |
|---|---|---|
| 1 | 0.7 | 330 |
| 2 | 1.0 | 300 |
| 3 | 1.3 | 240 |

TABLE 2
SPEED VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 8 MM)

| S. No | Speed | Time (min) |
|---|---|---|
| 1 | 1.5 | 309 |
| 2 | 1.6 | 300 |
| 3 | 1.7 | 249 |

TABLE 3
SPEED VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 10 MM)

| S. No | Speed | Time (min) |
|---|---|---|
| 1 | 0.95 | 330 |
| 2 | 1.1 | 267 |
| 3 | 1.2 | 258 |

For the piece whose thickness is 6mm

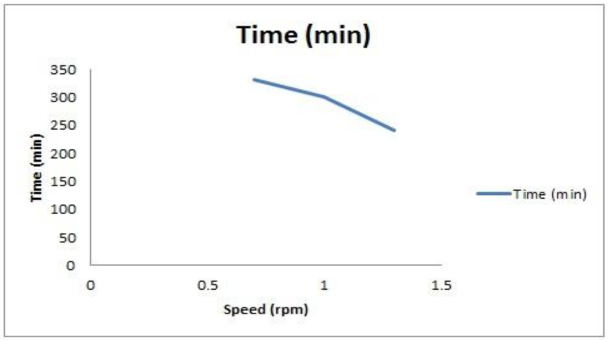


**Figure 2:** Graph-1 Speed vs Time (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

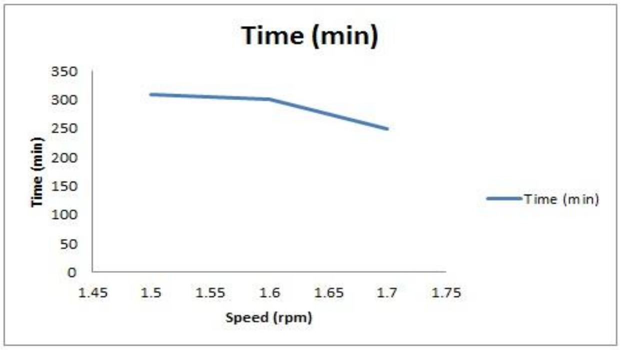


**Figure 3:** Graph-2 Speed vs Time (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

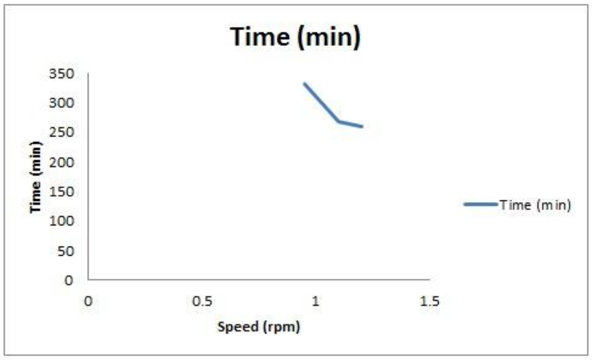


**Figure 4:** Graph-3 Speed vs Time (For the work piece whose thickness is 10 mm)

### 3.2 Speed vs. Metal removal rate:

As per graphs 4-6 (Figures 5 to 7) and tables 4-6

- There is a decrease in MRR with increase in speed for 6mm.
- There is a decrease in MRR with increase in speed for 8mm.
- There is a decrease in MRR with increase in speed for 10mm.

