PERFORMANCE OF CNC WIRE CUT EDM IN MISSILES

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ABSTRACT
Since few years, Engineering studies have been witnessing a rapid growth in the development of harder and difficult to machine materials. These materials find wide applications in many industries owing to their physical properties and high endurances .For such materials, the conventional edge tool machining is highly un economical and the degree of accuracy and surface finish is also very poor. Machining of these materials into complex shapes is difficult, time consuming and sometimes impossible. Consequently, non-conventional machining trends have emerged to overcome these difficulties. Electrical Discharge Machining (EDM) is one such method.
Keywords: CNC machine, CODINGS

AIM OF THE PROJECT

The aim of the project is to study the working principle and various other concepts involved in a non-traditional machining process called Electrical Discharge Machining (EDM). The project also involves making a component called "**Test specimen**" made of the Maraging steel, used in section-4 of Akash missile using the "**Ultima 1S**" Wirecut EDM machine in Bharat dynamics ltd facility.

NON- TRADITTONAL MACHINING

INTRODUCTION: From some time past engineering industries have witnessed a rapid growth in the development of harder and difficult-to-machine materials such as haste alloy, nitro alloy, wasp alloy, nimonics, carbides, stainless steel, heat resisting steels and many other high strength temperature resistant(HSTR) alloys. These materials find wide application in aerospace, nuclear engineering and other industries owing to their high strength to weight ratio, hardness and heat resisting qualities. For such materials the conventional edged lool machining is highly uneconomical and the degree of accuracy and surface finish are poor. Besides, machining of these materials into complex shapes is difficult, time consuming and some times impossible. Considering the seriousness of the problem, Merchants inl960's emphasized the need for the development of newer conceptsin metal machining. Consequently, non-traditional machining processes have emerged to overcome these difficulties.

Characteristics of non-traditional machining

• Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.
• In NTM, there may not be a physical tool present. For example in laser jet machining, machining is carried out by a laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining.

• In NTM, the tool need not be harder than the work piece material. For example, in EDM, copper is used as the tool material to machine hardened steels.

• Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM, AJM, WJM mechanical energy is used to machine material, whereas in ECM electrochemical dissolution constitutes material removal.

Classification of non-traditional machining processes

Classification of NTM processes is carried out depending on the nature of energy used for material removal. The broad classifications given as follows:

- Mechanical Processes
- Abrasive Jet Machining (AJM)
- Ultrasonic Machining (USM)
- Water Jet Machining (WJM)
- Abrasive Water Jet Machining (AWJM)
- Electrochemical Processes
- Electrochemical Machining (ECM)
- Electro Chemical Grinding (ECG)
- Electro Jet Drilling (EJD)
- Electro-Thermal Processes
- Electro-discharge machining (EDM)
- Laser Jet Machining (LJM)
- Electron Beam Machining (EBM)
- Ion Beam Machining (IBM)
- Plasma Arc Machining (PAM)
-Chemical Processes
- Chemical Machining (CHM)
- Photochemical Machining (PCM) etc

INTRODUCTION TO WIRE-CUT EDM

In all the machining processes EDM is one of the important non-traditional machining processes. Here we are mainly concerned about wire cut EDM. Wire cut EDM or Electrical Discharge Machining is a technique used to slice through metal. The technique uses thin brass wire for the purpose and can create intricate profiles with the process. The EDM machine uses spark discharges that are fast, repetitive, and controlled for cutting. This process works with electrically conductive metals. The process is specially suited for contours and cavities that are not possible with other cutting tools.EDM is also known as "spark machining" as it uses repetitive electrical discharges to remove metal. The electrical discharges are passed between the metal part and the electrode. A stream of continuously flowing liquid is used to remove the metal remnants produced during the process. A set of successively deeper craters is formed till the final shape is created by the discharges.

Different types of EDM:

1.Ram EDM

In ram EDM, a graphite electrode is used along with traditional tools. This electrode is connected to the ram with the help of a power source and is fed into the work piece. The whole process is carried out in a fluid bath. The fluid helps to flush away the material, serves as a coolant to reduce the heat, and acts as a conductor for passing current between the work piece and the electrode.

