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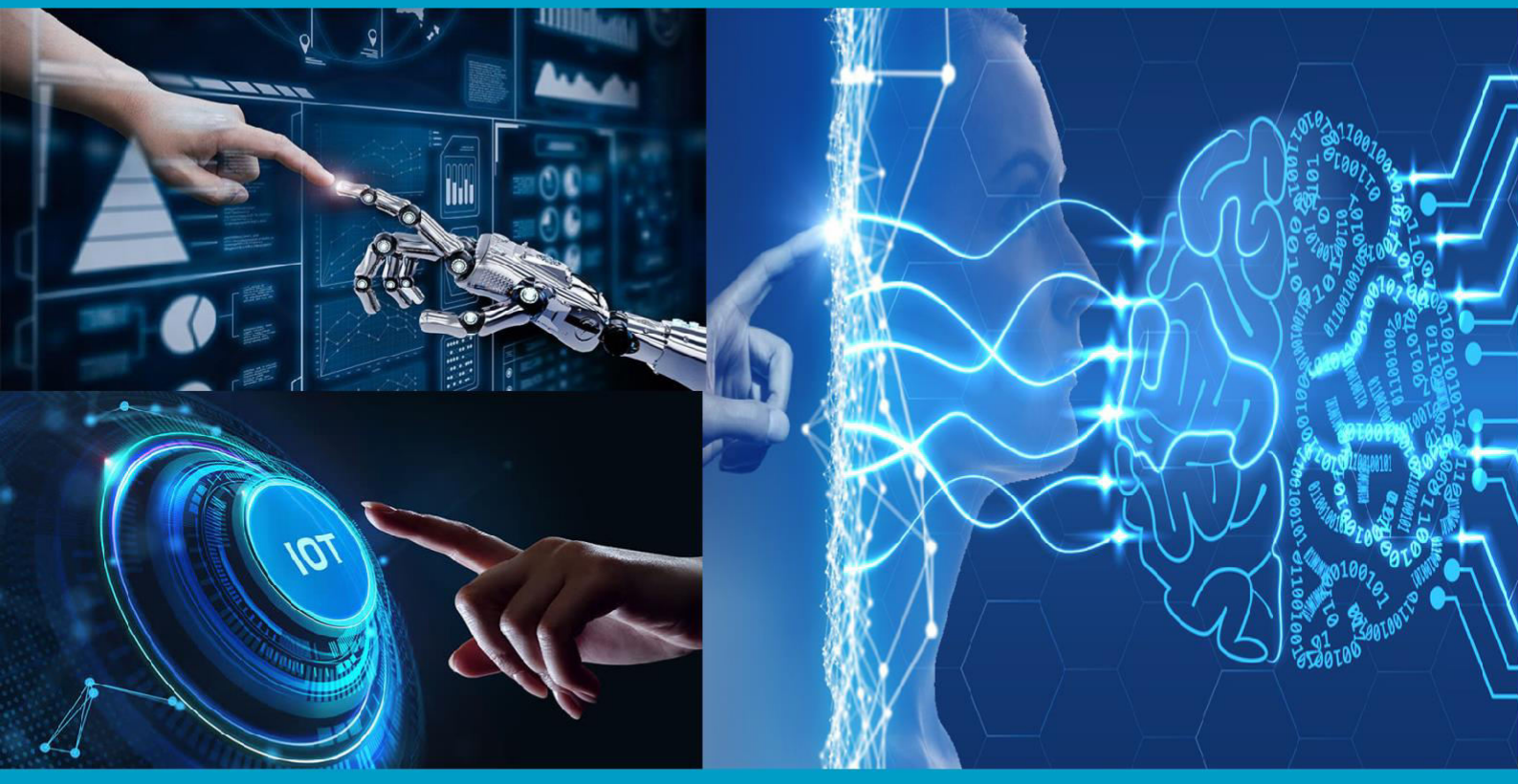

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Micro-Drilling Characteristics of D-2 Steel as a Function of Cutting Diameter

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ABSTRACT: The cutting parameter teaches us about an enhanced cutting parameter approach in dry turning of AISI D2 steel to ensure the least mechanical assembly wear and the lowest work piece material surface temperature. The net output informs us about the cutting rate and the importance of the cut, which are the most important parameters influencing the wear of equipment material. From there, ideal levels of equipment wear and work piece material surface temperature were envisioned. The study of the results indicated that liquid nitrogen had a significant influence on the surface temperature, power consumption, and surface hardness of the material. The most important i/p variables are cutting depth for power consumption and surface hardness. The optimized Power Consumption is 520 Watt at 280 RPM, 350oC, 0.60 mm cutting depth, and 0.32 mm/rev feeding speed.

