CHAPTER 3
SELECTION OF ELECTRODE FOR EDM ON INCONEL 600 ALLOYS

3.1. INTRODUCTION

The selection of the most appropriate electrode material is a key decision in the process plan for any sinking EDM job. The important variables to be considered for selection of electrode material are material removal rate, tool wear rate, surface roughness, machinability and material cost. Properties of different electrode materials and their influence on EDM performance as well as on fabrication of electrodes have been summarized in EDM handbooks. Electrode material should have the basic properties like electrical and thermal conductivity, a high melting temperature, low wear rate, and resistance to deformation during machining.

3.2. EDM ELECTRODE

Since electric current is cutting tool, in EDM, higher conductivity promotes more efficient cutting. Drozda explained that the tool electrode is responsible to transport the electrical current to the work piece. Therefore, any material to be used as a tool electrode is required to conduct electricity. Since EDM is a thermal process, it would be logical to assume that the higher the melting point of the material of electrode, the better the wear ratio will be between electrode and work piece. Even though EDM is often thought of as a zero force process, every individual spark is a very violent process on a microscopic scale, exerting considerable stress on the electrode material.

How well the material responds to these hundreds and thousands of these attacks on its surface will be a significant factor in determining the electrode material's performance regarding wear, surface finish, and ability to withstand poor flushing conditions. The mechanical properties of electrode materials most often considered for electrode materials are:

- Tensile strength
- Transverse Rupture Strength
- Grain Size
- Hardness
These mechanical properties affect the ease in fabrication of the electrode. According to the theory the mechanical properties of the work piece and the tool electrode have negligible influence on machining performance. However, the thermo physical properties of the work piece and electrode (thermal and electrical conductivity, thermal expansion, heat to vaporize from room temperate, melting and boiling temperature) have considerable influence on the process performance in terms of material removal rate, electrode wear and surface integrity of the work piece. The above mentioned desirable properties may provide general guidelines for electrode material selection but due to highly stochastic nature of EDM process, the basis for selection of particular work-tool interface is empirical rather than theoretical.

3.3. PROPERTIES OF EDM ELECTRODE

**Particle Size:** Generally, the smaller the particle size, the better the mechanical properties of the graphite, resulting in finer detail, better wear, and better work piece surface finish.

**Density:** Since graphite is a porous material, its density must be closely controlled. Generally, higher density is preferable.

**Flexural Strength:** Flexural strength is a measure of the strength. Generally, graphite with the smallest particle size has the highest flexural strength.

**Hardness:** Hardness is generally a function of the particle size, porosity, and binder material. Hardness can be very important to the success of machining and grinding operations. Graphite is widely used due to its significant production advantages over metallic electrode materials.

**Speed:** Graphite is faster than copper in both roughing and finishing, usually by a factor of 2:1.

**Machinability:** Graphite machines and grinds an order of magnitude faster than copper, and can also have more detail easily machined into it. Graphite Doesn’t have to be deburred like any metallic, further reducing electrode fabrication costs.
**Electrical Conductivity:** Since electric current is our cutting tool, higher conductivity promotes more efficient cutting.

**Melting Point:** Since EDM is a thermal process, it would be logical to assume that the higher the melting point of the electrode material, the better the wear ratio will be between electrode and work piece.

**Chemistry:** Just as in the case of Wire EDM, the chemistry of the electrode material can significantly affect the efficiency of the EDM process.

**Structural Integrity:** Even though EDM is often thought of as a “zero force” process, each individual spark is a very violent process on a microscopic scale, exerting considerable stress on the electrode material. How well the material responds to hundreds of thousands of these “attacks” on its surface, will be a significant factor in determining the electrode material’s performance regarding wear, surface finish, and ability to withstand poor flushing conditions.

In fact, there is a vast range of materials used for manufacturing electrodes like brass, tungsten carbides, electrolytic copper, copper-tungsten alloys, silver-tungsten alloy, tellurium-copper alloys, copper-graphite alloys, graphite etc. The five commonly used electrodes are: copper, brass, tungsten, zinc, and graphite. In addition, some electrode materials are combined with other metals in order to cut more efficiently. Tungsten has a melting point similar to graphite, but tungsten is highly difficult to machine. Metallic electrodes usually work best for machining materials which have low melting points as aluminum, copper, and brass. As for steel and its alloys, graphite is preferred. The general rule is: metallic electrodes should be applied for low temperature alloys and graphite electrodes should be applied for high temperature alloys. However, exceptions also exist.