2.Wire EDM

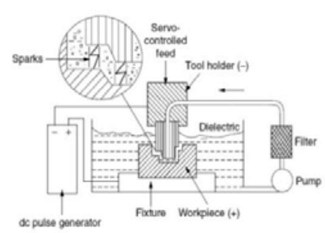
In this method, a thin wire is used as an electrode. The wire is fed in the metal and the discharges are used to cut the material. The process is carried out in a bath or flush of water. When closely observed, you can see that the wire does not touch the metal. All the cutting work is done by the electrical discharge. Computer software controls the whole operation including the path of the wire The process can produce all sorts of complex shapes that are very difficult with other processes.

PRINCIPLE OF EDM:

It is the most versatile electrical machining process where erosion is caused due to electric spark. The rate of metal removal and the resulting surface finish can be controlled by proper variation in energy and duration of spark discharge. It is the process of repetitive sparking cycles.

CONCEPT OF 4-AXES WIRE-CUT ELECTRIC DISCHARGE MACHINE

The ELEKTRA Wire-cut Electric Discharge Machine is comprised of a machine tool, a power supply unit (ELPULS), and a dielectric unit. A schematic diagram of a wirecut EDM is shown below



Electro discharge machining (EDM) Diagram

Machine Tool:

The machine tool comprises of a main work table (called as XY table), an auxiliary table (called as UV table), and a wire-drive mechanism. The work piece is mounted and clamped on the main work table. The main table moves along X and Y axes, in steps of 1 micron by means of servo motors. U & V axes are parallel to X & Y axes respectively.

As the material removal or machining proceeds, the electrode traverse along a predetermined path which is stored in the controller. The path specifications (path program) can be supplied to the controller through RS 232C port or floppy diskette from the part programming system ir directly through the controller keyboard.

When the XY table is moving along the predetermined path while the UV table is kept stationary, a straight cut with a predetermined path is formed.

In order to produce taper machining, the wire electrode has to be tilted. This is achieved by displacing the upper wire guide (along UV axes) with respect to the lower wire guide. The desired taper angle is achieved by simultaneous control of the movement of XY table and UV table along their respective predetermined paths stored in the controller. The path information of XY table and UV table is given to the controller in terms of linear and circular elements via NC program.

POWER SUPPLY

The power supply unit comprises of Electric pulse generator, motor driver units for X, Y, U, V axes and controller.

DIELECTRIC SUPPLY

While the machining is continued, the machining zone is continuously flushed with water passing through the nozzles on both sides of the workpiece. The spark discharge across the workpiece-wire electrodes causes ionization of the water which is used as a diclectric medium. It is important to note that ionization of water leads to the increase in water conductivity. An ion exchange resin is used in dielectric distribution system, in order to prevent the increase in conductivity and to maintain the conductivity of the water constant.

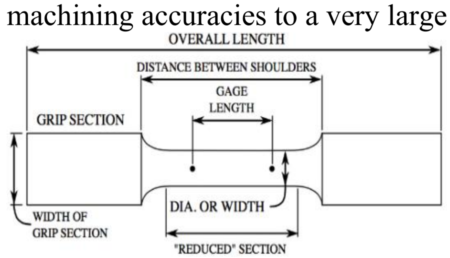
PART PROGRAMMING

The geometry of the profile and the motion of the wire electrode tool along the profile is fed to the controller. The profile geometry is defined in terms of various geometrical definitions of point, line and circle as the wire-tool path elements on graphical screen, by using a totally menu driven software, the wire compensation (for wire diameter and machining overcuts) and taper angle can be specified for the total path or for each path element separately. After the profile is fed to the computer, all the numerical information about the path is calculated automatically. The entered profile can be verified on the graphic display screen and corrected, if necessary. After successful profile definition, the profile is recorded by the computer on a floppy disc which can be used in the controller for execution.

WORK PREPERATION

1. WORKPIECE MATERIAL

Any slight dislocation in the workpiece material may result in distorted job. It is important to use the material free from residual stresses, arising from various processes. This may affect the machining accuracies to a very large extent.



Work piece material should be:

- Electrically conductive (at least 0.1 micro-ohm/cm).
- Suitable for clamping.

- Non-combustible.

- Non-violent chemical reactions with water, oxygen, hydrogen.