TABLE 4
SPEED VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Speed | Metal Removal Rate |
|---|---|---|
| 1 | 0.7 | 0.705 |
| 2 | 1.0 | 0.6 |
| 3 | 1.3 | 0.57 |

TABLE 5
SPEED VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 8MM)

| S. No | Speed | Metal Removal Rate |
|---|---|---|
| 1 | 1.5 | 0.88 |
| 2 | 1.6 | 0.84 |
| 3 | 1.7 | 0.72 |

TABLE 6
SPEED VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 10 MM)

| S. No | Speed | Metal Removal Rate |
|---|---|---|
| 1 | 0.95 | 1.25 |
| 2 | 1.1 | 1.0 |
| 3 | 1.2 | 0.90 |

For the piece whose thickness is 6mm

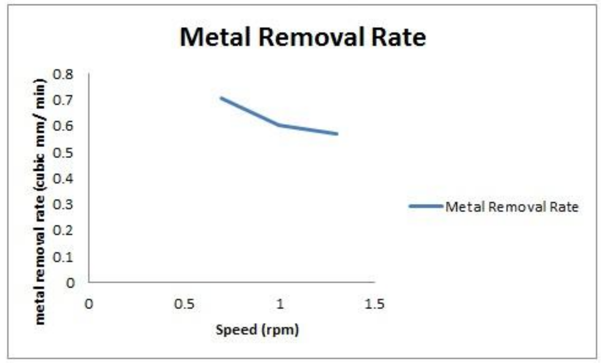


**Figure 5:** Graph-4 Speed Vs Metal removal rate (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

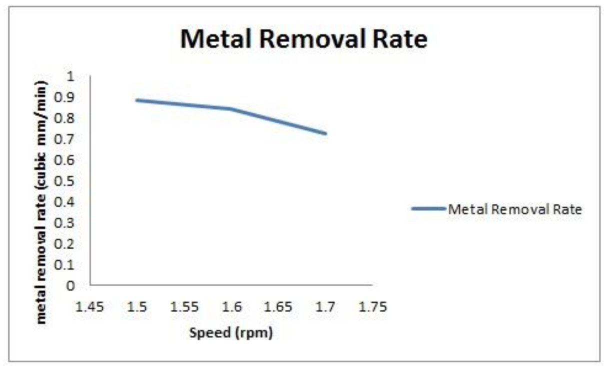


**Figure 6:** Graph-5 Speed Vs Metal removal rate (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

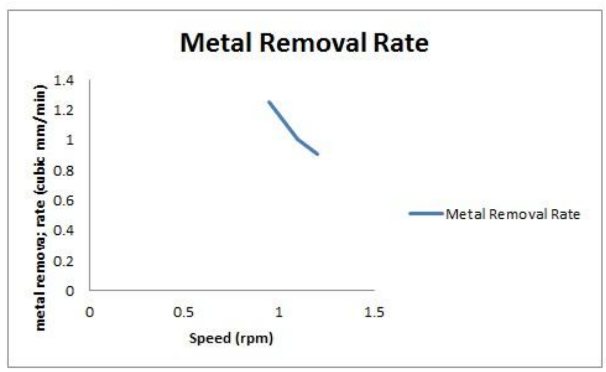


**Figure 7:** Graph-6 Speed Vs Metal removal rate (For the work piece whose thickness is 10mm)

### 3.3 Speed Vs Surface roughness:

**As per graphs 7-9 (Figures 8-10) and tables 7-9**

- There is a decrease in surface roughness with increase in speed for 6mm.
- There is a decrease in surface roughness with increase in speed for 8mm.
- There is a decrease in surface roughness with increase in speed for 10mm

TABLE 7
SPEED VS SURFACE ROUGHNESS (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Speed | Surface Roughness |
|---|---|---|
| 1 | 0.7 | 1.54 |
| 2 | 1.0 | 1.46 |
| 3 | 1.3 | 1.30 |

TABLE 8
SPEED VS SURFACE ROUGHNESS (FOR THE WORK PIECE WHOSE THICKNESS IS 8 MM)

| S. No | Speed | Surface Roughness |
|---|---|---|
| 1 | 1.5 | 1.5 |
| 2 | 1.6 | 1.42 |
| 3 | 1.7 | 1.37 |

TABLE 9
SPEED VS SURFACE ROUGHNESS (FOR THE WORK PIECE WHOSE THICKNESS IS 10MM)

| S. No | Speed | Surface Roughness |
|---|---|---|
| 1 | 0.95 | 2.07 |
| 2 | 1.1 | 1.98 |
| 3 | 1.2 | 1.51 |