KEYWORDS: Cutting Parameter, D-2 Steel, Liquid Nitrogen. Material Cutting

I. INTRODUCTION

Today's advanced materials, for example, fundamental earthenware manufacturing, high-temperature compounds, and metal-network composites, have gradually adjusted completed products with qualities like increased hardness, gigantic solidarity to weight proportion, controlled wear, and anticorrosive property. However, we need extra dimensional strength requirements for the final goods on net form in order to complete tasks more effectively. C-TAM machining has received extensive attention as a result of practical improvement concerns regarding traditional cooling specialists, with the goal of obtaining a less costly solution for the material cutting sector.

D2-STEEL

This steel is produced by the vacuum normalizing process, which involves heating in a furnace to a high temperature and then quickly cooling in vacuum medium. This steel is ideal for punches, dies, and injection moulding equipment. It is a difficult to machine material that necessitates the use of a specific wheel for surface grinding following heating treatments.

Composition

Table 1:D2 Steel Composition

C	Si	Cr	Mo	V
0.30%	1.50%	0.80%	0.80%	12.00%

Properties

D2 steel has the greatest proportion of C and the largest quantity of chromium. It has greater abrasion and wear resistance. It may be further heat treated to achieve surface hardness of 55-62 HRC and used for machining in a hot state. Cold work is also done using D2 steel.

Applications

- Stamping Die Sets
- Punches
- Forming-Rolls
- Shear-Blade Knives
- Tooling
- Scrap-choppers

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- Tired-shredders

I.1 Metal cuttingprinciple:

Material cutting is the most common method of eliminating undesirable debris from a work item.

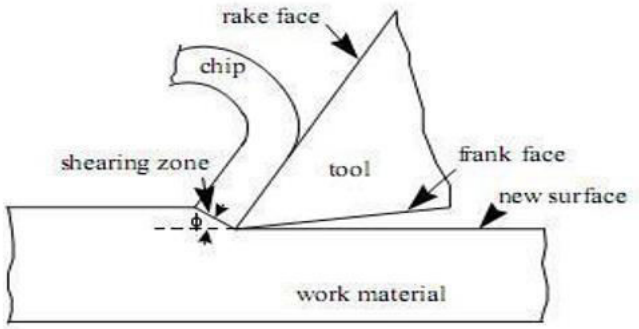

Figure 1: Basic of Material Cutting

Material cutting is the process of producing a finished product by eliminating undesirable trash from a particular work piece material. Fig. 1.1 depicted a thorough illustration of a standard material cutting method in which a sharp edge, wedge-shaped cutting tool was used to specify cutting depth and movement of relativeness to workpiece material by applying forces.

Metal is compressed towards the toolcut's tipping point. The material experiences shear forces, and a layer of material is removed, resulting in chips. Shearing of metal in front of the tool becomes effective if the work tool moves with regard to the work piece material. If shear occurs with regard to a plane, that plane is referred to as the shear plane.

The cost of material removal is high, and it is primarily based on MRR. On the other hand, cooling agent usage rises with MRR, which extends cutting tool life span by reducing friction between mating surfaces and heat produced in the shear zone. The temperature at the cutted zonal interface of the working tool to be used for cutting and the work piece material may be greatly altered by the cooling agent.

Material working fluids (MWF), often known as coolants, are a mixture of water and oil. Coolants are composed of 80% to 99% water, but are only utilised in the 5% range. Coolants are used in material working to lubricate and cool tools in order to prolong tool life, improve process quality, and achieve superior surface finishes.

The usage of a cooling agent is the cause of the high cost. When it comes to following sustainable development rules, some alternatives are to identify ways to limit the usage of cooling agents in metal removal processes, such as coolant less machining and cryogenic machining.

I.2 Cryogenic MachiningMethod

During the cutting strategy, a little amount of nitrogen liquid is applied to the rakeface of the cut instrument using the cryogenic machining process. Fluid N is supplied from either an outside mass tank or a high weight chamber near the machine through vacuum coat lines. Melted Nitrogen bubbles form a non-dangerous and inactive gas when they come into touch with heated surfaces (normal bubbling point=-1960C). Despite the fact that it successfully debuted in laboratories as a safe, cost-efficient, and effective coolant. Fluid Nitrogen necessitates a flying framework and conveyance by ventures capable of accommodating intricate instrument geometry and machine coordination.

