OTS: 60-41,676 JPRS: 5931

27 October 1960

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By B. M. Zlobinskiy,
I. I. Barber et al

- USSR -

Distributed by:

OFFICE OF TECHNICAL SERVICES
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WASHINGTON 25, D. C.

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1636 CONNECTICUT AVE., N. W.
WASHINGTON 25, D. C.

JPRS: 5931

CSO: 4817-N

PROBLEMS OF SAFETY DURING THE CASTING AND PROCESSING OF TITANIUM ALLOYS

/Following is the translation of an article by B. M. Zlobinskiy, I. I. Barber, P. I. Razumova and N. V. Manuyev entitled "Voprosy Bezopasnosti pri lit'ye i obrabotke splavov titana" (English version above) in Bezopasnost' Truda v Promyshlennosti (Work Safety in Industry), No. 6, June 1960, Moscow, pages 20-21./

The emergence of the industrial production of titanium and its alloys has given rise to new safety problems connected with particular properties of this metal.

Titanium exhibits a high chemical activity: it easily reacts not only with oxygen, but also with carbon dioxide and nitrogen; it burns intensely in an atmosphere of the latter. Titanium decomposes steam; the liberated hydrogen forms an explosive mixture with the oxygen of air. Many titanium compounds are rather dangerous because of their toxicity. Particular attention should be paid to protection from titanium dust in cases when it is given off in mixtures containing some other substances (quartz, for instance) which increase its noxious effects.

Titanium dust, as well as that of many of its alloys, is explosive; moreover its lower explosion treshold is relatively small.

Finely crushed titanium and titanium alloys can ignite spontaneously when coated with oil.

The manufacture of electrodes. Electrodes are made of spongy titanium alloyed under pressure in powerful hydraulic presses.

During loading the atmosphere becomes polluted with dust containing chromium, silicium and other elements in addition to titanium dioxide.

When a worker loads the container with the mixture, he finds himself within the operating range of the plunger every two or three minutes. Besides risk of injury, this leads to overstrain.

During pressing the sponge often sticks to the working cone of the matrix; as a result the electrode is pushed out with jolts accompanied by hydraulic shocks which are dangerous for the staff.

The press section should be placed in a separate building equipped with plenum and exhaust ventilation for a thorough improvement in work conditions; complex mechanization of mixture crushing, blending proportioning and press container loading is required. The local exhaust ventilation system should be equipped with humid dust collectors should operations where dust is given off be performed.

In order to avoid dropping the electrode at the output a guard ring can be placed around the guiding chute of the press while the electrode is removed by means of hoisting-conveying equipment. During shipment electrodes must be kept inside containers in order to prevent fracture.

The temperature of the press container must be automatically controlled so as to avoid overheating.

<u>The smelting of titanium alloys in electric furnaces.</u> Dust and fine cinder are liberated in the process of cleaning the furnace and preparing it for smelting. Difficult conditions arise when these operations are performed by hand.

Besides, risk of injury arises when a worker sets up the electrode on the bedplate of the furnace and checks the strength of the weld to the "residue" because of possible bad quality weld. Special hoists should be used for setting up electrodes; the latter should be checked in advance for strength and lack of humidity at their surface.

In order to prevent electrocution the quality of the insulation between electrode holder and furnace body as well as the reliability of the insulation of and the protection from all current-carrying furnace elements should be checked before every smelting. Sections of vacuum arc furnaces should be placed in a single-story fireproof building with a light roof, separated from other buildings.

A special apparatus should be used in order to avoid the presence of workers inside the furnace casing when the crystallizer is cleaned, dust and fine cinder being removed by means of a suitable dust suction system.

An explosion may occur as a consequence of the crystallizer being perforated by burning or of water penetrating into the furnace near the smelting region. Rigid control of the condition inside walls of the crystallizer is therefore necessary while operating the furnace. Automatic equipment controlling electric arc operation, metal temperature, cooling medium pressure and temperature switches the furnace off and gives an alarm signal whenever the established operating conditions are disturbed. The furnace crystallizer should be provided with an emergency valve for the escape of gases through the furnace casing into the atmosphere in the course of an explosion.

