# MACHINING OF AISI 304L AUSTENITIC STAINLESS STEEL : SURFACE ROUGHNESS AND TOOL WEAR ANALYSIS.

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**ABSTRACT-***Stainless steels are widely used in architectural, food processing, chemical, oil and gas industries. It possesses good properties like corrosion and heat resistant, high strength and weldability. Among these grades, austenitic stainless steel AISI 304L can be used in the as-welded state even in severe corrosive environments. It is difficult to cut alloy. Many researchers have focused to improve the machinability of AISI 304L.*

*This paper presents low speed eco-friendly dry machining of AISI 304L austenitic stainless steel with PVD coated indexible tool insert. Turning trials are conducted at four speeds (16.97m/min, 23.57m/min, 33.94m/min and 47.14m/min) at three feed rates (0.10mm/rev, 0.20mm/rev and 0.25mm/rev). Surface roughness and tool wear are two major aspects of machinability, are discussed in this paper and result will be helpful to understand dry machinability of AISI 304L at low speed.*

***KEYWORDS- AISI 304L Stainless Steel, dry machining, surface roughness, tool wear, PVD coating.***

## INTRODUCTION

Austenitic stainless steel are considered as difficult to machine due to their nature of high work hardening tendency, low thermal conductivity and high ductility [1], [2]. These factor increase the tendency of the material to form a built-up-edge on the tool. The chip remove in machining exert high pressure on the nose of the tool; these pressure when combined with the high temperature at the chip/tool interface, causes pressure welding of portions of the chip to the tool [3]. Devillez et al. [4] found the workpiece material adheres to the rake and flank faces of cutting tool, which forms built-up-edge, are the dominant wear modes during dry machining. Dry machining eliminates harmful cutting fluid cost, its storage, handling, utilizing and safe disposal of fluid. It reduces the overall production time and improves working conditions and is environment friendly.

The advantages of dry machining include: no pollution to atmosphere; no residue on the swarf which will reduce disposal and cleaning costs, non injurious to skin and allergy free [5]. Yahya et al. [6] investigated more tool wear and inferior surface finish occurs using dry machining. Both factor increases the machining cost and reduces the productivity. M Gunay et al. [7] found the machining involves many factors having potential for the sustainable development include cooling and lubricating fluid, waste disposal of fluids and energy consumption along with the tool life. G.M. Krolezk et al. [8] carried out experiment of dry and wet turning (cooling/lubricant conditions) with different carbide tools and concluded that selection of tool coating shall be adapted to appropriate types of machining to improve thermophysical, mechanical and tribological performance of machining process. At the time of cutting of stainless steel, high heat is generated and due to low thermal conductivity of stainless steel, ultimately heat flows to tool resulting in high temperature of the tool nose which results in welding and adhesion of workpiece material on to the rake and flank faces of tool and high tool wear occurs.

The exciting commercial range of coatings has demonstrated that very hard, brittle material such as TiC, TiN and $Al_2O_3$ in the form of very thin layer- less than 10micrometer. Among two methods of coating, the lower deposition temperature of PVD, results in lower residual stress in the coating compared with CVD [9]. During cutting, tool exposed to high temperature so thermal stability of tool coating is very important. The PVD coated Titanium Aluminum Nitride (TiAlN) film provide high oxidation resistance up to $900^0$C by formation of stable layers of $Al_2O_3$ and $TiO_2$ between tool and workpiece which is abrasive and wear resistant [10], [11]. Alper Uysal [12] found in drilling operation of AISI 304L stainless steel with nACo® coated and uncoated WC drill tool at increased cutting speed 50m/min, drill tool interface temperature increased and chips adhered on the drill tool tip, chisel edge and cutting edge. Both coated and uncoated drill damaged heavily, but coated drill tool were less damaged than uncoated drill tool, because coating layer reduced the drill tool-workpiece friction and increased the wear resistance. At low cutting speed 30m/min less drill tool damage occurs. Swapnagandha S. Wagh et al. [13] used PVD AlCrN/TiAlN coated carbide inserts for machining of AISI 304 stainless steel. Atul P. Kulkarni et al. [14] used AlTiCrN coated insert for dry turning of AISI 304 Stainless steel. Atul Kulkarni et al. [15] used PVD multilayer AlTiN/TiAlN coated carbide inserts for machining of AISI 304 austenitic stainless steel.

