EFFECT OF PVD COATED TOOLS ON HYPOEUTECTIC ALUMINIUM ALLOY DURING DRY MACHINING PROCESS.

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Abstract
The great challenge of today's Industries is to process smooth production. Material like Aluminium Alloys machining is a greater challenge for the Aerospace, Automobile due to their peculiar character weight by volume ratio. Silicon in the Al alloy is lesser than 12% is commonly known as Hypoeutectic Al Alloy. Machining is a further challenge for this Hypoeutectic alloy. Dry machining process is an economic and environmental healthy process. In the present study Hypoeutectic Aluminium alloy is machined using PVD coated Diamond like Carbon (DLC), AlCrN and Uncoated Carbide cutting tool. Minitab statistical software is used to produce L27 Array for 3 factor and 3 levels of variables to conduct turning experiment. Average Surface roughnesses are recorded to optimize the cutting parameters for each tool using Taguchi analysis for the dry machining process. AlCrN coated tool machining gives minimum Ra= 0.649 µm at 2000 rpm Speed, 0.02 mm/rev feed rate and 0.25mm depth of cut. The study also shows that coated tools shows appreciable results compared with uncoated tools to achieve optimized surface finish.

Key Words: Hypoeutectic, PVD, AlCrN, DLC;

Introduction
Aluminium is a silvery white metal, the thirteenth element in the periodic table. The surprising fact about Aluminium is that it's the most widespread metal on Earth, more than 8% of the Earth's core mass. After oxygen and silicon it is a third most common element on our planet. Aluminium offers a rare combination of valuable properties. It is one of the lightest metals in the world. It's almost three times lighter than iron but it's also very strong, corrosion resistant and extremely flexible. Its surface is always covered with oxide film which is thin and very strong layer. Aluminum alloys are useful & application oriented materials as it have low density ,good coefficient of thermal expansion, high wear resistance ,good corrosion resistance, so they are used in various industries such as in automotive, aerospace and aviation industries (1-12). Aluminium shows high strength to weight ratio and used in many aerospace and automobile Industries. Always we need to go with present trend. There are huge demands for Al alloys in material segments. Especially Aluminium material of 4-12% Si content has a good scope in machining industry. Aluminium Alloy produces built-up edge upon tool during machining process and this leads to a further problem for the smooth machining process in tern loss tool life. There it necessary to select perfect tool for the standard Al alloy. Aluminium strength and hardness increase by alloying with silicon, iron, nickel, manganese, chromium etc.

Literature survey
Global technology is striving hard to place new technology to produce finished product from raw material with short period of time with quality as well as less cost. Machining is the process of removal of unwanted material to get a finished product of required size and shape. There are many types of machining processes in which Turning is the process of removing of unwanted material by keeping the cutting tool fixed and rotating the work piece with its own axis. In this regard much of inventions have been taken place by keeping the interest on tool life and finished product [5-6].

In an international material field, material genome is a front line revolutionary technology in recent years and it also propels the development of new materials which will be beneficial for human kind

