APPLICATION OF ELECTROPOLISHING IN CSNS/RCS PRIMARY COLLIMATOR SCRAPERS

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Abstract

According to the requirements for the beam collimation system physical design of the rapid cycling synchrotron (RCS) of China Spallation Neutron Source (CSNS) , the primary collimator scrapers are made of 0.17±0.005mm thickness tungsten sheets. The machining of the tungsten sheet is very difficult because of high hardness and characteristics of the intrinsic brittleness of tungsten material. In this paper, electropolishing processing methods is used for tungsten sheets processing. Two special electropolishing devices are designed according to the principle and process of electropolishing. The processing of tungsten sheets are finally completed after a series of experiments. And the rules of electropolishing for tungsten sheet processing are obtained according to the experimental results.

INTRODUCTION

The rapid cycling synchrotron (RCS) of China Spallation Neutron Source (CSNS) is a high intensity proton ring with beam power of 100 kW. The RCS is designed to accelerate the proton beam from 80 MeV to 1.6 GeV[1] .In order to control the residual activation to meet the requirements of hands-on maintenance, a two-stage collimation system has been designed for the RCS. Halo particles with large amplitude will first hit the primary collimator. After interaction, the particles will be scattered by the primary collimator without being absorbed. Then after some certain distance, the particles will finally be absorbed by the secondary collimators downstream the primary one[2].

The primary collimator consists of four scrapers, which are set either horizontally or vertically. Each scraper has a dimension of 150mm×30mm .Three kinds of metal, copper, tungsten and tantalum, have been considered as material of the primary collimator for their high melting point and good thermal conductivity. And comprehensive consideration, tungsten is the best choice.The thicknesses of the materials are optimized for providing efficient scattering angles and high collimation efficiency[3].In order to provide adequate scattering angle, the scrapers need to be very thin:0.17mm.And the requiments of thickness tolerance is ± 0.005mm.Comparing with SNS scraper sheets' thickness 5.5mm[4], J-PARC scraper sheets' thickness 1mm[5]; the scraper sheets are very thin. So the application of 0.17mm thickness tungsten scrapers is the first time.

Standard tungsten plate on the market is 0.2mm.So it still needs be processed. Crutchley and Reid have said that brittleness is an intrinsic property of the metal which has a body-centered cubic structure in 1969[6]. The brittle - ductile transition temperature (BDTT) of tungsten is high; so tungsten is brittle at low temperatures. In addition, high temperature causes brittleness as a result of that tungsten recrystallization occurred grew, strength and hardness is decreased. Tungsten processing typically requires between the BDTT and recrystallization temperature.

In this paper, two special electropolishing devices are designed. And the CSNS/RCS primary collimator scrapers' sheets are prepared by lots of experiments. Then the rules of electropolishing for tungsten sheets processing are obtained according to the experimental results.

THIN TUNGSTEN SHEETS PROCESSING

The Design of the Electropolishing device

Electropolishing is an electrolyte and DC current electrochemical method. The tungsten sheet is used as anode, and steel as cathode. The temperature of the electrolyte is controlled by means of temperature controller. Figure1 shows the schematic diagram of the electropolishing device's working principle:

1. Controllable power
2. Anode (thin tungsten sheet)
3. Thermocouple
4. Temperature controller
5. Heater
6. Cathode (cylindrical container made of steel material)
7. Polishing liquid (Sodium orthophosphate solution)

A simple and practical electropolishing device is created according to Figure1, which is shown in figure2.

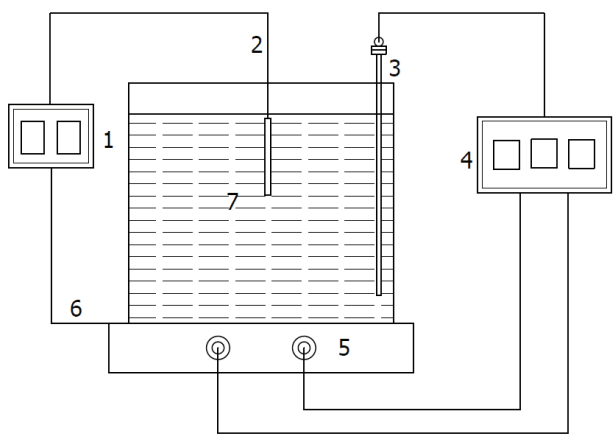

Figure 1: the schematic diagram of the electropolishing device's working principle.

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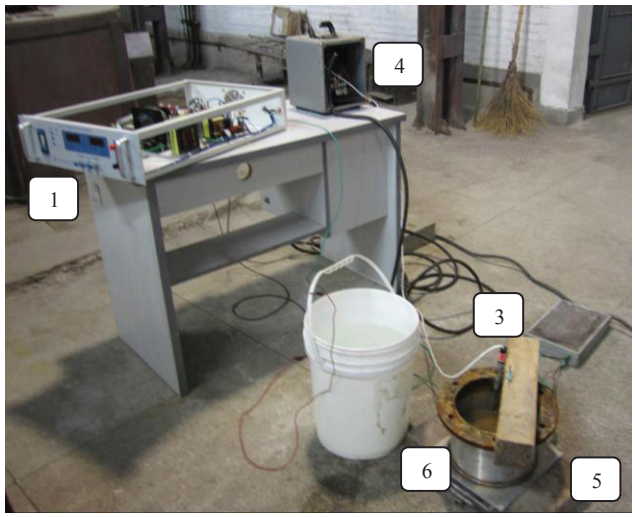

Figure 2: The photograph of the electropolishing device.

