INSPECTION OF CP TITANIUM MATERIAL AND ITS COEFFICIENT OF FRICTION

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Abstract - *The aim of this study is to evaluate the friction coefficient and wear behavior of commercially pure titanium by using pin-on-disc tribometer. These tests are carried out in accordance with American society for testing and materials and g-99 standards under the load conditions of 200kgf and sliding's speed of 100 rpm. As counter pairs, a tungsten ball with 26mm diameter and EN (European norms) steel disc was used. Results shows that have the different friction and the behavior of materials will analyze.*

Key Words: European norms, ASTM, Behavior, coefficient of friction, tribometer.

1. INTRODUCTION

CP Titanium or commercially pure titanium is represented by four distinct grades, specifically A, B, C and D. It's pure and unalloyed. It has better corrosion resistances, formability and strength and moderate formability. End users make use of these qualities such as, excellent corrosion resistances, formability and wieldable characteristic for much application.

Coefficient of friction plays a crucial role in productiveness and efficiency an many materials e.g:-titanium, aluminum, and steel with respect to the changes in material and thermal losses. Coefficient of friction affects the reliability of material, formability and fatigue and wear resistances. To observe the variation of friction and wear rate many factors has considered like load geometry, surface motion, temperature, slip, humidity etc.

Factors affecting the coefficient of friction: - the fabric that are connected, the materials and thus the character of their surface. Rougher surface have higher coefficient of friction but to slip apart. This is often smart in terms of a model during which friction is described as arising from chemical bonds between the atoms of the surfaces at their points of contact.

2. LITERATURE SURVEY

To determine the behavior of friction and wear rate many factors taken into consideration like load geometry, temperature, and speed etc. There are few heat transfer enhancement methods includes imparting turbulences by roughening the surface and introducing the inserts for increasing heat transfer coefficient.

The surface roughness and corrosion behavior is different after thermal oxidation. The CP-Ti specimens were prepared with three different roughness values from carbide paper, RA=0.1, 0.3 and 0.6 μm , and also the thermal oxidization process was conducted at a temperature of 850°C for 8h in an oxygen atmosphere. Structural, mechanical, corrosion and tribological properties of untreated and thermally oxidized CP-Ti with different surface roughness valves were investigated through diffraction, scanning techniques.

3. METHODOLOGY

In order to determine the wear behavior and coefficient of friction of commercially pure titanium, we have adopted a methodology called pin-on-disc Tribometer. The apparatus involved in this process are:

- Loads according to the condition.
- Rotating disc of chosen material according to the condition.
- Pin of chosen diameter.
- Lubricant according to the condition.

In the Pin-disc wear test method, we require two specimens. One, a pin with reduced tip, is positioned perpendicular to the disc, usually a flat circular one. A ball with certain diameter used because the pin specimen is revolving about the disk center. In both the cases, the sibling path is as circle on the disk surface. The plane of the disc is either in horizontal way or vertical way. The specimen is in contact Opposite to the disc at the specified load usually by means of arm or lever with attached weights. Other loading methods are used, like hydraulic or pneumatic. Wear results should be in terms of volume loss for the pin and thus the disk separately. When two different materials are tested in both pin and disk positions. If the linear measures of wear and tear and tear are used the length change or shape change the disc wear track is obtained by any suitable metrological methods, like electronic distance gagging or stylus profiling. Liner measures of wear and tear and tear and tear are converted to wear volume by using appropriate geometric relations. If the loss of mass is measured, the mass loss valve converted to volume loss using an appropriate valve for the specimen density. The number of injury in any of the system is depends on the quantity of things like applied load, machine characteristic, environment and thus the fabric properties.

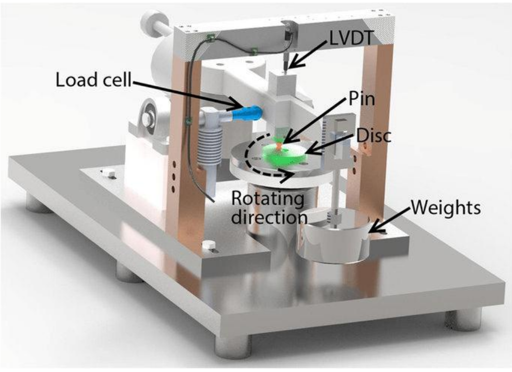


Fig1:- pin-on-disc tribometer

4. APPARATUS

Motor drive: - A variable speed motor drive, should capacity of maintaining constant speed +or- 1% rated full load motor speed under load is required. The motor should be mounted in such a way that its vibration does not affect the test. Rotating speeds are vary in between 0.3to 3 rad/sec (60 to 600 r/min).

