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IMPACT OF THE INCREASED ACTIVE SURFACE OF THE PLATINUM CATALYST ON THE TOTAL AMMONIA RECOVERY COEFFICIENT

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Abstract

In order to increase the active surface of platinum catalysts for ammonia oxidation and on the basis of theoretic considerations and tests in industrial environment, we have finally decided on their specific design. Efficiency on the newly designed catalyst was checked in industrial circumstances. A comparative analysis of the total ammonia recovery coefficient between the mentioned new catalysts and previously applied platinum catalysts was carried out. All advantages of catalysts with increased active surfaces were confirmed and a new method of their manufacturing process was selected.

Keywords: Platinum catalyst; Ammonia oxidation

1. Introduction

During the process of ammonia oxidation to nitric monoxide (NO), a set of catalyst gauzes was used based on platinum and platinum alloys. Usual thickness of catalyst gauzes was 1024 appertures/cm², while the wire diameter ranged between 0.06 mm to 0.08 mm. The number of gauzes in one set was 3 to 40, depending on the quantity and pressure of the gas mixture. During ammonia oxidation, the mixture of ammonia and air reacted with the platinum catalyst at the pressure of 0.1 to 1.0 MPa and t=780-920°C in a very short period of time, $1\text{-}2\times10^{-4}$ sec. For that time, 92-98% ammonia oxdized to NO and the rest transfered to N_2 or N_2O. In the ammonia oxidation process, platinum and rhodium evaporated, the catalyst activity was reduced and the life time was shorter. Depending on the gas mixture pressure,

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gauzes can be used from three months to one year. Platinum catalyst using time, platinum and rhodium loss during the ammonia oxidation and the degree of ammonia oxidation are the subject to numerous research projects. Different deactivation mechanisms for platinum catalysts have been studied by Sandjykov and Bartholomew [1,2,3].

Refining of platinum metals from used platinum catalysts to obtain platinum metals of high purity was the subject of research of numerous authors [4,5,6].

Impact of impurities on platinum catalyst activities have been studied by many authors [7,8,9,10].

A number of other research projects were directed to the phenomena occurring on the very surface of platinum catalysts during their use with a particular accent on the kinetics of the mass transported over them in the function of the time and active surface [11-17].

Reduced activity and selectivity of the gauzes have been studied by many authors [18-28].

However, even with many research projects, new techniques for platinum catalyst testings are always actual and with one aim only and that is to icrease the total ammonia recovery in the process nitric sideline production.

The purpose of this paper is:

1. to determine the ammonia consumption values per tonne of produced nitric acid (N) and the total ammonia recovery coefficient by applying platinum catalysts manufactured by weaving techniques.

2. to determine the ammonia consumption value per tonne of produced nitric acid and the total ammonia recovery coefficient by applying platinum catalysts with an increased active surface.

A set of catalysts comprised of woven and knitted catalysts in the weight ratio of 50 : 50.

2. Materials and Research Techniques

An ammonia oxidation reactor was used for testing on line I in the Nitric Acid Plant, in Pančevo. The reactor production capacity is 257 t of nitric acid per day, the temperature of the process 920°C and the working pressure 0.75 MPa. For the first group of tests, knitted platinum catalysts were used and presented in figure 1 with the following characteristics:

1. Chemical assays – 90%Pt, 5%Rh, 5%Pd
2. Round catalyst diameter – 1300 mm
3. Density of the material, 1024 appertures/cm², wire diameter 0.076 mm
4. Packaging weight, app. 16 kg

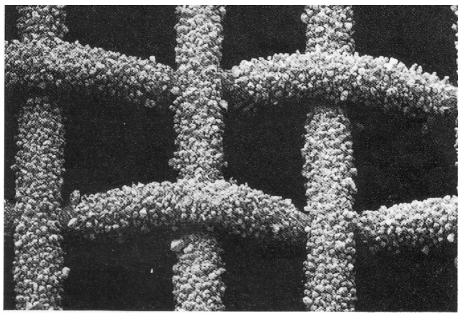

Fig. 1. Woven catalysts

Measurements were done and the following results were obtained for the ammonia consumption, the quantity of obtained nitric acid, the percentage of oxygen, pressure and volume of ammonia in the feed, ammonia oxidation coefficient, absorption coefficient and the total ammonia recovery coefficient.

3. Comparative analysis of obtained results

For the second group of tests, platinum catalysts were used. They are shown in picture 2 in the weight ratio of 50% woven and 50% knitted and the constant packaging weight of 16 kg. The wire diameter, catalyst diameter and chemical assays remained unchanged. The woven structure of the catalysts with increased active surface was selected after certain theoretical considerations and tests performed on industrial knitting machines.