to make a world better place. So it's important to bring the changes in traditional material to produce new material so as to support the development of electronic information, environmental protection aids, aerospace and other industries to accelerate research and reduce cost effectively[7].
As it have promising properties such as high specific strength, anti-erosion ,high process ability, conductivity, recoverability and eco-friendly design, Aluminium alloys are widely used in the fields of automobile sector,electric module packaging, electronic sector, renewable energy management systems[8].
The density of Aluminium is around 33% that of steel or copper. Moreover it's largely available commercially within the markets, metals, it's an efficient structural material due to the resulting high strength to weight ratio. It helps the transport industry to save more payloads or fuel. Increased applications in aerospace, cars, space shuttles, underwater, and construction applications are being identified for Aluminium and its alloys. This is largely attributed to light weight, physical improvement, and it is resistant to mechanical and tribological properties such as solid, rigid, abrasion and impact, and is not easily corroded [9]. Aluminum alloys are commonly grouped into an alloy designation series. The general 4xxx Series alloys, the main alloying factor is silicon. With the addition of Silicon in appropriate amounts (up to 12%) decreases melting range significantly without causing brittleness. If the silicon is ~1% in solid solution of aluminum mixture as a continuous phase, then pure silicon basic particles play very important role in the intermediate compositions. Aluminium alloys whose containing <12% Si are known as "hypoeutectic," those with nearly 12% Si as "eutectic," and those with >12% Si as "hypereutectic" [10]. Few remarkable studies have been carried out during our literature survey in the field Aluminium Alloy machining. Jhone P et al. [11] states that many tools such as high-speed steels, straight grade used in aluminum alloys machining behave different with respect their material and geometric properties. Diamond based tools improves surface roughness due their low chemical affinity for aluminum. Y. Sahin et al. [12] tested the tool wear for different coatings. He used 2014 Aluminum contains 0.8%Si content for turning using Al2O3, TiN and Ti (C,N) coated tools. After various turning tests he noticed better performance of Al2O3 –coated tool. Tasnim Firdaus et al. [13] conducted turning experiments for both dry and wet machining using T6061 Aluminum alloy rod. He used TiN and TiCN coatings on triangular tool inserts. He studied the time taken to machine each slot during the turning process. With this he found that during high speed TiN and TiCN act as suitable coatings for dry machining. In the same line TiN coated tools read lower temperatures in context with TiCN coated tools for both dry and wet machining conditions respectively. Hiromi et.al[14] tested 5.97% Si Aluminum alloyunder machining. He used DLC coating and Sintered Diamond coatings on cemented carbide tools and found the considerable reduction of adherent deposition layer in the chip flow direction on the tool edge. Prengel et.al[15] also conducted both dry and wet machining operations on a hypereutectic AlSi alloy Aluminum A390. He used TiN, TiAlN and TiB2 coated tools during dry machining. The substrate insert matereal was WC-6 wt.% Co hardmetal. During dry drilling the TiAlN multilayer coated tools shows the good performance. But PVD TiB2 had shown good performance over PVD PVD TiN and TiAlN coatings during the turning process.

Material and Method.

Material tests for the Hypoeutectic alloy are carried out at the Fabtech College of Engineering and Research in Sangola, India. The material has a tensile stress of 170 N/mm^2, a hardness of 56 BHN, and shear strength of 120 N/mm^2. TNMG160404HA H01 uncoated, AlCrN, DLC coated carbide inserts are used to machine Hypoeutectic alloy work pieces using CNC Lathe machine. Geometrical structure of the uncoated carbide insert includes 0^o Relief angle, Nose height (mm) ±0.08mm and Tolerance of Inscribed Circle IC ±0.05mm. Double sided cylindrical with hole, inscribed circle dia IC 16.00 mm, insert thickness i.e., 4.67mm, insert corner radius 0.4mm and H01 Grade is indicated in Fig. 1.

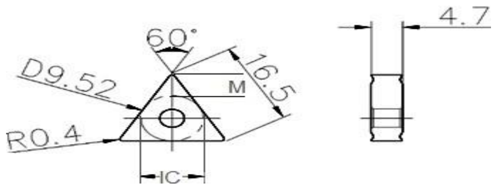

Fig. 1 TNMG160404HA H01 Insert Geometry.

Experimental work

To check the machining performance of Aluminium alloys (4-12% Si content), we collected waste piston materials from various garages across Sangola city. Finally we could come up 5 pistons for casting process. These pistons are casted and prepared a bar of 25mm(Ø) x 110mm(L) in Sharad Molding Industry Pandarpur. Later on the bar is machined in Fabtech Technical Campus, College of Engineering and Research Sangola workshop laboratory to send the specimen for material testing. The final machined material had 23mm(Ø) x 98.5mm(L) dimension. After testing the material we received 11.11% Si, 2.79% Cu, 0.74% Mg, 0.41% Ni, 0.27% Fe, 0.21% Zn chemical composition from Accurate Laboratory Services Pune.

Material	Si %	Cu %	Mg %	Ni %	Fe %	Zn %
Al alloy	11.11	2.79	0.74	0.41	0.27	0.21

Table 1. Lab report of Casted bar using waste piston materials

CNC turning system (HYTECH CNC LATHE Machine CLT-100 SERVO) at Fabtech College of Engineering and Research Sangola, India is used to conduct turning experiments. Speed, feed, and depth of cut are the most influencing parameters in turning process. Minitab 19.1 statistical software is used to create L27; three levels of variables are used for three machining parameters [5]. Mitutoyo Surftest SJ-210 Surface Roughness Tester is used to determine the Ra values of surface roughness. The average surface roughness R_a values for various machining parameters and cutting tools are shown in Table 1.