Revolution counter: - The machine should be equipped with a revolution counter that will record the number of disk revolution, and it has ability to terminate the machine after a pre-selected number of revolutions.

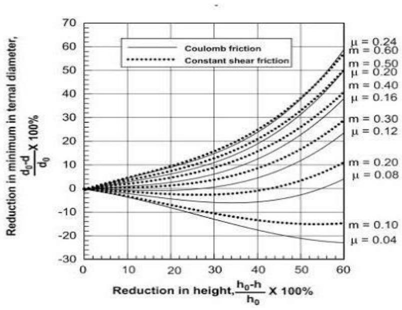
Pin specimen holder and lever arm: - during this methodology the specimen holder is hooked up to the lever arm that encompasses a pivot. Addition weights are one possibility of loading and produce a take a look at force proportional to the mass of the weights applied. The pivot of the arm ought to be situated at intervals the plane of the sporting contact to avoid further loading forces thanks to hefty construction to scale back wave motion throughout wear take a look at.

Wear measurement system: - Instrument accustomed get liner measures of wear and tear and tear should have sensitivity around two.5 five or higher. Any balance accustomed live the mass loss of the take a glance at specimen should have a sensitivity should be around zero.1mg or higher in low wear things larger sensitivity could even be required.

5. EFFECT OF COEFFICIENT OF FRICTION OF TITANIUM AND TITANIUM ALLOY

- The effect of atomic structure:-The coefficient of friction of commercially pure titanium is given within the range 0.30-0.34, with lower figures within the range 0.25-0.30 for titanium alloys. Practical tests can shows much higher figures, in a range of 0.8-0.9 for rubbing contact with untreated surface without lubrication. Three fundamental factors combine to supply titanium its high coefficient of friction and cause the poor tribological behavior of the metal. The first arises from titanium's atomic structure, and this can be marginally improved by bulk or surface alloying to from a harder and more wear resistant structure.
- Formability: -Formability may be a term applicable to sheet forming. Sheet operation like deep drawing, cup drawing, bending etc. involve intensive tensile deformation. Therefore, the issues of localized deformation referred to as necking and fracture because of dilution down ar common in several sheet forming operations. Property is also a serious concern in sheet operations.

- Coefficient of friction effects metal forming:-Friction between the 2 surfaces encompasses a significant effect on material deformation, forming, load, and component surface finish. The coefficient of friction, if controlled properly, could generate the specified stresses to deform the metal to the specified shape. Friction has a vital influence in metal forming operations because it contributes to the success or failure of the method. During deformation of the flat solid over a tool, Contact occurs only at the height asperities of both surfaces. To bear areas the processed material flows over the tool's surface, therefore all the models won't to study forming processes must include the way to require under consideration the contact with friction phenomena.



6. EFFECT OF FRICTION LAWS ON METAL FORMING PROCESS

- Deep drawing:-The process deep drawing operation has been selected to hunt out the thickness of formed cup and to hunt out how coefficient of friction is varying inside the formed. Deep drawing could also be a sheet forming process during which a sheet blank is radially drawn into a forming die by mechanical action of a punch. It's thus a shape transformation process with material retention. The strategy is taken into consideration 'deep' drawing when depth of the drawn part exceeds its diameter.

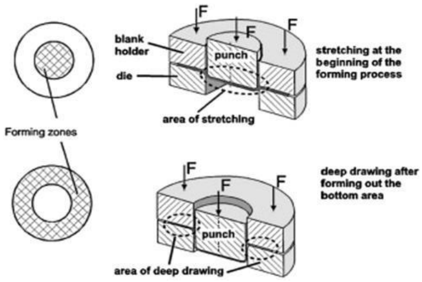


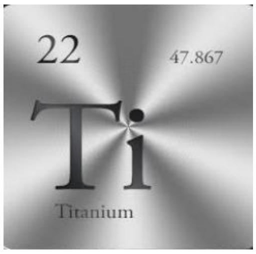
Fig2:- Overview of deep drawing operation

Fig3:- Specimen before deep drawing, Specimen after deep drawn

7. MATERIALS

Commercially pure Titanium (CP Titanium):- it's the softest and most ductile. It possesses good formability, and excellent corrosion resistant. The fabric is chosen for any application where simple formability is required and is often available as titanium plate and tubing. The titanium is element with symbol Ti and number 22. It's a transition metal with a silver color, rarity and high strength. Titanium is proof against corrosion in sea water.

