Comparative Evaluation of flank wear of uncoated, AlTiN and TiSiN Coated Cermet Insert by Machining of D2 Tool Steel

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Abstract: The life of a cutting tool is one of the major parameters which affects the cost and quality of machining. Hence manufacturing industries putting lots of effort and resources to increase tool life and productivity. This research focuses on increasing the life of cutting tool insert by suggesting new coating material for turning harden metals. An experimentation analysis is carried out on uncoated, conventional coated (AlTiN) and newly suggested coating (TiSiN) cermet insert. Experiments were carried out by selecting 90, 183, and 245 m/min as cutting speed, 0.2 mm/rev as feed, and 0.25 mm depth of cut. The result shows all three inserts give good performance at 90 m/min cutting speed. Tool life of AlTiN coated insert shows 20 min and TiSiN coated insert shows 22.21 min at 183 m/min cutting speed. At cutting speed 245 m/min all three types of cutting insert break even after 1 min of machining.

***Keywords*: Cermet inserts, AlTiN, TiSiN, flank wear, constant depth of cut, PVD, CVD.**

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I. INTRODUCTION

Cermet is a one type of composite material which contains combination of the properties of CERamic (TiC, TiN or TiCN) such as hardness, resistance to oxidation and heat resistance with properties of METals (binder like Ni, Ni-Co, Fe, etc.) such as toughness and impact strength in order to create ideal cutting material. It has very good controlled grain structures. Which is one of the strong reason that it shows higher wear resistance. It can maintain a sharp edge corner longer than carbide cutter. Modern cutting tool requires some of the principal properties for increasing production rate and accuracy such as good wear resistance, toughness, and chemical stability at high temperature. This is not possible to incorporate all these properties in to a single tool. So techniques has been developed for acquiring maximum properties in to a cutting tool. One of the effective techniques is coating of thin layer of one or more good wear resistant material. [1] Cermet insert will give 1.25 times higher tool life as compared to conventionally available coated carbide cutting tool insert.[2]

II. CUTTING TOOL COATING

Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD) are the two deposition process which are extensively used for coating a cutting tool inserts. PVD is used up the temperature range of 400 °C to 600 °C.[3] While the CVD is used up to the temperature range of 800 °C to 1000 °C. The processing temperature in PVD is lower as compared to CVD which results in a very fine grain structure, thermal crack free coating structure, good and bright coating surface having low coefficient of friction. PVD is also very useful to coat sharp edge and complex chip breaker surfaces.[4] PVD coating process is used to coat thin coating of TiN, TiCN, AlTiN, TiAlN, TiSiN, ZrN, film material on different cutting tool inserts. While thick and thin coating of TiC, TiN, TiCN and Al2O3 film material is done by using CVD process. PVD technology is commonly chosen over CVD due to its low process operating temperature and environment-friendly aspect.[5] Some of the PVD coating material provides good mechanical properties for machining like TiN gives excellent built up edge resistance, TiCN provides high fracture toughness and good abrasive wear resistance, AlTiN uses for tools machining cast iron, high nickel and titanium alloys, hardened steels, stainless steels and more, TiAlN is similar to AlTiN only it has a higher percentage of titanium content. Apart from this Al2O3, CVD coated insert gives excellent crater wear resistance. The modern TiCN based cermets with bevelled or slightly rounded cutting edges are suitable for finishing and semi-finishing of steels at higher speeds, stainless steels. The coated cermet inserts show better wear resistance than the uncoated ones.[6] PVD coating processes have very fast market growth as compared to CVD technologies in the latest years.[7]

A. AlTiN Coating:

AlTiN coated tool does not sustain higher temperature at high cutting speed because thermal stability of AITiN coating is up to 850°C. In case of AlTiN coated tool, higher cutting forces were observed during machin- ing. Due to high cutting forces, more heat was generated in the cutting zone that results in high cutting temperature.[5] AlTiN coatings have higher hardness and thermal conductivity at elevated temperature.[8] The Aluminium content in AlTiN coating changes, the hardness of the coating also changes. The hardness of AlTiN can be achieved maximum hardness of 3200 HV. By increasing Al and Ti content ratio to 1.5.[9]

