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# AN EXPERIMENTAL STUDY ON ROUNDNESS ERROR IN WIRE EDM FOR FERRO MATERIALS

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**Abstract:** Heavy-duty alloy alloys such as SS316, EN24, and H13 play a major part in the current industrial phenomena for the manufacturing of dies and moulds. There is a strong preference for Wire EDM use for alloy material machining because of the cost savings and reduced tool wear that it provides. Additionally, precise machining of cavities, inserts, holes and radius is a benefit of Wire EDM because of its high level of precision. The roundness of the item is critical in all of these machining scenarios. Pulse deviation has been automatically adjusted in Wire EDMs, and the number of cutting repeatability has been raised depending on product quality. The roundness of inserts is critical to their assembly. By adjusting the distance between the nozzle and cutting head, the roundness error may be increased or decreased. An insert-based investigation with constant thickness and a constant radius yielded excellent results with several radiuses in one profile.

**Key words**: the nozzle's distance from the workpiece's centre, circularity inaccuracy, ferro materials.

**Introduction**

An electrode made of a thin wire is used in a WEDM process that converts electricity into heat for cutting materials. Alloy steel, conductive ceramics, and aerospace materials may all be machined with this method, regardless of how hard or durable they are. The WEDM process has the ability to create a fine, accurate, corrosion and wear resistant surface. In the typical EDM process, an electrode is used to initiate the sparking process, and WEDM is regarded a unique adaptation of that technique. As an alternative, a wire electrode constructed of 0.05-.30 mm-diameter copper or brass is used in WEDM, which is capable of producing very tiny corner radiuses. By utilising a mechanical tensioning device, it is possible to reduce the risk of making components that are out of tolerance.

Problem statement

Because most Wire EDM machine manufacturers have optimised their machines' power input parameters and material removal rate, relatively little research has been done on the machines' output machining targets. Taking into account the influence of nozzle distance fluctuation on the end product's precision, dimensional inaccuracies must also be addressed with careful investigation. In order to improve the dimensions

Roundness is an important metric in the investigation of insert failure in dies and moulds.

**Dimensions of the project**

In order to get the best possible outcomes, the distance between nozzles must be efficiently optimised for the wire to move, and the qualities of various materials must also be considered. Wire EDM's specialisation has also led to a need for greater dimensional accuracy in the number of material removal cuts, as well as an increase in the number of finish passes to check for error variance in the final product.

Efforts were required to find a way to reduce the variation in cutting speed while increasing the number of cuts.

**Methods and materials**

Considerations for materials such as ferro alloys with and without corrosion and high strength led to the selection of SS316, EN 24, and H13. For the machining of 6mm and 10mm materials, nozzle distances were taken of 9mm and 29, which is a deviation from typical practise to examine the difference in radius accuracy. When working with two levels and eight parameter variations, the Taguchi technique of L12 orthogonal array is used. The levels are standard to nozzle distance and three cuts as parameters with three different materials and two different thicknesses.

| | | PARAMETERS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LEVELS | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | 2 | L4 | L4 | L8 | L8 | L8 | L8 | L12 | L12 | L12 | L12 | L16 |
| | 3 | L9 | L9 | L9 | L18 | L18 | L18 | L18 | L27 | L27 | L27 | L27 |
| | 4 | L16 | L16 | L16 | L16 | L32 | L32 | L32 | L32 | L32 | | |
| | 5 | L25 | L25 | L25 | L25 | L25 | L50 | L50 | L50 | L50 | L50 | L50 |

Above table shows the TAGUCHI experimental methods of orthogonal array with experimental study.

| | | |
|---|---|---|
| Nozzle height from top surface | Level 1- 9mm | Level 2- 29mm |
| Thickness variance- work piece | 6mm, 10mm | 6mm, 10mm |
| Number of cuts | 1 cut, 2&3 cuts | 1 cut,2&3 cuts |