Fig4:- Commercially pure titanium



Atomic number:-22

Atomic weight: - 47.867

Melting point:-1941K (1668°C or 3034°F)

Boiling point: - 3560K (3287°C or 5949 °F)

Density: - 4.5 grams per cubic centimeter.

Phase at room temperature: solid

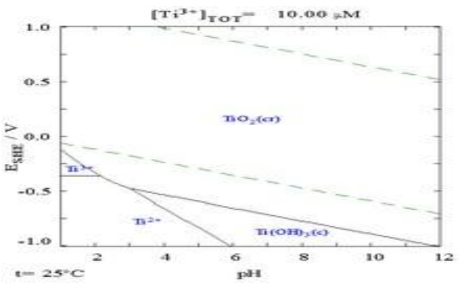
Element Classification: - Metal.

Chemical properties: - There are two types of the chemical properties that affect the titanium.

- Health effect on titanium
- Environment effect of titanium

Health effect: - Titanium appears to have no harmful effect on plants or human. It had also not been shown to have any role in maintaining good health.

Environmental effect of titanium:-Like aluminum and Mg metal and its alloys oxidize straight away upon exposure to air. Metal promptly reacts with element at one, 200°C (2,190°F) in air, and at 610°C (1,130°F) in pure element, forming oxide. It is, however, slow to react with water and air at close temperature as a results of it forms a passive compound coating that protects the majority metal from additional reaction. Once it forms, this protecting layer is solely 1-2mm thick however continues to grow slowly. Reaching a thickness of 25nm in an 4 years. Atmospherically passivation offers metal glorious resistance to corrosion, nearly admire metallic element. Metal is capable of holding attacks by dilute element and hydrochloric acids, chloride solutions and most organic acids. However, metal is unsound by targeted acids. As indicated by its negative oxidation-reduction potential, metal is thermodynamically a awfully reactive metal that burns in traditional atmosphere at lower temperature than the temperature.



8. SAMPLE CUTTINGS

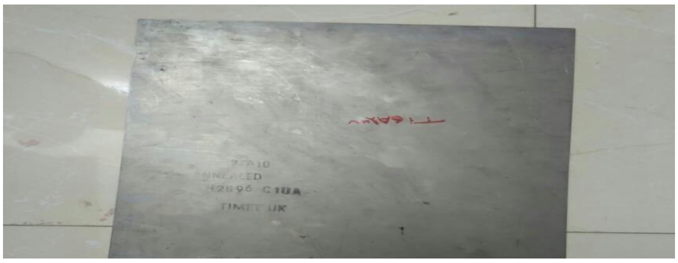


Fig5:-Plain sheet of cp titanium before cutting

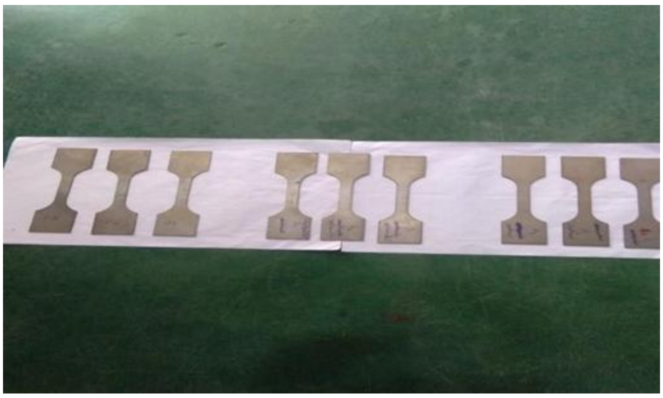


Fig6:- Test samples after cutting

9. DESIGN OF CUTTING SAMPLES

The dimensions of plain commercially titanium sheet 400x265mm.