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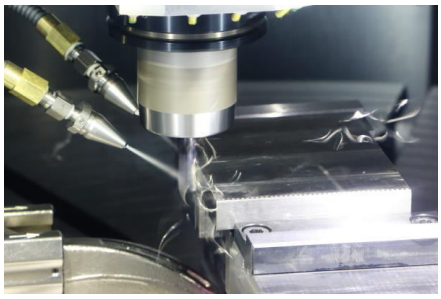

Figure 2: Cryogenic machining

1.3 Advantages of Cryogenic Machining

Metal machining generates very high temperatures, which are the primary cause of work tool failure. Traditional coolants are used to reduce heat and protect tooling. However, traditional coolants have several disadvantages, ranging from work piece material contamination to environmental dangers and high disposal costs. Cryogenic machining systems provide significant savings over standard coolants.

- Reduced device wear
- Surface Integrity & Parting Qualities
- Environmentally friendly green assembly
- No additional danger Coolant-element
- Least Over heading Charging

II. RELATED WORKS

Many academics and researchers are investigating cryogenic machining and heat aided machining. Investigate the effect of speed, feed, and depth of cut on yield characteristics such as surface roughness, device wear, hardness, Power Consumption, and so on on D2 steel. Literature on cryogenic and thermal assisted machining using the Taguchi method has been compiled from a variety of sources, including internet articles and international journals (available at websites sciencedirect.com, scholar.com, and international journal.org) using keywords such as cryogenic process, D2 steel, and thermal assisted machining. In order to conduct the present study, the following literature has been reviewed:

Chinchanikar and colleagues [2015] The researcher investigated a plethora of facts of machining of this kind of steel employing various cutting tool materials and discovered exceptional results. Das and colleagues [2014] This study informs us about an improved approach for cutting parameters in dry turning of AISI D2 steel to provide the least mechanical assembly wear and the lowest work piece material surface temperature. The test game plan was developed using the Taguchi-L9 Orthogonality display approach, and ANOVA is being used to examine the delayed effect of the cutting parameters on the variable yields. The ensuing recommendations for cutting rate and magnitude of cut are the most important elements influencing the wear of equipment material. The instrument wear was lowest when the cut was 0.5 mm, the feed was 0.25 mm/fire up, and the cutting speed was 150 m/min. The lowest workpiece material surfacing temperature was obtained at a cutting speed of 150.00 m/min, significance of cutting of 0.500 mm, and feeding of 0.25000 mm/fire up. From there, ideal levels of equipment wear and work piece material surface temperature were envisioned.

Giraud and colleagues [2013] Dynamic shear tests were done on 4mm thick plates of AZ31B-O magnesium amalgam utilising a Gleeble machine and an exceptionally well-organized equipment.

Umbrello and colleagues [2012] The results of a trial technique to determine the effect of cryogenic coolant on surface trustworthiness in symmetrical metal evacuation of solidified AISI 52100 steel are presented in this research. The examinations were prepared under dry and cryogenic circumstances using chamfered CBN instrument modifications. Several test approaches were used to inspect the machined surface, including analysing electron magnifying lenses (SEM) for surface geography characteristics.

Pusavec and colleagues [2010] The witticism of this investigation was to supply a few guidelines in eco-friendly machining forms, using cryogenic temperatures, reduced environmental, expanded security, and so on. The investigation delves into the complexities of cryogenic liquids and their use in metal evacuation forms as an alternative to oil-based cutting solutions. The nuances of fluid nitrogen and the strategies for using it in metal extraction forms, known as the Cryogenic Machining Method.

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The designers of Ahmad-Yazid et al. [2010] have represented the most current attempt in metal slicing cooling is employing chilled air and cryogenic cooling. For this low-effort refrigeration purpose, a Ranque-Hilsch vortex tube (RHVT) is used. The history of the Ranque-Hilsch vortex tube, numerous studies conducted on it, its exposition, and applications for the quick material cutting cooling application for kick the bucket and form steels are completed. A future study topic has been suggested.

Weinert et al. [2009] believed that the elimination of cooling greases in current dry machining and MQL advances had resulted in significant advancements in machining innovation. Many machining processes and work piece material materials have been developed by using modern cutting apparatuses and machining approaches. Wet machining process production time is being reduced somewhat while work piece material quality is being improved.