This paper presents use of low speed machining while turning of AISI 304L austenitic stainless steel using PVD coated indexible trigon tool insert. Surface roughness and tool wear are the main issue, which have been discussed in this work.

## EXPERIMENTAL DETAIL AND METHODOLOGY

For the analysis 12 rods of AISI304L austenitic stainless steel are used with 20mm in diameter and 80mm in length. From 80mm length of workpiece 40mm length is used for holding and 30mm length is used for turning (Fig. 1). The hardness of the material is 82HRB. The TiAlN PVD coated on K-20 grade cemented carbide indexible tool inserts specification WNMG080408 (Fig. 2) hardness 91HRA are used for turning. For each sample a new cutting edge of cutting tool is used. The tool holder MWLNR2020M08 is used. Chemical composition of AISI304L austenitic stainless steel is give in table 1.

**Table 1. Chemical composition of AISI 304L**

| Elements | % by wt. |
|---|---|
| C | 0.27 |
| Si | 0.9 |
| Mn | 1.8 |
| P | 0.035 |
| S | 0.28 |
| Cr | 18.0 |
| Ni | 8.0 |
| Iron | Balanced |

Continuous turning operation is carried out on Royal Foundry Lathe Model No. RF1000 equipped with 5 KW, 3 ø electric motor. Twelve workpieces are machined at four cutting speeds (16.97m/min, 23.57m/min, 33.94m/min and 47.14m/min) and three feed rates (0.1mm/min, 0.2mm/min and 0.25mm/min). Throughout the experimentation, depth of cut is kept constant at 0.75mm.

With above mentioned cutting parameters machining is carried out with 30mm length of cut and surface finish is measured by 2D Surface profilometer (Make: Taylor Hobson, Model: Talysurf Surtronic).

**Figure 1. AISI 304L machined rods**

**Figure 2. PVD coated trigon tool insert**

**Table 2.**
**Surface roughness of twelve samples at different cutting speed and feed rates**

| Sample Number | Cutting speed (m/min) | Feed rate (mm/rev) | Surface Roughness Ra (μm) |
|---|---|---|---|
| S1 | 16.97 | 0.10 | 2.41 |
| S2 | 16.97 | 0.20 | 2.90 |
| S3 | 16.97 | 0.25 | 3.15 |
| S4 | 23.57 | 0.10 | 1.80 |
| S5 | 23.57 | 0.20 | 2.54 |
| S6 | 23.57 | 0.25 | 2.88 |
| S7 | 33.94 | 0.10 | 1.59 |
| S8 | 33.94 | 0.20 | 2.10 |
| S9 | 33.94 | 0.25 | 2.44 |
| S10 | 47.14 | 0.10 | 1.16 |
| S11 | 47.14 | 0.20 | 1.60 |
| S12 | 47.14 | 0.25 | 2.09 |

## EXPERIMENTAL RESULTS

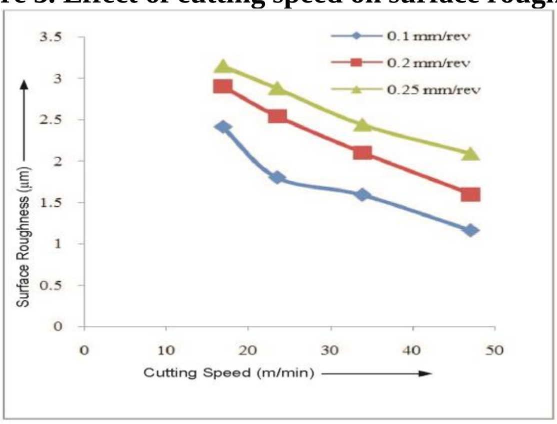
### A. ANALYSIS OF SURFACE ROUGHNESS

Surface roughness mainly depends on cutting speed, feed and type of tool material used in machining.