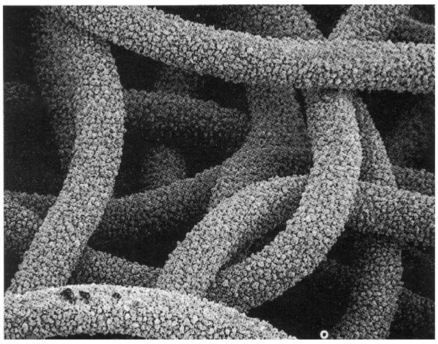

Fig. 2. Knitted catalysts

For the second group of tests, same measurements and calculations were done as for the first experiment

4. Results and discussion

For the first group of platinum catalyst tests, woven ones were used. Obtained values and calculations for the ammonia consumption per tonne of produced nitric acid (n), ammonia oxidation coefficient, apsorption coefficient and the total ammonia recovery coefficient (k) are given in table 1.

The parameter is calculated according to the formula:

$$N = A / C$$

The total ammonia recovery coefficient is calculated according to the formula:

k = molar ammonia mass / molar nitric acid mass x 1 / N

In the time of exploitation which lasted 102 days, 23,581t of nitric acid was produced in the reactor. For this quantity, 6990t of ammonia was used. The mid parameter value was N = 0.297. The mid value of the total ammonia recovery coefficient with this parameter was 0.91. Metal loss during the use of the catalyst was 9,237.49g or 0.392g/t of produced acid.

Dependence of ammonia consumption per one tonne of produced acid in the function of time is shown in figure 3.

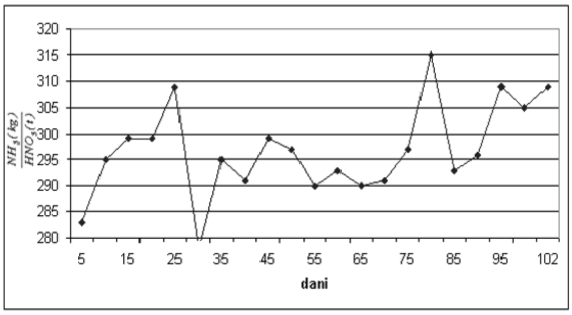

Fig. 3. Dependence of ammonia consumption per one tonne of produced acid within the exploitation time

Dependence of the total ammonia consumption per one tonne of produced acid in the function of the catalyst explotation time is shown in figure 4.

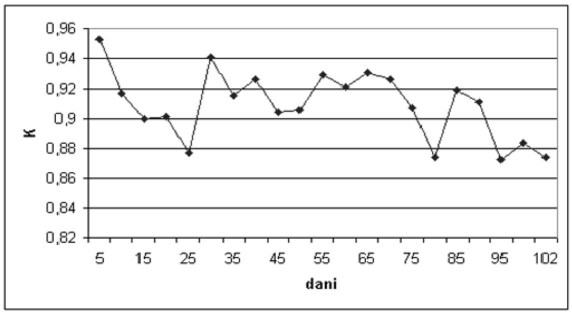

Fig. 4. Dependence of the total ammonia consumption coefficient within the catalyst exploitation time