A. *TiSiN Coating*

PVD-TiSiN coating can distinctly improve the hardness of cutting tool by 25% and 65%, respectively, leading to the tool life being enhanced.[10] TiSiN coating gives excellent hardness, high thermal and oxidation resistance. TiSiN is typically coated on high speed cutting tools used on CNC machines for machining of hardened steels from 50 to 65 HRC. TiSiN is suitable especially for monolithic hard metal cutting inserts. It can be used in dry machining applications. TiSiN – PVD coating will improve the hardness of cutting tool by 65%.[10] TiSiN coating gives good mechanical properties and also exhibit a better oxidation resistance up to 700 °C.[11] It also have high hardness, low friction coefficient and high oxidation corrosion resistance.[12] TiSiN is used for protective hard coating for cutting application.[13] TiSiN coating improves surface finish and can avoid grinding operation while turning on 35HRC AISI 4340 steel.[14]

III. EXPERIMENTATION

Two different type of coating named AlTiN and TiSiN was used during machining of D2 steel. AlTiN and TiSiN coating were deposited on to the uncoated TiCN (designation: TNMG160408HQ) based cermet cutting tool using Oerlikon Balzers's PVD coated machine. After deposition process on the cermet insert, the AlTiN, TiSiN coated and uncoated inserts were subjected to undergone continuous turning test under dry cutting condition on a CNC Lathe machine (M/S Jyoti CNC Pvt. Ltd. – Model No-DX 150) as shown in figure 1.

Figure 1. Experimental Setup for turning process

Sandvik Coromant which is one of the biggest company in the field of cutting tool manufacturer in the world, defines that hard materials should have hardness vaule as above 42 HRC up to 65 HRC. [1] D2 tool steel is selected for turning process as work piece material. As per ASTM A681- 08 (Standard Specification for Tool Steels Alloy) Hardness of D2 steel (50 HRC) was taken as 255 BHN (Annealed) and 269 BHN (Cold Drawn). [15] The operating parameters for machining D2 steel by using cermet insert was selected from ASM Specialty Handbook mentioned in table 1.

TABLE 1 PROCESS PARAMETERS FOR TURNING[16]

Sr. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of cut (mm)
1	90	0.2	0.25
2	183		
3	245		

Cutting process were performed based on experimentation matrix as shown in Table 2.

TABLE 2. DESIGN OF EXPERIMENTS FOR CERMET UNCOATED AND COATED INSERTS

Sr. No.	Type of Insert	Cutting Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)	Machining Time (min)
1	Cermet – Uncoated	90	0.2	0.25	5
2					10
3					15
4					20
5					25
6	Cermet – Uncoated	183	0.2	0.25	5
7					10
8					15
9					20
10					25
11	Cermet – Uncoated	245	0.2	0.25	5
12					10
13					15
14					20
15					25
16	Cermet – AlTiN Coated	90	0.2	0.25	5
17					10
18					15
19					20
20					25
21	Cermet – AlTiN Coated	183	0.2	0.25	5
22					10
23					15
24					20
25					25
26	Cermet – AlTiN Coated	245	0.2	0.25	5
27					10
28					15
29					20
30					25
31	Cermet – TiSiN Coated	90	0.2	0.25	5
32					10
33					15
34					20
35					25
36	Cermet – TiSiN Coated	183	0.2	0.25	5
37					10
38					15

39					20
40					25
41	Cermet – TiSiN Coated	245	0.2	0.25	5
42					10
43					15
44					20
45					25

Analytical calculation done before actual experiment for cutting speed 90 m/min, 183 m/min and 245 m/min at a time 25 min, 20 min, 15 min, 10 min and 5 min. Table 3 shows analytical calculation for cutting speed 90 m/min at a 25 min.

