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PERFORMANCE PARAMETER OF COATED, UNCOATED AND CRYOGENICALLY TREATED HSS CUTTING TOOL

M.Prakash[1], N.Muthukumar[2], B.Premalatha[3] , M.Rameeza[4]

1. Final Year, M.E., Engineering Design,
Gojan school of Business and Technology Redhills,
Chennai – 600 054.
prakash11691@gmail.com

2. Assistant professor, Department of Mechanical Engineering,
Gojan school of Business and Technology,
Redhills, Chennai – 600 054.

3. Assistant professor, department of Mechanical engineering
T.J.S engineering college
Peruvoyal kavaraipettai-601206

4. Junior Research fellow,
Combat Vehicle Research Development & Establishment,
Avadi, Chennai.

ABSTRACT-This research work presents the results of an performance parameter of Tungsten carbide coated, Shallow cryogenic treated, Deep cryogenic treated and Untreated HSS tools. The high speed steel is used for its good quality and reliability at cheaper rate when compared to other cutting tools. Thus it is very important to increase the ability of the tool further for its reliability. So the best way is to increase the hardness, for the improvement of high hardness and good wear resistance various heat treatment and cold treatment process are used. One such effective and currently used treatment process is cryogenic treatment. It offers much better wear resistant and hardness for the high speed steel. Experiments were performed to measure the hardness and corrosion resistance. Microstructure analysis is performed to identify the microstructure of the specimen. Turning was carried out and the machining time was found out. Tool life, MRR and volume of wear were calculated. Comparison is made between tungsten carbide coated, shallow cryogenic treated, deep cryogenic treated and untreated tools.

***Keywords*: HSS Tool, Hardness, Microstructure, Corrosion resistance, Machining time, Tool life, MRR, Volume of wear.**

I. INTRODUCTION

Metal cutting process forms the basis of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every product of our modern civilization. The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. Changes in work piece materials, manufacturing processes and even government regulations catalyze parallel advances in metal cutting tooling technology. Traditional tool materials such as HSS continue to undergo substantial improvement in their properties through suitable modifications in their composition by optimizing the processing technique as well as incorporating various surface treatments. Use of cryogenic treatment in enhancing properties of tool materials has received wide acceptance by researchers and industries, recently. The research publications during the past two decades show an increase in interest, on the use of cryogenic treatment, on various cutting tool materials, die materials and bearing materials to exploit the positive effects of such a simple and cost effective technique. Improvements in hardness, fatigue resistance, toughness, and wear resistance of cryogenically treated materials, have been reported invariably in every scientific publication. Specifically, reports on the improvement in tool life of a wide variety of cutting tool materials, due to the use of cryogenic treatment, has attracted the attention of cutting tool industries and manufacturing sector, since it is going to have a remarkable impact on improving economy of production.Tool life is a major factor that is considered in production planning itself since it affects tool changing strategies and throughput time of finished product in any manufacturing industry. Hence any improvement in tool life will have a direct impact on the cost of production, tool changing time and indirectly help achieve production target. Cryogenic Treatment (CT) is another option available that helps improve the wear resistance and life of tool, by bringing about property changes across the entire volume of the material unlike the coated tools where in the enhancement in wear resistance takes place only at the surface of the tool. Hence after every regrinding the advantages of CT can be brought back into full play.

Experimental Investigation of Cryogenic Cooling by Liquid Nitrogen in the Orthogonal Machining Process by M.Dhananchezian, M. Pradeepkumar and A. Rajadurai in the year 2009 tells that, cutting temperature is the determining factor for other machinability indices of material. The conventional cutting fluids are ineffective in controlling the cutting temperature in the cutting zone. Cryogenic cooling is environmental friendly new approach for desirable control of cutting temperature. Current work involved the experimental study of the effect of cryogenic cooling on cutting temperature, cutting force, chip thickness and shear angle in the orthogonal machining of AISI 1045 steel and Aluminium 6061-T6 alloy. It has been observed that in cryogenic cooling method, the temperature was reduced to 19–28% and the cutting force was increased to a maximum of 15% then dry machining of AISI 1045 steel. In machining of Aluminium 6061-T6 alloy, the temperature was reduced to 27–39% and the cutting force was increased to a maximum of 10%[1].Enhancement of Tool Material Machining Characteristics with Cryogenic Treatment: A Review by RupinderSingh, and Kamaljit Singh in the year 2010 tells that, for cost effective machining it is necessary to identify and quantify changes in tool material machining characteristics. The execution of cryoprocessing on cutting tool materials increases wear resistance, hardness, and dimensional stability and reduces tool consumption and down time for the machine tool set up, thus leading to cost reductions[2]. The present research paper reviews the machining characteristics of tool material with cryogenic treatment for industrial applications. A review of cryogenic cooling in high speed machining (HSM) of mold and die steels by Aznijar Ahmad-Yazid1, ZahariTaha and Indra Putra Almanar in the year 2010 tells that, metal cutting generates heat which influences the quality of a finished product, the force needed in cutting as well as limiting the life of the cutting tool. There are various attempts by researchers all over the world to understand the mechanism and theory behind the temperature built-up during machining in order to achieve optimized machining procedure and best workpiece results. Theories are developed, experiments conducted as well as models and simulations proposed[3].

