THE MAIN PROBLEMS OF TITANIUM AND TITANIUM ALLOYS CIVIL APPLICATION

DR. S.S.USHKOV AND DR. A.S.KUDRYAVTSEV
CRISM "PROMETEY", USSR

The twentieth century has been marked by the development of new materials like aluminium nad titanium alloys, plastics etc. The Kroll method development opened the way for the industrial production of titanium.

At first, the most attractive feature of titanium alloys seemed to be high specific strength. From this point, titanium is highly eff1cient structural material for aviation and rocket-space technique. Later attention was drawn to high corrosion resistance of titanium in aggressive media including sea water.

CRISM "Prometey" has been performing investigations of titanium alloys as structural materials for marine purposes for many years. As we know from literature similar investigations have been carried out by many scientists from different countries e.i. USA, Great Britain, France, Germany, Sweden, Japan and others. The conclusions we made from our investigations are very similar to those of our foreign colleagues. In this brief paper we shall consider some aspects of titanium alloys application in ships engineering industry and national economy.

1. Titanium alloys possess high corrosion resistance in sea water and outperform all metals and alloys traditionally applied for marine conditions. But in the extreme conditions one can observe crevice corrosion and pitting.

2. The main factors of crevice corrosion and pitting to appear are as follows: high temperature (more than 70-120 C), high chlorides concentration (particularly local under salt deposits) and acidity (pH) of solution. The safe temperature range is up to 1000 C. Pronounced gain in crevice corrosion resistance is obtained after cathodic alloying (alloy Ti-O,2Pd).

3. Pitting corrosion of titanium in sea water is possible in exceptional cases: at high temperatures, under salt layer in crevices and when unsuccessful alloy composition is applied (High content of Al, O_2, H_2 etc).

4. Contact with other metals has no effect on titanium alloys corrosion resistance. For this reason, particular attention is to be given to the assurance of corrosion resistance of metals and alloys being in contact with titanium. It is necessary to set up isolating pads and protection where it is possible to decrease the level of corrosion of metals in contact with titanium up to the required level.

5. The least detrimental is the contact of titanium with austenitic stainless steel, silver, inconel (in sea water). Aluminium bronze shows low

sensitivity to contact corrosion. Tin bronze OTs10-2 Gunmetal type is applied in friction joints. This bronze is slightly corroding in contact with titanium.

6. Corrosion cracking phenomenon of titanium alloys in sea water is well known. Investigations carried out in the USSR and abroad have shown that a tendency to corrosion cracking is mainly dependent on the alloy composition. Technically pure titanium with oxygen content being less than 0,15%, alloys with aluminium content up to 3% and strength of less than 600 MPa are practically unsensitive to corrosion cracking in sea water. Al (more than 6%) and Sn, Cr, alloying has a detrimental effect on corrosion mechanical strength of titanium alloys. Introduction of isomorphic betastabilizators: Mo, V, Nb, Ta is very useful especially Mo. Final heat treatment is of high importance for corrosion-mechanical strength.

7. Proper consideration of the particularities of titanium corrosion resistance in sea water, efficient alloys selection, service conditions regulation allow to take maximum advantage of the extremely high corrosion resistance of titanium alloys in marine conditions and reduce negative phenomena to a minimum.

8. The level of fatigue strength at multi- and low-cycle loading is considered to be the most important characteristic of metals used in machine building.

9. In this case the finishing operations of mechanical treatment are of high importance and surface plastic deformation (SPD) in particular. Various methods of SPD nave been developed in the USSR. They include: rolling, sheet blasting, special treatment by needle strikers etc.
The selection of proper method allows to use the high natural properties of titanium alloys in reference to fatigue failure resistance.

10. Titanium and its alloys show a tendency to fretting in the similar way as steels of the same strength level. Fretting is very hazardous for titanium alloys in corrosion medium for titanium loses its high corrosion resistance. In this case, the only method to improve titanium fatigue range is SPD.

11. Titanium alloys have low antifriction properties. For this reason titanium application in friction joints is possible only with surface hardening. In the USSR there are three main trends in surface hardening applied for antifriction properties improvement: fittings seal surfaces deposit by super hard alloys, thermal oxidation of friction surfaces and detonation coating by metals oxides and carbides.