For the piece whose thickness is 6mm

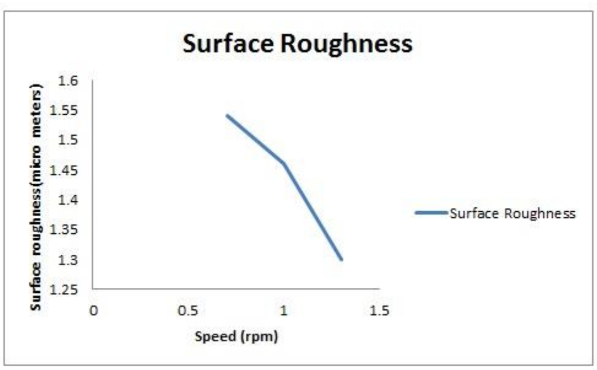


**Figure 8:** Graph 7 Speed Vs Surface roughness (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

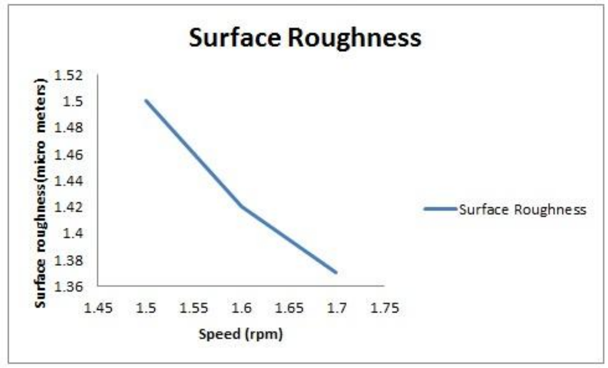


**Figure 9:** Graph 8 Speed Vs Surface roughness (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

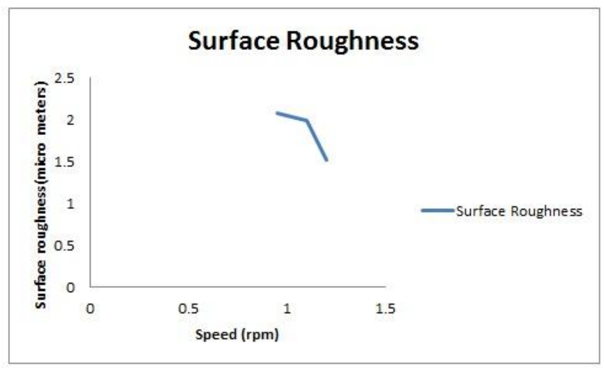


**Figure 10:** Graph 9 Speed Vs Surface roughness (For the work piece whose thickness is 10mm)

### 3. 4. Time Vs Metal removal rate:

**As per graphs 10-12(figures 11-13) and tables 10-12**

- There is a increase in MRR with increase in speed for 6mm.
- There is a increase in MRR with increase in speed for 8mm.
- There is a increase in MRR with increase in speed for 10mm.

TABLE 10
TIME VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Metal Removal Rate | Time (min) |
|---|---|---|
| 1 | 0.705 | 330 |
| 2 | 0.6 | 300 |
| 3 | 0.57 | 240 |

TABLE 11
TIME VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 8 MM)

| S. No | Metal Removal Rate | Time (min) |
|---|---|---|
| 1 | 0.88 | 309 |
| 2 | 0.84 | 300 |
| 3 | 0.72 | 249 |

TABLE 12
TIME VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 10MM)

| S. No | Metal Removal Rate | Time (min) |
|---|---|---|
| 1 | 1.25 | 330 |
| 2 | 1.0 | 267 |
| 3 | 0.90 | 258 |