Dumitrescu and colleagues [2006] Problems with combining CO2 and Nd-YAG lasers into a machining focus aided machining development. Huge amount of power in blending in with various frameworks Consuming diode lasers consolidate more significant effectiveness; however, because to their lower Power Consumption thickness, their current metal preparation uses are constrained to surface solidifying and joining.

III. PROBLEM FORMULATION AND METHODOLOGY

Taguchi Method

The optimum condition is explored in every accessible condition with the aim of making the influence of wild components produce the least variety accessible framework operate limit. The most important parameter structuring tools are symmetrical clusters change and SN proportion assessment.

Process Optimization

It teaches us about the mechanisms needed to create a structure as convincing as possible, especially the numerical technique involved. Similarly, improvement involves keeping a portfolio in such a way that yield is increased for a given threat level, or risk is reduced for a certain accounted yield level. The general benefit is that it increases competence while also lowering costs. Scientific Modeling OAs Strategies Successful use of OAs reduces the number of tests to be considered. Using the OAs trial structure, the results of numerous elements on the exhibition trademark in an investigation may be examined.

Experiments for Design

Table 2: Experiment of Design (Taguchi Method)

Exp.	A	B	C	D
1	1	3	3	3
2	2	2	3	1
3	2	3	1	2
4	1	1	1	1
5	3	2	1	3
6	3	2	1	3
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

I. ProblemFormulation

The issue is analyzing the CTAM results on turning operations of steel D - 2 acting as a cutting tool with a carbide tip point.

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Table 3: Input Parameters and Its Values

Parameters	Values		
	Sate 1	State 2	State 3
Temp. (°C)	250	300	350
Speed (rpm)	155	209	280
Feeding (mm/rev)	0.12	0.18	0.32
Cutting Depth (mm)	0.4	0.6	0.8

The AISI D2 steel length 150 mm and diameter 25mm in cylindrical form is used to analyse the research procedure. Experiment setup was built in such a manner that all of the above-mentioned input parameters were used.

IV. EXPERIMENTATION

Cutting depth (mm) (0.20, 0.40, and 0.60), work-piece temperature (oC) (250, 300, and 350), feed rate (mm/rev) (0.12, 0.18, and 0.32), and speed (rpm) were chosen as input parameters (155, 209, and 280) The work piece material is pre-heated in the Muffle Furnace to temperatures (oC) of 250, 300, and 350, while the rotating cutting tool tip is cooled using liquid Nitrogen. DOE allows you to alter the input settings.

Taguchi Technique optimizes the output characteristics of surface hardness (highest-the-best), power consumption (lowest-the-best), and tool tip surface temperature (lower the better). The following items were utilised in the experiment:

I.1 Tong tester

A tong tester, according to electrical engineers, is a device with two jaws that open to grasp around a metal. This is mostly used to measure current in various metals, although physical current is essentially non-existent, as seen in Figure 3.

Figure 3: TongTester

4.2 InfraredThermometer

It is a non-touchable gadget that estimates the temperature of the targeted object by using infrared light radiation. The contact temperature was measured by infrared temperature estimate with rapid response, high exactness, easy activity, lengthy and safe extended help life.

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Figure 4: Infrared Thermometer

4.3 Machine for Lathe

It is a mechanical mechanism that rotates the substance of the working component against a device. The axle is the machine's movable part that holds the work piece material or, in certain situations, the device material. It is propelled by an electric engine through a series of equipment preparations and belt drives. The revolutional speed is controlled by adjusting the geometry of the drive train. The turning method on the machine, as indicated in Fig. 4.3

Figure.5: Turning operation on lathe machine

V. RESULTS AND ANALYSIS

A appropriate arrangement was devised to combine the cryogenic method with the C-TAM technique to get the optimum results.

5.1 InputParameters

The following parameters were examined for this study:

- Speed (rpm)
- Temperature of the work piece material (C) after pre-heating in a Muffle furnace
- Cutting depth (mm)
- Feed Rate (mm/rev)

All of the settings are selected in conjunction with the tool's recommendations.

Testing andAnalysis

After removing the material, the following properties connected with machining develops samples will be analysed:

- Surface Hardness (Rockwell) (HRC)
- Output Table for SNRs *Sm Surface Temperature of Cutting Tool Tip (C) After LN2 Cooling
- Energy Consumption (Watt)

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Experimental Data

Depending on the input machining settings. Minitab 17 generated the Design of Experiment (DOE). Table 4 depicts the DOE of experiments.

5.1 DOE byapplying TaguchiMethod

Table 4: Taguchi Design of Experiment Taking Four Factors.

