ISSN 2347 - 3983
International Journal of Emerging Trends in Engineering Research (IJETER), Vol. 3 No.1, Pages : 17 – 21 (2015)
*Special Issue of ICEEMC 2015 - Held during January 27, 2015, Chennai, India*

# Precision Grinding of Ti6Al-4V using the Novel bondless diamond grinding wheel – A review

**Ananda Kumar Eriki[1], Prahlada Rao K[2], Naga Malleshwara Rao G[3] and A.K. Sinha[3]**
[1]Ph-D Research Scholar, Department of Mechanical Engineering, JNTU-Anantapur, A.P, India, erikiananda@yahoo.co.in
[2]Professor, Department of Mechanical Engineering, JNTU-Anantapur, Andhra Pradesh, India, drkprao1@yahoo.com
[3]Professor, Department of Mechanical Engineering, SVCET-Chittoor, Andhra Pradesh, India, nmgujjar@gmail.com
[4]Senior Lecturer, Dept. of Mech. Engg, Nilai University, Nilai, 71800, Malaysia, anjani_184@yahoo.com

**Abstract***:* Titanium composites are to a great degree hard to machine and extravagant (expense funds when pounding with the novel bondless jewel crushing wheel). While machining the Ti composites, the cutting zone temperature is so high (lessening of temperature of cutting zone, great change in the chip-granulating coarseness cooperation and the utilization of novel bondless precious stone crushing wheel). The novel bondless wheel is tried on Plano surfaces for surface quality because of fine and thick structure of consistently appropriated precious stone wheel coarseness. The novel system for aspheric era can give the preparatory result or not. The principle objective is to study the execution of vast diamond wheel in granulating operation of Ti6al-4v, some warm examination, basic profundity of cut and molecule measurement.

**Key words:** Ti6-4, Titanium alloy, Precision grinding Novel bondless diamond grinding wheel, 6Al-4V.

## INTRODUCTION

Titanium (Ti) was found in 1794 and is the ninth most regular component in the world's hull, happening as rutile, Tio2, and limonite, Feo-Tio2. Extraction of titanium in sums that were substantial enough for commercialization came to fruition with the advancement of the Kroll transform in 1936. Titanium has high quality to-weight degree that makes it alluring for some applications. ie. Air ship, petrochemical, biomaterials, for example, orthopedic inserts, titanium combinations have been produced for administration at 550°c for drawn out stretches of time and at up to 750°c for shorter periods. Unalloyed titanium, known as financially immaculate titanium, has brilliant consumption safety. Aluminum, Vanadium, Molybdenum, Manganese and other alloying components when added to Titanium composites grant properties, for example, enhanced workability, quality and solidifying. The properties and assembling qualities of Titanium amalgams are to a great degree delicate to little varieties in both alloying and remaining components, control of organization and preparing are, in this way, vital, particularly the counteractive action of surface defilement by hydrogen, oxygen or nitrogen amid handling [1]. These components cause embrittlement of titanium and, thus, lessen sturdiness and malleability. The suitability of CNMG insert in turning of the titanium alloy (Ti-6Al-4V) was investigated in this study. The following conclusions were arrived based on the series of experiments and analysis [2].

The centered cubic structure of titanium (β-titanium, above 880 ° C is ductile, whereas its HCP structure (α-titanium) is somewhat brittle and is very sensitive to stress corrosion. [3] A variety of other structures (α, near- α, α- β and β) can be obtained by alloying and heat treating, so that the properties can be optimized for specific applications. The size effect is an impediment which translates into the amount of material removal (cubic mm per minute) decreasing while the amount of energy increases. This results in elevated temperatures that are highly localized. In grinding thousands of cutting edges are present. In bonded wheels, the bond is weak and is usually subject to wear. The creation of a bondless diamond grinding wheel has shown success during grinding of glass lenses and in machining the chip packaging of Intel's Pentium III chip for failure analysis [4]. Preheating helps in appreciable lowering the cutting force values during cutting and reducing acceleration amplitude of vibration [5]. The tool life models that the cutting speed is the main factors on the tool life, followed by the feed and axial depth of cut. Increase many of these three cutting variables leads to reduction of tool life [6].