For the piece whose thickness is 6mm

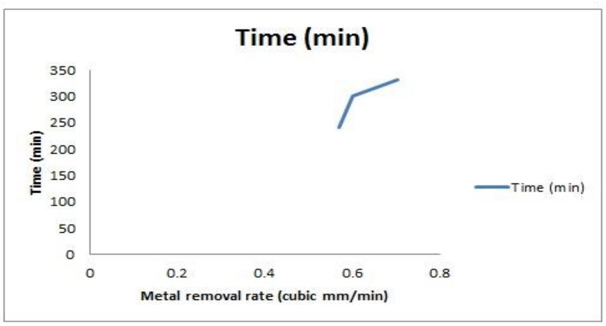


**Figure 11:** Graph 10 Time Vs Metal removal rate (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

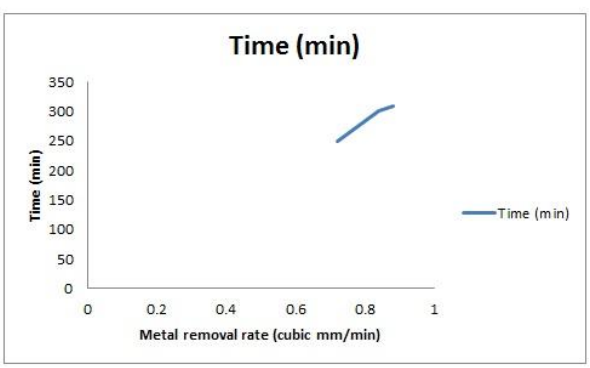


**Figure 12:** Graph 11 Time Vs Metal removal rate (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

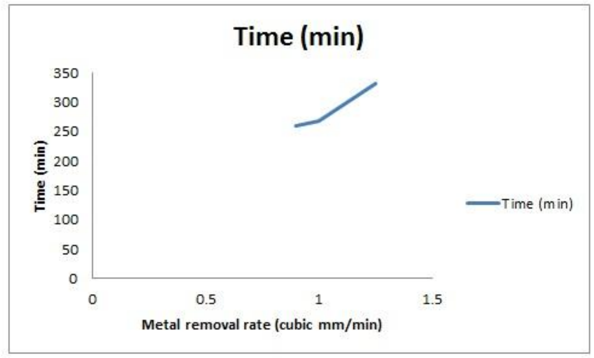


**Figure 13:** Graph 12 Time Vs Metal removal rate(For the work piece whose thickness is 10mm)

### 3. 5. Surface roughness Vs Time:

**As per graphs 13-15 (figures 14-16) and tables 13-15**

- There is a increase in Surface Roughness with increase in time for 6mm.
- There is a increase in Surface Roughness with increase in time for 8mm.
- There is a increase in Surface Roughness with increase in time for 10mm.

TABLE 13
SURFACE ROUGHNESS VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Surface Roughness | Time (min) |
|---|---|---|
| 1 | 1.54 | 330 |
| 2 | 1.46 | 300 |
| 3 | 1.30 | 240 |

TABLE 14
SURFACE ROUGHNESS VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 8 MM)

| S. No | Surface Roughness | Time (min) |
|---|---|---|
| 1 | 1.5 | 309 |
| 2 | 1.42 | 300 |
| 3 | 1.37 | 249 |

TABLE 15
SURFACE ROUGHNESS VS TIME (FOR THE WORK PIECE WHOSE THICKNESS IS 10MM)

| S. No | Surface Roughness | Time (min) |
|---|---|---|
| 1 | 2.07 | 330 |
| 2 | 1.98 | 267 |
| 3 | 1.51 | 258 |