2. WIRE ELECTRODE

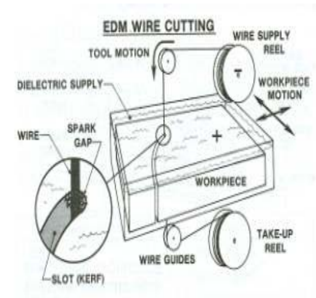
The wire electrode is required to have a sufficient tensile strength and should be of uniform diameter and free from kink or twist. The electrode wire material should be:

- Brass/super alloy (coated)
- Diameter variation within + or - 0.002mm
- Tensile strength more than 50Kgf/mm2
- Even winding, free from breaks/kinks.

2.1 Wire diameter and minimum corner radius:

Wire diameter of the wire imposes a restriction on the minimum achievable corner radius.

Minimum corner radius = (0.5*diameter) + overcut



2.2Current carrying capacity of the wire:

As a thumb rule, a brass wire of 0.2 mm in diameter can easily pass current of about0.3 to 0.7 amperes(A) in air, but the same wire can pass current of about 6 to 9 A in water. While machining, therefore, wire should be surrounded by the water column to avoidbreakage.

2.3 Wire tension (WT):

Wire tension determines how much wire is to be stretched between upper and lower wire guides. More the thickness of job, more is the tension required. Improper setting of tension may result in job inaccuracies as well as wire breakage. Following chart gives nominal values of wire tension for different setting. Minimum tension (for 0 setting of WT) is approx 500 gms

TENSION (Gms) NOMINAL VALUES

WT	SOFT WIRE	HARD WIRE
1	500-550	550-650
2	500-550	550-650
3	500-550	550-650
4	500-550	550-650
5	550-650	750-800
6	750-850	580-950
7	950-1020	1050-110
8	1100-1150	1250-1300
9	1150-1200	1450-1520
10	1250-1300	1600-1650
11	1400-1450	1700-1850
12	1500-1550	1950-2000
13	1600-1650	2100-2200

2.4 Wire feed (WF)

Due to spark erosion, the travelling wire-electrode becomes thin and brittle. Wire feed is the rate at which the wire electrode travels along the wire guide path. It is always desirable to set the wire feed to maximum. This will result in less wire breakage, better machining stability and slightly more cutting speed. With wire feed set at 8m/min, on an average a 0.25mm dia. brass wire spool of 5kg will last for 24 sparking hours. Setting WF at 15 will correspond to 15m/min(approx.)

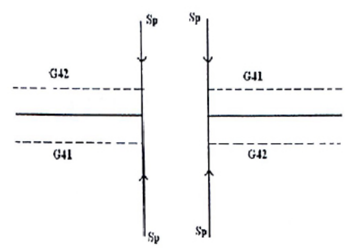
2.5 Overcut

It is the lateral distance between the wire and workpiece during the sparking.

Overcut is larger if:
- machining gap voltage is higher
- discharge energy is higher
- wire tension is lower
- guide span is higher
-job thickness is higher
- dielectric conductivity is higher
- machining is unstable

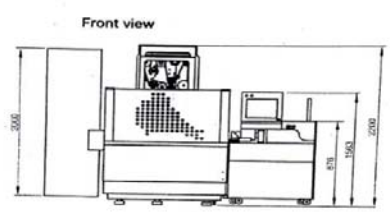
2.5 Wire Compensation (OFFSET)

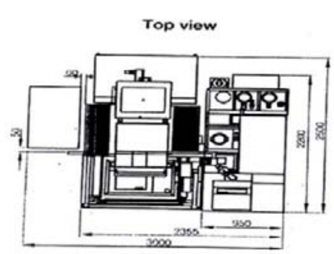
Wire compensation = (0.5*wire diameter) + overcut. Wire compensation can be to the left (G41) or right (G42) of profile depending upon the direction of motion and wire being inside or outside of profile as shown:



JOB PREPERATION

ABOUT THE MACHINE: ULTIMA 1S





Features:
5 axes CNC
High resolution linear optical scale for X, Y axes (0.5 μm)
Max. cutting speed: 200 mm^2/min
Surface finish: 0.4 p. Ra ae2 Pulse technology
Windows-based CNC
Auto power recovery
LCD screen
Touch screen monitor std. for Ultra cut S3 optional for Ultra cut SO
16-step programmable flushing
Capability of machining Poly-Crystalline Diamond
(PCD) and other exotic material
Programming Tool: ELCAM
Table size - 670 X 490 mm
Taper ±30° / 50 ram
Submerged machining technology
Front loading
Higher automation
Capable of machining PCD
0.1 mm diameter wire can be used

