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EFFECTS ON POWER BY CRYOGENIC THERMAL ASSISTED TURNING ON D2 STEEL

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ABSTRACT

The need for high strength and wear resisted materials is rising with the advancement in technologies. But the difficulty has been found in machining these materials efficiently, due to their extra strong properties as compared to conventional materials. Various techniques has been devised to tackle the problems associated the machining of hard materials. Thermal assisted machining is one approach to soften the work-piece and ease the cutting operation. On the other hand cryogenic machining is the technique to cool down the tool with the aid of liquid nitrogen and reduce the tool wear.

The aim of present research is to devise a new technology C-TAM, which is the combination of both thermal assisted machining (TAM) and cryogenic machining. The work will be simultaneously heated and the tool be cooled with liquid nitrogen. This set-up will avail the benefits of both the technologies, and improvement will be graphed by taking various input and output parameters. The turning operation are carried out on D2 steel which is a hard material. The input parameters have been used are work piece temperature, Feed Rate, Speed, Depth of Cut and output parameters is Power Consumption. To obtain optimum results Taguchi method has been used. Optimize Results for Power Consumption is 520 Watt at temperature 350°C, speed 280 RPM, Feed Rate 0.32 mm/rev, Depth of cut 0.6 mm.

Keywords: *Thermal Assisted Machining, Cryogenic Machining, D2 Steel, work piece temperature, C-TAM, tool wear.*

I. INTRODUCTION

In recent years advanced materials, such as structural ceramics, high-temperature alloys and metal-matrix composites, have increasingly been used to endow products with attributes such as high hardness, large strength-to-weight ratio, enhanced wear and corrosion resistance. However, dimensional requirements for the finished products commonly preclude reliance on net shape forming processes and finishing operations are needed. When applied to such materials, conventional machining processes suffer from low material removal rates, rapid tool wear and/or severe damage to the work piece. However, these problems may be mitigated by using a hybrid process termed thermally-assisted machining (TAM), for which an intense heat source is used to thermally condition the work piece before material is removed by conventional means. Prompted by the environmental concern about conventional cutting fluid, cryogenic machining has received increased attention with the aim of finding an economic alternative for metal cutting industry.

Introduction to D2 Steel

D2 steel is steel that is heat treated in vacuum i.e. raised to aupper critical temp and quenched in vacuum process it is an ideal steel to use for punch, dies and injection mould tools. Machining is hard on this steel and requires a special wheel for surface grinding after heat treatment. It also hardly moves during the treatment process so you can manufacture parts as thin as 2 mm and leave only 0.004 mm for finish grinding. Composition of D2 Steel is given below

C	Si	Cr	Mo	V
1.50%	0.30%	12.00%	0.80%	0.90%

Properties of D2 steel is an air hardening, high-carbon, high-chromium alloy steel. It have high wear and abrasion resistant properties. It is heat treatable and have surface hardness in the range 55-62 HRC, and is machine-able in the annealed condition. D2 steel is widely used in cold work applications requiring high compressive strength. D2 steel has high chromium content gives it mild corrosion resisting properties.

Applications

- Stamping or Forming Dies
- Punches
- Forming Rolls
- Knives, Slitters, Shear Blades
- Tools
- Scrap choppers
- Tyre shredders

Introduction to Cryogenic Machining Process

The cryogenic machining process consists, introducing small quantity of Liquid Nitrogen on to the rake face of the cutting tool, during the cutting process. Liquid nitrogen is either transported from a bulk tank outside the building or from a pressurized cylinder close to the machine through vacuum jacket lines. The control box, integrated with the machine controller, would signal the Liquid Nitrogen flow on demand, through flexible lines, to specifically designed nozzles either integrated into the clamp or mounted close to the insert. The nozzle discharges a stable, precise liquid Nitrogen jet towards the chip/tool interface and care is taken not to impinge the cryogenic jet directly onto the work piece to prevent work piece freezing. Liquefied Nitrogen boils on contact with warmer surfaces (normal boiling point=-196^{o}C) to form a non-toxic and inert gas. Liquid Nitrogen requires industrial delivery and jetting system capable of accommodating diverse tool geometries and integration with lathe machine.

Figure:- Cryogenic machining

II. LITERATURE REVIEW

Chinchanikar, et al. [2015] The researchers have worked on many facts of machining of hardened steel using different tool materials and conclude the significant results. Researchers have investigate the effects of cutting parameters, tool materials, different coatings and tool geometry on different machinability aspects like, the tool life, surface roughness, cutting forces, chip morphology, residual stresses and the tool–chip interface temperature under dry, semi-dry and flood cooling environment during machining of hardened steels while many of them have proceed to characterize the wear phenomenon**.**

Das, et al. [2014] In this paper an optimization method of the cutting parameters (depth of cut,cutting speed and feed) in dry turning of AISI D2 steel is used to achievelow work piece surface temperature and minimum tool wear. The experimental layout was designed based on the Taguchi's L9 Orthogonal array technique and analysis of variance (ANOVA) was performed to identify the effect of the cutting parameters on the variables response.