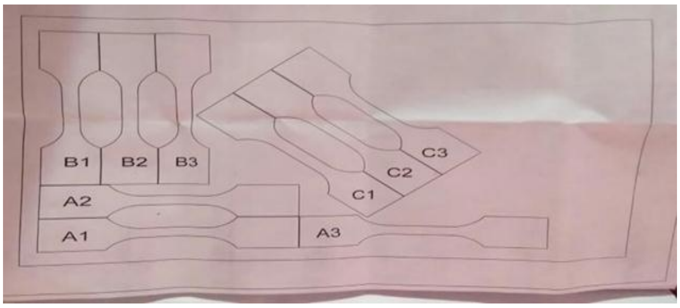


Fig7:-The dimensions of test samples after cutting

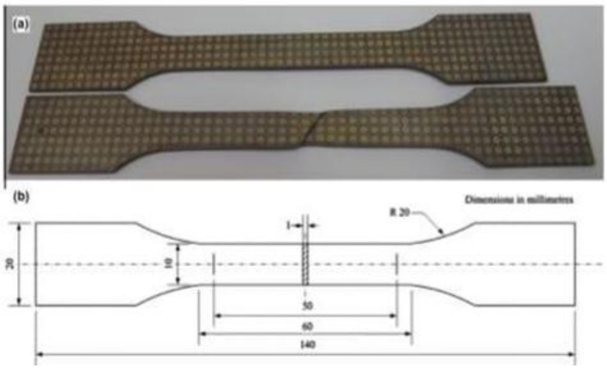


Fig8:- Dimensions of the tensile samples (165*35mm)

10. PROCEDURE

Immediately before testing, and before measuring or weighing, clean and dry specimen. Make sure in removing all the dirt and foreign matters from the specimen. Use non-chlorinated, non-film-forming cleaning agents and solvent. Dry materials with open grains are used to get rid of all traces of the cleaning agents and solvents. Dry material with open grains to removes all marks of the cleaning fluids which will be entrapped within the material. Steel specimen having residual magnetism should be demagnetized. The specimen dimensions to the closest 2.5 μm or weigh the specimen nearest to 0.0001g. Insert the disk securely within the device in order that the disk is fixed perpendicular to the disk surface when in-tuned, so as to take care of the mandatory contact condition. Start the motor and adjust the speed to the required valve while holding the pin specimen out of the contact with the disk. Stop the motor. Set the revolution within the system up to desired revolution. Begin the test with the specimen connected under load. The test is stopped when the required number of revolutions is achieved. Tests shouldn't be interrupted. Remove the specimens and clean off any loose wear of materials. Note the existence of feature on or near the wear and tear scar such as: protrusions, displaced metal, discoloration, micro racing, or spotting.

Repeat the test with additional specimens to get sufficient data for statically significant results.

11. CALCULATION & REPORTING

The wear measurements should be reported because the volume loss in cubic millimeters for the pin and disk, separately. Use the subsequent equations for calculating volume losses when the pin has initially a spherical end shape of radius R and therefore the disk is initially flat, under the conditions that only 1 of the 2 members wears significantly.

Pin (spherical end) volume loss, mm3 = 3.14 (wear scar diameter, mm)4.

64 (sphere radius, mm)

Use the subsequent equations for calculating volume losses when the pin has initially a spherical end shape of radius R and also the disk is initially flat, under the conditions that just one of the 2 members wears significantly.

Disc volume loss, mm3 = 3.14 (wear track radius, mm)(track width, mm)3.

6 (sphere radius, mm)

Here isn't any significant disk wear. This is often an approximate geometric relation that's correct to I Samuel for (wear scar diameter/sphere radius) <0.3, and is correct to five you take care of (wear scar diameter/sphere radius) <0.7.

Calculation of wear and tear volumes for pin shapes of other geometries use the acceptable geometric relations, recognizing that assumptions regarding wear of every member is also required to justify the assumed final geometry. Wear scar measurements should be done a minimum of at two representative locations on the pin surfaces and disk surfaces, and also the ultimate results averaged. In situations where both the pin and also the disk wear significantly, it'll be necessary to live the wear and tear depth profile on both members. An appropriate method uses stylus profiling. Profiling is that the only approach to work out the precise final shape of the damage surfaces and thereby to calculate the amount of fabric lost thanks to wear. Within the case of disk wear, the standard wear track profile is integrated to urge the track cross-section area, and multiplied by the standard track length to urge disk wear volume.

