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Recycling of titanium alloys in plasma furnace

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1. Introduction

Melting process of titanium and its alloys is very complicated as:
- liquid titanium reacts with nearly all refractories applied for furnace lining,
- titanium at high temperature reacts with oxygen and nitrogen from furnace atmosphere.

In relation with these facts the furnace for titanium and its alloys melting should meet some requirements:
- melting process should be carried out in vacuum or inert atmosphere,
- crucible for melting process should not react with melting titanium,
- heating equipment should enable to achieve temperature near 1800°C.

The analysis carried out [1-8] leads to the conclusion, that plasma arc furnace may be a good metallurgical unit as:
- applications of high purity inert gas (He) for generating plasma jet and low pressure in melting chamber let to create the conditions very similar to that of vacuum furnace,
- plasma furnace has small ratio of installed power to the mass of melting metal (30-40 kW/kg),

In Foundry Section of Poznań University of Technology a stand for titanium alloys and reactive metals melting has been built and tested.

The main objective of this article is to present our experience in construction of the basic elements of prototype stand for Ti alloys plasma melting as well as the first results received during recycling of Ti alloy with the application of this stand.

2. Stand construction

The prototype stand for plasma melting of metals and alloys in conditions of low pressure (see Fig. 1) consists of some basic elements like:
- working chamber with water-cooling system,
- direct current plasma torch with „hollow cathode" adopted for working at low pressure with supplying and cooling system,
- vacuum installation and cooling system for outlet gases with the equipment for pressure measuring and flow of working gas,
- equipment for measuring temperature of melted metal,
- water-cooled copper crucible.

Schematic diagram of the supplying system is shown in Fig. 1. The stand is supplied from low voltage switch gear with a switch fuse (RB-200A). To the low voltage switch gear is connected the rectifier unit DP3a-100 (apparent power rating S=180 kVA and active power rating P=100 kW) with long time current-carrying capacity I=600 A. An automatic battery of capacitors with power rating 110 kVA is connected to the high voltage winding of transformer for the compensation of apparent power. The rectifier unit is equipped with automatic ignition set. A pilot arc was generated inside a „hollow cathode". Once the transfer arc ignites to the melting metal, the pilot arc is automatically disconnected.

In order to measure melting metal temperature through a sight glass of the chamber the Raytek two-colour pyrometer was applied.

3. Experimental results

During the melts testing the homogeneous scrap of titanium alloys TiAl6V4 as a charging materials was used. Chemical compositions of the scrap are shown in Table 1.

Pure helium (see Table 2) was applied as a working gas for plasma jet generating.

The scheme of melting process is presented in Fig. 2. Mean operating parameters of the stand and quality of the alloy received after recycling process are presented in Tables 3 and 4.

Table 1

Chemical composition of the titanium alloys TiAl6V4 (scrap)

Element	Chemical composition, % weight
N	0.0205
O	0.3250
H	0.0028
C	0.0400
S	0.0040
Mo	0.0080
Zr	0.0200
W	0.0170
Ni	0.0310
Fe	0.1800
Mn	0.0130
Cr	0.0300
V	3.8000
Si	0.0380
Al	6.2500
Cu	0.0050
Nb	0.0180
Sn	0.0050
Ti	balance