Standardization of types of smelting furnaces will provide for remote control of the smelting process and for observation by means of a telescope system; this will create safe work conditions.

Processing under pressure. When hot, titanium is characterized by a high chemical activity; as a result the surface of the metal is saturated with gases. Even small additions of hydrogen, oxygen, carbon, nitrogen cause brittleness. Saturation with hydrogen is the cause of metallic breakdown under deformation and often under normal working conditions. Such a breakdown often occurs with an explosive force. The hydrogen content of titanium alloys should therefore not exceed 0.02 percent, that of carbon 0.2 percent. Limits on other additions are being introduced.

The high chemical activity of titanium requires the fastest possible heating and processing. The preheating temperature (initial temperature of plastic deformation) should be as low as possible and processing should stop at temperatures higher than 750° in the case titanium and 800-850° in the case of its alloys. Excessively high temperatures lead to increased contamination of the metal, while low ones increase its brittleness and resistance.

In the case of volume swageing processes the minimum temperature of the manufactured part as well as that of the seam (which cools before) should be limited since metal chips ejected from the latter may cause injuries.

Operation within narrow temperature ranges is best achieved through the automation and mechanization of titanium processing under pressure.

When selecting a particular pressure processing treatment under safe loads with multiple deformation of the metal should be preferred (swageing in hydraulic presses rather than drop forging, for instance). Cold titanium alloys are characterized by the lowest plastic properties. In the case of cold sheet drawing, titanium alloys should be subjected to multiple deformations (each not exceeding 20 to 30 percent) under higher pressures and at slower rates than those accepted in the case of low-carbon steels.

We recommend to accompany cold rolling with small amounts of cogging (up to 5 percent each) and to use planetary mills as a rule.

The number of drawing operations should be increased three-fold in the case of sheet titanium as compared to stainless steel.

Cold bending should be performed under the following conditions: sheet bending: radius larger than 6 times the thickness, (cold bending of sheets thicker than 4.5 mm should be avoided altogether), cold bending of rods whose sections is larger than 150 mm^2 and of pipes whose diameter is larger than 20 mm (and whose wall thickness exceeds 4mm) is not recommended.

Titanium alloys should not be broken into billets by means of hammers; this can be done using crank presses only if the break region is notched in advance.

Cutting is best performed in the heated state with hydraulic presses; all safety measures should be complied to; the region around the cutting region should be shielded in particular.

Because of the danger presented by metal chips flying away, we recommend shielding in the case of forging, swageing, rolling, drawing and other processes and placing the staff as far as possible from the processing site.

Cast titanium alloys exhibit minimum plasticity and can therefore be cut only after heating and preliminary plastic deformation (upsetting, drawing) larger than 35 percent.

As temperature is increased, the resistance to deformation of titanium alloys drops sharply, their plasticity increases, and the danger of breakdown and of metal chips flying away is reduced correspondingly when a tool is machined. This is why the so-called "warm processing" at 500 to 600° is finding widespread acceptance instead of cold working under pressure.

The strength of titanium alloys at high temperatures (800 to 1000°) is in fact higher than that of steel due to their impurity content. Titanium is sensitive to notching and tearing, so that a slow rate of deformation corresponding to lower values of resistance to deformation is preferable when it is treated under pressure.

According to these considerations plastic deformation of titanium alloys, in particular during the initial stages of processing, should be performed at slow rates.

Alloy cinder forms a finely dispersed dust which pollutes the atmosphere of industrial buildings; we therefore stress the need for measures aimed at preventing the formation of cinder and removing dust by suction.

Preheating and cleaning surfaces. Preheating is indispensible when titanium and its alloys are hardened, annealed, tempered, strengthened, chemically heat-treated and pressed.