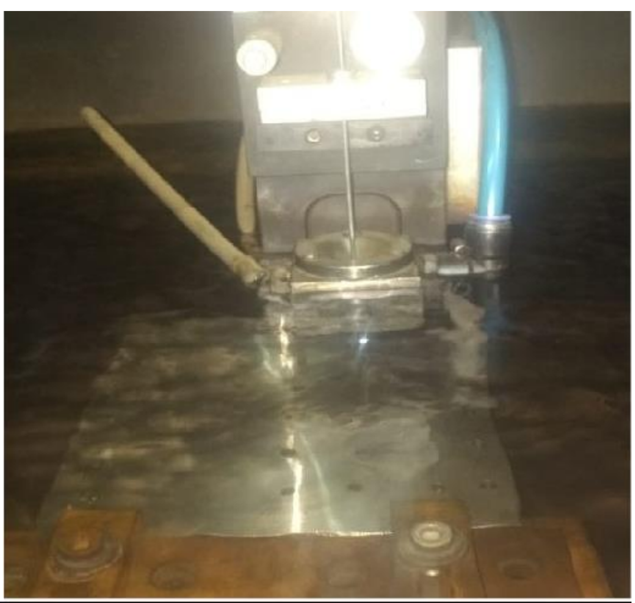
The variables listed in the above table may be used in experiments.

The design technique for testing the difference in cutting speed in different profiles and thickness has been noticed for various diameters and profiles. Wire cam software was used to develop the programme and prepare the design for the Wire EDM process in AutoCAD 2017. Each drawing and profile's experimental arrangement is shown in the following experimental table.Thickness considered as A1, A2 cuts consider as C1, C2, C3 and levels as L1and L2

| Expt No | Levels (L) | Thickness (A) | No of cuts (C) |
|---|---|---|---|
| 1 | L1 | A1 | C1 |
| 2 | L1 | A1 | C2 |
| 3 | L1 | A1 | C3 |
| 4 | L1 | A2 | C1 |
| 5 | L1 | A2 | C2 |
| 6 | L1 | A2 | C3 |
| 7 | L2 | A1 | C1 |
| 8 | L2 | A1 | C2 |
| 9 | L2 | A1 | C3 |
| 10 | L2 | A2 | C1 |
| 11 | L2 | A2 | C2 |
| 12 | L2 | A2 | C3 |

**Standard parameters considered for experiments of Wire Cut EDM**

| Parameter Name | Unit | |
|---|---|---|
| Tension | N | 6 |
| Feed | m/min | 12 |
| Flushing pressure | $Kg/cm^2$ | 4 |
| Current | A | 100 |



The wire-cut work piece and CMM machine setup is shown in the figure. It is possible to utilise the VAST XXT scanning sensor in ZEISS DuraMax to collect contours.
Size of probe: 1 mm

- **Single-point measurement and scanning**

- **Change of stylus guided by CNC**

- Adapter plate with a diameter of 25 mm for maximum repeatability

- 30 to 150 mm axial stylus length

From 30 to 65 mm, the radial stylus is available.

Using a CMM, a variance in measurement is calculated.

An orthogonal CMM with three accurate axes comes included with a touch-trigger probe as part of the basic equipment set up. Upon making contact with the item under test, the probe's position is automatically recorded. In order to get the most accurate findings, several measurements are taken of the component and then combined. using a computer to determine the component's roundness Since data collection takes so much time, the amount of data points tends to be minimal. Such measures are impaired as a consequence of this problem.

**Rotational Datum Approach**

To determine the roundness of a component, a scanning probe may be used to detect its change in radius from an exact rotational reference (one that remains in contact with the surface and collects a high-density of data points). After fitting a circle to the data, the roundness of the object may be computed. knowledge of the component centre.

There are many dedicated instruments made for the measurement of roundness. The advantages of these instruments are that they can measure roundness extremely accurately in a short measurement time.