Experimental analysis of cryogenic treatment on coated tungsten carbide inserts in turning by ShivdevSingh ,Dilbag Singh and Nirmal S Kalsi in the year 2012 tells that, the results of an experimental investigation of cryogenically treated, coated and uncoated tungsten carbide cutting tool inserts in turning of AISI 1040 steel. Three different tungsten carbide inserts coated with aluminum chromium nitride (AlCrN), titanium nitride (TiN) and uncoated WC were taken and treated cryogenically. Experiments were performed to evaluate the cutting forces and tool wear at different machining conditions[4].Effects of Cryogenic Treatment on High-speed Steel Tools by Lakhwinder Pal Singh and Jagtar Singh in the year 2011 tells that, High-speed steel (HSS) tools are the most commonly used tools in small and medium-scale industry. So far, a few studies have been carried out pertaining to the life of HSS single point cutting tool[5]. Studies on cryogenically treated (CT) cutting tools show microstructural changes in the material that can influence the life of the tools significantly. This paper primarily reports performance of CT HSS tools as compared to untreated (UT) HSS tools. The results show that CT HSS tools exhibit better performance based on tool wear, surface roughness of the work specimen, and power consumption during operation than the UT HSS tools.

II. FINITE ELEMENT ANALYSIS

Finite element structural analysis is a method of predicting the behavior of a real structure under specified load and displacement conditions. The finite element modeling isgeneralization of the displacement or matrix method of structural analysis to two and three-dimensional problems andthree-dimensional problems. The basic concept of FEM thatstructure to be analyzed is considered to be an assemblage ofdiscrete pieces called elements that are connected together at afinite number of points or nodes. Fromthe solid modeling can easily predict the behavior of real model under specified load and displacement conditions.First prepare a model for drill bit. Modelling is done through solid work software and analysis also carried out to findthe stress and shear of the tool before and after carbide coated.