Machining parameter	Level 1	Level 2	Level 3
Speed (rpm)	2000	2500	3000
Feed rate (mm/rev)	0.01	0.02	0.03
Depth of cut (mm)	0.25	0.5	0.75

Table 2. Design of Experiment (DOE)

Taguchi Design of L27 (3*3) Array is used.

Standard Order	Machining Parameters			Uncoated Carbide Tool	AlCrN Coated Tool	DLC Coated Tool
	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)			
1	2000	0.01	0.25	0.759	0.649	0.741
2	2000	0.01	0.5	0.82	0.685	0.879
3	2000	0.01	0.75	0.854	0.784	0.914
4	2000	0.02	0.25	0.863	0.759	0.821
5	2000	0.02	0.5	0.955	0.764	0.854
6	2000	0.02	0.75	0.961	0.77	0.867
7	2000	0.03	0.25	0.999	0.786	0.871
8	2000	0.03	0.5	1.007	0.812	0.885
9	2000	0.03	0.75	1.062	0.869	0.919

10	2500	0.01	0.25	0.91	0.796	0.833
11	2500	0.01	0.5	0.922	0.803	0.846
12	2500	0.01	0.75	0.931	0.815	0.896
13	2500	0.02	0.25	0.924	0.845	0.815
14	2500	0.02	0.5	0.936	0.867	0.846
15	2500	0.02	0.75	0.949	0.881	0.885
16	2500	0.03	0.25	0.961	0.872	0.863
17	2500	0.03	0.5	0.977	0.911	0.912
18	2500	0.03	0.75	1.063	0.978	0.969
19	3000	0.01	0.25	0.94	0.761	0.949
20	3000	0.01	0.5	0.985	0.772	0.956
21	3000	0.01	0.75	1.023	0.786	0.967
22	3000	0.02	0.25	0.995	0.874	0.991
23	3000	0.02	0.5	1.04	0.886	1.037
24	3000	0.02	0.75	1.105	0.902	1.048
25	3000	0.03	0.25	1.159	1.116	1.041
26	3000	0.03	0.5	1.216	1.158	1.145
27	3000	0.03	0.75	1.275	1.195	1.196

Table 3. Design of Experiments with Responses

4. Result and Discussion

MiniTab 19.1 statistical software is used and analysis is made on Taguchi method for uncoated, AlCrN coated and DLC coated carbide inserts. Statistical analysis is made for each tool a respective Response tables and also graphs for SN ratio, Means are generated.

Level	**Speed** (rpm)	**Feed** (rev/mm)	**Depth of cut** (mm)
1	0.9200	0.9049	0.9456
2	0.9526	0.9698	0.9842
3	1.0820	1.0799	1.0248
Delta	0.1620	0.1750	0.0792
Rank	2	1	3

Table 4. Uncoated Carbide Tool- Response Table for Means

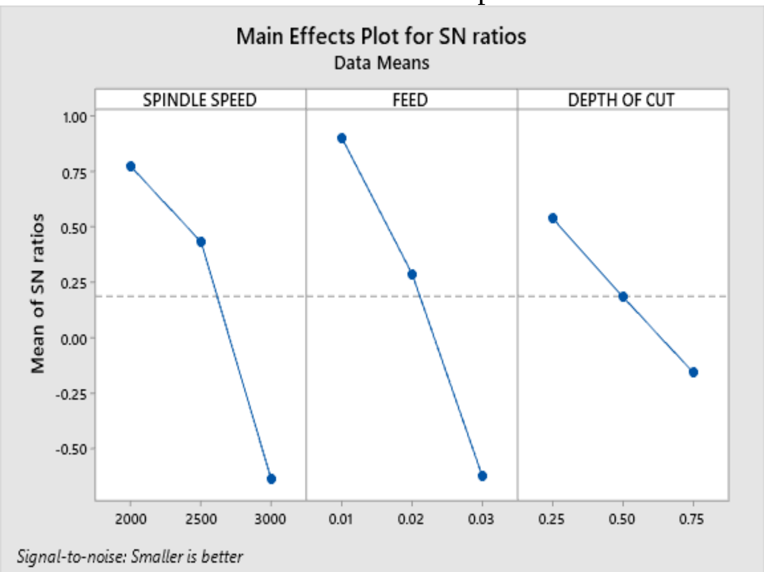

Fig 2. Uncoated carbide tool- Main effect plot for SN ratios.