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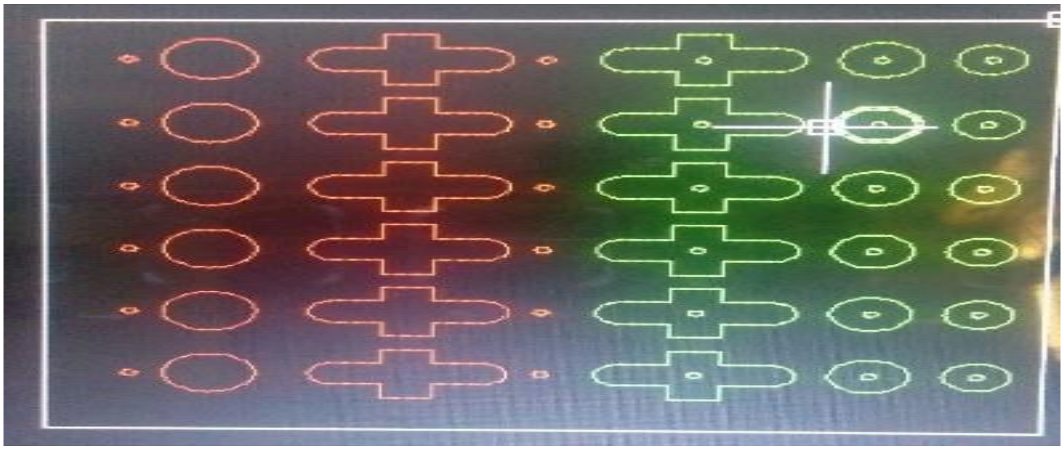


**Figure shows the profile design of work piece for Wire cut EDM**

**Results and discussions**

The following are the results obtained for the below drawing as observed with cutting speed related to circularity error

Cutting speeds variation of EN24 ▯ 10mm

Cutting speeds variation of EN24 ▯ 12mm

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.66 | 0.0063 |
| 2 | 6.80 | 0.0057 |
| 3 | 8.02 | 0.0050 |
| 4 | 5.64 | 0.0048 |
| 5 | 6.80 | 0.0073 |
| 6 | 8.00 | 0.0065 |
| 7 | 4.68 | 0.0050 |
| 8 | 6.40 | 0.0070 |
| 9 | 7.92 | 0.0053 |
| 10 | 4.62 | 0.0043 |
| 11 | 6.42 | 0.0071 |
| 12 | 7.90 | 0.0057 |

**Cutting speeds variation of EN24 ▯ 14mm male**

| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.66 | 0.0063 |
| 2 | 6.86 | 0.0057 |
| 3 | 8.02 | 0.0050 |

| | | |
|---|---|---|
| 4 | 5.66 | 0.0048 |
| 5 | 6.90 | 0.0073 |
| 6 | 7.98 | 0.0065 |
| 7 | 4.64 | 0.0050 |
| 8 | 6.48 | 0.0070 |
| 9 | 7.90 | 0.0053 |
| 10 | 4.64 | 0.0043 |
| 11 | 6.44 | 0.0071 |
| 12 | 7.94 | 0.0057 |

**Cutting speeds variation of EN24 profile-1 female**

| Expt no | Cutting speedmm/min | Roundness error(Δ) |
|---|---|---|
| 1 | 5.66 | 0.0066 |
| 2 | 6.80 | 0.0060 |
| 3 | 8.04 | 0.0051 |
| 4 | 5.64 | 0.0049 |
| 5 | 6.88 | 0.0072 |
| 6 | 7.98 | 0.0068 |
| 7 | 4.66 | 0.0051 |
| 8 | 6.48 | 0.0071 |
| 9 | 7.98 | 0.0056 |
| 10 | 4.60 | 0.0044 |
| 11 | 6.42 | 0.0073 |
| 12 | 7.98 | 0.0059 |

**Cutting speeds variation of EN24 profile-2 male**

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.68 | 0.0067 |
| 2 | 6.90 | 0.0062 |
| 3 | 8.00 | 0.0053 |
| 4 | 5.66 | 0.0051 |
| 5 | 6.84 | 0.0073 |
| 6 | 8.02 | 0.0070 |
| 7 | 4.68 | 0.0052 |
| 8 | 6.44 | 0.0073 |
| 9 | 7.95 | 0.0057 |
| 10 | 4.62 | 0.0046 |
| 11 | 6.48 | 0.0075 |
| 12 | 7.92 | 0.0060 |

H13 Material:

**Cutting speeds variation of H13 ⍰ 10 mm**

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.62 | 0.0059 |
| 2 | 6.80 | 0.0049 |
| 3 | 8.02 | 0.0043 |
| 4 | 5.60 | 0.0070 |
| 5 | 6.82 | 0.0059 |
| 6 | 7.98 | 0.0045 |
| 7 | 4.64 | 0.0063 |
| 8 | 6.44 | 0.0051 |
| 9 | 8.05 | 0.0040 |
| 10 | 4.60 | 0.0063 |
| 11 | 6.48 | 0.0052 |
| 12 | 7.95 | 0.0044 |