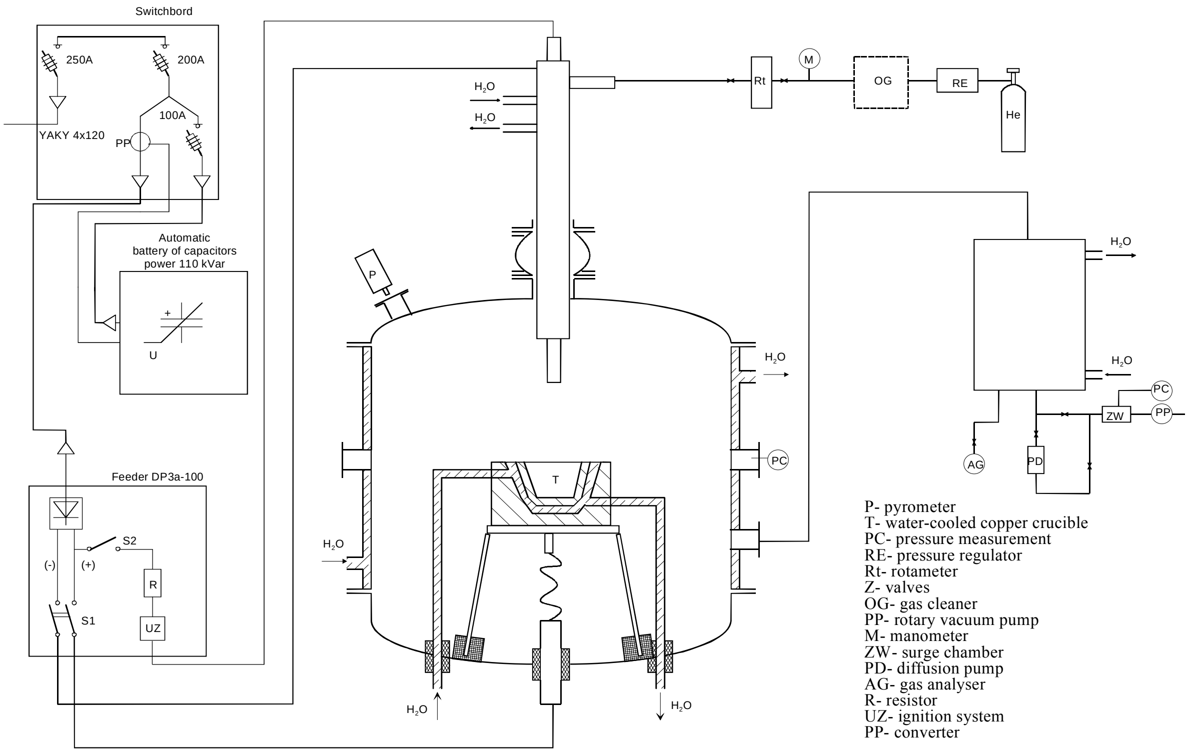

Fig. 1 Prototype stand for plasma melting of metals and alloys

Table 2

Chemical composition of helium (working gas)

Impurity	Content, % volume
H_2	≤ 0.5
N_2	≤ 3.0
O_2	≤ 2.0
CH_4	≤ 0.5
H_2O	≤ 2.0
CO_2	≤ 0.5
CO	≤ 1.0
Ar	≤ -
He	≥ 99.999

Table 3

Parameters of laboratory plasma stand during testing melts

Parameters	N° of melt					
	1.1*	1.2**	2.1*	2.2**	3.1*	3.2**
Pressure before rotameter, hPa	1613	1613	2213	2213	2163	2063
Pressure in chamber, hPa	193	193	165	171	160	380
Outflow of gas, l/h	4924	4924	4375	4375	4267	7680
Arc current intensity, A */**	451	778	441	780	450	777
Arc voltage, V */**	40.0	40.0	39.0	40.6	37.5	46.5
Arc power, kW	18.0	31.1	17.2	31.7	16.9	36.1
Arc length, m	0.07	0.07	0.07	0.07	0.06	0.06
Mass of charge, g	227	227	220	220	289	289