A	B	C	D
1	3	3	3
2	2	3	1
2	3	1	2
1	1	1	1
3	2	1	3
3	2	1	3
3	1	3	2
3	2	1	3
3	3	2	1

Table 5.2 *Experimental Readings Taking Input Parameters*

Temperature(°C)	Speed(rpm)	Feeding Rate (mm/rev)	Depth of cutting (mm)
250	155	0.12	0.2
250	209	0.18	0.4
250	280	0.32	0.6
300	155	0.18	0.6
300	209	0.32	0.2
300	280	0.12	0.4
350	155	0.32	0.4
350	209	0.12	0.6
350	280	0.18	0.2

5.2 Experimentalresults

The results of using the Taguchimethod on the input parameters of depth of cut, Feed Rate temperature, and speed to the output parameters of surface temperature, power consumption, and surfacing hardness.

Table 5: Experimental Reading Results

Temp (^{O}C)	Speeding	Feeding Rate	Cutting Depth	Power Consumption (watt)	Surface Hardness (HRC)	Surface temp(^{O}C)
250	155	0.12	0.2	528	60	28.2
250	209	0.18	0.4	550	61	30.3
250	280	0.32	0.6	682	62	36.6
300	155	0.18	0.6	620	62	34.0

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300	209	0.32	0.2	638	62	32.0
300	280	0.12	0.4	630	63	33.2
350	155	0.32	0.4	660	64	35.0
350	209	0.12	0.6	618	64	36.6
350	280	0.18	0.2	650	64	34.0

5.3 PowerConsumption

SNR Analysis for Power Consumption

SNR is the criterion used to analyse the output of the Taguchimethod. Smaller is preferable.

Table 6:SNR Results Using Taguchi Method

Temp	Speeding	Feeding Rate	Cutting Depth	Consumed Power	S/N Ratio
250	155	0.12	0.2	528	-54.4527
250	209	0.18	0.4	550	-54.8073
250	280	0.32	0.6	682	-56.6757
300	155	0.18	0.6	620	-55.8478
300	209	0.32	0.2	638	-56.0964
300	280	0.12	0.4	630	-55.9868
350	155	0.32	0.4	660	-56.3909
350	209	0.12	0.6	618	-55.8198
350	280	0.18	0.2	650	-56.6754

3.1 Analysis of Variance for SN ratios(ANNOVA)

The data for Energy Consumption computed using experimental terms were analysed using ANNOVA to determine the important parameters. The final findings of ANNOVA discovered for response parameters are listed below.

Table 7: SNR ANOVA

Parameter	Df	Seq.SS	Adj.SS	Adj.MS	f	p	Remarks
Temp.	2.0	1.01874	1.01874	0.509370	12.54	0.04*	Significant
Speed	2.0	0.83816	0.83816	0.419081	14.25	0.03*	Significant
Feed Rate	2.0	1.65932	1.65932	0.829659	0.95	0.01*	Significant
Depth of cut	2.0	0.55885	0.55885	0.279426	8.54	0.02*	Significant
Total	8.0	4.07507					

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*The values of P for cutting depth, temperature, feeding rate, and velocity are 0.02, 0.04, 0.01, and 0.03 respectively. If the value is P0.05, it is legitimate and noteworthy. As a result, all four factors have substantial importance.

VI. CONCLUSION & FUTURE SCOPE

6.1 Conclusions

Based on the findings of the trials, the following conclusions were reached:

- The results showed that liquid nitrogen has a significant impact on the surface temperature, power consumption, and surface hardness of the material.
- The most important i/p variables are cutting depth for power consumption and surface hardness.
- Tooling speeds have a minor role in the CTAM of D2 alloy steel.
- The optimised surface temperature is 24.44 oC at a speed of 209 RPM, a temperature of 350oC, a cutting depth of 0.60 mm, and a feeding speed of 0.32 mm/rev.
- The optimised Surface Hardness result is 64.68 HRC at 209 RPM, 350oC, 0.60 mm cutting depth, and 0.12 mm/rev feeding speed.
- The optimised result for Power Consumption is 520 Watt at 280 RPM, 350oC, 0.60 mm cutting depth, and 0.32 mm/rev feeding speed.

6.2 Futurescope

According to the present study, there are far too many opportunities for additional growth in this work.

- This approach may be enhanced in the future by employing new output parameters and different input parameters.
- C-TAM Technique may be utilised on various equipment such as shapers, grinders, and milling machines.
- This process might be used to manufacture other hard alloy materials.

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