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Performance enhancement of Cutting Tools by using Cryogenic Treatments

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Abstract - *This dissertation concentrates on improving the life of micro tools. According to research by A. Aramcharoen in 2008, Tin coated micro tools give best performance. In this study we have introduced Cryogenic science to the micro tools to improve the life span of micro tools. The task of tools is to improve surface finish and take the accuracy of dimensions to a desired level. With continuous use of tools, ability of tools to complete these tasks vanishes and this life period of tool should be as high as possible because manufacturing of tools take too many efforts and high time as well as money investment. The improvement in life of the tools using Cryogenic treatment, without ignoring the factors like surface finish of the work piece, cutting forces acting etc. is studied in this paper.*

***Key Words*:** Micro tools, tin coated, Cryogenic, tools, manufacturing.

1. INTRODUCTION

Demand of miniaturization of electrochemical devices in Aerospace, Automobile, Biomedical and Defence industries is increasing rapidly and this is the key drive for developing a new method of manufacturing highly efficient tools. Machining with worn tool increases the cutting forces, surfaces and ultimately overall machining performance. Cryogenic treatment has taken tools to the improved level of performance in micro machining in terms of life of tools, cutting forces, surface finish etc. In the study it is observed that, in micromachining the rapid tool wear generates extremely higher cutting forces and this deteriorates surfaces. Technology of introduction of Cryogenics to the tools shows advantages both in terms of improved tool life and quality of the manufactured component. Cryogenic treatment is also known as sub-zero heat treatment. This treatment has made significant contributions to the improvement of wear resistance, life dimensional integrity and tool life.

Cryogenic Coolants gave a promising strategy with the potential to eliminate many of the issues like production cost, health issues and wear on surface of cutting tools. Traditional cooling fluids are replaced with liquid carbon dioxide (CO2) or liquid nitrogen (LN2). The two media vary considerably both in terms of their boiling temperature and in terms of cooling delivery mechanism. In cryogenic treatment the formation of martensite and precipitation of η-phase is body phenomena so it gives better hardness and wear resistance than coating on cutting tool.

1.1 Micromachining

In the past several years industries are seen highly interested in micro machining. Companies are developing new technologies to complete the unique challenges posed by micro manufacturing and focusing on development of appropriate machining systems to support this growth. Companies have used various machining technologies such as Electro Discharge Machining and Laser to produce micro details for many years. Unbelievable acceleration in study in this field has seen. Manufacturers are developing new micro machining techniques to support this growth. The focus of companies is on parts somewhat larger than a human hair. Cryogenic treatment began to be used in the late sixteenth century to boost the mechanical properties of materials. The formation of eta carbide in metal matrix has major role in improvement of the mechanical properties of cutting tools.

It is observed that, mechanical micro cutting overcome the limitations of photolithography based micromachining. While cutting, tool radius immediately chip-off due to tool wear. Using worn increase in the cutting forces and decrease in the overall machining performance is seen. Use of cutting fluid, various coatings on the tools and hybrid machining is done for the improvement. But these methods have too many technical as well as cost constraints. Cryotreated have given an improved performance in micro machining in terms of tool life, cutting forces, surface finish etc.

2. APPLICATIONS OF MICROMACHINING.

1. Medical Components.
2. Micro Molds.
3. Electronic Tooling.
4. MEMS (Micro-Electrical-Mechanical-System).
5. Fluidic Circuits.
6. Micro-Valves.
7. Particle Filters.
8. Subminiature Actuators & Motors.

3. ADVANTAGES OF CRYOGENIC TREATMENT ON TOOLS

1. Transformation of almost all soft retained austenite into the hard martensite takes place after cryogenic treatment.
2. It enhances thermal conductivity by increasing the particle size of the cementite carbide.
3. Brittleness decreases.
4. Residual stresses decreases.
5. Abrasive wear resistance increases.
6. Tensile strength, Toughness and Stability is increases.
7. Denser molecular structure is obtained.
8. It forms micro fine carbide (eta) fillers to enhance large carbide structures.
9. It can be used for coated as well as uncoated tool steel.

4. EXPERIMENTATION

We have to use Titanium alloy (Ti-6Al-4V) as work piece material for our experiment. It has very high strength to weight ratio and excellent corrosion resistance property as well. And because of this property it can be used in Biomechanical and Aerospace sector very efficiently.