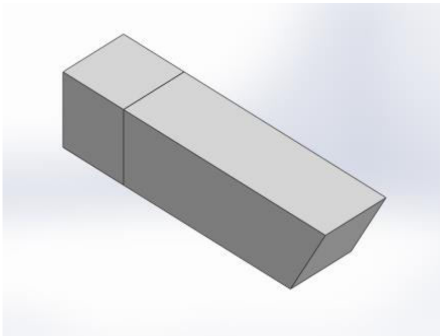

Fig.1. Uncoated cutting tool

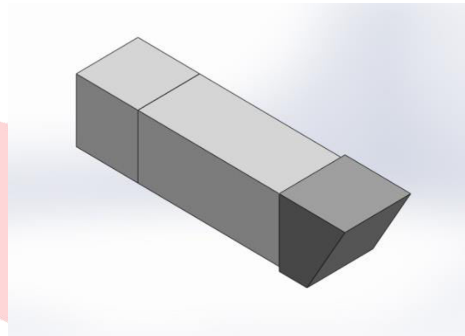

Fig.2. Coated tool

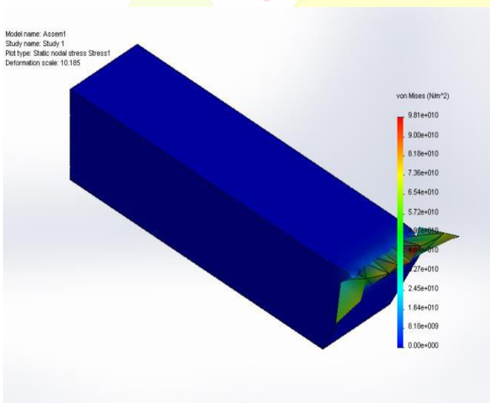

Fig .3.Thermal Stress of Un-Coated cutting tool at 100^{o} c

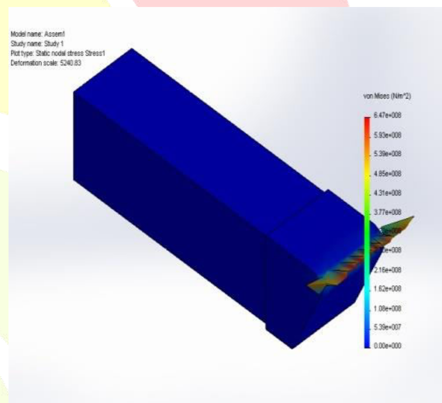

Fig .4.Thermal Stress of Coated cuttig tool at 100^{o} c

III. EXPERIMENTAL PROCEDURE

A. Hardness:

In order to investigate any changes in hardness values of the tools before and after coating and cryogenic treatment, the Vickers hardness (HV) values were obtained using a microhardness tester. The test was conducted in accordance with ASTM standards, in particular, ASTM E384-99.A minimum of three tests were conducted for measurement of micro hardness. The average value of hardness is presented in Table.1.

Table.1. Hardness

	HSS tool (HV)	**HSS toolafter tungsten carbide coating(HV)**	**HSS toolafter Shallow Cryogenic treatment(HV)**	**HSS toolafter Deep Cryogenic treatment(HV)**
HARDNESS	848	944	947	988
	844	953	947	978
	840	958	958	988
AVERAGE	**844**	**952**	**950**	**984**

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B . Salt spray test:

The apparatus for testing consists of a closed testing chamber, where a salted solution (mainly, a solution of 5% sodium chloride) is atomized by means of a nozzle. This produces a corrosive environment of dense saline fog in the chamber so that parts exposed in it are subjected to severely corrosive conditions. Typical volumes of these chambers are of 15 cubic feet (420 L) because of the smallest volume accepted by International Standards on Salt Spray Tests - ASTM-B-117, ISO 9227 (400 litres) and now discontinued DIN 50021 (400 litres). It has been found very difficult to attain constancy of corrosivity in different exposure regions within the test chambers, for sizes below 400 litres. Chambers are available from sizes as small as 9.3 cu ft (260 L) up to 2,058 cubic feet (58,300 L).

Fig .5. Salt spray equipment

Fig.7. Photograph of the shallow Cryogenic treated specimen before and after the Salt spray test

Fig .6. Photograph of the Tungsten carbide coated specimen before and after the Salt spray test

Fig .8. Photograph of the deep Cryogenic treated specimen before and after the Salt spray test

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Table.2. Corrosion resistance

HSS tool	HSS tool after Tungsten carbide coating	HSS toolafter shallow Cryogenic treatment	HSS toolafter deep Cryogenic treatment
Red rust formation noticed at 24Hrs	Red rust formation noticed upto24Hrs	Red rust formation noticed at 24Hrs	Red rust formation noticed at 48Hrs

C. Micro structure Data collection and presentation

Fig .9. Micro photograph of uncoated specimen

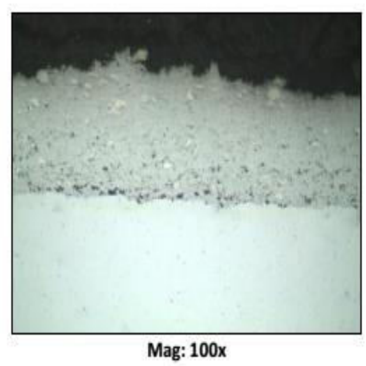

Fig .11. Micro photograph of Tungsten carbide coated specimen

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Fig .10. Micro photograph of Shallow Cryogenic treated specimen

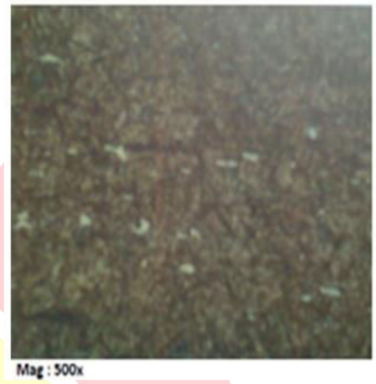

Fig .12. Micro photograph of Deep Cryogenic treated specimen

D . Measurement of Machining Time/Cutting Time

During machining, the time taken for machining is measured with the help of a stop watch. The measured values are tabulated as follows:

Table .3. Machining time

S.NO.	Diameter of Work piece (mm)	Machining time	
		HSS Tool (min)	Deep Cryogenic Treated Hss Tool(min)
1	24	1.54	1.25
2	23	1.39	1.04
3	22	1.10	0.50
Average time taken for machining		4.03	2.79

E. Material Removal Rate (MRR)

During machining, the Material Removal Rateis measured between untreated and deep cryogenic treated HSS tool. The measured values are tabulated as follows:

Table .4.Material Removal Rate

S. NO.	UNTREATED HSS CUTTING TOOL		DEEP CRYOGENIC TREATED HSS CUTTING TOOL	
	MACHINING TIME (min)	MRR (m^3/min)	MACHINING TIME(min)	MRR(m^3/min)
1	1.54	2.2860×10^{-5}	1.25	1.8555×10^{-5}
2	1.39	2.0633×10^{-5}	1.04	1.5438×10^{-5}
3	1.10	1.6329×10^{-5}	0.50	7.422×10^{-6}

F. Tool Life:

During machining, the tool life is measured between untreated and deep cryogenic treated HSS tool. The measured values are tabulated as follows:

Table .5.Tool life

S. NO.	UNTREATED HSS CUTTING TOOL		DEEP CRYOGENIC TREATED HSS CUTTING TOOL	
	MACHINING TIME(min)	MRR (m^3/min)	MACHINING TIME(min)	MRR (m^3/min)
1	1.54	2.2860×10^{-5}	1.25	1.8555×10^{-5}
2	1.39	2.0633×10^{-5}	1.04	1.5438×10^{-5}
3	1.10	1.6329×10^{-5}	0.50	7.422×10^{-6}

IV . RESULT AND DISCUSSION

A. HARDNESS

The hardness testing was conducted in the Micro Vickers Hardness machine. From the results of the hardness test it was found that the hardness value increased after coating, after shallow cryogenic treatment and after deep cryogenic treatment. Comparing the results of different treatments on the tool, deep cryogenic treated tool has high hardness value. The hardness value of deep cryogenic treated tool is high when compared to other tools.

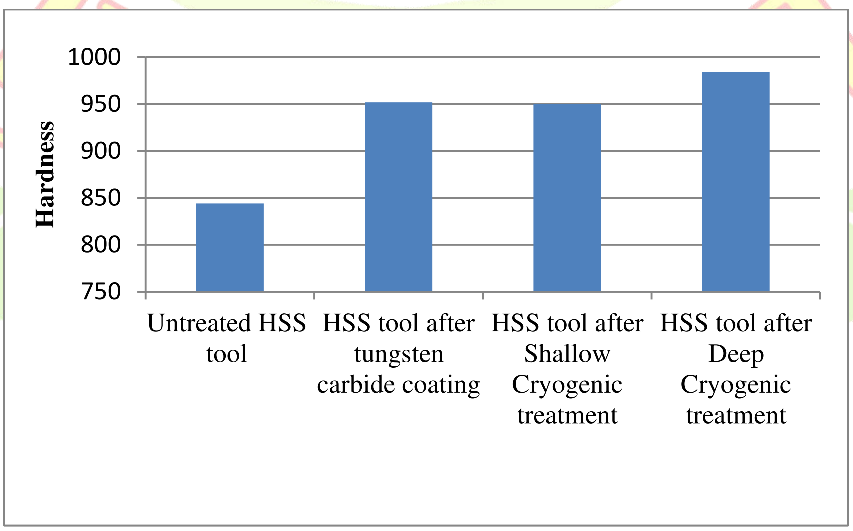

Fig .13. Hardness Comparison

B.SALT SPRAY TEST

The rate of corrosion of untreated and cryogenic treated tools is shown in the fig .15.The rate of corrosion of Deep Cryogenictool is high when compared to other tools. Hence Deep Cryogenictool has high corrosion resistance.