Cutting speeds variation of H13 ⍰ 12 mm

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.62 | 0.0059 |
| 2 | 6.82 | 0.0054 |
| 3 | 7.98 | 0.0047 |
| 4 | 5.64 | 0.0043 |
| 5 | 6.82 | 0.0069 |
| 6 | 7.99 | 0.0063 |
| 7 | 4.62 | 0.0048 |
| 8 | 6.44 | 0.0067 |
| 9 | 8.04 | 0.0050 |
| 10 | 4.58 | 0.0041 |
| 11 | 6.40 | 0.0069 |
| 12 | 7.98 | 0.0053 |

**Cutting speeds variation of H13 ⍰ 14 mm**

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.62 | 0.0061 |
| 2 | 6.80 | 0.0053 |
| 3 | 8.02 | 0.0049 |
| 4 | 5.62 | 0.0043 |
| 5 | 6.80 | 0.0069 |
| 6 | 8.02 | 0.0061 |

| | | |
|---|---|---|
| 7 | 4.62 | 0.0047 |
| 8 | 6.43 | 0.0067 |
| 9 | 7.98 | 0.0046 |
| 10 | 4.62 | 0.0039 |
| 11 | 6.46 | 0.0069 |
| 12 | 7.98 | 0.0054 |

**Cutting speeds variation of H13 profile -1**

| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.60 | 0.0063 |
| 2 | 6.84 | 0.0056 |
| 3 | 7.96 | 0.0047 |
| 4 | 5.62 | 0.0043 |
| 5 | 6.84 | 0.0069 |
| 6 | 8.04 | 0.0061 |
| 7 | 4.66 | 0.0049 |
| 8 | 6.40 | 0.0069 |
| 9 | 8.00 | 0.0054 |
| 10 | 4.62 | 0.0042 |
| 11 | 6.44 | 0.0070 |
| 12 | 8.00 | 0.0056 |

**Cutting speeds variation of H13 profile -2**

| Expt no | Cuttingspeed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.60 | 0.0062 |
| 2 | 6.86 | 0.0059 |
| 3 | 8.00 | 0.0050 |
| 4 | 5.60 | 0.0047 |
| 5 | 6.80 | 0.0071 |
| 6 | 8.02 | 0.0069 |
| 7 | 4.64 | 0.0049 |
| 8 | 6.42 | 0.0068 |
| 9 | 8.00 | 0.0054 |
| 10 | 4.60 | 0.0044 |
| 11 | 6.42 | 0.0071 |
| 12 | 8.00 | 0.0059 |

**SS 316 Material**:

**Cutting speeds variation of SS 316 ⍰ 10 mm**

| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.60 | 0.0058 |
| 2 | 6.92 | 0.0049 |
| 3 | 8.08 | 0.0042 |
| 4 | 5.58 | 0.0071 |
| 5 | 6.90 | 0.0058 |
| 6 | 8.06 | 0.0046 |
| 7 | 4.70 | 0.0063 |
| 8 | 6.46 | 0.0050 |
| 9 | 7.95 | 0.0041 |
| 10 | 4.68 | 0.0062 |
| 11 | 6.46 | 0.0053 |
| 12 | 7.94 | 0.0043 |

**Cutting speeds variation of SS 316 ⍰ 12 mm**

| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.62 | 0.0058 |
| 2 | 6.94 | 0.0055 |
| 3 | 8.06 | 0.0048 |
| 4 | 5.57 | 0.0043 |
| 5 | 6.94 | 0.0068 |
| 6 | 8.08 | 0.0064 |
| 7 | 4.72 | 0.0047 |
| 8 | 6.42 | 0.0067 |
| 9 | 7.97 | 0.0051 |
| 10 | 4.66 | 0.0042 |
| 11 | 6.44 | 0.0068 |
| 12 | 7.90 | 0.0052 |

**Cutting speeds variation of SS 316 ⍰ 14 mm**

| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.60 | 0.0060 |
| 2 | 6.92 | 0.0054 |
| 3 | 8.08 | 0.0050 |
| 4 | 5.57 | 0.0041 |
| 5 | 6.92 | 0.0070 |
| 6 | 8.08 | 0.0062 |