For the piece whose thickness is 6mm

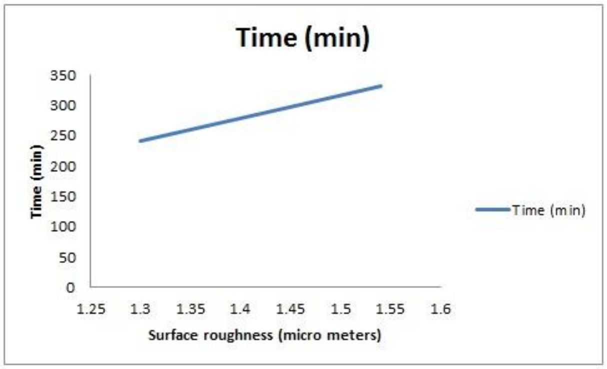


**Figure 14:** Graph 13 Surface roughness Vs Time (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

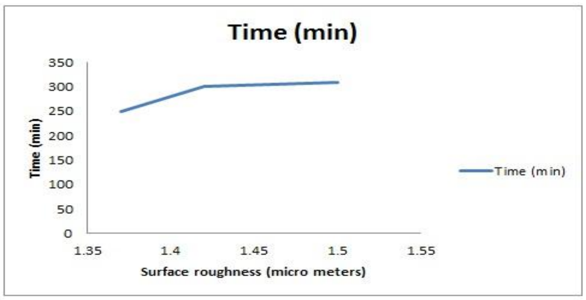


**Figure 15:** Graph 14 Surface roughness Vs Time (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

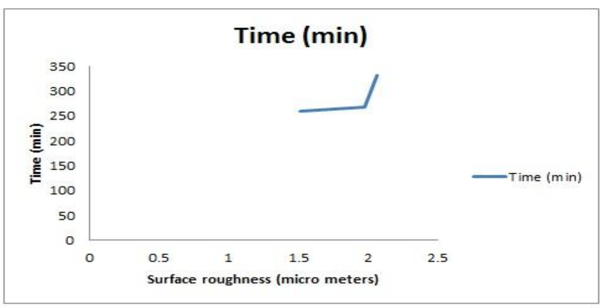


**Figure 16:** Graph 15 Surface roughness Vs Time (For the work piece whose thickness is 10mm)

### 3.6. Surface roughness Vs Metal removal rate:

**As per graphs 16-18 (figures 17-19) and tables 16-18**

- There is a increase in Surface Roughness with increase in MRR for 6mm.
- There is a increase in Surface Roughness with increase in MRR for 8mm.
- There is a increase in Surface Roughness with increase in MRR for 10mm.

TABLE 16
SURFACE ROUGHNESS VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 6 MM)

| S. No | Surface Roughness | Metal Removal Rate |
|---|---|---|
| 1 | 1.54 | 0.705 |
| 2 | 1.46 | 0.6 |
| 3 | 1.30 | 0.57 |

TABLE 17
SURFACE ROUGHNESS VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 8 MM)

| S. No | Surface Roughness | Metal Removal Rate |
|---|---|---|
| 1 | 1.5 | 0.88 |
| 2 | 1.42 | 0.84 |
| 3 | 1.37 | 0.72 |

TABLE 18
SURFACE ROUGHNESS VS METAL REMOVAL RATE (FOR THE WORK PIECE WHOSE THICKNESS IS 10 MM)

| S. No | Surface Roughness | Metal Removal Rate |
|---|---|---|
| 1 | 2.07 | 1.25 |
| 2 | 1.98 | 1.0 |
| 3 | 1.51 | 0.90 |