Technical Specifications:
Table Size: 670 X 490 mm
Maximum workpiece height: 250 mm
Maximum workpiece weight: 800 Kg
Main Table Traverse (X, Y): 400, 300 mm
Positioning Accuracy: 0.005 mm
Positioning Repeatability; ±0.002 mm
Aux. table traverse (u, v): 80, 80 mm
Maximum paper angle: ± 30° / 50 mm
Maximum JOG speed: 900 mm / min
Resolution: 0.0005 mm
Maximum wire spool capacity: 6 Kg
Wire electrode diameter: 0.25 mm (Standard), 0.1,0.15,0.20,0.30 mm (optional)

Pulse Generator- ELPULS - 50 S specifications:
Pulse peak voltage: 2 Steps
CNC controller: EMT 100 W - 5
Controlled axes: X, Y, u, v, Z simultaneous / independent
Interpolation: Linear and Circular
Least input increment: 0.001 mm
Least command input (X, Y, u, v): 0.0005 mm
Maximum programmable dim. (X, Y, U, V): ±99999.999 mm
Input power supply: 3 phase, AC 415V, 50 Hz
Connected load: 14 KVA includes dielectric system and cooling system
Average power consumption: 10 KVA
Data input / output: Standard ASCII keyboard, isolated RS 232 C serial interface USB memory stick, Ethernet
Dielectric Unit- DL
Dielectric Fluid: De-ionized water
Tank Capacity: 900 Liters
Filtration: Paper cartridge
Cooling System: 2600 K Ca

PROGRAM CODES

G-Code

G00	Rapid Linear Interpolation
G01	Linear Interpolation
G02	Clockwise Circular Interpolation
G03	Counter Clockwise Circular Interpolation
G04	Dwell
G05	High Speed Machining Mode
G10	Offset Input By Program
G12	Clockwise Circle With Entrance And Exit Arcs
G13	Counter Clockwise Circle With Entrance And Exit Arcs
G17	X-Y Plane Selection
G18	Z-X Plane Selection
G19	Y-Z Plane Selection
G28	Return To Reference Point
G34	Special Fixed Cycle (Bolt Hole Circle)
G35	Special Fixed Cycle (Line At Angle)
G36	Special Fixed Cycle (Arc)
G37	Special Fixed Cycle (Grid)
G40	Tool Radius Compensation Cancel
G41	Tool Radius Compensation Left
G42	Tool Radius Compensation Right
G43	Tool Length Compensation
G44	Tool Length Compensation Cancel
G45	Tool Offset Increase
G46	Tool Offset Decrease
G50.1	Programmed Mirror Image Cancel
G51.1	Programmed Mirror Image On
G52	Local Coordinate Setting
G54 - G59	Work Coordinate Registers 1 Thru 6
G60	Unidirectional Positioning
G61	Exact Stop Check Mode
G65	Macro Call (Non Modal)
G66	Macro Call (Modal)

G68 Programmed Coordinate Rotation
G69 Coordinate Rotation Cancel
G73 Fixed Cycle (Step)
G74 Fixed Cycle (Reverse Tapping)
G76 Fixed Cycle (Fine Boring)
G80 Fixed Cycle Cancel
G81 Fixed Cycle (Drilling / Spot Drilling)
G82 Fixed Cycle (Drilling / Counter Boring)
G83 Fixed Cycle (Deep Hole Drilling)
G84 Fixed Cycle (Tapping)
G85 Fixed Cycle (Boring)
G86 Fixed Cycle (Boring)
G87 Fixed Cycle (Back Boring)
G88 Fixed Cycle (Boring)
G89 Fixed Cycle (Boring)
G90 Absolute Value Command
G91 Incremental Value Command
G92 Work Offset Set
G101 User macro 1 (substitution) =
G102 User macro 1 (addition) +
G103 User macro 1 (subtraction) -
G104 User macro 1 (multiplication)
G105 User macro 1 (division) /
G106 User macro 1 (square root)
G107 User macro 1 (sine) sin
G108 User macro 1 (cosine) cos
G109 User macro 1 (arc tangent) tan
G110 User macro (square root)
G200 User macro 1 (unconditional branch)
G201 User macro 1 (zero condition branch)
G202 User macro (negative condition branch)