Table -1: Chemical composition of Ti-6Al-4V

	V	Al	Fe	O	C	N
Min	3.5	5.5	--	--	--	--
Max	4.5	6.75	0.3	0.2	0.08	0.05

	H	Y	TI	Remainder Each	Remainder Total
Min	--	--	--	--	--
Max	0.015	0.005	Balance	0.1	0.3

Table -2: Physical properties of Ti-6Al-4V

	Density (g/cubic.cm)	Young's Modulus (GPa)	Shear Modulus (GPa)	Bulk Modulus (GPa)
Min	4.429	104	40	96.8
Max	4.512	113	45	153

	Poisson's Ratio	Yield Strength	Ultimate Strength	Hardness Rockwell	Uniform Elongation
Min	0.31	880	900	36	5
Max	0.37	920	950	--	18

Grinding on Ti-6Al-4V is done by using Tungsten Carbide tool, Tin coated Tungsten Carbide tool and Cryogenic treated tungsten carbide tool, shallow (-100°C) and deep (-196°C) cryogenic treatments are done on different tools. And the comparative study regarding wear and tool life at various cutting parameters is done.

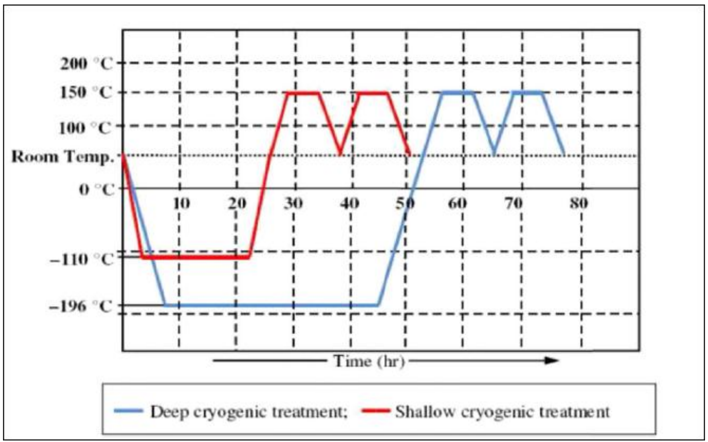

Chart - 1: Typical Cryogenic Process.

It is found that, the contribution of soaking temperature to decide the mechanical properties of material is 72%, soaking period is 24%, rate of cooling is 10% and tempering temperature is 2% while effect of tempering period is insignificant.

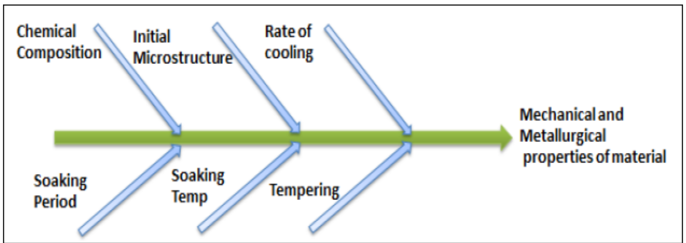

Fig -1: Factors affecting mechanical properties of material.

4.1 Input Parameters

1. Speed : 100000 rpm
2. Feed : 4 um/flute
3. Depth of Cut : 150 um
4. Dry Environment (no coolant)

4.2 Output Parameters

1. Cutting Forces : (Fx, Fy, Fz)
2. Surface Roughness (Ra)

4.3 Technical Description

1. Axes X, Y
   - i. Travel distance : 100 mm.
   - ii. Drives : Precision Ground Ball Screw/Brushless DC Servomotor
   - iii. Max. Feed Rate : 0.06-6000 mm/min
   - iv. Maximum Load : Horizontal 25 kg, Vertical 10 kg
   - v. Resolution : 0.5µ m
   - vi. Accuracy : ±0.5µm
2. Axis Z

   Frictionless pneumatic dual counterbalanced mechanism for high precision.
   - i. Travel distance : 60 mm
   - ii. Drives : Non-Contact Direct Drive/Brushless Linear Servomotor
   - iii. Max. Feed Rate : 0.06-6000mm/min
   - iv. Maximum Load : Vertical 10 kg
   - v. Resolution : 1 nm
   - vi. Accuracy : ±0.3 um
3. Spindle
   - i. Spindle Speed : 5000 -170000 rpm with variable frequency drive
   - ii. Tool Holder : Mega 4S (High accuracy collet system with a run out in collet of 1 µm)
   - iii. Tool Shank Dia. : 3 m

5. RESULTS

Table -3: Cutting forces at different soaking period.

Tool (Hrs.)	Cutting forces (N)
UNTREATED	0.24
SCT 08	0.21
SCT 16	0.21
SCT 24	0.2
DCT 08	0.19
DCT 16	0.18
DCT 24	0.17

It is observed that as the temperature decreases and soaking period increases the forces on the cutting tool decrease due to the increasing hardness and brittleness at tool tip.