Preliminary Experimental Scheme and Experimental Data

Standard tungsten plate on the market is 0.2± 0.02mm and its thickness deviation is relatively large.

Common electropolishing process parameters are selected. The tungsten sheet is used as anode, steel as cathode. And the electrolyte is positive sodium phosphate solution. And the anode current density needs 9A/dm². Temperature controlled around 50 degree centigrade.

After several tests, it can be learned that tungsten sheets electropolishing rates are 0.01mm/5 min in the case of the above tungsten electropolishing process parameters. Tungsten sheet after electropolishing process is shown in figure 3. Thickness variation is shown in table 1.

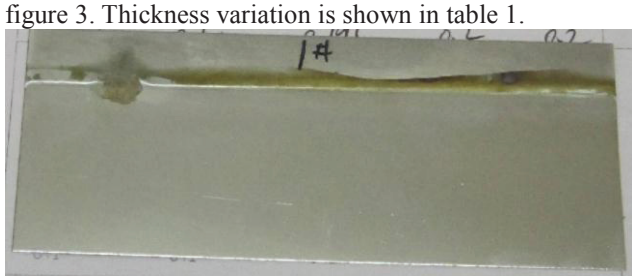

Figure 3: The photo of the tungsten sheet after electro-polishing

Table 1: The Thickness of Tungsten Sheets before and after Electropolishing (unit: μm)

NO.1 Origin Data	213	212	215	215	217	218	215	210
	212	210	209	213	215	217	218	215
	207	205	206	208	207	212	217	217
	202	202	204	204	204	211	215	219
NO.2 Origin Data	212	210	212	214	207	210	207	209
	213	215	211	208	206	209	207	208
	207	207	206	204	200	200	201	204
	202	204	203	200	207	207	207	207
NO.3 Origin Data	216	215	213	211	200	200	202	201
	215	215	211	212	199	200	202	203
	213	214	210	213	205	206	204	203
	213	212	214	214	203	206	205	205
NO.4 Origin	225	228	225	221	213	213	212	216
	225	227	227	220	217	214	215	216
Data	226	228	227	222	217	216	218	216
	228	229	229	226	217	214	216	219
NO.1 New Data	169	170	170	172	175	176	166	168
	168	168	174	175	173	177	176	174
	165	167	171	169	171	177	179	185
	165	168	169	169	169	179	188	188
NO.2 New Data	169	173	171	175	174	174	166	167
	177	175	179	176	176	177	172	173
	175	173	176	174	171	172	177	172
	173	173	173	172	176	178	180	180
NO.3 New Data	176	177	178	171	165	165	168	167
	180	184	179	179	167	173	175	179
	182	187	184	182	181	184	183	181
	181	189	189	187	183	186	188	188
NO.4 New Data	175	175	176	171	170	174	168	169
	183	183	181	176	174	177	170	172
	186	184	183	178	177	180	172	173
	185	187	186	181	176	182	173	173

Judging from above experimental results, the thickness dimension uniformity has been improved a lot, but it still does not meet the design requirements. The initial thickness of the tungsten sheets are difficult to change, so a new electropolishing device has to be transformed to make the current density distribution on the tungsten sheet as uniform as possible.

Electropolishing Device Improvement

In order to uniform distribution of current density for each region of the thin tungsten sheet, the cylindrical container is transformed into a rectangular container. Negative electrode is instead by two electrode plates which are made of steel material. Figure 4 shows the schematic diagram of the improved electropolishing device's working principle:

1. Controllable power
2. Anode (thin tungsten sheet, the Current divided into three points on the thin tungsten sheet)
3. Thermocouple
4. Temperature controller
5. Heater
6. Cathode (two electrode plates, the Current divided into six points on two electrode plates)
7. Polishing liquid (Sodium orthophosphate solution)

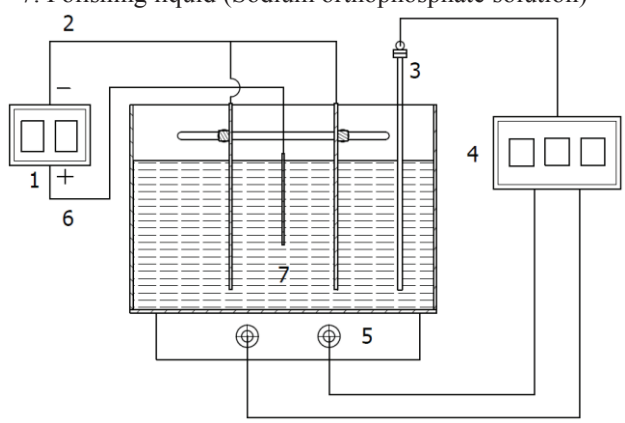

Figure 4： The schematic diagram of the improved electropolishing device's working principle.