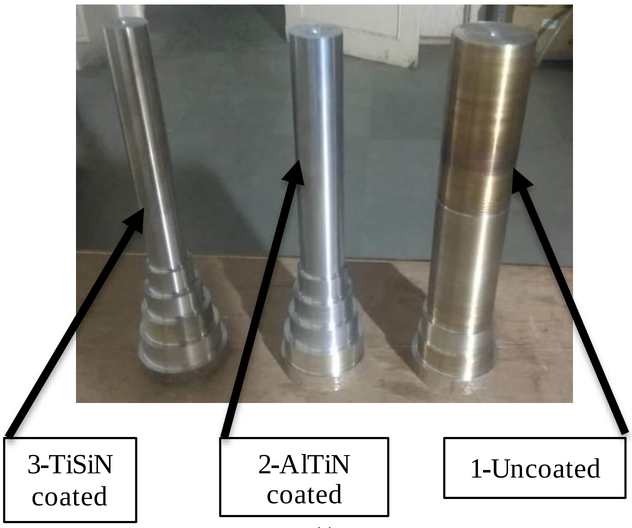
TABLE 3 ANALYTICAL CALCULATION AT CUTTING SPEED 90 M/MIN AND TIME 25 MIN

No. of Pass	Cutting Length (a)	Total Length (b)	w/p dia d (c)	RPM (d)	Feed (e = 0.2 x d mm/min)	Time in min (f = a/e)	Time in Sec (g = f x 60)	Cumulative time (min)
1	185	185	55.5	516	103	1.79	107.5	1.79
2	185	370	55	520	104	1.78	106.5	3.57
3	185	555	54.5	525	105	1.76	105.5	5.33
4	185	740	54	530	106	1.74	104.6	7.07
5	185	925	53.5	535	107	1.73	103.6	8.80
6	185	1110	53	540	108	1.71	102.6	10.51
7	185	1295	52.5	545	109	1.70	101.7	12.21
8	185	1480	52	550	110	1.68	100.7	13.88
9	185	1665	51.5	556	111	1.66	99.77	15.55
10	185	1850	51	561	112	1.65	98.80	17.19
11	185	2035	50.5	567	113	1.63	97.83	18.82
12	185	2220	50	572	114	1.61	96.87	20.44
13	185	2405	49.5	578	115	1.60	95.90	22.04
14	185	2590	49	584	116	1.58	94.93	23.62
15	185	2775	48.5	590	118	1.57	93.96	25.19

Size of work piece is diameter 56 mm x 200 mm length for 90 m/min cutting speed. Now as mentioned in analytical calculation initially turning process is carried out for 25 min and up to 185 mm length. Next operation is performed for 20 min and up to 165 mm length. Now time is reduced to 15 min and up to 145 mm length. Turning process is performed for 10 min and up to 125 mm length. At last work piece is machined for to 2.5 min and up to 105 mm length. Due to the steps mentioned in this experiments the final component is converted in to the shape given in figure 2.

(a)

(b)



(c)

Figure 2. (a) Initial shape and (b) finished components machined at 90 m/min cutting speed (c) finished components machined at 183 m/min cutting speed

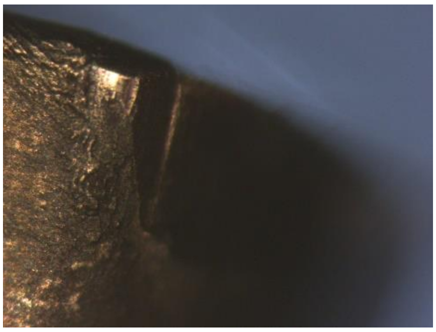
IV. RESULTS AND DISCUSSION

Surface roughness at each step of the component was measured with the help of surface roughness tester (M/S. Mitutoyo SJ-201).