While mass loss results might even be used internally in laboratories to match of equivalent densities, this check technique reports wear as volume loss thus there isn't any confusion caused by variations in density. Check that to use and report the only out there density price for the materials tested once conniving volume loss from measured mass loss.

Use the next equation for conversion of mass loss to volume loss.

Volume loss, mm3 = mass loss, g x 1000

Density, g/cm3

12. EQUATIONS

Exact equations for determining wear volume are as follows for:

A spherical ended pin:

Pin volume loss = (3.14h/6)[3d2/4 + h2]

Where:

h = r – [r2 – d2/4]1/2

d = wear scar diameter, and

r = pin end radius.

Assuming no significant disk wear (fordisc)

Disk volume loss = 2*3.14*R [r2 sin-1 (d/2r) – (d/2r) - (d/4)(4r2 – d2)1/2]

Where:

R = wear track radius, and

d = wear track width.

Assuming no significant pin wear.

13. MICROSTRUCTURE TEST

Fig9:- Microstructure test

This Microstructure test involves 5 steps:

- Cut-off
- Mounting
- Grinding
- Polishing
- Etching

CUTTING – Step darling involves taking off a bit to be tested as a sample of the fabric by means of a cut-off machine (e.g. a wet abrasive cutoff machine of the series called "Brilliant" and also the corresponding clamping tools which are designed to clamp at strategic positions. If the specimen is large enough, it are often mounted and so ground and/or polished with a holder without further preparation.

MOUNTING – the method of compressing and heating Bakelite powder around a bit of metal so as to create a solid disk or puck that may be accustomed handle the sample easier.

GRINDING - Grinding may be a material removal and surface generation process wont to shape and finish components made from metals and other materials. The surface finish and precision obtained by grinding is better than ten times than with either turning or milling. Grinding paper of 180 to 1500 grades is employed.

POLISHING - Like grinding, polishing is employed to get rid of the damage remaining from the previous steps. This can be achieved with steps of successively finer abrasive particles.

DIAMOND POLISHING - The diamonds are used as an abrasive for material removal and also best in planeness. No other abrasive can produce similar results. Thanks to its hardness diamonds cut extremely well through all materials and phases. Grain size of 0.375, 0.5 micrometers of diamond paste is employed for polishing and for final polish o.5 micrometer of aluminum is employed for mirror like finish.

ETCHING – The traditional method of using strong acid or chop into the unprotected parts of a metal surface to make a design in incised within the metal. In modern manufacturing, other chemicals could also be used on other varieties of material.

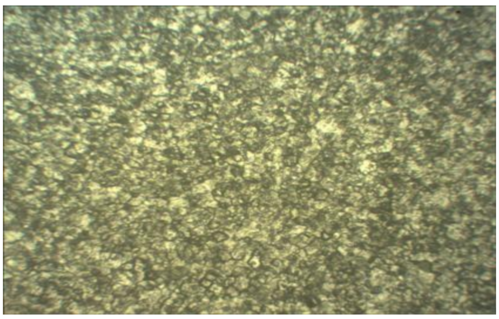


Fig10:- Microstructure

14. RESULT

Microstructure consists of recrystallized grains of primary alpha in the matrix.

Test results of specimen:-

- **Tensile properties of CP titanium:-**Tensile test had performed on CP Titanium as per the ASTM (American society for testing materials) standards, under the procedure of ASTM E8-15 . From the test results obtained, we had observed the various mechanical properties of CP titanium as shown in below table. And the graph has drawn between load vs. Displacement.

  Test Results:-

Initial and final parameters		**Observed data**	
Specimen type	flat	Ultimate load (KN)	15.68
Specimen width in (mm)	12.49	UTS (Mpa)	1046.03
Specimen Thickness in (mm)	1.20	Elongation (%)	13.01
Cross sectional area in (mm^2)	14.99	Yield stress (Mpa)	981.98
Original Gauge Length in(mm)	50.03	Yield Load (KN)	14.72
Final Gauge Length in (mm)	56.54	% Reduction area	32.15
Extensometer (GL)	25.00		

Table1:- UTM Test results of CP Titanium.