**1. Effect of cutting speed on surface roughness:** The curves of surface roughness against cutting speed (Fig. 3) reflects that surface roughness values are high at low cutting speed (16.97m/min) and low at high cutting speed (47.14m/min) for same feed rate group of samples. For 0.10mm/min feed rate group, sample no. S1, S4, S7, and S10 the cutting speed are increasing from 16.97m/min, 23.57m/min, 33.94m/min to 47.14m/min respectively; while the surface roughness value are decreasing from 2.41μm, 1.80μm, 1.59μm to 1.16μm respectively. The same tendency is investigated for feed rate 0.20mm/min and 0.25mm/min group of samples.

Thus, the surface roughness values are increasing on decreasing of cutting speed and surface roughness values are decreasing on increasing of cutting speed.

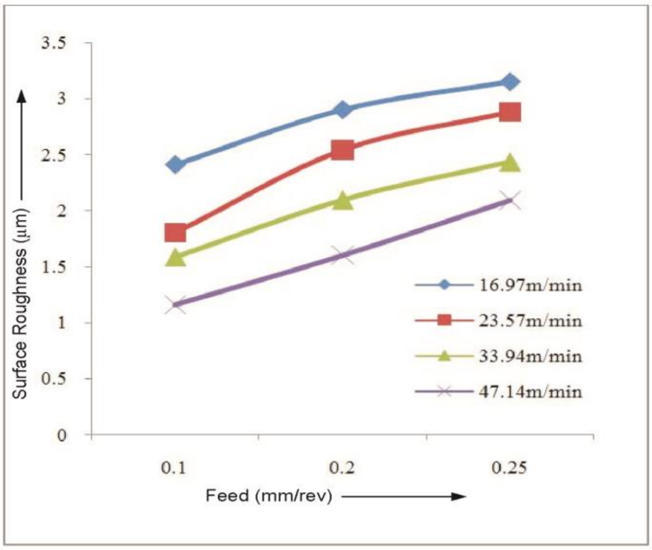
**Figure 3. Effect of cutting speed on surface roughness**



**2. Effect of feed rate on surface roughness:** The curves of surface roughness against feed rates (Fig. 4) reflects that surface roughness values are high at high feed rate (0.25mm/rev) and low at low feed rate (0.10mm/rev) for same speed group of samples. For 47.14m/min speed group, sample no. S10, S11 and S12 the feed rate are increasing from 0.10mm/rev, 0.20mm/rev to 0.25mm/rev respectively; while the surface roughness value are also increasing from 1.16µm, 1.60µm to 2.09µm. The same tendency is also investigated for cutting speed 33.94m/min, 23.57m/min and 16.97m/min group of samples.

Thus, the surface roughness values are increasing on enhancing the feed rate and surface roughness values are decreasing on reducing the feed rate.

**Figure 4. Effect of feed rate on surface roughness**




## B. ANALYSIS OF TOOL WEAR

Swapnagandha S. Wagh et al. [13] concluded the AlCrN/TiAlN coating demonstrate better thermal stability and chemical inertness at elevated temperature which prevents the formation of built-up-edge.

The flank wear is caused by abrasive and adhesive action between cutting tool and machine surface. It starts at the cutting tip and then widens as contact area increases and forms the wear land [14].

The PVD coated Titanium Aluminum Nitride (TiAlN) film provide high oxidation resistance up to $900^0$C by formation of stable layers of $Al_2O_3$ and $TiO_2$ between tool and workpiece which is abrasive and wear resistant [10], [11].

The cutting speeds are low and length of cut is small in all the experiment and heat generation is low, no considerable tool flank wear is found.

## CONCLUSIONS

Issue related with surface roughness and tool wear during low speed machining of AISI 304L austenitic stainless steel with PVD coated cemented carbide tool insert, turning trials are conducted at four speeds (16.97m/min, 23.57m/min, 33.94m/min and 47.14m/min) at three feed rates (0.10mm/rev, 0.20mm/rev and 0.25mm/rev) at constant depth of cut 0.75mm. Surface roughness values are increasing on decreasing of cutting speed and surface roughness values are decreasing on increasing of cutting speed. Again surface roughness values are increasing on enhancing the feed rate and surface roughness values are decreasing on reducing the feed rate.