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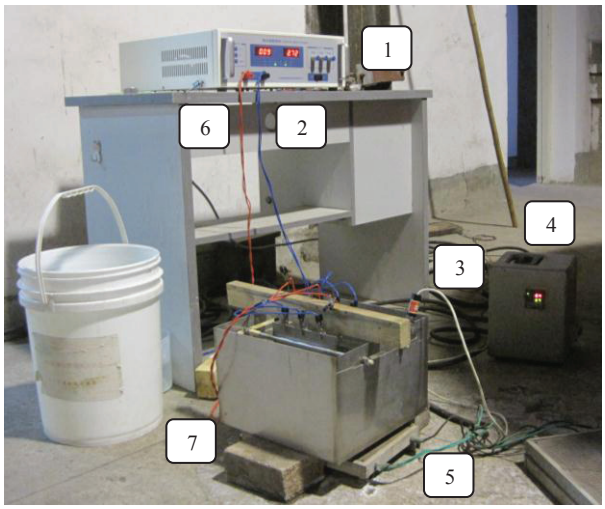

Figure 5: Photo of the improved electropolishing device

Improve Experiments Results

After transformation, the uniformity of current density on the tungsten sheet has been greatly improved. Current and voltage in the electrolysis process is stable, and is always maintained 8A and 4V. However, the processing of the tungsten sheet still faces enormous challenges, because that the initial thickness of the thin tungsten sheets has too much deviation and is difficult to make the final results meet the precision requirements of the design.

After several tests and explore, the best way has been found: protecting the thinner region in the process of polishing, reducing the current appropriately, each polishing time as short as possible, increasing the numbers of polishing. Repeated measurements have been done according to Figure 6's 36 points. The thickness of tungsten sheets before and after electropolishing by improved device is shown in talbe 2. Tungsten sheet after electropolishing process is shown in figure 7.

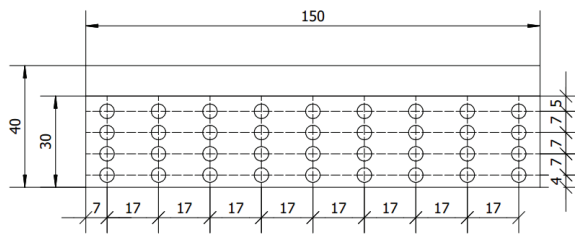

Figure 6: Measurement regions in tungsten sheet

Table 2: The Thickness of Tungsten Sheets before and after Electropolishing by Improved Device (unit: μm)

NO.1 Origin Data	228	226	225	219	218	219	217	218	218
	225	226	225	219	217	216	216	215	214
	221	223	223	217	216	217	215	215	216
	218	221	223	217	218	217	218	216	215
NO.2 Origin Data	207	202	204	206	212	213	211	211	211
	203	202	206	206	211	212	211	211	212
	204	204	204	207	208	212	210	210	211
	203	204	203	207	211	208	209	209	208
NO.3 Origin Data	205	202	204	203	202	202	201	199	181
	205	203	205	205	204	203	202	202	180
	209	208	209	205	205	203	203	204	184
	208	208	209	207	206	203	202	204	184
NO.4 Origin Data	206	207	208	208	213	212	213	217	217
	205	208	208	208	208	212	212	216	217
	207	209	209	211	210	211	213	216	218
	205	207	207	208	214	215	215	216	218
NO.1 New Data	170	175	175	175	176	171	173	170	167
	167	174	172	173	172	169	170	170	171
	175	171	169	168	174	166	169	170	172
	171	174	172	174	175	169	176	174	175
NO.2 New Data	172	172	173	174	174	176	175	172	173
	173	172	172	175	173	175	175	175	174
	172	173	172	176	174	174	175	175	174
	172	174	175	175	173	172	174	174	172
NO.3 New Data	169	170	173	172	171	171	170	167	166
	170	171	175	176	173	173	172	171	169
	172	173	176	175	172	175	173	172	169
	172	175	177	175	174	174	172	173	167
NO.4 New Data	174	174	175	173	174	172	174	173	172
	175	172	173	175	171	173	174	176	174
	172	174	174	175	172	173	173	174	175
	175	174	171	173	171	174	174	175	175

Figure 7: The photo of the improved tungsten sheet

Conclusion

Two special electropolishing device have been designed according to the principle and process of electropolishing. And several tests prove that tungsten sheets electropolishing rates are 0.01mm/5 min in above standard tungsten electropolishing process parameters condition. The new type of device can provide high accurate tungsten sheets. And the current density is uniform due to the shape of the improved electropolishing device. Finally tungsten sheets are prepared for CSNS/RCS scrapers, which have reached high-precision design requirement: 0.17 ± 0.005mm.

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