- **Tensile samples:-**

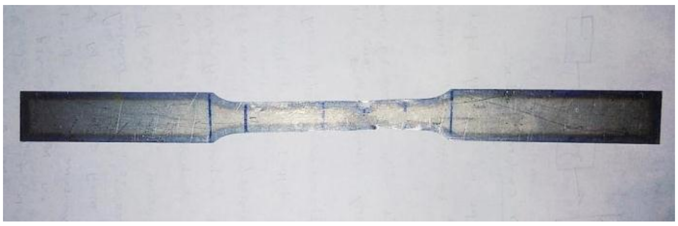


Fig11: - Tensile sample before test

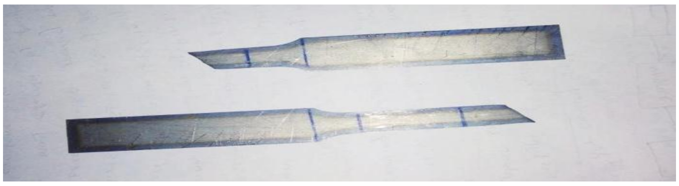
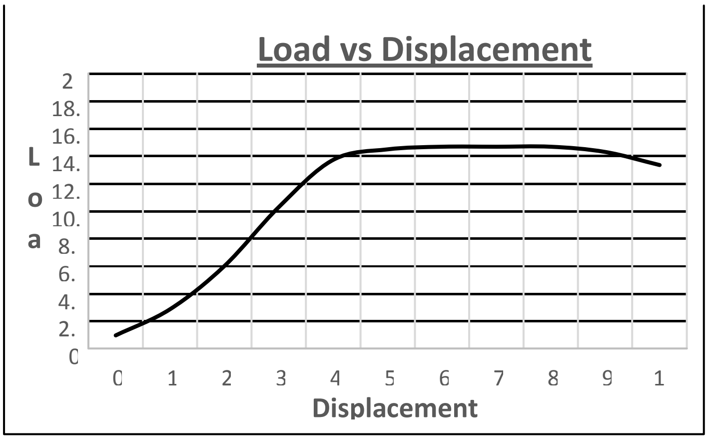


Fig 12:- Tensile sample after test

Graph representsload and displacement of CP Titanium



➢ **Hardness test report:-**Hardness test had been performed on CP titanium to find out the strength of material. Test had performed on Vickers Hardness (HV) machine as per ASTM E 384-17 under the applied loaf of 10 kgf by using 136° Diamond pyramid inventor on surface of material.

14.1. TEST RESULT

Location	**Observed values in HV**			**Avg value in HV**
	Impression 1	**Impression 2**	**Impression 3**	
On surface	180	182	183	181.67

Table2:- Hardness test result.

➢ **Coefficient of friction test on tribometer :-**

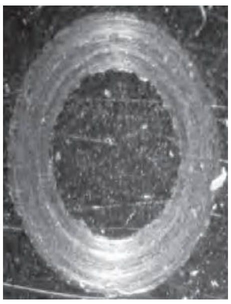


Fig13:- CPTitanium before test Fig14:- CPTitanium after test

14.2. SAMPLE PARTICULARS

To find out wear index and coefficient of friction materials has been tested under the following sample particulars.

Sample details	**CP Titanium**
Sample description	With grease, without grease
Quantity	02 no's
Test required	Wear index & co-efficient of friction

Table4:- Sample particular

14.3. TEST CONDITIONS

Test had performed on CP Titanium under the following test conditions.

Load	**200 kgf**
Disc material	EN steel
Speed of disc	100 rpm
Tungsten ball (Pin**)**	2.5mm diameter
Lubricant used	Grease

Table3: - Test conditions

14.4. COEFFICIENT OF FRICTION TEST RESULT

After completion of the check, we have a tendency to found that there is a considerable volume loss in one in every of the CP metal samples to that grease is not applied and on the alternative hand, volume loss in negligible for the sample to that grease is applied.

SI.No	**Test parameters**	**Unit**	**Results**	
			With grease	**Without grease**
1	Volume loss	mm^3	negligible	0.193
2	Surface Roughness	µm	NA	0.733
3	Co-efficient of friction	-	0.17	0.42

Table5:- Friction test result.