## Approach

To explore the execution of bondless crushing wheel in granulating of Ti6al-4v, to study the impact of cutting parameter, (cutting speed, food, and length of cut) in pounding Ti6al-4v with bondless wheels, to create the ideal cutting parameters in pounding Ti6al-4v compound and to tentatively and systematically distinguish conditions that advances heat dissemination amid pounding methods. Taking into account microstructures that can be delivered by alloying, titanium composites are gathered as α, α-β and β alloys. α titanium and α-β compounds have been utilized for dental and orthopedic purposes. β titanium amalgams are consistently considered as hopeful materials for insert applications in light of their simplicity of formability, expanded quality and lower flexible modulus, despite expanded expense. The impact of cleaning techniques/methods on the quality and trustworthiness of workpiece surfaces acquired after distinctive cleaning systems on Ti-6-4 hotness safe combination. The principle destination of this examination is to the study the execution of unfathomable precious stone wheels in pounding

**International Journal of Emerging Trends in Engineering Research (IJETER), Vol. 3 No.1, Pages : 17 – 21 (2015)**
*Special Issue of ICEEMC 2015 - Held during January 27, 2015, Chennai, India*

operation of Ti6al-4v. Some cutting parameters, for example, cutting speed, feed, and profundity of cut will be considered [8].

### Generate aspheric surface using CAD/CAM

The nonstop way pounding with expansion of the most recent CAD/CAM demonstrating apparatus is Unigraphics. The entire granulating arrangement is changed over into straightforward 2d explanatory line way. The granulating wheel follows the nonstop explanatory line profile to create aspheric lens as shown in Fig.1. In the zone era system, synchronized tilting development of the rotating table with apparatus development was customized to keep purposes of contact settled amid profile era. This synchronized development of the turning table is equipped for creating precise aspheric profiles just when the wheel is new. Settled contact point idea in this project quickens nearby wear on the toric surface of the wheel. This would bring about the making of the level arrive on the toric profile of the wheel [7]. As this level wear area builds, the ensuing surface fails to offer the profile exactness and the aspheric parameter "P" is the central point that gets included. In the proposed technique the contact point between the lens and the toroidal glass wheel is permitted to differ inside particular zone on the toric surface of the mug wheel. Disseminated contact between the lens and the mug wheel can be made by situating the lens at an altered edge. The toroidal container wheel is modified to follow the settled aspheric profile without the tilting point of the lens while machining. The effect of this adjustment is to disperse the wear of the toroidal container wheel all through the particular range. Fig. 1 demonstrates the contact point geometry for both surfaces.

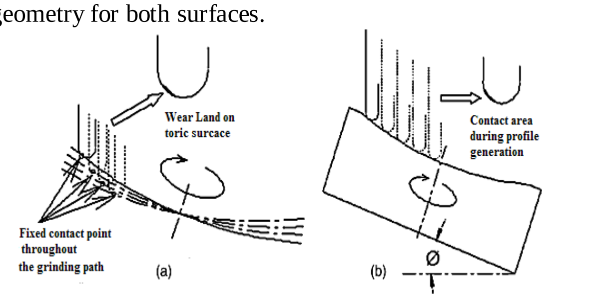



**Fig 1: (a)** Fixed point contact throughout the profile generation during zone. **(b)** Contact point changes during profile generation in proposed method

### Quantification of ductile

The visual assessment to gauge measure of malleable and break regions on the ground surface prompts predisposition, conflict and high reliance on the engineer's experience and translation ability. Inconceivable improvements on quantitative assessment utilizing picture transforming systems, stress-erosion splitting (SCC) and cleft consumption have been demonstrated to happen in situations containing chlorides or other halide particles. Therefore, it is general practice to keep away from the utilization of chlorinated solvents, cutting liquids, and so forth as shown in Fig.2.