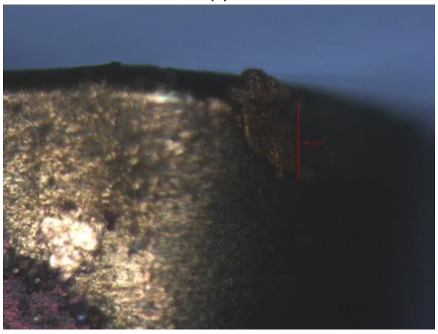
MRR is also calculated at each machining time. Flank Wear of cermet (Coated and Uncoated) were measured with the help of Optical Microscope available at VVP Engg. College, Rajkot. Optical Microscope is of Redical Scientific Equipments Pvt. Ltd and model number RMM 3 having four lenses ranging from 5x, 10x, 20x and 50x. Flank wear is measured of uncoated, AlTiN and TiSiN coated insert machined at different machining time (25min, 20min, 15min, 10min and 5min.) Table 4 shows MRR and flank wear of each insert at 90 m/min cutting speed.

TABLE 4. MRR AND FLANK AT 90 M/MIN CUTTING SPEED OF EACH INSERT

Sr. No.	Type of Insert	Analytical Time (min)	Machining Time (min)	MRR (mm^3/min)	Flank Wear Vb(µm)
1	Uncoated	25.19	25.39	4980.10	441.167
2		20.39	20.48	4364.00	338.375
3		15.49	15.49	4393.94	299.858
4		10.2	10.27	4444.75	237.246
5		2.76	2.52	4714.59	136.661
6	AlTiN coated	25.19	25.39	4629.08	188.302
7		20.39	20.49	4436.03	141.162
8		15.49	15.52	4518.14	106.332
9		10.2	10.28	4424.97	93.711
10		2.76	2.52	5019.86	45.587
11	TiSiN coated	25.19	25.39	4573.81	172.424
12		20.39	20.49	4497.11	121.499
13		15.49	15.52	4471.42	105.197
14		10.2	10.28	4476.83	85.605
15		2.76	2.52	4828.89	38.669



(a)



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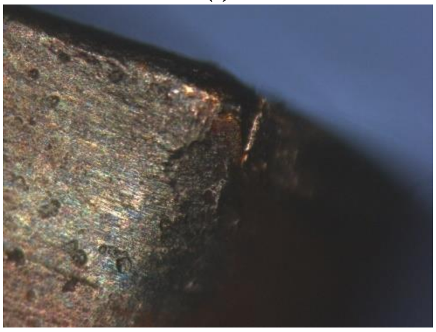


(c)

Figure 3 Flank Wear of (a) uncoated (b) AlTiN coated and (c) TiSiN coated insert machining at 90 m/min cutting speed up to 25 min.

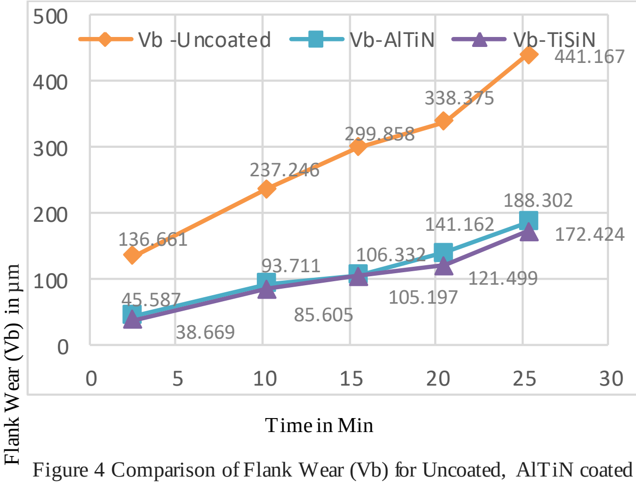


Figure 4 Comparison of Flank Wear (Vb) for Uncoated, AlTiN coated and TiSiN coated insert at 90m/min Cutting speed