*/ - second tap of transformer

**/ - third tap of the transformer

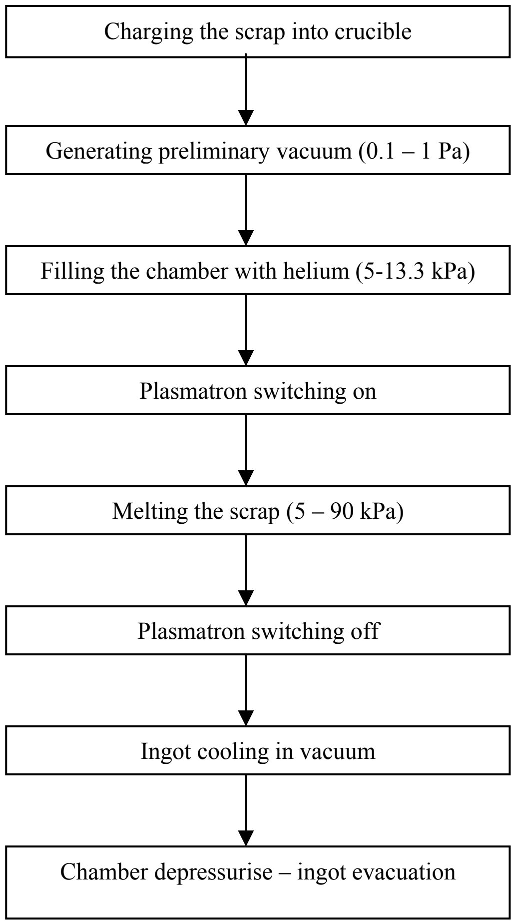

Fig. 2 Scheme of the melting process

Table 4

Chemical composition of charge (W) and ingots after recycling

Element contents, ppm	Number of melt			
	Scrap, W	1	2	3
C	400	400	400	400
S	40	40	40	40
Mo	80	50	60	50
Zr	200	190	180	180
W	170	185	190	195
Ni	310	310	310	310
Fe	1800	1800	1750	1750
Mn	130	125	125	125
Cr	300	270	340	270
V	38000	38700	38800	38800
Si	380	390	370	350
Al	62500	62300	62400	62300
Cu	50	50	60	60
Nb	180	185	180	180
Sn	50	60	50	70
Ti	bal-ance	balance	balance	balance

Table 5

Analysis of gas contents in the charge and ingots after recycling process for preliminary vacuum 0.13 MPa (melts N° 1 - 3)

Gas	Arithmetic average gas contents in charge X^w, ppm	Average gas contents in ingot after recycling		Efficiency of degassing, $(X^w - X) / X^w$
		X, ppm	Standard deviation σ_{n-1}, ppm	
N	205	173.4	3.5	0.16
O	3250	3097	115	0.05
H	28	17.3	3.1	0.38

4. Conclusions

Recycling of titanium alloy (TiAl6V4) in plasma furnace has shown that:

- plasma melting is a useful technology for titanium alloys recycling (very high ratio of the mass of ingot to the mass of charge - above 99%),
- only very small changes in chemical composition after recycling process have been observed,
- application of high purity gas (He) for generating plasma jet and low partial pressure of oxygen, nitrogen and hydrogen in the melting chamber create the conditions very similar to vacuum furnace environment,
- inside the plasma furnace the conditions favourable for degassing of melted alloys arise (preheating of the surface of liquid titanium alloy and the process of dissolving solid nitride in liquid alloy [8]),
- decreasing of hydrogen and nitrogen contents in the alloys after recycling process was noticed.

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TITANO LYDINIŲ PERLYDYMAS PLAZMINĖJE LYDKROSNYJE

R e z i u m ė

Straipsnyje aprašyta laboratorinė reaktyviųjų metalų ir lydinių plazminė lydymo krosnis bei pateikti titano lydinio TiAl6V4 perlydymo eksperimentinio tyrimo rezultatai. Lydinio cheminės sudėties ir dujų kiekio jame prieš perlydymą ir po jo analizės rezultatai rodo, kad eksperimentinis įrenginys tinka titano lydiniams perdirbti. Lydymo kameroje kaip šilumos šaltinį naudojant plazminį inertinių dujų srautą galima sukurti žemo deguonies, azoto ir vandenilio dalinio slėgio atmosferą.

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RECYCLING OF TITANIUM ALLOYS IN PLASMA FURNACE

S u m a r r y

The scheme of prototype stand for reactive metals and alloys melting and the results of experimental investigation on recycling process of titanium alloy grade TiAl6V4 are presented in this paper. On the basis of chemical compositions and gases contents in analysis the alloy (before and after remelting process) it was shown that the application of prototype stand is a very effective way of the recycling process of titanium alloys. The application of plasma jet generated from inert gas as a heat source inside the melting chamber enables creating the atmosphere with low partial pressure of oxygen, nitrogen and hydrogen.

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ПЕРЕПЛАВКА ТИТАНОВЫХ СПЛАВОВ В ПЛАЗМЕННОЙ ПЕЧИ

Р е з ю м е

В статье описана лабораторная плазменная печь для плавки реактивных металлов и сплавов и предъявлены результаты экспериментальных исследований плавки титанового сплава марки TiAl6V4. На основе результатов анализа химического состава и содержания газа в сплаве до и после переплава показано, что экспериментальная установка пригодна для переплавки титановых сплавов. Применение плазменной струи из инертных газов как источника тепла внутри плавильной камеры позволяет создать атмосферу с низким уровнем парциального давления кислорода, азота и водорода.

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