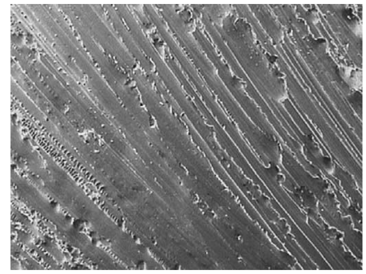


**Fig 2:** SEM; Generated aspheric surface with massive ductile streaks.

## MECHANICAL PROPERTIES OF TI6AL-4V

The fracture toughness (KIc) of Ti 6Al-4V lies between that of aluminum alloys and steels. Microstructures that tend to have higher toughness are those with greater amounts of lamellar alpha/beta and coarser structures in general. The ELI grade of Ti 6Al-4V exhibits toughness superior to the standard grade.

The High-cycle fatigue limits for Ti6Al-4V are greatly influenced by both microstructure and surface conditions. Some generalize fatigue limits for annealed wrought material is shows in Table1.

**Table 1:** Strength/Axial Fatigue limited range for Ti6Al-4V

| | |
|---|---|
| Ultimate bearing strength | 1380-2070 MPa |
| Compressive yield strength | 825-895 Mpa |
| Ultimate shear strength | 480-690 Mpa |
| Smooth | 400-700 MPa |
| Notched | 140-270 MPa |

The fatigue strength (FS) must incorporate the sort of stacking and recurrence of burden cycling. Lower frequencies, 1-2 Hz, are most proper for insert assessments. Prior studies looking at the consumption weakness conduct of Ti-6al-4v, Co-Cr-Mo and 316l stainless steel utilized a recurrence of 1 Hz. Studies reporting impacts of hotness treating on mechanical properties of Ti-6al-4v demonstrated critical changes over the toughened material because of high temperature treating the beta titanium combinations will brings about changes in weariness quality shown in Fig.6, 7. The relationship between the versatile modulus and terminating temperature as a capacity of rough grain sort and holding for both high immaculateness and titanium-doped aluminum oxide structures, the flexible modulus is created as the confirmation temperature is expanded, and is very subject to the measure of holding material that encompasses the grating grain.

## MATERIALS AND METHODS

Ores containing titanium are initially decreased titanium carbide in a curve heater, and after that changed over to titanium chloride in a chlorine air. This compound is diminished further by refining and by filtering (dissolving), this arrangement structures wipe titanium.

### Workpiece Material

The wipe is then pressed into billets, liquefied and put into ingots, to be transformed later into different shapes. The unpredictability of these operations adds significantly to the expense of titanium. The distinctive dispersion coefficients of $\alpha$ and $\beta$ titanium are impacted by the microstructure and therefore impact the mechanical conduct of the two stages, e.g. creep execution, hot workability, and super plasticity.

The constrained volume dispersion in α titanium deciphers into a predominant drag (creep) execution of α titanium and α containing Ti composites contrasted with β titanium, Fig. 3.

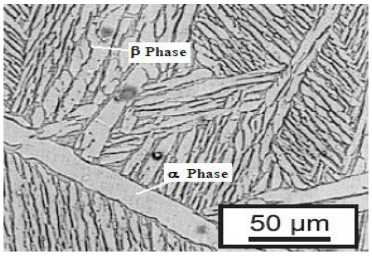



**Fig 3:** SEM; Lamellar microstructure of Ti-6Al-4V.

### Cutting tool Material

The wheel was additionally used to crush the chip bundling to get level surfaces for recognition of blemished copper follows in the chip bundling. The development of this wheel happened with the need to machine the silicon bite the dust on Intel's Pentium III for disappointment examination of the 45 million transistors under the kick the bucket. Disappointment examination includes the evacuation of around 700 μm of the kick the bucket to abandon around 100 μm on the pass on to empower seeing blemished transistors on a back emanation infra-red magnifies.

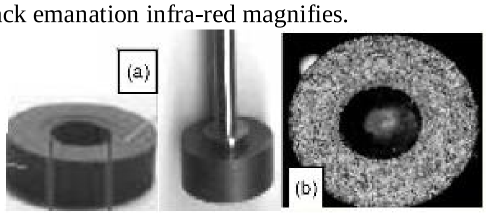



**Fig 4: (a)** Bondless wheel with and without shank **(b)** With hole for chip and avoidance of zero velocity.

The precious stones in the wheel are become and in this manner clung to one another and are additionally attached to a metallic substrate. Its distinction with a reinforced jewel wheel is apparent from Bondless granulating wheels were effectively used to machine glass and silicon and pliable streaks were effortlessly gotten. The bondless wheel advances more micro-cutting activity than the reinforced precious stone wheel, as shown in Fig. 4 (a,b). The bondless wheel likewise has any longer life effortlessly of the request of 500% with cutting compels that are lower.