12. Thermal oxidation is the most efficient and simple method for industry introduction. Two oxidation methods are proposed, namely: "high temperature" and "low-temperature". At low-temperature oxidation the heating is conducted at $T < 800$ C during some hours followed by furnace cooling. For these conditions alloys without additional elements atre suitable for they

give loose seals. As a result of this treatment the hardened alloy 10-60 mkm in thickness is formed on the surface.

High-temperature oxidation is accomplished at T > 800 C during some hours followed by water cooling. It is possible to perform oxidation in graphite. In this case graphite is workingscale-forming decreasing medium, and what is more important makes it possible to increase the depth of oxidation layer and allows to use alloys with vanadium.

There is no need for any finishing operations on oxidated parts. Only paste polishing is possible with layer removal up to 5 mkm.

12. Account must be taken of changes in structural strength (its decrease) under the effect of surface hardening while using titanium alloys in oxidated state. Oxidation of low-alloyed alloy (Ti-4,5Al type) is decreasing long-term strength of alloy at tension and bending very little by 10%. The effect of sea water is also very low. High-strength alloying titanium alloys application in oxidation state in sea water is considered to be unefficient in these cases due to the fact that their corrosion-mechanical strength is decreasing pronouncely (2 times).

13. In cases when thermal oxidation or deposit do not give desired anti-friction properties detonation coatings is used. For detonation coatings equipment with the following characteristics has been developed:

- shooting rate, shot/s 3-5
- coating thickness for one shot, mkm 3-20
- spraying spot, mm 20-40
- productivity (for one shift)
    a) of sprayed material, kg/hour 1-5
    b) of area, m^2/year 200-600
- working media consumption (oxygen + acetylene), m^3/hour 1,0-4,5

We have asssimilate experience in application of oxide, carbide, metallide and combined coatings. Oxide coatings (a Al_2O_3, Cr_2O_3, ZrO_2 and their mixtures) possess absolute corrosion resistance in sea water and high erosion-cavitation resistance. They may be used for work under the friction conditions in sea water at specific pressures up to 20 MPa (short-term up to 40 MPa) alone and with OTs10-2 bronze. Detonation coatings practically have no effect on mechanical properties of the part, except the fatigue limit which decreases by 20-30 %.

Carbide and metallide-base coatings have the better carrying capacity and endurance (on wear) but their application in sea water is limited by not high corrosion resistance. These coatings are performing well only in unaggressive media.

Qualifying the detonation coatings it is necessary to point out the fact that they have allowed to increase the service life of parts for machine building – especially friction joints by 2-3 times.

14. At present the “Prometey" institute possesses a set of technical and technological documentation and production technologies for titanium semi products and products including the rolling of sheets, tubes, profiles; forging, wire drawing, stamping, shape casting, welded structures, manufacture and the documentation on the special problem of tribo-technique – detonation, plasma, and laser coatings which exhibit a set of unique physico-mechanical properties.

Available are industrial opportunities to manufacture the pilot and common structures using the methods mentioned above and accumulated technical potential. Mainly they include pipe-line systems, fittings, pumps, tanks to store electrolytes, reactors pressure vessels, metallurgical high-resistant titanium crucibles for melting and holding of food aluminium alloys, heat exchanges, centrifuges and separators etc.

15. We consider titanium alloys promising for application in food industry equipment, particularly for the production of juices, wine, milk, meat etc. Were corrosion is impermissible not only from the point of equipment safety but for sanitary-hygienic reasons.

In the majority of mentioned technological media titanium alloys exceed traditional chrome-nickel-stainless steels in resistance, they do not content impurities noxious for food as lead, arsenic, zinc and berillium and undoubtedly may be applied for mentioned equipment.

Titanium alloys have found a wide application in medical technique as for medicinal drugs so for the production of dentures and implants.

In conclusion I would like to show photos - slides as examples of our production:

- foils
- bleaching towers
- shape coating
- bellows
- springs
- heat exchanges
- jewelry