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APPLICATION OF THE SIMPLEX METHODS FOR TESTING THE INFLUENCE OF COLD DEFORMATION LEVELS, ANNEALING TEMPERATURE AND CHEMICAL CONTENT ON THE MECHANICAL CHARACTERISTICS OF SOME ALLOYS OF THE Pd-Au SYSTEM

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Abstract

The effect of degree of cold deformation, annealing temperature and chemical composition on the mechanical properties of some Pd-Au alloys was investigated in this work. The HV, Rm and A were determined with different gold content in the alloy and in the function of annealing temperatures at constant annealing time and deformation degree. Optimization of mechanical properties of some Pd-Au alloys were performed by the method of simplex lattice design. Defined mathematical model will allow the selection of operating parameters of the PdAu alloy production process for the catalyst catchers, which can be used to reliably predict the values of mechanical properties such as hardness, tensile strength and elongation that are a key factor in the use of palladium catalysts to catch platinum metals in the high-temperature catalytic processes.

Keywords*: Pd-Au system, mechanical characteristic, Simplex method, optimization*

1 INTRODUCTION

Platinum group of metals plays a very important role in the process of chemical catalysis, i.e., in the production of nitric acid, where, in the process of ammonia oxidation, Pt-Rh and Pt-Rh-Pd are used as catalysts. Depending on working conditions in a reactor, the losses of precious metals occur from the catalytic networks due to the formation of volatile metal oxides PtO_2, PdO and RhO_2 that are dragged away by a gas flow [1,2]. One way for as much as possible trapping and recycling the oxidation products of precious metals, formed in the production process of nitric acid, is the use of so-called Pd catalysts-traps set in a combination with the conventional platinum catalysts. The role of Pd-catalyst-trap consists in reduction of volatile platinum oxide from gas flow to the metal form and retention of platinum metal on the surface of Pd catalyst-trap [1-3].The aim of this work was to determine the optimal parameters of Pd-Au alloy production using the Simplex method [4-7].

2 EXPERIMENTAL

All experimental testing presented in this paper were performed on the following samples: PdAu3%, PdAu5% and PdAu7%. For the experimental researches, palladium produced in electrolysis of RTB Bor, in the form of black powder of purity 99.95%, and gold in the powder form of purity 99.95%, were used. For the hardness testing, Pd-Au plates, 2.5 mm thick, were used, and for Rm and A testing 0.5 mm thick Pd-Au wires were used. Hardness was measured using a universal apparatus for hardness measurement produced by Karl Frank, Type 38532. Mechanical characteristics of Rm and A were tested on a universal device for tensile testing, type „Mohr + Federhaf + Losenhansen“ – Manheim. In order to achieve a soft state of wires of the final dimension Ø0.5 mm that is required for the production of Pd catalysts-traps by weaving, all samples in a wire form, obtained with different degrees of deformation, were subjected to the recrystallization annealing, intermediate and final. According to the previous research [4], the highest values of hardness and tensile strength of all tested specimens were achieved after deformation with a deformation degree of 80%. Due to this, the Simplex method, was used to investigate the effect of annealing temperature on the mechanical properties of all samples investigated at a constant deformation degree (ε = 80%) and constant annealing time (15 minutes). The annealing temperatures were in the interval 750 - 950°C.

3 RESULTS AND DISCUSSION

The experiment included using of simplex plan of the fourth-degree polynomial with 15 experimental points, given in Table 1.