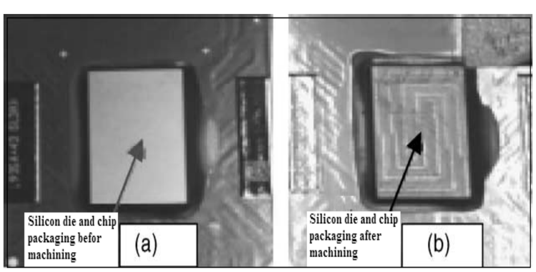
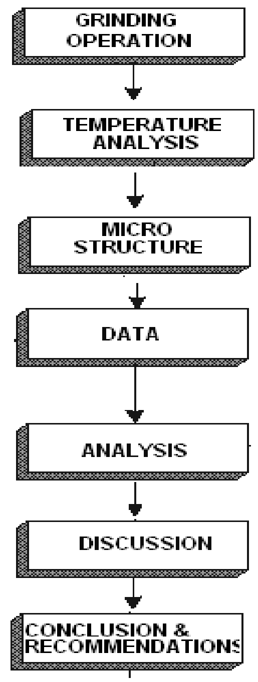



**Fig 5: Pentium III chip (a)** before **(b)** after machining for failure analysis of 45 million transistors, and observe Cu traces in the chip packaging.

The grinding of a silicon wafer (Integrated Circuit Chips) using a CNC milling machine is a precision machining process. Figure 5 (a, b) shows an IC silicon chip before and after grinding it on vertical machine. Conventional surface grinding techniques using large diameter wheels may not be appropriate for machining thin wafer IC silicon dies, as the force will likely damage the capacitors and transistors contained on the chip. Non-traditional focused ion beam machining may not work as the heat generated might damage the transistors. Also, an end-milling technique using small diameter wheels at the maximum speed of a conventional milling centre is often not fast enough to minimize cutting forces. [8]

Two wheel was also used to grind the chip packaging to get flat surfaces for detection of defective copper traces in the chip packaging.

## METHODOLOGY




### Diameter tolerance

Upgraded surface medications and transforming strategies permit Fort Wayne Metals to offer tighter and more controlled resistances. The outline in the privilege section subtle elements standard distance across resilience for Ti 6al-4v ELI in wire and loop structures, most measurements can be delivered to tighter resistances

### Surface condition

Ti 6al-4v ELI tends to stick, fuss or frosty weld withdrawing passes on amid transforming. Basic industry practice to maintain a strategic distance from this condition normally utilizes substantial drawing or pickling at completion size bringing about a course or exceptionally textured surface. Post Wayne Metals has developed handling procedures with upgraded surface medicines which oblige insignificant carving at completion size to evacuate lingering oxide, yielding a cleaner and smoother surface completion

### Grinding operation

Komanduri and Shaw developed an equation for the radius of curvature $\rho$ that a particle (platelet) of thickness h will assume after grinding:

$$\rho = \frac{Eh^2}{6T} \quad (1)$$

ρ = 1.732 cm for steel (2)

Where E = 207 × $10^3$ N/mm$^2$, T=2 J/m$^2$ and h=0.98 mm

According to Komanduri and Shaw,young's modulus E drops to almost zero with increase in temperature approaching melting point, and surface tension *T* assumes the value for liquid glass/steel which will be the same as that for the solid within a factor of 2.

### Critical depth of cut in grinding

Bifano's model is used here to discuss the critical depth of cut. The model indicates the dependence of the critical undeformed chip thickness on material properties for ductile-regime grinding.

$$t = b\left(\frac{E}{H}\right)\left(K_c{}^2\right) \quad (3)$$

t=83 mm

Where t, critical depth of cut; b, a constant; E, young's modulus; H, hardness; $K_c$, fracture toughness. Using *b* = 1 in Eq. (3) it was found that in ultra-precision machining of six different glasses, the calculated value of t was higher than those obtained from the experiments. It was also found that the critical depths for dry grinding were larger than those for indenting in a vacuum. To compensate for this, a value of *b* = 0.12 was proposed for micro-grinding table 2.