Level	Spindle Speed	Feed	Depth of cut
1	0.7642	0.7612	0.8287
2	0.8631	0.8387	0.8509
3	0.9389	0.9663	0.8867
Delta	0.1747	0.2051	0.0580
Rank	2	1	3

Table 5. AlCrN Coated Tool- Response Table for Means

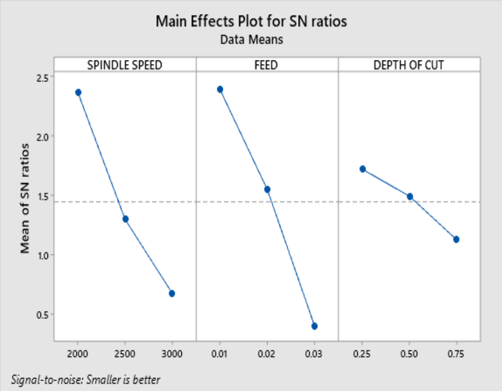

Fig 3. AlCrN Coated Tool– Main effect plot for SN ratios

Level	Spindle Speed	Feed	Depth of cut
1	0.8612	0.8868	0.8806
2	0.8739	0.9071	0.9289
3	1.0367	0.9779	0.9623
Delta	0.1754	0.0911	0.0818
Rank	1	2	3

Table 6. DLC Coated Tool- Response Table for Means

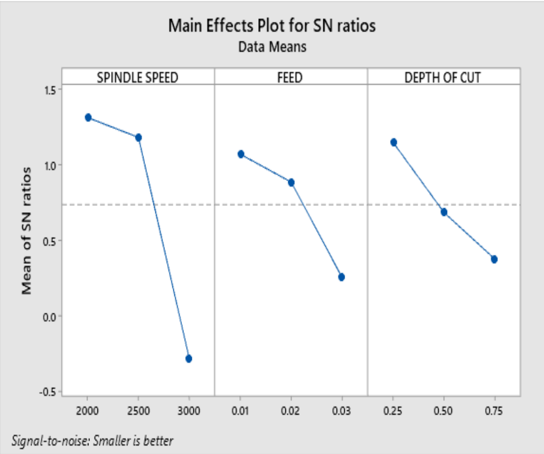

Fig 4. DLC Coated Tool– Main effect plot for SN ratios

Using Taguchi Analysis of Signal to Noise (SN) ratio and Means tables and charts cutting parameters and surface roughness are optimized. Smaller is the better roughness and parameters (feed, speed, depth of cut) those are contributing on roughness's are identified in rank wise using tables.

Tool Name	Optimized Surface Roughness (Ra) µm	Maximum Surface Roughness (Ra) µm
Uncoated Carbide Coated Tool	0.759	1.275
AlCrN Coated Tool	0.649	1.195
DLC Coated Tool	0.741	1.196

Table 7. Minimum and Maximum R_a values using S/N ratio charts for all three tools.

With the overall study it evident that coated tools shows good performance compared with uncoated tools to achieve optimized surface roughness. Table 7 indicates Minimum and Maximum R_a values using S/N ratio charts for all three tools. Therefore coating is necessary for the tool.

5. Conclusion

Hypoeutectic Aluminium alloy is machined with three cutting tools; uncoated carbide, AlCrN Coated carbide and Diamond like Carbon coated carbide tools. L27 Array for 3 factor and 3 levels of variables are adapted using MiniTab 19.1 statistical software. 81 experiments turning experiments are completed on CNC lathe machine under dry machining condition. After the experimental process measure the average surface roughness and finding minimum surface roughness and optimizing the cutting parameters using Taguchi Analysis.

- Under the operating cutting parameters 2000 rpm, 0.01 mm/rev and 0.25 mm the average surface roughness value R_a for uncoated carbide tool would be 0.759µm.
- For AlCrN coated carbide the average surface roughness value R_a is 0. 649µm under the operating cutting parameters 2000 rpm, 0.02 mm/rev and 0.25 mm.
- Interestingly DLC coated carbide tool shows average surface roughness value R_a 0.741µm under the operating cutting parameters 2000 rpm, 0.02 mm/rev and 0.25 mm the for
- Coated tools shows good performance compared with uncoated tools to achieve optimized surface roughness. Therefore coating is necessary for the tool.
- AlCrN Carbide Cutting tool gives superior surface finish as compared with all other inserts. The optimized surface roughness R_a 0.649µm is achieved which the lowest roughness value as compared with other all is cutting tools.

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