15. APPLICATION

- **Pigments, additives and coatings:-**

Fig15:-Titanium oxide is most commonly used compound Titanium

About ninety fifth of all Ti ore is destined for refinement into Ti dioxide (TiO_2), Associate in nursing intensely white permanent pigment used in paints, paper, toothpaste, and plastics. it is also utilized in cement, in gemstones, as Associate in Nursing optical pacified in paper, and a strengthening agent in atomic number 6 composite fishing rods and golf clubs.Tio2 pigment is with chemicals inert, resists weakening in daylight, and is very opaque: it imparts a pure and sensible white color the brown or gray chemicals that kind the majority of home plastics. In nature, this compound is found among the minerals anatine, brookite, and mineral Paint created with Titania will well in severe temperatures. Pure pigment options a really high index of refraction Associate in nursing an optical dispersion higher than diamond to boot to being a very necessary pigment, titanium dioxide is to boot used in sunscreens.

- **Aerospace and marine**

Fig16: - Aerospace

Because metal alloys have high lastingness to density quantitative relation, high Corrosion resistance, high crack resistance, and talent to set about to moderately high temperatures while not crawl, they are used in craft, armor plating, service ships, spacecraft, and missiles. For these applications, metal is alloyed with metal, zirconium, nickel, vanadium, and alternative parts to manufacture a variety of parts as well as vital structural elements, fire walls, framing, exhaust ducts (helicopters), and hydraulic systems. In fact, regarding 2 thirds of all metal made is utilized in craft engines and frames. The metal 6AL4V alloy accounts for just about five hundredth of all alloys utilized in craft applications.

- **Industrial**

Fig17:- Titanium bars

Welded atomic number 22 pipe and method instrumentality (heat exchangers, tanks, method vessels, valves) square measure utilized within the chemical and organic compound industries primarily for corrosion resistance. Specific alloys square measure utilized in oil and gas down hole applications and nickel hydrometallurgy for his or her high strength (e. g.: atomic number 22 beta C alloy), corrosion resistance, or both. The pulp and paper trade uses atomic number 22 in method instrumentality exposed to corrosive media, like agent or wet gas. Alternative applications embody supersonic attachment, Wave attachment and sputtering targets. Titanium chemical compound ($TiCl_4$), a colorless liquid, is important as associate degree intermediate among the method of constructing TiO_2 and is to boot accustomed manufacture the Ziegler–Natta catalyst. Atomic number 22 chemical compound is to boot accustomed iridize glass and, as a result of it fumes powerfully in dampish air, its accustomed build smoke screens.

- **Jewelry:-**

Fig18: - Titanium ring

Because of its durability, titanium has become more popular for designer jewelry titanium rings. Its inertness makes it a decent choice for those with allergies or people who are wearing the jewelry in environments like swimming pools.

Titanium is additionally alloyed with gold to supply an alloy which will be marketed as pure gold because the first of alloyed Ti is insufficient to need a lesser mark. The resulting alloy is roughly the hardness of 14- karat gold and is more durable than pure gold.

- **Medical:-**

Fig19:- Dental implants Fig20:- Orthopedic implants

Because titanium is biocompatible (non-toxic and not rejected by the body), it has many medical uses, including surgical implements and implants, such as hip balls and sockets (joint replacement) and dental implants that can stay in place for up to 20 years socket titanium is often alloyed with about 4% aluminum or 6% Al and 4% vanadium.

- **Nuclear waste Storage:-**

Fig21:- Titanium nuclear storage

Because of its corrosion resistance, containers fabricated from titanium are studied for the long-term storage of nuclear waste. Containers lasting quite 100,000 years are thought possible with manufacturing conditions that minimize material defects. A titanium "drip shield" could even be installed over containers of other types to boost their longevity.

16. CONCLUSION

The pure titanium was observed to exhibit excellent tribological properties while performing pin-on-disc test. A fluctuation within the value of coefficient of friction is thanks to lubricant used. It's found that coefficient of friction is 0.17 for lubricated specimen and 0.42 for UN lubricated specimen at 200 kg load. We come to understand that, although CP Titanium has low wear resistance, we will improve it by proper lubrication, specified it will be employed altogether the applications where wear resistance crucial Coefficient of friction plays an crucial role in productiveness and efficiency of Titanium with reference to the changes in material and thermal losses. It affects the reliability of materials, formability, fatigue, hardness, wear resistance and other properties of fabric.

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