Table 1. Measured values and calculated values for woven catalysts

No	A	B	N=A/B	Total coeff. of ammonia recovery, k	Apsorption coeffi-cient	Oxidation coefficient	% O_2	% NOx	C	D	% NH_3	% NH_3, rač	Vair., Nm³/h	E
1	53	178	0.298	0.907	0.985	0.92	2.66	0.15	0.74	96	10.2	8.31	32100	2910
2	69	247	0.279	0.967	0.986	0.98	2.09	0.15	0.74	96	10.53	10.59	32000	3788
3	69	247	0.279	0.967	0.989	0.977	2.08	0.12	0.75	95	11.18	10.44	32500	3788
4	69	246	0.28	0.963	0.983	0.979	2.66	0.17	0.75	97	10.2	10.42	32550	3788
5	68	243	0.28	0.965	0.979	0.985	2.66	0.2	0.74	96	9.75	10.45	32000	3733
6	68	242	0.281	0.961	0.984	0.977	2.56	0.15	0.74	96	9.25	10.21	32850	3733
7	65	233	0.279	0.968	0.982	0.986	2.68	0.17	0.75	95	9.23	9.8	32850	3569
8	68	243	0.28	0.965	0.984	0.98	2.69	0.15	0.75	95	9.44	10.19	32900	3733
9	53	163	0.325	0.83	0.989	0.84	2.35	0.12	0.74	95	10.91	8.13	32900	2910
10	69	220	0.314	0.861	0.984	0.875	2.12	0.17	0.74	96	10.44	10.3	33000	3788
11	69	230	0.3	0.9	0.981	0.917	3.31	0.2	0.75	96	10.53	10.3	33000	3788
12	69	231	0.299	0.904	0.986	0.917	2.65	0.15	0.74	96	10.63	10.24	33200	3788
13	69	231	0.299	0.904	0.986	0.917	2.76	0.15	0.74	96	10.71	10.24	33200	3788
14	69	229	0.301	0.896	0.983	0.911	2.36	0.17	0.74	96	10.21	10.51	32250	3788
15	70	233	0.3	0.899	0.981	0.916	2.45	0.2	0.74	97	10.54	9.98	34650	3843
16	70	232	0.302	0.895	0.982	0.911	2.46	0.19	0.74	96	10.64	10.18	33900	3843
17	69	231	0.299	0.904	0.981	0.922	2.33	0.19	0.75	96	10.92	10.04	33950	3788
18	69	231	0.299	0.904	0.981	0.921	2.98	0.19	0.74	96	10.11	10.02	34000	3788
19	69	230	0.3	0.9	0.986	0.913	2.75	0.15	0.75	96	10.42	9.97	34200	3788
20	70	234	0.299	0.903	0.983	0.918	2.51	0.17	0.74	96	10.28	10.02	34500	3843
21	70	234	0.299	0.903	0.979	0.922	2.97	0.22	0.75	96	10.6	9.89	35000	3843
22	70	234	0.299	0.903	0.984	0.917	3.26	0.17	0.74	96	10.67	10.02	34500	3843
23	70	233	0.3	0.899	0.981	0.916	3.33	0.2	0.74	96	10.46	10.04	34450	3843
24	68	230	0.296	0.913	0.981	0.931	3.36	0.2	0.74	96	10.3	9.89	34000	3733
25	59	168	0.351	0.769	0.983	0.782	3.03	0.17	0.74	96	9.83	8.47	35000	3239
26	70	243	0.288	0.937	0.985	0.951	3.66	0.15	0.75	96	10.11	9.87	35100	3843
27	70	244	0.287	0.941	0.985	0.956	4.01	0.15	0.75	96	9.79	9.89	35000	3843
28	70	244	0.287	0.941	0.983	0.957	4.32	0.17	0.74	96	9.96	9.91	34950	3843
29	70	245	0.286	0.945	0.983	0.961	3.46	0.17	0.75	95	10.08	9.91	34950	3843
30	68	237	0.287	0.941	0.982	0.958	3.35	0.17	0.74	96	9.47	9.69	34800	3733
31	66	232	0.284	0.949	0.984	0.965	3.59	0.15	0.74	96	9.22	9.38	35000	3624
32	66	232	0.284	0.949	0.982	0.966	4.82	0.17	0.74	97	9.65	9.38	35000	3624
33	72	236	0.305	0.885	0.982	0.901	4.84	0.17	0.74	96	9.4	10.28	34500	3953
34	72	242	0.298	0.908	0.982	0.924	2.21	0.17	0.75	96	9.49	10.24	34650	3953
35	66	217	0.304	0.888	0.98	0.906	2.21	0.2	0.75	96	9.81	9.42	34850	3624
36	71	238	0.298	0.905	0.98	0.924	2.5	0.2	0.75	97	9.9	10.06	34850	3898
37	71	243	0.292	0.924	0.978	0.945	2.77	0.22	0.74	97	9.83	10.02	35000	3898
38	71	246	0.289	0.935	0.98	0.955	2.64	0.2	0.74	96	9.91	10.02	35000	3898
39	71	246	0.289	0.935	0.978	0.957	2.67	0.22	0.74	96	9.82	10	35100	3898
40	71	246	0.289	0.935	0.979	0.956	2.72	0.2	0.74	96	9.55	10	35100	3898
41	41	147	0.279	0.968	0.98	0.988	2.7	0.2	0.75	96	9.82	6.03	35100	2251
42	55	164	0.335	0.805	0.979	0.822	2.67	0.2	0.75	95	9.7	7.89	35250	3020
43	72	243	0.296	0.911	0.979	0.931	2.34	0.2	0.74	97	9.52	10.24	34650	3953
44	72	245	0.294	0.919	0.98	0.938	3.11	0.2	0.74	96	9.9	10.15	35000	3953
45	72	245	0.294	0.919	0.977	0.94	3.03	0.22	0.74	96	9.53	10.28	34500	3953
46	73	244	0.299	0.902	0.978	0.923	2.93	0.22	0.74	96	9.88	10.39	34550	4008
47	73	242	0.302	0.895	0.983	0.911	2.43	0.17	0.74	96	9.78	10.37	34650	4008
48	73	243	0.3	0.899	0.974	0.923	2.19	0.25	0.74	96	9.65	10.27	35000	4008
49	71	243	0.292	0.924	0.98	0.943	2.12	0.2	0.74	96	9.77	10.15	34500	3898
50	71	240	0.296	0.913	0.979	0.932	1.04	0.2	0.74	95	9.6	10.06	34850	3898
51	71	238	0.298	0.905	0.985	0.919	2.43	0.15	0.75	95	9.92	10.22	34250	3898

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*(table 1. continuation from the previos page)*7