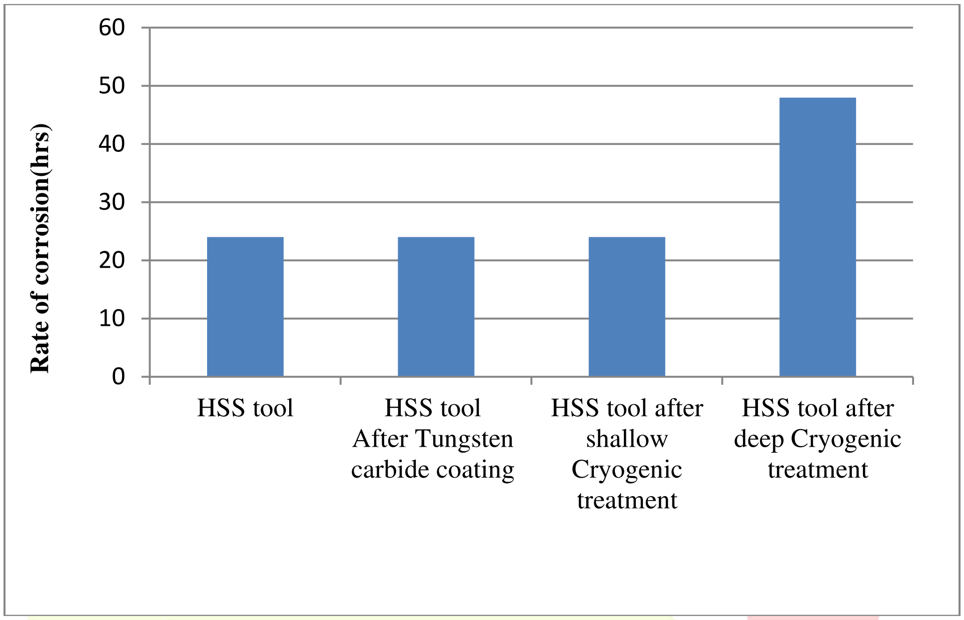

Fig .14. Corrosion comparison

C.MICROSTRUCTURE ANALYSIS

The microstructure of the untreated cutting tool is observed to be tempered martensite. Micro Examination of the specimen revealed primary & secondary carbides present in the tempered martensite. Observed grain boundaries are clearly visible in the background.When compared to the untreated HSS tool, shallow cryogenic treated tool has refined microstructure, whereas deep cryogenic treated tool has more refined microstructure.

D.MACHINING TIME

It is clear that the machining time has been reduced for deep cryogenic treated HSS tool when compared to the untreated HSS tool.

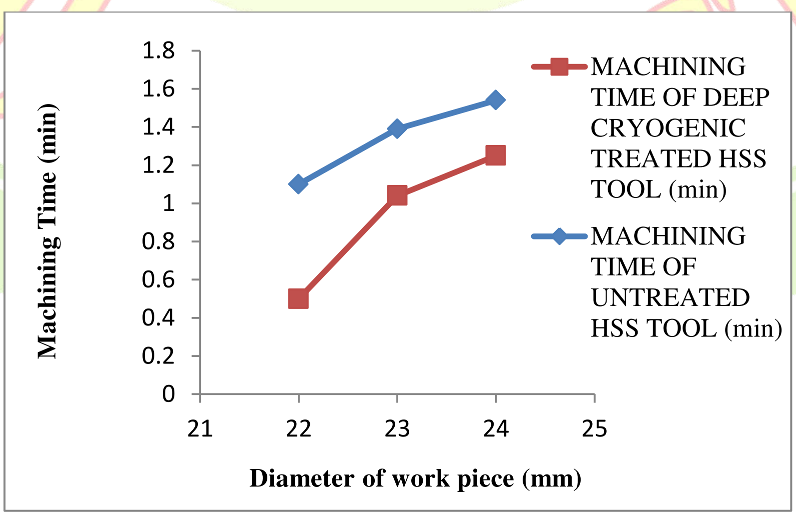

Fig .15. Machining time

E.WEIGHT OF THE TOOL

Table .6. Weight of the tool before and after machining

Tool weight (gm)			
Before machining		After machining	
HssTool	Deep cryogenic treated hss tool	Hss tool	Deep cryogenic treated hss tool
68.005	65.075	68.001	65.073

From the above table it is clear that the weight of the untreated HSS tool is reduced by 0.004 gm after machining, whereas the weight of the deep cryogenic treated HSS tool is reduced by 0.002 gm after machining. Thus the material removal rate is reduced to 50% in deep cryogenic treated HSS tool.