Tool wear occurs at flank and rake face of tool due to abrasion, adhesion, diffusion, plastic deformation, etc. Wear on flank face is called flank wear. Flank wear can be measured as average and maximum of wear land and represented by Vb and Vbmax.[17] The Flank wear of cermet cutting tool increase with respect to cutting speed.[18]

Figure 4 shows Value of Flank Wear (Vb) at 90 m/min cutting speed for different interval of time and for all three types of insert. It is clear that at 25 min machining time uncoated shows maximum flank wear (Vb = 441.167 µm) and TiSiN coated insert shows minimum flank wear (Vb = 172.424 µm) value. AlTiN and TiSiN coated insert show near about same wear up to 15 min machining time but during 20 min and 25 min machining time AlTiN insert shows slightly higher flank wear as compared to TiSiN coated insert.

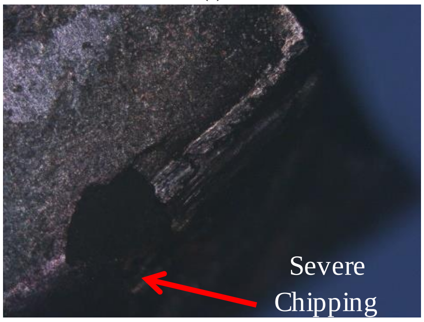
Now if we will turning at a cutting speed of 183 m/min than the value of MRR will be increased and subsequently the value of flank wear will also increase as compared to 90 m/min cutting speed.

Table 5 shows MRR and flank wear of all three insert at 183 m/min cutting speed.

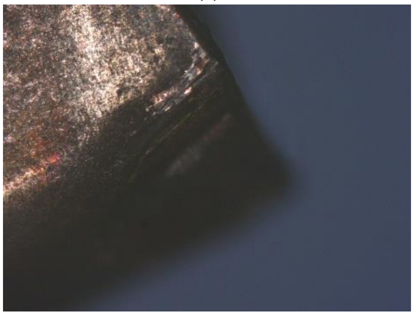
Sr. No.	Type of Insert	Analytical Time (min)	Machining Time (min)	MRR (mm^3/min)	Flank Wear Vb (µm)
1	Uncoated	25.51	12.71 (Tool Edge Break)	5779.57	Tool Edge Break
2		20.42	12.23 (Tool Edge Break)	8731.63	Tool Edge Break
3		15.28	10.25 (Tool Edge Break)	10378.75	Tool Edge Break
4	AlTiN coated	25.51	20.4	8391.49	825.525
5		20.96	20.2	9047.97	677.597
6		15.37	15.46	8232.77	238.841
7		10.29	10.26	9572.04	191.009
8		5.21	5.25	9162.98	84.86
9	TiSiN	25.51	25.48	8585.24	754.02

10	coated	20.96	20.61	9038.43	501.451
11		15.37	15.37	8619.27	255.084
12		10.29	10.51	10451.83	203.877
13		5.21	5.34	9265.93	141.448

(a)



(b)



(c)

Figure 5 Flank Wear of (a) uncoated (b) AlTiN coated and (c) TiSiN coated insert machining at 183 m/min cutting speed up to 25 min.

Figure 5 shows Value of Flank Wear (Vb) at 183 m/min cutting speed for different interval of time machining with for AlTiN and TiSiN coated insert. It is clear that at 25 min machining time AlTiN coated insert shows 825.525 μm flank wear which is maximum with respect to TiSiN. TiSiN coated insert shows maximum 754.02 μm flank wear at 25 min machining time. Other values of flank wear at 20 min, 15 min, 10 min and 5 min for AlTiN and TiSiN coated insert are shown in above graph.

At cutting speed 245 m/min all three types of insert experiencing severe chipping and the corner of the insert worn out totally. As shown in figure no. 7 the insert corner could not be used for further machining process.