52	71	250	0.284	0.951	0.978	0.972	2.06	0.22	0.75	96	10.23	10.11	34650	3898
53	72	245	0.294	0.919	0.978	0.939	2.02	0.22	0.75	96	10.03	10.32	34350	3953
54	71	246	0.289	0.935	0.98	0.955	2.57	0.2	0.74	96	10	10.13	34600	3898
55	71	247	0.287	0.939	0.978	0.961	2.79	0.22	0.74	96	9.88	10.13	34600	3898
56	71	244	0.291	0.928	0.978	0.949	3.11	0.22	0.74	96	9.91	10.10.	34700	3898
57	73	249	0.293	0.921	0.977	0.943	3.84	0.22	0.74	95	9.62	10.31	34850	4008
58	74	252	0.294	0.919	0.977	0.941	3.99	0.22	0.74	96	9.67	10.41	34950	4063
59	74	251	0.295	0.916	0.977	0.937	2.94	0.22	0.74	97	9.57	10.4	35000	4063
60	73	250	0.292	0.925	0.979	0.945	3.18	0.22	0.74	98	10.42	10.54	34000	4008
61	74	251	0.295	0.916	0.978	0.936	2.93	0.22	0.74	95	10.12	10.54	34500	4063
62	74	255	0.29	0.93	0.98	0.949	3.36	0.2	0.74	96	10.14	10.54	34500	4063
63	74	256	0.298	0.934	0.981	0.952	2.94	0.2	0.74	96	10.36	10.55	34450	4063
64	74	258	0.287	0.941	0.975	0.966	2.52	0.25	0.74	96	9.81	10.49	34650	4063
65	74	256	0.289	0.934	0.978	0.955	2.75	0.22	0.74	96	9.83	10.54	34500	4063
66	74	255	0.29	0.93	0.983	0.947	2.85	0.17	0.74	96	9.82	10.62	34200	4063
67	74	255	0.29	0.93	0.981	0.949	2.76	0.2	0.74	96	10.27	10.62	34200	4063
68	74	253	0.292	0.923	0.98	0.942	2.8	0.18	0.74	96	9.21	10.54	34500	4063
69	74	254	0.291	0.927	0.978	0.948	2.87	0.22	0.74	95	9.9	10.51	34600	4063
70	74	253	0.292	0.923	0.98	0.942	2.91	0.2	0.74	96	10.09	10.53	34520	4063
71	61	210	0.29	0.93	0.978	0.951	2.6	0.22	0.75	96	9.96	8.84	34550	3349
72	73	242	0.302	0.895	0.979	0.914	2.66	0.2	0.75	97	9.64	10.38	34600	4008
73	73	244	0.299	0.902	0.982	0.919	3.94	0.17	0.74	96	9.68	10.27	35000	4008
74	67	226	0.296	0.911	0.979	0.93	3.9	0.2	0.74	97	9.59	9.6	34650	3678
75	73	243	0.3	0.899	0.979	0.918	3.98	0.2	0.74	96	9.4	10.49	34200	4008
76	72	244	0.295	0.915	0.979	0.935	4.24	0.2	0.74	96	9.35	10.28	34500	3953
77	73	248	0.294	0.917	0.979	0.937	3.82	0.2	0.74	95	9.44	10.42	34450	4008
78	28	102	0.275	0.984	0.974	0.98	4	0.25	0.74	96	9.55	4.27	34500	1537
79	40	97	0.412	0.655	0.974	0.672	4.3	0.23	0.75	109	8.95	5.65	36675	2196
80	71	237	0.3	0.901	0.984	0.916	3.74	0.15	0.75	97	9.21	9.3	38000	3898
81	70	243	0.288	0.937	0.979	0.957	3.86	0.2	0.75	96	9.69	9.23	37800	3843
82	69	237	0.291	0.927	0.984	0.943	4.2	0.15	0.75	96	9.16	9.21	37350	3788
83	70	239	0.293	0.922	0.973	0.947	3.8	0.25	0.75	96	9.36	9.18	38000	3843
84	64	216	0.296	0.911	0.98	0.93	3.87	0.2	0.74	96	9.83	8.79	36450	3514
85	69	230	0.3	0.9	0.982	0.916	3.55	0.17	0.74	94	9.54	9.11	37800	3788
86	70	233	0.3	0.899	0.977	0.92	4.65	0.22	0.74	93	9.53	9.33	37350	3843
87	70	236	0.297	0.91	0.978	0.931	3.76	0.22	0.74	97	9.97	9.23	37800	3843
88	70	236	0.297	0.91	0.977	0.932	3.61	0.22	0.74	97	9.63	9.23	37800	3843
89	70	239	0.293	0.922	0.977	0.943	3.72	0.22	0.74	95	9.62	9.13	38250	3843
90	68	231	0.294	0.917	0.977	0.938	3.69	0.23	0.74	95	10.15	9.19	36900	3843
91	45	145	0.31	0.87	0.98	0.888	3.52	0.2	0.74	97	9.84	6.24	37120	3733
92	69	220	0.314	0.861	0.979	0.88	3.74	0.2	0.74	97	9.36	6.11	37800	2471
93	69	223	0.309	0.873	0.977	0.893	4.69	0.22	0.75	96	9.51	6.29	37000	3788
94	71	232	0.306	0.882	0.979	0.901	4.67	0.2	0.74	95	9.48	6.11	38900	3788
95	71	232	0.306	0.882	0.982	0.898	4.38	0.17	0.74	96	9.71	9.09	39000	3898
96	71	230	0.309	0.875	0.982	0.89	3.8	0.17	0.74	96	9.71	9.11	38900	3898
97	70	229	0.304	0.883	0.979	0.9	4	0.2	0.74	96	9.4	9.23	37800	3898
98	69	227	0.304	0.888	0.98	0.907	3.28	0.2	0.74	96	9.86	9.11	37800	3843
99	69	227	0.304	0.888	0.978	0.908	3.74	0.2	0.75	96	9.28	9.11	37800	3788
100	69	228	0.303	0.892	0.976	0.914	3.81	0.22	0.75	94	9.34	9.18	37800	3788
101	69	226	0.305	0.884	0.978	0.904	3.56	0.2	0.75	96	9.29	9.22	37500	3788
102	40	128	0.313	0.864	0.978	0.884	3.67	0.2	0.75	96	8.96	5.59	37300	3788