M - Codes

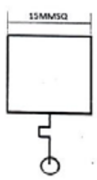
MOO Program stop (modal commands preserved)
MO I Optional Program stop
M02 End of program (modal commands preserved)
M03 AWT JUMP code
M05 ST CANCEL(ignores contact direction of op in one Direction only)
M06 No electrical discharge
M10 External Signal Output ON
M20 External Signal Output OFF

M33 - M37 External Signal Output ON
M43 - M47 External Signal Output OFF -ON and OFF codes are paired, for example: M33 (ON) and M43 (OFF).
M70 - M77 External Signal Output
M98 Sub-prgram call-up
M99 Sub-program completion
M199 Termination of Q File Execution Codes

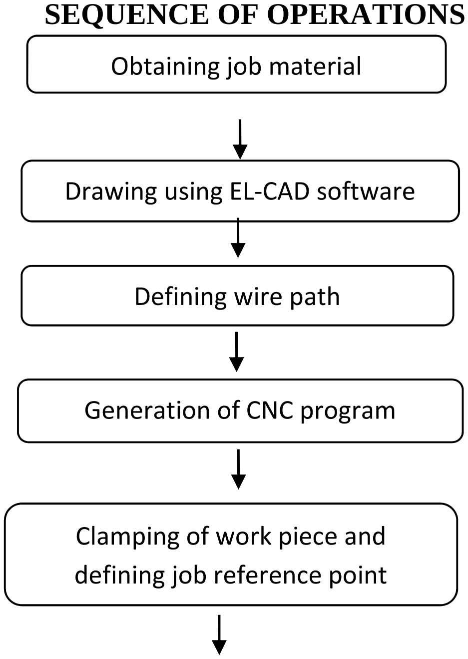
T80 Wire run
T81 Wire run stop
T82 Auto Drain OFF
T83 Auto Drain ON
T84 Pump On
T85 Pump Off
T86 Flush On
T87 Flush Off TN Table to Next (for cutting tapers)
M33 - M37 External Signal Output ON
M43 - M47 External Signal Output OFF -ON and OFF codes are paired, for example: M33 (ON) and M43 (OFF).
M70 - M77 External Signal Output
M98 Sub-prgram call-up
M99 Sub-program completion
M199 Termination of Q File Execution Codes
T88 Oil/Water (enables machining in oil to be performed)
T89 Oil/Water (for machining in water)
T90 AWT1 (anneals and then cuts the wire)
T91 AWTI (pass the cut wire through the bottom guide & connect it)
T94 Water Submerged Machining TP Table to Program (for cutting tapers)

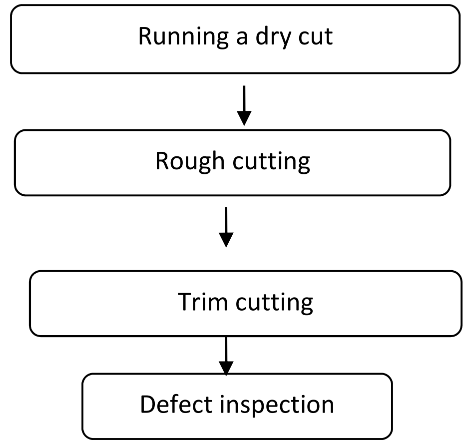
TEST CONDITIONS

1. Input Supply - 3amp 415 V AC (+/- 1%).
2. Room temperature is maintained at 20°C (+/- 1 C).
3. Dielectric water temperature is maintained l"C below the room temperature.
4. Proper heat treatment of the workpiece material is done to minimise the residual stresses.
5. Profile entry is taken from a start hole.
6. Upper and lower nozzles are very close to the workpiece (within 0.1mm to 0.2mm) during rough cut. For A, Dl, El, Fl, keep the flow meter valve lully open and adjust the gap between nozzle and workpiece to achieve the required flow given in the chart.
7. Wire used is ELEKTRA DURACUT (special brass).
   - SOFT WIRE: ELEKTRADURACUT
   - HARD WIRE: BERCOCUT BEDRA WIRE HARD CUZN37 900N/MM2.
8. For steel workpiece, material hardness of workpiece is 48-50Rc.
9. . Surface finish mentioned in the chart is measured after glass beading.
10. Profile for Test Cut (Punch).