**Table 2:** Machining parameters

| | |
|---|---|
| Speed (v) | 30 m/min |
| Feed (f) | 20 mm/min |
| Depth of cut (d) | 10μ m |

### Temperature analysis

Ti 6al-4v fashioned items are normally utilized as a part of either a plant toughened or arrangement treated and matured condition. Quick extinguishing after arrangement treatment (water extinguish or identical) is essential so as to expand the development of alpha' martensite stage, which thusly augments the maturing reaction. Other hotness medications utilized on Ti 6al-4v incorporate anxiety mitigating for shaped or welded parts, and beta toughening, which is utilized for enhancing damage tolerance. Ti 6al-4v, in the same way as other titanium amalgams, has a high fondness for gasses including oxygen, nitrogen and hydrogen. Ingestion of oxygen results in the arrangement of a greatly hard, fragile oxygen-stabilized alpha stage layer known as alpha case after warming in air. [9]

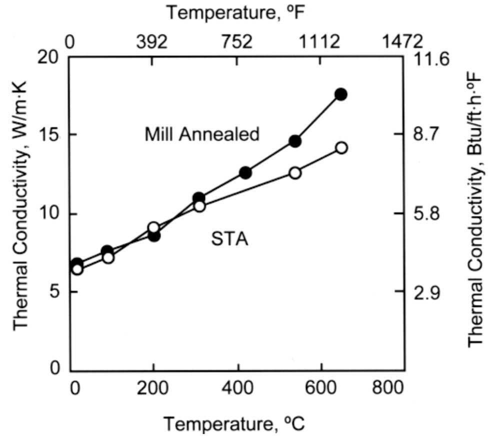



**Fig 6:** Thermal conducting of Ti6Al-4V

### Thermal expansion of Ti6Al-4V

Intermediate and final annealing of Ti 6Al-4V products is often performed in a vacuum or inert gas atmosphere to avoid alpha case formation and the associated material loss. [10]

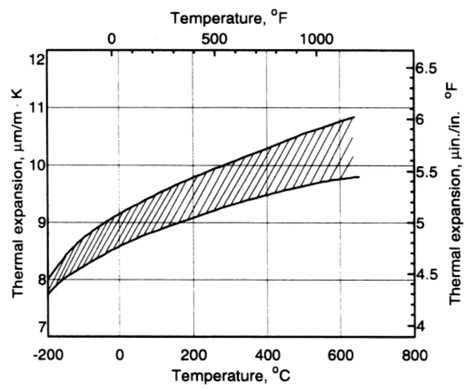



**Fig 7:** Thermal expansion of Ti6Al-4V

### Corrosion Resistance

Ti 6al-4v quickly and spontaneously structures a steady, constant, firmly follower oxide film upon introduction to oxygen in air or water. This record for its amazing erosion safety in a mixture of media, Ti 6al-4v is profoundly impervious to general erosion in watery arrangements including seawater, and in addition in oxidizing acids, chlorides (in the vicinity of water), rocket forces and salts. Conditions under which Ti 6al-4v is defenseless to general erosion are in the vicinity of lessening acids or dry chlorine gas. Stress-erosion breaking (SCC) and fissure consumption have been indicated to happen in situations containing chlorides or other halide particles. Hence, it is general practice to dodge the utilization of chlorinated solvents, cutting liquids, and so forth, in handling titanium. Titanium and its compounds, including Ti 6al-4v, are vulnerable to hydrogen em-brittlement.[9] Vaporous or cathodic hydrogen can diffuse into the metal, structuring fragile hydrides. Subsequently, it is vital to minimize hydrogen pickup amid preparing, especially hotness treating and corrosive pickling. Particulars for Ti 6al-4v plant items commonly point out a greatest hydrogen utmost of around 150 ppm.