A = ammonia mass, t B = nitric acid mass, t C = ammonia pressure in Mpa

D = ammonia temperature in ° C E = ammonia volume in Nm^3

For the second group of tests, a combination of woven and knitted catalysts was applied.

Measured values and calculations for the ammonia consumption per tonne of produced nitric acid (N), the oxidation coefficient, apsorption coefficient and the total ammonia recovery coefficient are given in table 2.

Table 2. Measured and estimated values for the combination of woven and knitted platinum catalysts

No	A	B	N=A/B	Total coeff. of ammonia recovery, k	Apsorption coefficient	Oxidation coefficient	% O_2	% NOx	C	D	% NH_3	% NH_3 rač	Vair., Nm³/h	E
1	68	219	0.311	0.87	0.978	0.889	1.91	0.2	0.75	95	9.3	8.8	38700	3733
2	70	252	0.278	0.972	0.977	0.995	2.05	0.22	0.75	96	9.58	9.77	35500	3843
3	67	237	0.283	0.955	0.983	0.972	1.56	0.17	0.75	97	9.94	9.66	34420	3678
4	66	236	0.28	0.965	0.979	0.986	1.35	0.2	0.75	96	9.59	9.48	34600	3624
5	66	237	0.278	0.97	0.982	0.987	1.56	0.17	0.75	96	9.67	9.52	34420	3624
6	67	237	0.283	0.955	0.98	0.975	1.52	0.2	0.75	97	9.78	9.6	34650	3678
7	66	235	0.281	0.961	0.979	0.982	1.6	0.2	0.75	96	9.42	9.47	34650	3624
8	66	234	0.282	0.988	0.974	0.983	1.61	0.25	0.75	96	9.52	9.48	34600	3624
9	66	231	0.286	0.957	0.979	0.965	1.28	0.2	0.74	95	9.47	9.48	34600	3624
10	66	235	0.281	0.945	0.979	0.982	1.68	0.2	0.74	96	9.45	9.31	35300	3624
11	63	234	0.281	0.961	0.982	0.978	1.86	0.17	0.75	96	9.41	9.02	34870	3459
12	66	231	0.286	0.96	0.976	0.968	2.1	0.22	0.75	95	9.19	9.3	35320	3624
13	66	229	0.288	0.945	0.976	0.96	2.71	0.22	0.75	95	9.2	9.36	35100	3624
14	63	219	0.288	0.937	0.978	0.96	2.66	0.22	0.74	96	10.01	8.97	35100	3459
15	65	223	0.291	0.939	0.974	0.961	2.86	0.25	0.74	95	9.5	9.28	34870	3569
16	65	230	0.287	0.926	0.974	0.966	1.83	0.25	0.74	95	9.46	9.36	35100	3624
17	67	236	0.284	0.941	0.973	0.977	2.69	0.25	0.74	95	9.29	9.49	35100	3678
18	67	236	0.284	0.951	0.977	0.974	2.82	0.22	0.75	96	9.4	9.44	35300	3678
19	66	234	0.282	0.951	0.977	0.98	2.75	0.22	0.75	96	9.6	9.36	35100	3624
20	67	234	0.286	0.957	0.977	0.965	2.85	0.22	0.74	96	9.59	9.49	35100	3678
21	66	233	0.283	0.943	0.98	0.973	2.76	0.2	0.75	96	9.89	9.41	34870	3624
22	66	235	0.281	0.953	0.978	0.983	2.67	0.22	0.74	96	9.84	9.36	35100	3624
23	66	231	0.286	0.961	0.977	0.968	2.27	0.22	0.74	97	9.46	9.41	34875	3624
24	66	232	0.284	0.945	0.985	0.963	2.72	0.15	0.75	97	10.12	9.36	35100	3624
25	67	233	0.288	0.949	0.981	0.957	2.79	0.19	0.74	95	9.87	9.49	35100	3678
26	67	235	0.285	0.939	0.978	0.969	2.63	0.22	0.74	95	9.88	9.46	35200	3678
27	67	236	0.284	0.947	0.978	0.973	2.56	0.22	0.74	95	9.96	9.46	35200	3678
28	67	234	0.286	0.951	0.981	0.961	2.24	0.19	0.74	96	9.9	9.49	35100	3678
29	65	234	0.278	0.943	0.982	0.99	2.49	0.19	0.7	95	10.3	9.18	35325	3569
30	67	236	0.284	0.972	0.978	0.972	2.59	0.22	0.74	95	10.1	9.49	35100	3678
31	66	235	0.281	0.951	0.981	0.98	2.11	0.19	0.74	94	9.76	9.41	34900	3624
32	66	236	0.28	0.961	0.988	0.977	2.28	0.12	0.74	94	10.42	9.38	35000	3624
33	67	236	0.284	0.965	0.981	0.97	2.32	0.19	0.75	94	9.94	9.46	35200	3678
34	66	235	0.281	0.951	0.986	0.975	2.8	0.14	0.74	94	9.77	9.33	35200	3624
35	67	236	0.284	0.961	0.98	0.97	2.41	0.19	0.74	95	9.63	9.56	34800	3678
36	67	238	0.282	0.951	0.983	0.976	2.25	0.17	0.74	94	10.11	9346	35200	3678
37	67	233	0.288	0.959	0.984	0.955	2.77	0.17	0.74	97	10.39	9.46	35200	3678
38	66	234	0.282	0.939	0.984	0.973	2.79	0.17	0.74	96	10.57	9.55	34300	3624
39	67	237	0.283	0.957	0.985	0.969	2.76	0.15	0.74	95	10.13	9.51	35000	3678
40	67	239	0.28	0.955	0.981	0.982	3.31	0.19	0.74	96	9.99	9.49	35100	3678