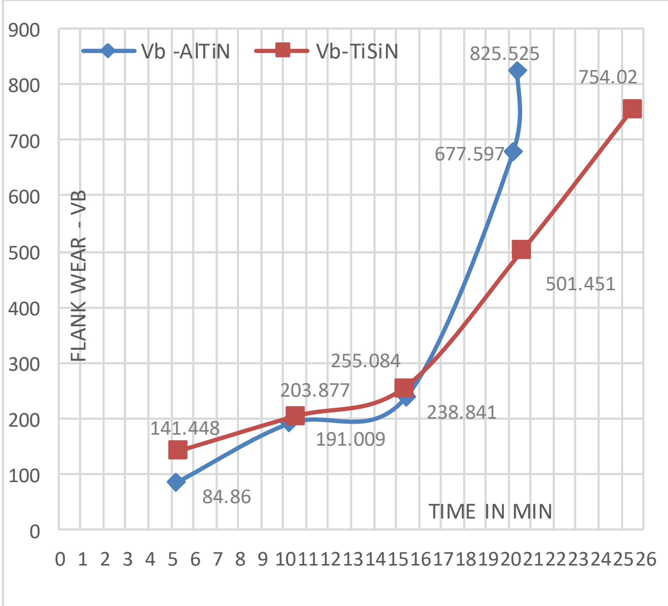
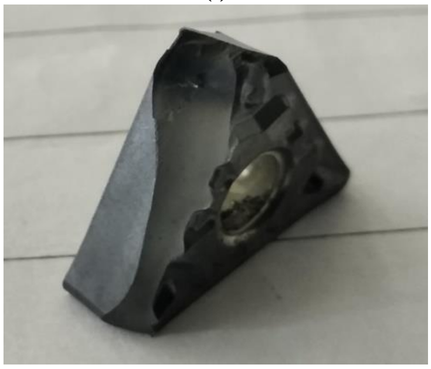


Figure 6 Comparison of Flank Wear (Vb) for Uncoated, AlTiN coated and TiSiN coated insert at 183 m/min Cutting speed

(a)



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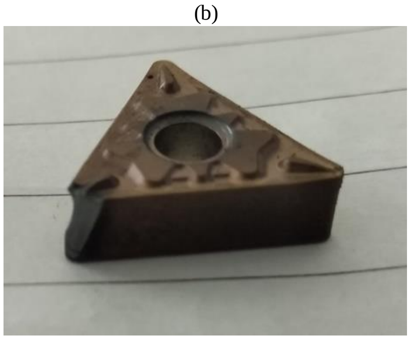

(c)

Figure 7. Insert showing breakage of its edge machining at 245 m/min cutting speed with (a) Uncoated Cermet (b) AlTiN Coated Cermet (c) TiSiN Coated Cermet insert

V. Conclusion

This research conclude that better tool life can be achieve by providing coating on cermet insert as compared to uncoated one.

1. At 90 m/min cutting speed maximum flank wear is observed at 25 min machining with uncoated cermet insert.
2. At the same cutting speed AlTiN and TiSiN gives 188.302 µm and 172.424 µm flank wear respectively.
3. Value of Material Removal Rate (MRR) at 90 m/min cutting speed for uncoated, AlTiN and TiSiN coated insert are 4980.10 mm^3/min, 4629.08 mm^3/min and 4573.81 mm^3/min respectively.
4. While in case of 183 m/min cutting speed and 25 min machining time maximum flank wear observed are 825.525 µm and 754.02 µm for AlTiN and TiSiN coated insert respectively. 8585.24 mm^3/min and 8391.49 mm^3/min MRR recorded for AlTiN and TiSiN coated insert respectively.
5. By applying TiSiN coating, tool life of cermet insert is improved by 12.046 % per edge/corner as compared to AlTiN coated insert.

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