The results reveal that depth of cut and cutting speed are the most significant parameters influencing the tool wear.

Giraud et al. [2013] Dynamic shear tests using a Gleeble machine have been performed on 4 mm thickness disks of AZ31B-O magnesium alloy, using a special designed tool. In order to include the effects of the cryogenic cooling in the material behavior, the specimens have been submitted to temperatures ranging from -25°C to 40.This paper represents the success of a FE model for metal cutting process is strongly dependent on the accurate characterization of the work piece material, under similar conditions as those found in metal cutting.

III. PROBLEM FORMULATION AND METHODOLOGY

Introduction of TAGUCHI Method

The Taguchi experimental design method is a well-known, unique and Power Consumption technique for optimization of process parameters. Taguchi method is widely used for experimental analysis and product or process optimization. The optimum condition has been selected so that the influence of uncontrollable factors causes minimum variation to system performance.

Process Optimization

It refers to the procedures used to make a design as effective or functional as possible, especially the mathematical techniques involved. Process optimization is the discipline of adjusting a process to optimize some specified set of parameters without violating some constraint.

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TAGUCHI' S Design of Experiments (DOE)

Table:- Taguchi's Design of Experiment

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

Problem Formulation

The problem is to study the effect of cryogenic thermal assisted machining on turning of D2 steel by using the carbide tip cutting tool. The machining input parameters temperature, speed, feed and depth of cut has to be varied as follows

Table:-The Input Parameters And Its Values

Parameters	Values		
	Level 1	Level 2	Level 3
Temperature (°C)	250	300	350
Speed (rpm)	155	209	280
Feed (mm/rev)	0.12	0.18	0.32
Depth of cut (mm)	0.2	0.4	0.6

For performing the research work, the AISI D2 steel diameter 25mm and length 150 mm in cylindrical shape has been used. Experimentation setup has been made so that all above mentioned inputs have been applied. The experiments have been carried out on center lathe machine with speed variation and liquid nitrogen.

IV. EXPERIMENTATION

The experimentation on turning operation has been done on D2 steel with carbide tip tool on lathe machine located at SGI Shri Ganga Nagar. The selected input parameters are work-piece Temperature (ºC) (250, 300, and 350), Speed (rpm) (155, 209, and 280), Feed rate (mm/rev) (0.12, 0.18, and 0.32) and Depth of cut (mm) (0.2, 0.4, and 0.6). The work piece is pre-heated up to temp (ºC) 250, 300 and 350 in Muffle Furnace, while turning cutting tool tip is cool down by using liquid Nitrogen. Input parameters are varied according to design of experiment.

The output parameter i.e. power consumption (lower-the better) are optimized by Taguchi Technique. The equipment used for the experimentation are as follows:

Tong tester
In electronic and electrical engineering, a current clamp or current probe having two jaws which open to allow clamping around an electrical conductor. This allows the electrical current in the conductor to be measured, without having physical contact with it.

Infrared Thermometer
Infrared thermometer is a non-contact Thermometer, the instrument measuring the measured object by receiving the infrared light radiation to determine the temperature of the measured object. Than the contact temperature measurement, infrared temperature measurement with high precision, fast response, easy operation, safe and long service life. Ideal for moving objects with the place and thermocouple temperature measurement cannot be measured in many places to replace thermocouple temperature to reduce Power Consumption even lower maintenance costs.

Lathe Machine
On lathe machine work piece is hold in chuck and rotated. The spindle is the part of the lathe that rotates. Lathe is run by electric motor by belt drives and gear trains.
Carbide Tip Tool

Carbide tip tool is a common material for cutting tool. For example, lathe bits, Carbide tip tool drill bits, saw blades, router bits and dental drilling tips are generally made of carbide. It stays sharper longer than most other materials.

Liquid Nitrogen
Liquid nitrogen is used for many cooling and cryogenic application

V. RESULT SAND DISCUSSION

A suitable arrangement made to apply the C-TAM technique as well as cryogenic technique simultaneously to get better results. The nozzle of setup has been arranged near the spindle of lathe machine so the aerosols are spread in tool and work piece interfaces.

Input Parameters
Following are the parameters considered for this study:

- Work piece Temperature (˚C) after pre-heating in Muffle furnace
- Speed (rpm)
- Feed Rate (mm/rev)
- Depth of cut (mm)
- The Combinations of these parameters are selected as the tool recommendations.