Practical experience provides evidence for the possible spontaneous ignition of ingots when they are removed from the furnace. This occurs as a consequence of the formation of fine and minute titanium particles scratched off by the bedplate from the billet once the surface layer is removed; these particles have a high chemical activity; another cause may be contact and then reaction of a portion of the ingot not protected by the surface layer with iron oxide from the bedplate.

At high temperature titanium is extremely active and reacts intensely with haloids as well as oxygen, sulfur, carbon, nitrogen and other elements. Ingots must therefore be heated in muffles in the case of gas or masout furnaces, while muffles, vacuum or neutral atmospheres (helium, argon) should be used with electrical furnaces.

Preheating in vacuum facilitates the removal of hydrogen and other gaseous impurities from the metal. Since no cinder is formed in this process, the dangerous alkali etching operation, which in addition enhances the hydrogenic brittleness of the metal, can be excluded. The use of inert protective media gives good qualitative results and is a safe, but costly process.

In preheating by means of electrical furnaces in the absence of atmosphere control or without vacuum, the use of bedplates and supports made of oxidizable materials as well as excessive sliding and shaking of ingots during their motion inside the furnace should be avoided.

Induction heating is convenient for cylindrical billets. The advantage is its speed (3 to 5 min) thanks to which oxidation is reduced. The corresponding units can be set up for 12 to 15 kg billets and a preheating temperature of 1000°, the frequency of the induction current being 2500 cycles.

We recommend to anneal titanium alloy pipes by the contact method in order to keep the surface clean and to exclude further contamination of the metal. The pipe is placed on asbestos cement supports and a current at the industrial frequency passes through it (up to 1000 amps, 36 volts). Preheating up to a temperature of 750 to 800° lasts 2 to 2.5 min.

After hot rolling, hardening and annealing, sheets, strips and wires made of titanium alloys are covered by an oxide layer which should be removed before the next treatment or before the manufactured product is cut. Layers of titanium oxides are resistant even to the strongest chemical reagents. Oxides which form at temperatures below 700° are soluble in concentrated sulfuric acid to a certain degree, whereas those obtained at 1000° and higher temperatures are insoluble for practical purposes. The removal of the layer from the surface of the metal does not therefore amount to dissolving this layer, but to dissolving the metal under it; the oxide layer must be broken for that purpose. This is achieved by means of shot peening or trimming (rolling on a trimming mill with 3 to 5 percent cogging) or by processing in an alkali melt.

Processing in a $NaOH + NaNO_3$ melt at 420 to 470° has found widespread acceptance as an efficient process, but it is dangerous due to possible spontaneous ignition of the metal in the bath. This follows from an overheating of the later due either to the formation of a contact between a portion of sheet free of oxides with iron oxides found at the separating comb or to the contamination of sheet edges with oil, mazout, kerosene, dust reacting with titanium when heated in the bath.

The etching of titanium by acids following alkali or other types of processing requires the normal safety measures.

The collection, storage and use of waste materials. Waste in the form of chips, cuttings, shavings, templets, discard, filings and dust are obtained in many operations. Bulky waste materials are not a fire hazard for storage, whereas fine ones are fire and explosion hazards.

The collection, storage and preparation of waste for future use as raw material must be carried out in agreement with a strict classification according to alloy type, smelting characteristics and form; a special building should be provided for storage.

Filings, chips and other waste materials are collected in a special tare in workshops at least once during every shift. Their accumulation is not tolerated. In order to avoid fire hazards dust-like waste products should be stored in a separate dry room (in a building at least 3rd degree fireproof) of the explosionproof type with a continuously operating ventilation system. Direct sources of fire are not allowed in this building; inflammable liquid chemicals and other products should not be stored there.

Fire hazard waste materials in the form of dust, which are not intended for use, should be mixed with sand and burried. Workshops should be regularly washed or cleaned by means of vacuum cleaners operating under explosionproof conditions.

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