The cutting speeds are low and length of cut is small in all the samples and heat generation is low, no considerable tool flank wear is found.

## REFERENCES

[1] T. Akasawa, H. Sakurai, M. Nakamura, T. Tanaka, K. Takano, *Effects of free-cutting additives on the machinability of austenitic stainless steels*, Journal of Materials Processing Technology 143–144 (2003) 66–71., Elsevier
[2] Ulaş Çaydaş, Sami Ekici, *Support vector machines models for surface roughness prediction in CNC turning of AISI 304 austenitic stainless steel*, J Intell Manuf (2012) 23:639–650, DOI 10.1007/s10845-010-0415-2., Springer.
[3] F.C. Campbell, *Manufacturing Technology for Aerospace Structural Materials*, p 204.
[4] A. Devillez, G. Le Coz, S. Dominiak, D. Dudzinski, *Dry machining of Inconel 718, workpiece surface integrity*, Journal of Materials Processing Technology 211 (2011) 1590– 1598., Elsevier.
[5] P.S. Sreejith, B.K.A. Ngoi, *Dry machining: Machining of the future*, Journal of Materials Processing Technology 101 (2000) 287-291., Elsevier.

[6] Yahya Dogu, Ersan Aslan, Necip Camuscu, *A numerical model to determine temperature distribution in orthogonal metal cutting*, Journal of Materials Processing Technology 171 (2006) 1-9., Elsevier.
[7] Mustafa GÜNAY, Emre YÜCEL, *An Evalution on Machining Processes for Sustainable Manufacturing*, Gazi University Journal of Science, GU J Sci, 26(2): 241-252 (2013).
[8] G.M. Krolczyk, P. Nieslony, R.W. Maruda, S. Wojciechowski, *Dry cutting effect in turning of a duplex stainless steel as a key factor in clean production*, Journal of Cleaner Production (2016) 1-12, Elsevier.
[9] Edward M. Trent, Paul K. Wright, *Metal Cutting Fourth Edition ; Cutting Tool Materials II Cemented Carbide.*, p 224, Published by Elsevier.
[10] S. Huddedar, Atul P. Kulkarni, Girish G. Joshi, Vikas G. Sargade, 2012, *Microstructure and mechanical properties of AlTiCrN, AlCrN coatings deposited by cathodic arc evaporation (PVD) technique*, Proceeding of 21st International conference on processing and fabrication of advanced material, 1, p. 514.
[11] Yucel Birol, *Sliding wear of CrN, AlCrN and AlTiN Coated AISI H13 hot work tool steels in aluminium extrusion*, Tribiology International 57 2013), 101-106.
[12] Alper Uysal, A Study on Drilling of AISI 304L Stainless Steel with Nanocomposite-Coated Drill Tools, Arab J Sci Eng (2014) 39:8279–8285, Springer.
[13] Swapnagandha, S. Wagh, Atul P. Kulkarni, Vikas G. Sargade, *Machinability studies of austenitic stainless steel (AISI 304) using PVD cathodic arc evaporation (CAE) system deposited AlCrN/TiAlN Coated Carbide inserts*, Procedia Engineering 64 ( 2013 ) 907-914.
[14] Atul P. Kulkarni, Girish G. Joshi, Vikas G. Sargade, *Dry turning of AISI 304 austenitic stainless steel using AlTiCrN coated insert produced by HPPMS technique*, Procedia Engineering 64 (2013) 737-746.
[15] Atul Kulkarni, Vikas Sargade, Chittaranjan More, *Machinability Investigation of AISI 304 Austenitic Stainless Steels using Multilayer AlTiN/TiAlN Coated Carbide Inserts*, 2nd International Conference on Materials Manufacturing and Design Engineering, Procedia Manufacturing 20 (2018) 548-553.