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41	67	237	0.283	0.963	0.982	0.973	2.46	0.17	0.74	96	9.2	9.46	35200	3678
42	27	99	0.273	0.955	0.983	1.007	2.91	0.17	0.75	94	10.16	4.06	35000	1482
43	39	127	0.307	0.99	0.982	0.895	2.66	0.2	0.74	97	11.13	5.82	34650	2141
44	66	227	0.291	0.879	0.985	0.942	2.65	0.15	0.74	95	10.24	9.52	34425	3624
45	66	228	0.289	0.929	0.979	0.952	2.44	0.2	0.74	96	9.66	9.52	34450	3624
46	66	228	0.289	0.933	0.98	0.952	2.65	0.2	0.75	97	10.13	9.57	34250	3624
47	66	230	0.287	0.933	0.985	0.955	1.78	0.15	0.74	96	10.01	9.63	34000	3624
48	66	228	0.289	0.941	0.986	0.946	2.44	0.15	0.75	96	10.57	9.58	34200	3624
49	66	230	0.287	0.933	0.986	0.955	2.78	0.15	0.75	97	10.44	9.52	34450	3624
50	66	229	0.288	0.941	0.98	0.956	2.84	0.2	0.74	96	10.04	9.63	34000	3624
51	66	230	0.287	0.937	0.986	0.954	2.27	0.15	0.74	96	10.57	9.58	34200	3624
52	66	228	0.289	0.941	0.983	0.949	2.3	0.17	0.75	97	9.98	9.47	34650	3624
53	66	229	0.288	0.933	0.98	0.956	2.18	0.2	0.74	97	10.14	9.52	34425	3624
54	66	228	0.289	0.937	0.98	0.952	2.5	0.2	0.74	96	9.76	9.5	34525	3624
55	66	226	0.292	0.933	0.982	0.941	1.74	0.17	0.74	96	9.46	9.57	34250	3624
56	66	227	0.291	0.925	0.986	0.942	2.75	0.14	0.74	96	9.83	9.58	34200	3624
57	66	227	0.291	0.929	0.985	0.943	2.7	0.14	0.74	95	9.2	9.58	34200	3624
58	66	230	0.287	0.929	0.985	0.955	2.9	0.15	0.74	96	9.85	9.57	34250	3624
59	66	227	0.291	0.941	0.983	0.945	2.73	0.17	0.74	96	9.9	9.58	34200	3624
60	66	227	0.291	0.929	0.983	0.945	2.25	0.17	0.75	96	9.73	9.57	34250	3624
61	66	228	0.289	929	0.985	0.947	2.58	0.15	0.75	97	9.69	9.55	34300	3624
62	66	228	0.289	0.933	0.983	0.949	2.7	0.17	0.74	96	9.82	9.58	34200	3624
63	66	227	0.291	0.933	0.982	0.945	2.28	0.17	0.74	96	9.64	9.55	34300	3624
64	34	108	0.315	0.929	0.983	0.873	2.64	0.17	0.74	96	9.94	5.14	34425	1867
65	67	229	0.293	0.858	0.979	0.943	2.64	0.2	0.75	97	9.51	9.71	34200	3678
66	67	226	0.296	0.923	0.985	0.925	2.62	0.15	0.74	96	9.77	9.66	34400	3678
67	68	229	0.297	0.911	0.985	0.923	2.21	0.15	0.74	96	10.26	9.83	34250	3733
68	67	231	0.29	0.909	0.98	0.95	2.3	0.2	0.74	97	9.88	9.76	34000	3678
69	70	241	0.29	0.931	0.981	0.947	1.82	0.19	0.74	97	10.13	10.1	34200	3843
70	68	231	0.294	0.93	0.982	0.934	1.8	0.17	0.74	96	9.69	9.78	34450	3733
71	68	231	0.294	0.917	0.98	0.936	1.63	0.2	0.74	97	10.14	9.9	33975	3733
72	68	230	0.296	0.917	0.979	0.933	1.71	0.2	0.74	97	9.4	9.84	34200	3733
73	68	228	0.298	0.913	0.984	0.92	1.85	0.17	0.74	96	10.4	9.83	34250	3733
74	68	229	0.297	0.905	0.979	0.929	1.71	0.2	0.74	95	9.6	9.82	34300	3733
75	67	230	0.291	0.909	0.983	0.943	1.83	0.17	0.75	94	10.19	10.2	34200	3678
76	67	229	0.293	0.927	0.985	0.937	188	0.15	0.74	94	9.76	9.74	34100	3678
77	68	233	0.292	0.923	0.983	0.942	2	0.17	0.75	94	9.75	9.73	34650	3733
78	68	232	0.293	0.925	0.987	0.934	2.12	0.15	0.74	94	11.2	9.78	34425	3733
79	68	222	0.306	0.921	0.983	0.897	1.93	0.17	0.74	94	9.99	9.78	34450	3733
80	30	105	0.286	0.881	0.985	0.959	1.36	0.15	0.74	96	10.05	9.59	34200	1647
81	27	67	0.403	0.945	0.986	0.679	2.93	0.15	0.74	95	10.98	3.98	35775	1482
82	66	228	0.289	0.67	0.987	0.945	1.28	0.12	0.74	97	9.49	9.58	34200	3624
83	66	232	0.284	0.933	0.985	0.963	1.62	0.15	0.75	97	10.05	9.7	33750	3624
84	66	234	0.282	0.949	0.985	0.972	1.73	0.15	0.74	97	10.18	9.75	33525	3624
85	66	234	0.282	0.957	0.988	0.969	2.02	0.12	0.74	95	10.11	9.7	33750	3624
86	66	233	0.283	0.957	0.985	0.967	1.65	0.15	0.74	97	10.2	9.71	33700	3624
87	66	231	0.286	0.953	0.985	0.959	1.5	0.15	0.74	96	9.99	9.75	33525	3624
88	66	233	0.283	0.945	0.985	0.967	2.33	0.15	0.74	96	10.22	9.68	33800	3624
89	67	232	0.289	0.953	0.988	0.947	2.06	0.12	0.75	97	9.67	9.6	34650	3678
90	66	227	0.291	0.935	0.985	0.943	1.84	0.15	0.75	97	9.8	9.64	33975	3624