Table 1 *The experiment plan and experiment results*

Coded values of factors			**Mode of recrystallization annealing**		**Mean values of mechanical properties**			
Z_1	**Z_2**	**Z_3**	***t*** **(^{0}C)**	**τ (min)**	**HV**	**Rm (MPa)**	**A, %**	
1	0	0	750	5	102	270	21.3	Y1
0	1	0	750	7	119.7	320	15.1	Y2
0	0	1	950	5	83	259	21.3	Y3
0.5	0.5	0	750	3	95.2	250	23.3	Y12
0.5	0	0.5	850	3	95.2	250	23.6	Y13
0	0.5	0.5	850	5	102	265	21.3	Y23
0.75	0.25	0	750	3	95.2	250	23.3	Y1112
0.25	0.75	0	750	5	102	270	21	Y1222
0.75	0	0.25	800	3	95	250	23.4	Y1113
0.25	0	0.75	900	5	83.3	263	21.3	Y1333
0	0.75	0.25	800	7	119	300	16.1	Y2223
0	0.25	0.75	900	3	80.3	248	23.5	Y2333
0.5	0.25	0.25	800	5	101	267	21.1	Y1123
0.25	0.5	0.25	800	5	101	266	21.1	Y1223
0.25	0.25	0.5	850	3	95	250	23.5	Y1233
0.16	0.15	0.69	887.5	3	93.2	249	23.5	
0.459	0.166	0.375	825	7	119.3	300	16.9	

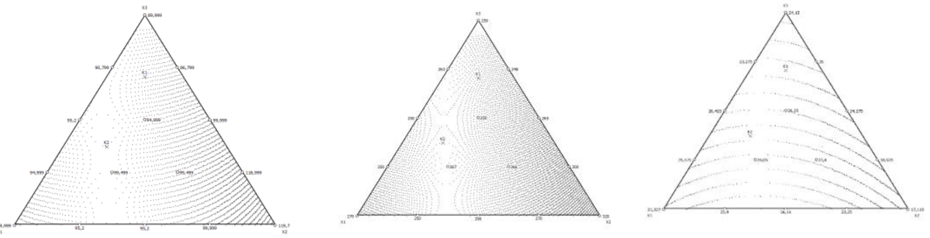
By an analysis the experimental data by the simplex method [5-7] with the specially developed software in the Delphi environment, the dependence of the output parameters (HV, Rm, A) of the input parameters (temperature and time) was obtained in the form (1-3):

$$Y_{HV} = 100.99x_1 + 119.70x_2 - 60.59x_1x_2 + 18.94x_1x_2(x_1 - x_2) - \\ -18.97x_1x_2(x_1 - x_2)^2 \quad (1)$$

$$Y_{Rm} = 270x_1 + 320x_2 - 180x_1x_2 + 26.66x_1x_2(x_1 - x_2) - 26.72x_1x_2(x_1 - x_2)^2 \quad (2)$$

$$Y_A = 21.31x_1 + 16.11x_2 + 24.06x_1x_2 - 0.69x_1x_2(x_1 - x_2) + 3.01x_1x_2(x_1 - x_2)^2 \quad (3)$$

To check the adequacy of selected models are used for the control points plan K_1 and K_2 that performed additional experimental tests. Analysis showed the adequacy of the fourth-degree model for all mechanical characteristics according Student's t-criterion for the coefficient with credibility of 0.995 and 14 independence degrees in the control points (t_k (for K_1_0.94157; for K_2_2.49087) <t_ (kr) (0.995; 14) _2.98). Based on these checks, it can be claimed with a probability of 99.5% that the adopted mathematical model is adequate and the model parameters are important for the selected mode of heat treatment. Based on these tests, a claim might be with a probability of 99.5% that the adopted mathematical model is adequate and the model parameters relevant to the selected parameters. Using these equations and specially developed software in the Delphi environment, diagrams of iso-line of mechanical characteristics can be drawn depending of the selected parameters (annealing temperature and chemical content), Figure 1.



a) b) c)

Figure 1 *Simplex triangle of iso-lines of mechanical characteristics depending on the annealing temperature and chemical content a) HV, b) Rm, c) A*

The results of mathematical processing confirm that there is a strict dependence of a change in mechanical properties (HV, Rm, A) of PdAu alloys at a constant deformation degree of 80%, annealing temperature and chemical content of Au in the PdAu alloys, defined by the regression polynomial of the fourth degree according to equations (1-3).

4 CONCLUSION

Using the Simplex method, the effect of gold content in the alloy of Pd-Au system, as well as the annealing temperature on certain mechanical properties, was investigated. It is observed that the dependence Rm, Hv and A can be described by the fourth-order polynomial. The PdAu5 alloy has satisfactory values of hardness and tensile strength and, above all, elongation, which is a key factor in the use of palladium catalysts in the "capture" of platinum metals in the catalysis process at high temperatures.

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