**Work piece material removal rate:** A correct choice of EDM parameters to the pair tool/work piece electrode materials will increase its value.
**Electrode resistance to wear:** The volumetric and corner wears in electrode are very important in finish EDM operations of fine details. Minimization of those wears requires choosing proper parameters and electrode material.

**Work piece surface roughness:** Good work piece surface quality is obtained by the proper choice of electrode material, good flushing conditions and adequate EDM parameter settings.

**Tool electrode material machinability:** Copper and graphite are the most commonly used. However, it is important to select an electrode material where the macro and micro geometry can be easily machined. It promotes the reduction of machining time and costs.

**Electrode material cost:** On average, fine graphite is about three times more expensive than copper. The choice shall be done considering the company facilities.

3.4. **EDM ELECTRODE MATERIALS**

Electrode materials fall into two main categories: metallic and graphite. Today, metallic electrodes are only used in perhaps 10% of sinking EDM applications. The primary advantage of metallic electrode materials is their electrical conductivity and mechanical integrity. Mechanical integrity is especially important in both sharp corner and poor flushing conditions. The primary disadvantages of metallic electrodes are difficulty in fabrication and low cutting speeds. Graphite is a preferred electrode material for 90% of all sinking EDM applications. Therefore, it is important that we expend considerable effort to understand electrodes have a greater rate of metal removal in relation to its wear.

**Metallic Electrodes:** In the early days of EDM (tube type power supplies and R/C generator circuits) metallic electrodes were used exclusively. Today, metallic electrodes are only used in perhaps 10% of Sinker EDM applications (with the exception of Small hole drilling). The primary advantage of metallic electrode materials is their electrical conductivity and mechanical integrity. Mechanical integrity is especially important in
Both sharp corner and poor flushing conditions (those subject to DC arcing). The primary disadvantages of metallic electrodes are difficulty in fabrication and low cutting speeds. Let’s examine the most common metallic electrode materials is further detail.

**Brass:** Brass was one of the first EDM electrode materials. It is inexpensive and easy to machine. Today, however, brass is seldom used as an electrode material in modern EDMs, due to its high wear rate. In certain applications or in older machines with RC power supplies for which wear is not a primary concern, brass still has limited use, since it exhibits a higher degree of stiffness and is easier to machine than copper. Brass, however, is one of the most commonly used materials for High Speed Small Hole Machines.

**Copper:** With development of the transistorized, pulse-type power supplies, Electrolytic (or pure) Copper became the metallic electrode material of choice. This is because the combination of Copper and certain power supply settings enables low wear burning. Also, Copper is compatible with the polishing circuits of certain advanced power supplies. Many shops in both Europe and Japan still prefer to use Copper as the primary electrode material, due to their tool making culture that is averse to the “untidiness” of working with graphite. Due to its structural integrity, Copper can produce very fine surface finishes, even without special polishing circuits. This same structural integrity also makes. Copper electrodes are highly resistant to DC arcing in poor flushing situations. Copper is frequently used to make female electrodes on a Wire EDM for subsequent use in reverse burning punches and cores in the Sinker EDM.

There are a number of significant disadvantages associated with Copper electrodes.

- Copper electrodes will generally burn only half as fast as graphite electrodes.
- Copper is a soft and gummy material to machine or grind.
- Copper is an extraordinarily difficult material to de-burr.

It can take longer to deburr a Copper electrode than to manufacture it. The addition of 1-3% Tellurium to Copper improves its machinability to a level similar to brass,
eliminating the “gummy” properties normally exhibited by Copper when it is machined or ground. Unfortunately, the EDM performance of Copper is somewhat compromised by the addition of the Tellurium. Compared to Electrolytic Copper, Tellurium Copper (also known as TELCO) exhibits 15-25% higher wear and 10% decreased metal removal rate. However, because of the ease of machining this material, most shops are willing to accept this trade-off. Most Copper comes in the “as rolled” condition. Being a cold rolled material, the bars exhibit a significant amount of stress movement, especially when being machined by Wire EDM cutting. Copper is also commonly used for tubing for certain brands of High Speed Small Hole Machines. Copper electrodes are also the preferred material for all High Speed Small Hole applications involving aerospace alloys as well as Carbide.

**Silver:** Silver is occasionally used as an electrode material, due to its superior electrical conductivity, purity, and structural integrity. The use of Silver electrodes and fine finish power supplies can produce extraordinary fine finishes in coining dies, where the use of orbiting to improve the finish would distort the cavity detail. Obviously, due to the cost, Silver is rarely used.