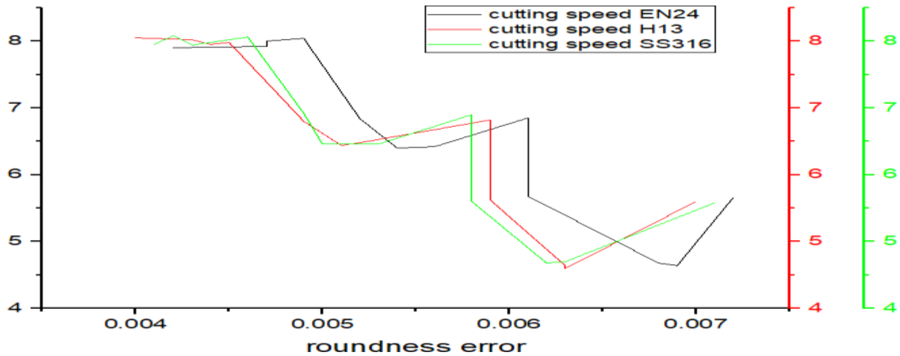
| | | |
|---|---|---|
| 7 | 4.70 | 0.0046 |
| 8 | 6.40 | 0.0064 |
| 9 | 7.98 | 0.0044 |
| 10 | 4.66 | 0.0041 |
| 11 | 6.38 | 0.0070 |
| 12 | 7.92 | 0.0049 |

**Cutting speeds variation of SS 316Profile1**

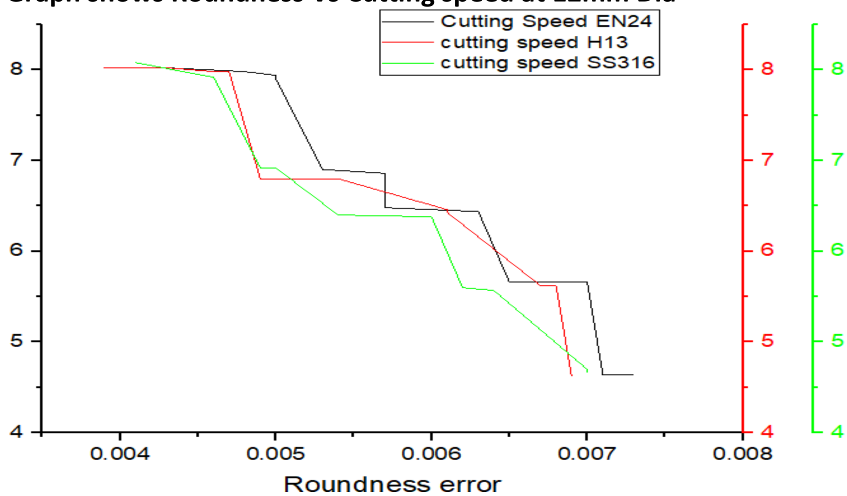
| Expt no | Cutting speed mm/min | Roundness error(Δ) |
|---|---|---|
| 1 | 5.62 | 0.0061 |
| 2 | 6.94 | 0.0055 |
| 3 | 8.10 | 0.0048 |
| 4 | 5.58 | 0.0041 |
| 5 | 6.90 | 0.0070 |
| 6 | 8.10 | 0.0062 |
| 7 | 4.72 | 0.0047 |
| 8 | 6.44 | 0.0066 |
| 9 | 7.98 | 0.0055 |
| 10 | 4.66 | 0.0043 |
| 11 | 6.40 | 0.0072 |
| 12 | 7.94 | 0.0058 |