Testing and Analysis

After machining, the following machining Properties of samples will be tested to analyze:

- Surface Temperature of cutting tool tip (˚C) after cooling by liquid Nitrogen
- Power Consumption (Watt)
- Rockwell Surface Hardness (HRC)

Table:- Experimental Readings Taking Input Parameters

Temp (°C)	Speed(rpm)	Feed Rate(mm/rev)	Depth of cut(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

Experimental results

The results of output parameters i.e. Power Consumption, Surface Hardness and surface temperature by using Taguchi method on the input parameters i.e. temperature, speed, Feed Rate and depth of cut.

Analysis of Variance for SN ratios (ANNOVA)

The data obtained by via experimental runs for Power Consumption were subjected to ANNOVA for finding out the significant parameters. The results of ANNOVA thus obtained for response parameters are shown below

Table:-Experimental Reading Results

Source	Df	Seq. SS	Adj. SS	Adj. MS	F	P	Remarks
Temp.	2	1.01874	1.01874	0.509370	12.54	0.04*	Significant
Speed	2	0.83816	0.83816	0.419081	14.25	0.03*	Significant
Feed Rate	2	1.65932	1.65932	0.829659	0.95	0.01*	Significant
Depth of cut	2	0.55885	0.55885	0.279426	8.54	0.02*	Significant
Total	8	4.07507					

The value of P for Temperature, Speed, Feed Rate and Depth of Cut are 0.04, 0.03, 0.01, and 0.02. If the value of P<0.05 the value is significant. So all four parameters have significant value.

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Graphs of Effect of Parameters on Power Consumption

Power Consumption versus temp, speed, Feed Rate, depth of cut

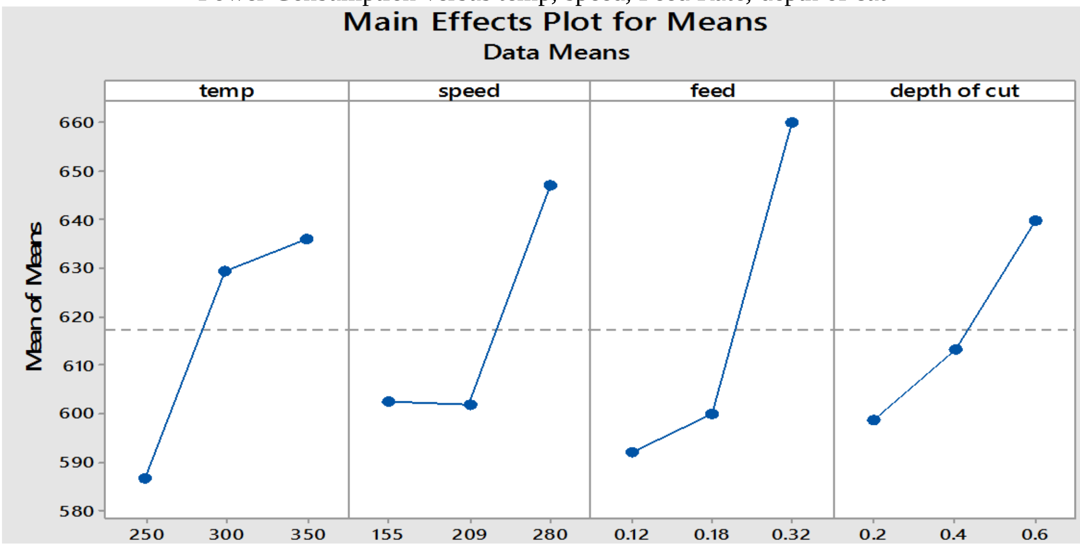
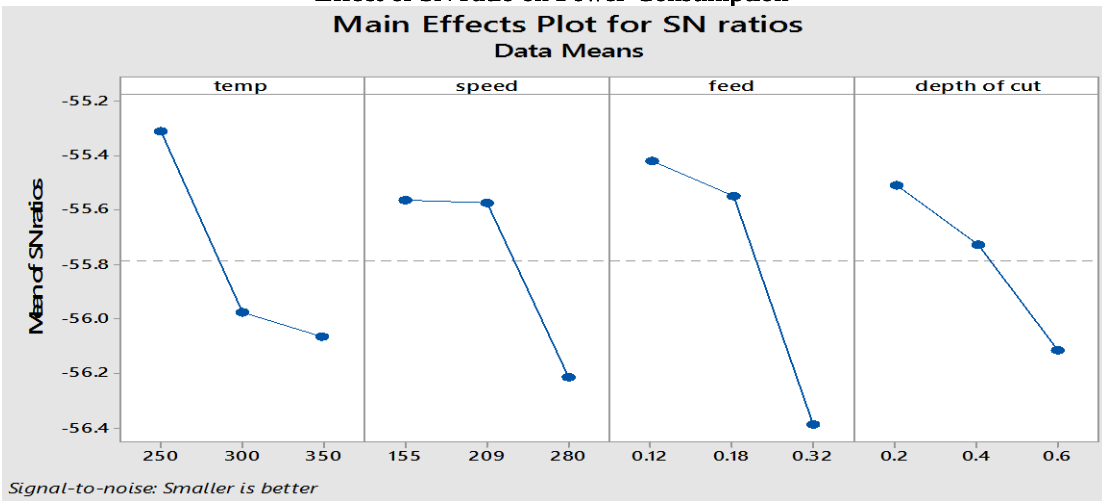