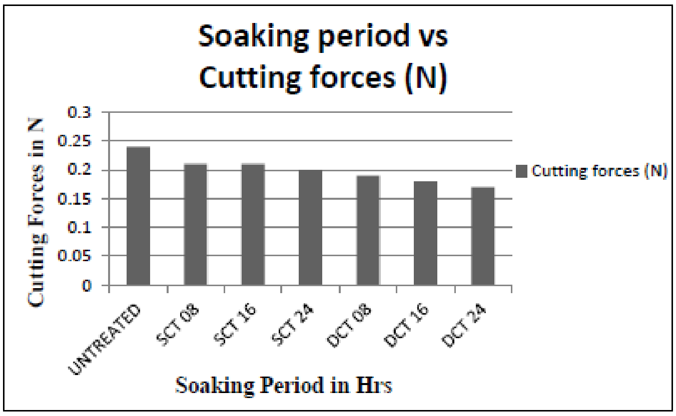

Chart - 2: Soaking period verses cutting forces.

The application of Cryotreated micro cutting tool in micromachining improves the surface quality and dimensional accuracy of the machined component.

Table -4: Surface roughness (Ra) values at different soaking periods.

Tool (Hrs.)	Ra Values (um)
UNTREATED	0.52
SCT 08	0.42
SCT 16	0.4
SCT 24	0.37
DCT 08	0.33
DCT 16	0.22
DCT 24	0.15

After observing all the slots under Surface Profilometer we got the highest surface finish in the deep 24 Hrs. and the lowest surface finish in uncoated tool.

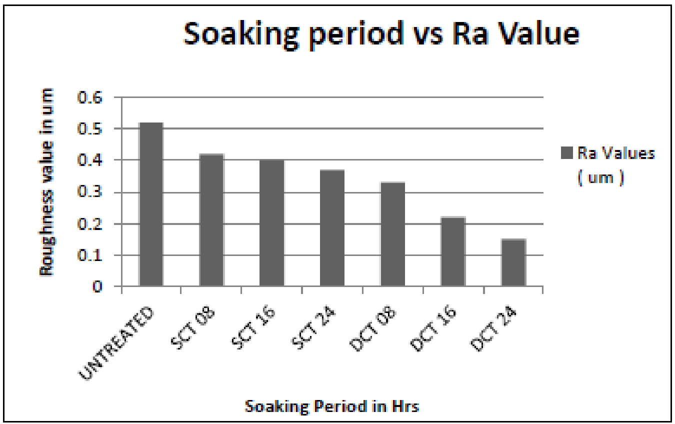

Chart - 3: Soaking period Ra values in um

6. CONCLUSIONS

From the above results, conclusions drawn are;

1. Cryogenic treatment improves mechanical properties of cutting tool by producing η carbide in metal matrix. As well as mechanical properties can be altered by using various cryogenic treatment cycles.

2. Tool life is increased because of generation of η carbide.

3. Decreasing temperature and increasing soaking period results in decrease in forces on the cutting tool.

4. Performance of Cryotreated tool is better than the untreated tungsten carbide tool. DCT 24 gives highest hardness and excellent surface finish and very small cutting forces as compare to other tools.

REFERENCES

[1] Simon Isakson, M. Ibrahim Sadik, Amir Malakizadi, Peter Krajnik Chalmerrs University of Technology, Department of Industriaal and Material science, Gothenburgg, Sweden (Procedia CIRP 71 [2018] 254-259)

[2] Binxun Li, Tao Zhang, Song Zhang, School of Mechanical engineering,Shandong University, Jinan 250061,China(Procedia CIRP 71 [2018] 35-40)

[3] S. T. Dhande, V. A. Kane, M. M. Dhobe, C. L. Gogte, PESCOE Aurangabad, MIT Aurangabad (Procedia Manufacturing 20 [2018] 318-328)

[4] NikolaosTapoglou, Maureen I Aceves Lopez, Ian Cook, Christopher M Taylor, AMRC with boeing, University of Sheffield, Advanced manufacturing park, United kingdom(Procedia CIRP 71 [2018] 35-40)

[5] A. Aramcharoen a,_, P.T. Mativenga a, S. Yang b, K.E. Cooke b, D.G. Teer b Manufacturing and Laser Processing, School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester M60 1QD, UK bTeer Coatings Ltd., UK(International Journal of Machine Tools & Manufacture 48 (2008) 1578– 1584)