SEQUENCE OF OPERATIONS:





OPERATION:

1.Selecting the job

job is obtained as a cast or forged or machined product, machined a little larger than the final dimensions.

2.Drawing using ELCAM software as per job drawing

ELCAM is a tried and tested, database-driven and professional CAE system in all aspects, which was developed for the specific requirements of electrical engineering and mechatronics.

ELCAM creates all required documents for the documentation of switchgears, machine controls, cabling, building installations and process engineering plants. ELCAM is used to create circuit diagrams, terminal and terminal connection diagrams, order and device lists, BOMs, input/output lists, tables of contents, wiring and cable lists, assembly and installation diagrams as well as layout diagrams for the cabinet.

3.Defining of wire path in connect mode

A path must be defined to tool(wire) in which the direction of cutting is supposed to proceed.

To get the required component, first we direct the wire to cut a slot of 9.0(+0.2)mm width upto 79.0(+/-0.1)mm depth from the top face and along with it, a R2.0 (TYP) corner radius with equality

4.Generation of CNC program s per drawing in CNC programming mode :

PROGRAM:

=;WELDER QUALIFICATION SPECIMEN(TI)(DRG:PD40-17)

```
G71
G9
G21
G40
G7
G50
G90
G75
```

;Wire compensation definations

```
D0=0
D1=0.165
E10600219
;#1.0 Cavity=1 rough cut
G0 X119Y28U0V0
M21
G24D0;D0=0
G1X120Y25
E10600210
G42D1;D1=0.185
G1X120Y20
G1X43Y20
G1X43Y19.25
G2X30Y6.25-1300
G1X-43Y19.25 10J13
G1X43Y20
G1X-140Y-20
G1X-43Y-20
G1X-43Y-20
G1X-43 Y-19.25
GLX-30Y-6.25
G2X43Y-19.2510J-13
G1X43Y-20
G1140YY-20
G1X140Y20
G1X120Y20
M0
G42D0;D0=0
G1X120X21
G40
M0
```

5. Clamping

The workpieceis clamped rigid and convenient for the operation on the table and the reference point is set precisely. The dimensional input given to the machine, will be based on this reference.

6. Dry Cut

A dry cut is performed at high speed to check the correctness of the program given. Any flaws in the program can be detected in this process. If the program is found to be correct, actual machining can begin.

7. Rough Cut

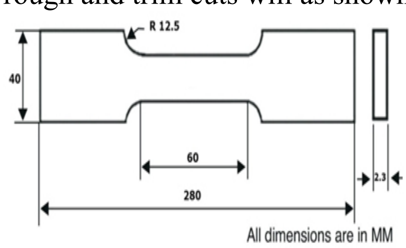
The job is subjected to a rough cut forming the required contour on the job material. The tool electrode (wire) is slowly fed into the job electrode (workpiece) with its path controlled by the program given by us and thus produces the required cut. The rough cut of the bracket tin lasts for approximately 480 minutes. Flushing is done continuously throughout the process as the debris is to be carried away and the dielectric properties of the inter-electrode gap must be restored.

8. Trim Cut

The job under operation, is subjected to a single trim cut as the surface finish requirement for a bracket fin is moderate. Usually in a machining, 2 to 3 trim cuts are employed based on the surface finish requirement. The purpose of the trim cutting is

- Higher job accuracy
- Improved surface finish
- Reducing inaccuracies due to minor job deformations after 1st cut.
- Reducing bow effect on cut surface due to adverse flushing conditions.
- Improving die life by removing the thermally affected layer formed in the first cut.

The structure of the job after the successive rough and trim cuts will as shown below:



9. CONCLUSION

1. The working principle and various other concepts involved in a non-traditional machining process called Electrical Discharge Machining (EDM) were studied
2. The project also involves making a component called "**Test specimen**" made of

the Maraging steel, used in section-4 of Akash missile using the "**Ultima 1S**" Wirecut EDM machine in Bharat dynamics ltd facility.

3. This test specimen undergoes tensile test in Universal Testing Machine (UTM) to measure and determine the weld strength at the joint.

10. References

1. Prajapati, Navneet K. and Patel, S. M.," Optimization of process parameters for surface roughness and material removal rate for SS 316 on CNC turning machine." International Journal of Research in Modern Engineering and Emerging Technology, Vol. 1, Issue: 3, pp.40-47, 2013.

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