For the piece whose thickness is 6mm

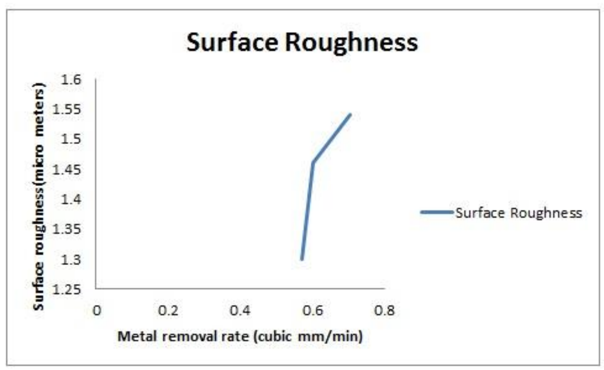


**Figure 17:** Graph 16 Surface roughness Vs Metal removal rate (For the work piece whose thickness is 6 mm)

For the piece whose thickness is 8mm

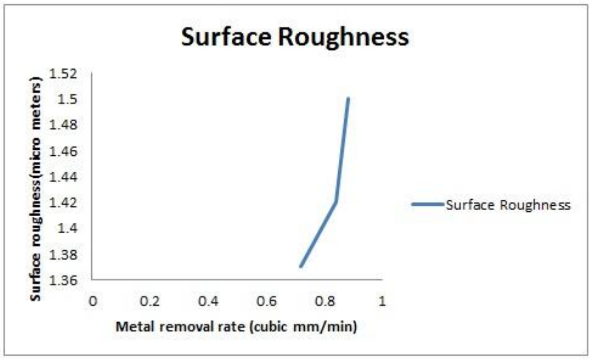


**Figure 18:** Graph 17 Surface roughness Vs Metal removal rate (For the work piece whose thickness is 8 mm)

For the piece whose thickness is 10mm

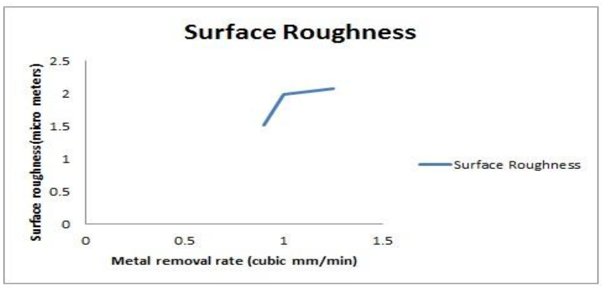


**Figure 19:** Graph 18 Surface roughness Vs Metal removal rate (For the work piece whose thickness is 10 mm)

### 3.7. Microscopic Structure of work piece

**As per figures 20-23 shown below:**

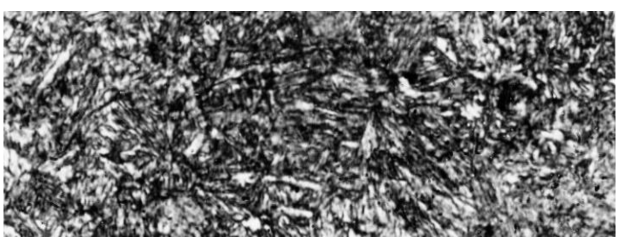

**Figure 20:** x64 micro-scope structure of 6mm for 0.7 rpm

**Figure 21:** x64 micro-scope structure of 6mm for 1.3 rpm

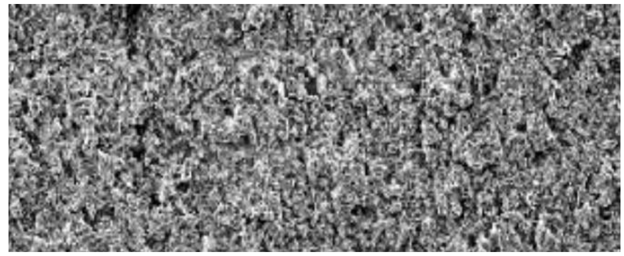

**Figure 22:** x64 micro-scope structure of 8mm for 1.5 rpm

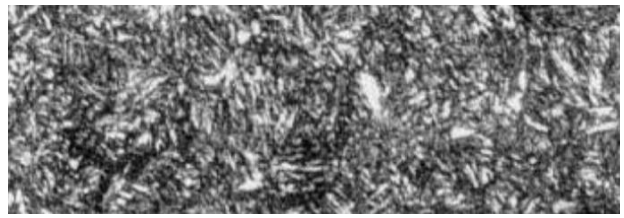

**Figure 23:** x64 micro-scope structure of 8mm for 1.7 rpm

## 4 Conclusion

From the above study the following observations are made:

- There is a decrease in Metal removal rate with increase in speed
- There is a decrease in Surface roughness with increase in speed
- There is a decrease in Time with increase in speed

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