Table:-Analysis of Variance for SN Ratios

Temp (^{O}C)	Speed (RPM)	Feed Rate (mm/rev)	Depth of cut (mm)	Power Consume (watt)
250	155	0.12	0.2	528
250	209	0.18	0.4	550
250	280	0.32	0.6	682
300	155	0.18	0.6	620
300	209	0.32	0.2	638
300	280	0.12	0.4	630
350	155	0.32	0.4	660
350	209	0.12	0.6	618
350	280	0.18	0.2	650

Effect of SN ratio on Power Consumption



Optimize Results for Power Consumption is obtained at temperature 350°C, speed 280 RPM, Feed Rate 0.32, Depth of cut 0.6

VI. CONCLUSION

Based on the experimental results, the following conclusions are as follows:

- The analysis of the result revealed that, the liquid nitrogen has a great effect on Power Consumption.
- The most significant input parameter is depth of cut for power consumption.
- Speeds of tool have the minimum involvement in the CTAM of D2 alloy steel.
- Optimize results for Power Consumption is 520 Watt at temperature 350°C, speed 280 RPM, Feed Rate 0.32 mm/rev, Depth of cut 0.6 mm.

VII. FUTURE SCOPE

- From the current study it has been observed that there are more scopes in this work for further research.
- This technique can further be extended by taking other output parameters and using various other input parameters.
- C-TAM Technique can be used on other machines like shaper, grinding, milling
- Other hard alloy material could be machined using this technique

REFERENCES

1. ***Ahmad-Yazid, A. and Almanar***, *I.P., 2010. A review of cryogenic cooling in high speed machining (HSM) of mold and die steels. Scientific Research and Essays, 5(5), pp.412-427.*
2. ***Anderson, M., Patwa, R. and Shin, Y.C.,*** *2006. Laser-assisted machining of Inconel 718 with an economic analysis. International Journal of Machine Tools and Manufacture, 46(14), pp.1879-1891.*
3. ***Bermingham, M.J., Palanisamy, S., Kent, D. and Dargusch***, *M.S., 2012. A comparison of cryogenic and high pressureemulsion cooling technologies on tool life and chip morphology in Ti–6Al–4V cutting. Journal of Materials Processing Technology, 212(4), pp.752-765.*
4. ***Bhattacharya, A., Das, S., Majumder, P. and Batish, A.,*** *2009. Estimating the effect of cutting parameters on surface finish and Power consumption during high speed machining of AISI 1045 steel using Taguchi design and ANOVA. Production Engineering, 3(1), pp.31-40.*
5. ***Chinchanikar, S. and Choudhury, S.K.,*** *2015. Machining of hardened steel experimental investigations, performance modeling and cooling techniques: a review. International Journal of Machine Tools and*

Manufacture, 89, pp.95-109.

6. ***Das, D., Dutta, A.K. and Ray, K.K.,** 2009. Influence of varied cryotreatment on the wear behavior of AISI D2 steel. Wear, 266(1-2), pp.297-309.*
7. ***Das, S.R., Kumar, A. and Dhupal, D.,** 2014 Estimating the Effect of Cutting Parameters on Tool Wear and Work piece Surface Temperature in Turning of AISI D2 Steel.*
8. ***Takacs, M. and Farkas, B.Z.,** 2014. Hard cutting of AISI D2 steel. In Proceedings of the 3rd International Conference on Mechanical Engineering and Mechatronics (pp. 14-15).*
9. ***Umbrello, D., Micari, F. and Jawahir, I.S.,** 2012. The effects of cryogenic cooling on surface integrity in hard machining: A comparison with dry machining. CIRP Annals-Manufacturing Technology, 61(1), pp.103-106.*
10. ***Venugopal, K.A., Paul, S. and Chattopadhyay, A.B.,**2007. Tool wear in cryogenic turning of Ti-6Al-4V alloy. Cryogenics, 47(1), pp.12-18.*
11. ***Weinert, K., Inasaki, I., Sutherland, J.W. and Wakabayashi, T.,** 2004. Dry machining and minimum quantity lubrication. CIRP Annals-Manufacturing Technology, 53(2), pp.511-537.*