## CONCLUSION

The novel technique for aspheric era gave preparatory results. The surface created by the new technique delivered great measure of malleable region. The results demonstrate that the utilization of universally useful machine can give adaptable yield regarding mixed bag of lenses without utilizing any uncommon reason machine. The measurement strategy is settled for portraying the nature of the ground surface. Cleaning parameter can be planned later relying on rate of bendable region found on the ground surface. This would diminish the steady time cycle for cleaning lenses. Spherical glass chips are generally reported shockingly here amid surface granulating of glass. Circular chips were watched just with the 5 m in-food amidst normal long chips; by chance under wet conditions the best surface completion and the least cutting strengths happened with this in-feed. A study of thermal analysis, critical depth of cut and particle dimension is obtained.

i. Little focal composite configuration has effectively turned out to be a fruitful method to evaluate the device life in end-processing of titanium amalgam Ti-6al-4v utilizing uncoated WC-Co embeds under dry conditions.
ii. The apparatus life models demonstrate that the cutting velocity is the fundamental variables on the instrument life, took after by the food and pivotal profundity of cut. Expand a number of these three slicing variables prompts lessening of hardware life.
iii. From the device life first-request model, it is discovered that an increment of cutting velocity, hub profundity of cut and bolster by 100%, will prompt diminishment of hardware life by 70%, 27%, and 37%, separately.

## REFERENCES


[1] Eriki, A.K., K. Prahalada Rao., and G.N., Malleshwara Rao. "Machining of Ti6Al4V alloy using novel bondless diamond layered grinding wheel for precision grinding". *International Journal of Mechanical and Production Engineering (IJMPE).* vol.2, no.11, pp. 57-62, Nov 2014.

[2] Eriki, A.K., K. Prahalada Rao., G.N., Malleshwara Rao. and Babu, A.R. "Effects of various parameters on CNMG turning insert in machining Ti6Al4V". *International Journal of Engineering and Technology Innovations.* vol.1, no.2, pp. 1-5, May 2014.

[3] Eriki, A.K., K. Prahalada Rao. and K.C. Varaprasad. (2014). "Machinability Improvement in Turning of Titanium Alloy (gr2) using Cubic Boron Nitride (cBN) Cutting Tool", *Applied Mechanics and Materials.* vol. 564, pp. 507-512 May 2014.

[4] Eriki, A.K., K. Prahalada Rao. And A. Johnrajan. (2014), "LN2 grinding of Ti6Al4v using novel bondless diamond grinding wheel," in *Proc. 3rd International Conference on Advanced Material Engineering & Technology (ICAMET),* Vietnam, 2014, pp. 123-1127.

[5] Turnad L. Ginta, A.K.M. Nurul Amin, and Mohd Amri Lajis, The performance of uncoated tungsten carbide insert in end milling titanium alloy Ti-6A-4V through work piece preheating, *American J. of Engineering and Applied Science (Science publication,* Vol.2(1), 2009, pp147-153.

[6] Turnad L. Ginta, A.K.M. Nurul Amin, H.C.D. Mohd Radzi, and Mohd Amri Lajis, Tool life prediction by response surface methodology in end milling titanium alloy Ti6Al-4V using uncoated WC-Co inserts, *European Journal of Scientific Research,* Vol.28(4), 2009, pp.533-541.

[7] Turnad L. Ginta, A.K.M. Nurul Amin, H.C.D. Mohd Radzi, and Mohd Amri Lajis, Development of surface roughness models in end milling titanium Ti6Al-4Vusing uncoated tungsten carbide inserts, *European Journal Scientific Research,* Vol.28(4), 2009, pp.542-551.

[8] Venkatesh, V.C., Izman, S., et al, The novel bondless wheel, spherical glass chips, and a new method of aspheric generation, *Journal of Materials Processing Technology*, Vol.167, pp. 184-190, 2005

[9] Kalpakjian, S. & Schmid, S.R., Manufacturing Engineering and Technology, 5th Ed., Prentice Hall, pp. 157-158, 2006,

[10] Wang, Z.Y., & Rajurkar, K.P., Cryogenic machining of hard to cut materials, Wear, Vol. 219, pp.168-175, 2000.