F.VOLUME OF WEAR (V)

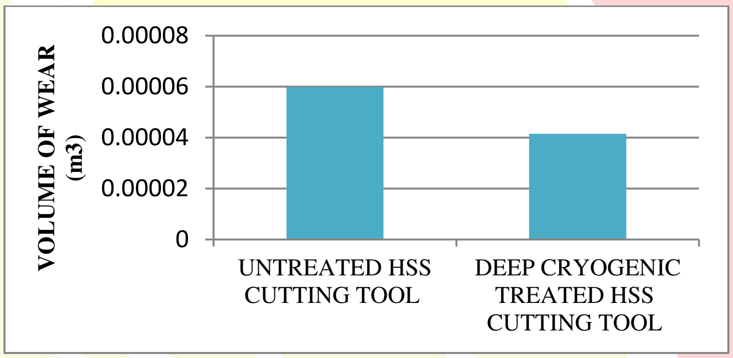

Fig .16. Volume of wear

From the above figure it is clear that the volume of wear (V) of deep cryogenic treated HSS cutting tool is less when compared to untreated HSS cutting tool. Hence the wear resistance has improved after deep cryogenic treatment.

G.MATERIAL REMOVAL RATE (MRR)

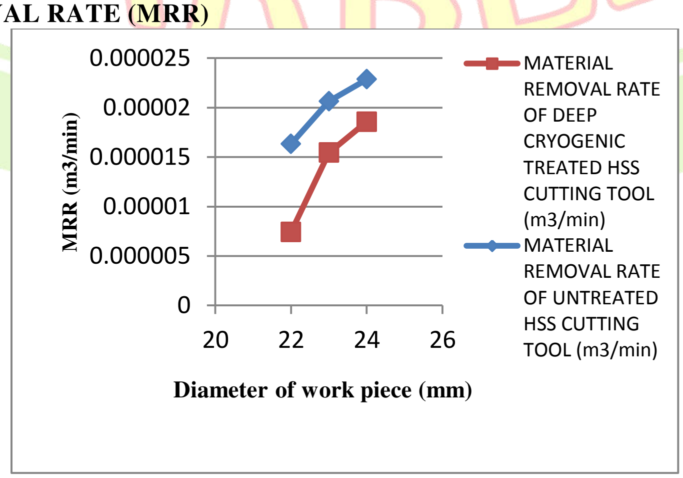

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Fig .17. Material removal rate

From the above figure it is clear that the material removal rate (MRR) of deep cryogenic treated HSS cutting tool is less when compared to untreated HSS cutting tool. Hence the wear resistance has improved after deep cryogenic treatment.

H.TOOL LIFE (T):

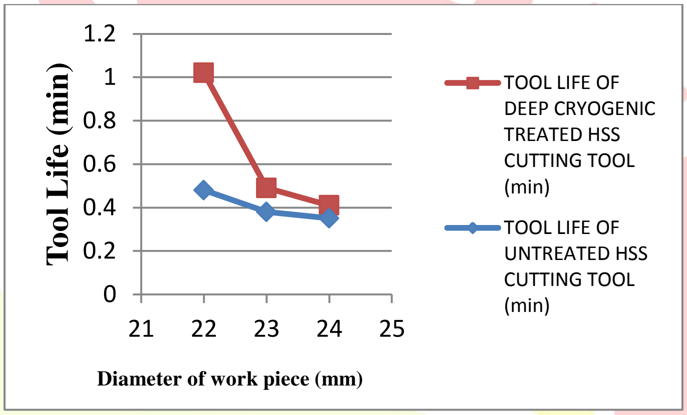

Fig .18. Tool life

From the above figureit is clear that the tool life of deep cryogenic treated HSS cutting tool is higher when compared to the untreated HSS cutting tool.

V. CONCLUSION

Experimentally it was found that the hardness value has increased for deep cryogenic treated tool when compared to the other tools. This shows that deep cryogenic treated cutting tool can withstand heavy load when compared to other treated tools. Because of improvement in hardness, the wear resistance and life of the cutting tool will be higher. The microstructure of the HSS cutting tool is observed to be tempered martensite. After deep cryogenic treatment the grain size is well refined. After turning, it is clear that the machining time has been reduced for deep cryogenic treated tool when compared to the untreated HSS tool. From the weight measurement, it is clear that the weight of the untreated HSS tool is reduced by 0.004 gm, whereas the weight of the deep cryogenic treated HSS tool is reduced by 0.002 gm after machining. Thus the material removal rate is reduced to 50%. The volume of wear (V) and the material removal rate (MRR) of deep cryogenic treated HSS cutting tool is less when compared to untreated HSS cutting tool. Hence the wear resistance has improved after deep cryogenic treatment. The tool life of deep cryogenic treated HSS cutting tool is higher when compared to the untreated HSS cutting tool. Deep cryogenic treated tool were performed better than other tools.

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