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91	64	230	0.278	0.929	0.988	0.982	1.94	0.12	0.75	96	10.17	9.26	34425	3514
92	64	220	0.291	0.97	0.985	0.942	2.17	0.15	0.74	97	9.99	9.49	33500	3514
93	65	224	0.29	0.928	0.983	0.946	2.51	0.17	0.74	96	10.04	9.5	34000	3569
94	67	231	0.29	0.93	0.983	0.947	1.32	0.17	0.74	96	10.29	9.71	34200	3678
95	67	231	0.29	0.931	0.985	0.945	1.44	0.15	0.75	96	10.17	9.77	33975	3678
96	68	233	0.292	0.931	0.985	0.939	1.64	0.15	0.74	97	9.97	9.84	34200	3733
97	67	232	0.289	0.925	0.99	0.944	1.47	0.1	0.74	97	10.04	9.76	34000	3678
98	66	231	0.286	0.935	0.99	0.955	1.63	0.1	0.75	96	9.93	9.68	33800	3624
99	66	231	0.286	0.945	0.995	0.95	1.87	0.05	0.75	97	10.29	9.7	33750	3624
100	67	232	0.289	0.945	0.991	0.944	2.67	0.1	0.74	97	10.54	9.74	34100	3678
101	67	224	0.299	0.935	0.988	0.914	1.51	0.12	0.74	97	10.03	9.76	34000	3678
102	68	223	0.305	0.903	0.99	0.894	3.74	0.1	0.74	96	10	9.95	33800	3733
103	66	222	0.297	0.885	0.988	0.919	3.66	0.12	0.74	95	9.87	9.63	34000	3624
104	67	221	0.303	0.908	0.987	0.902	2.52	0.12	0.75	96	9.52	9.49	35100	3678
105	67	220	0.305	0.891	0.99	0.895	2.33	0.1	0.74	96	10.05	9.76	34000	3678
106	66	220	0.3	0.887	0.99	0.909	1.88	0.1	0.75	96	9.9	9.5	34500	3624
107	66	220	0.3	0.9	0.99	0.909	1.9	0.1	0.74	96	10.26	9.5	34500	3624
108	66	218	0.303	0.9	0.988	0.903	1.87	0.12	0.74	95	10.01	9.38	35000	3624
109	43	119	0.361	0.892	0.988	0.756	2.34	0.12	0.75	96	9.88	6.71	32800	2361
110	65	225	0.289	0.747	0.988	0.946	2.72	0.12	0.74	95	10.13	9.73	33100	3569
111	65	227	0.286	0.935	0.99	0.952	1.58	0.1	0.74	96	10.26	9.77	32950	3569
112	64	226	0.283	0.943	0.99	0.963	2.69	0.1	0.74	96	10.12	9.62	33000	3514