**Tungsten:** Due to the combination of its high density, tensile strength, and melting point, Tungsten had been the electrode material of choice for certain limited EDM applications. It is important to note that Tungsten, due to its relatively poor electrical conductivity, cuts much slower than Brass or Copper. Also, due to its high cost and very low machinability, Tungsten is seldom used.

**Silver Tungsten:** Silver Tungsten is a powder metal product which combines the wear resistance of Tungsten with the high conductivity of Silver, to give an unmatched combination of low wear and fine surface finish for EDM applications with fine detail. Silver Tungsten is made by the same process as Copper Tungsten. Due to its high cost and limited availability, Silver Tungsten has a very limited range of applications.
**Tungsten Carbide:** Due to its extraordinary stiffness and low wear properties, Tungsten Carbide is often the preferred electrode material for applications requiring very small holes put in by sinker. Since Tungsten Carbide is very brittle, it is best utilized with rotating spindles that have tilt and centering adjustments or guide bushings, since Carbide cannot be trued in the spindle by bending.

**Graphite Electrodes:** Graphite is the preferred electrode material for 90% of all sinker EDM applications. Thus, it is important that we expend considerable effort to understand its properties and application to EDM. Graphite was introduced to the EDM industry approximately 50 years ago. One of the early well known brands of graphite was manufactured by General Electric, and known by the trade name of “Gentrode”. Graphite is made from Carbon derived from petroleum. The powdered Carbon is mixed with a petroleum based binder material and then compacted. How the graphite is compacted in this stage of production is vitally important to its ultimate properties. All early graphite’s were made by compressing the powder/binder mixture in only one direction, resulting in properties or “grain” similar to wood, that varied relative to the direction of pressing. As an outgrowth of the space program, methods were developed to isostatically press graphite such that its properties became “isotropic”, that is the same in all directions. All high quality, high performance graphites are now manufactured this way. After compacting, the “green” compacted material undergoes a series of thermal treatments that convert the Carbon to graphite.

Graphite has certain properties quite different than wrought metal based electrode materials:

- Graphite has an extremely high melting point. Actually, graphite does not melt at all, but sublimes directly from a solid to a gas (just as the Carbon Dioxide in dry ice) at a temperature thousands of degrees higher than the melting point of Copper. This resistance to temperature makes graphite an ideal electrode material.

- Graphite has significantly lower mechanical strength properties than metallic electrode materials. It is neither as hard, as strong, nor as stiff as metallic electrode materials. However, since the EDM process is one of relatively low macro mechanical forces, these property differences are not often significant.
Copper Tungsten: Copper Tungsten (CuW) is a powder metal product designed to combine the best EDM properties of Copper and Tungsten. Copper Tungsten combines the high electrical conductivity of copper with the high melting point of tungsten. The combination of these two metals creates an electrode material with very good wear properties. Copper Tungsten is unmatched for its wear resistance, holds up very well in sharp corners, and is readily machined and ground without the burr issues associated with Copper. Copper Tungsten is also the preferred material for EDMing Carbide.

Copper Tungsten cannot be manufactured by conventional alloying techniques, since the Copper would vaporize before the Tungsten began to melt. That is why Copper Tungsten is made by the powder metal process. Copper and Tungsten powder are pressed into a pre-form and then sintered. During sintering, the material shrinks by approximately 25% and great care must be taken to avoid porosity, which is a common defect in some Copper Tungsten electrodes (a porous spot will leave a bump in the EDM cavity). The better grades of Copper Tungsten are made by the Press-Sinter- Infiltrate process, which virtually eliminates porosity.

Copper Tungsten is generally sold in the 70W:30Cu grade. It is possible to purchase Copper Tungsten with different ratios. A higher Tungsten content would improve the corner wear at the expense of lower cutting stability and higher cost. A lower Tungsten content would suffer increased corner wear, but enable smoother burning in addition to reducing the cost of the material. (Copper is cheaper than Tungsten).

3.5. CONCLUSION

Moreover the researchers had conducted EDM experiments with high cost electrode like tungsten carbide; titanium carbide and boron carbide on INCONEL alloy. Copper Tungsten electrode is generally sold in the 70W:30Cu grade. Copper Tungsten electrode is improving the EDM performance on INCONEL alloy with low cost. Since no reliable theory is available to guide the EDM on INCONEL 600 alloy with a low cost electrode, an attempt is needed to study the EDM characteristics.