**Cutting speeds variation of SS 316 Profile- 2**

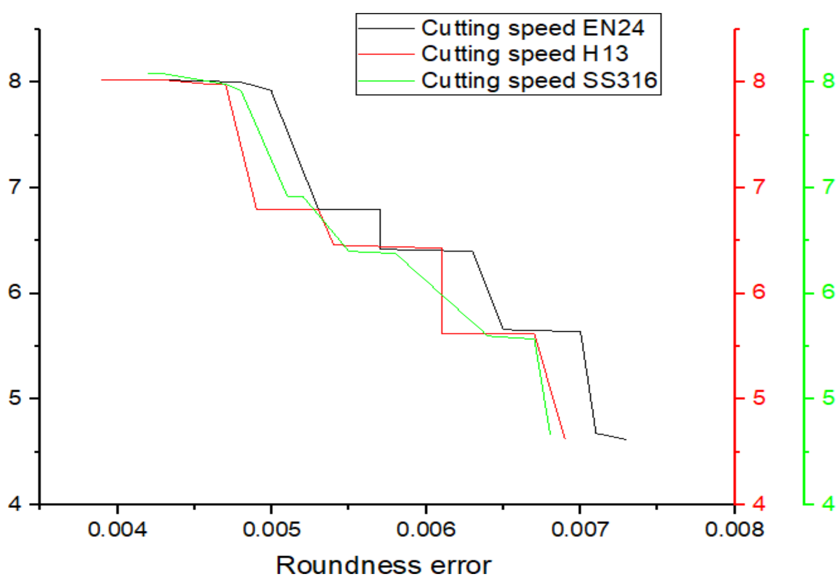
| Expt no | Cutting speed mm/min | Roundnesserror(Δ) |
|---|---|---|
| 1 | 5.60 | 0.0064 |
| 2 | 6.92 | 0.0060 |
| 3 | 8.12 | 0.0048 |
| 4 | 5.60 | 0.0049 |
| 5 | 6.92 | 0.0069 |
| 6 | 8.10 | 0.0070 |
| 7 | 4.70 | 0.0051 |
| 8 | 6.44 | 0.0069 |
| 9 | 7.98 | 0.0053 |
| 10 | 4.68 | 0.0042 |
| 11 | 6.38 | 0.0070 |
| 12 | 7.92 | 0.0060 |

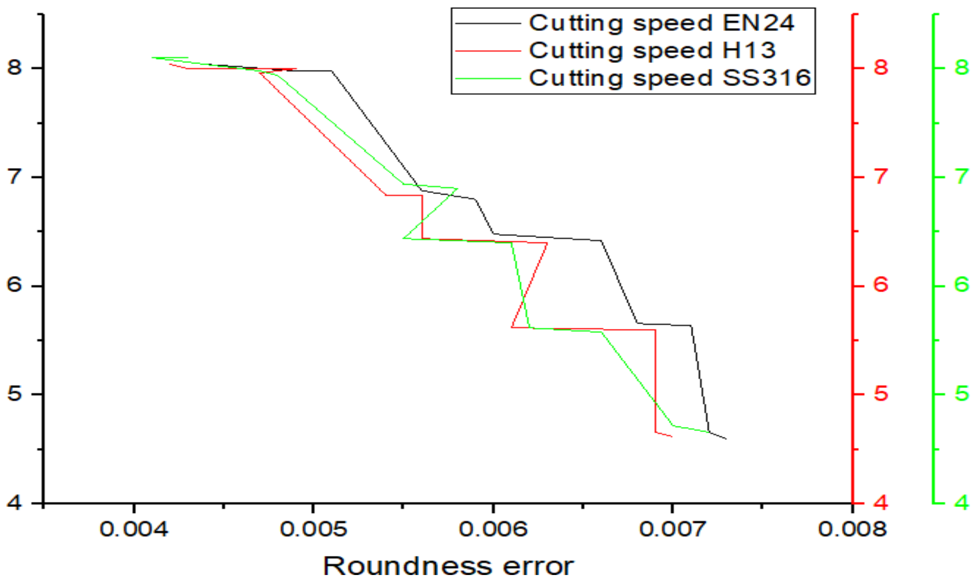



**Graph shows Roundness Vs Cutting speed at 12mm Dia**




**Graph shows Roundness Vs Cutting speed at 14mm Dia**






**Graph shows Roundness Vs Cutting speed at Profile 1**

At Profile 2, this graph demonstrates the relationship between roundness and cutting speed.

This experiment clearly shows that roundness error is directly related to cutting speed, since the rate of material removal increases with increasing cutting speed, resulting in a consistently low error deviation after machining. Roundness errors in advanced Wire EDM procedures were reduced by increasing the number of cuts that were made.

Conclusion:

There is a lot of experimentation that takes into account numerous radiuses in the profiles. Errors are reduced as work piece thickness increases, and nozzle distance has an impact on cutting speed. In order to complete the optimization of parameters in a sophisticated way, many radius profiles must be taken into consideration. It's necessary to confirm this with several profiles since the maximum measured variance in inaccuracy dimensionally is 0.004.

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