A = ammonia mass, t B = nitric acid mass, t C = ammonia pressure in MPa
D = ammonia temperature in ° C E = ammonia volume in Nm^3

When the mentioned platinum catalysts were used for 112 days, 24,369t of nitric acid were produced. To produce this quantity, 7046 t of ammonia was used. Mid value of the parameters for this quantity was 0.289.

Mid value of the total ammonia recovery coefficient was 0.94. Metal loss during the catalyst exploitation was 8.821g or 0.0362g platinum per tonne of produced nitric acid.

Dependence of ammonia consumption per tonne of produced nitric acid on the exploitation time is shown in figure 5.

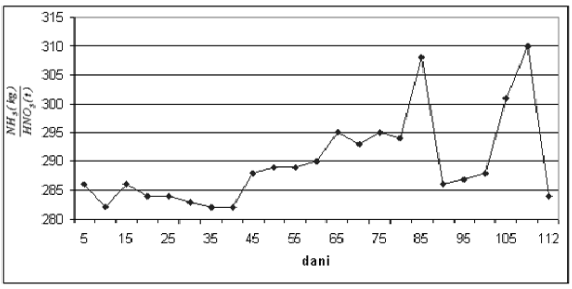

Fig. 5. Dependence of ammonia consumption per tonne of produced nitric acid on the exploitation time

Dependence of the total ammonia recovery coefficient on the catalyst exploitation time is shown in figure 6.

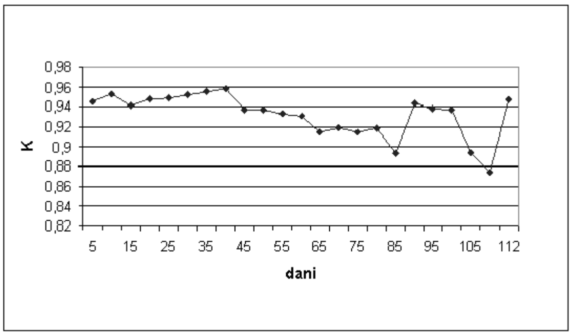

Fig. 6. Dependence of the total ammonia recovery coefficient on the catalyst exploitation time

Obtained results depend on the quantity of ammonia used to produce one ton of nitric acid and the total ammonia recovery coefficient in the exploitation time are presented in figure 7 and 8.

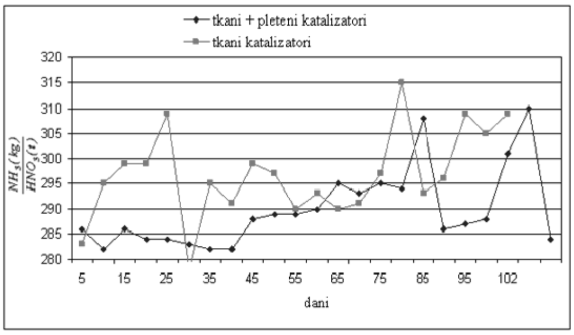

Fig. 7. Dependence of parameters on the exploitation time with used woven and combined woven and knitted catalysts

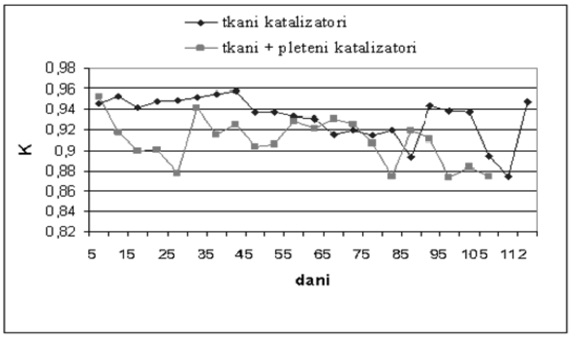

Fig. 8. Dependence of the total ammonia recovery coefficient on the exploitation time when woven and a combination of woven and knitted catalysts was used.

4. Conclusion

When results of application of woven and a combination of woven and knitted catalysts were comparatively analyzed, the following was concluded:

- When platinum catalysts with an increased active surface were used, ammonia consumption per tone of produced nitric acid dropped while the total ammonia recovery coefficient increased.

- Ammonia consumption was 8 kg per ton of produced nitric acid lower when a combined package of catalysts was applied.

- Total ammonia recovery coefficient when combined catalysts were applied was by 2.87% higher in comparison to the same when only woven catalysts were applied.

- Packagings with combined catalysts had a life longer by 10 days.

- Platinum loss when woven and knitted catalysts were combined was by 416.49g lower than with woven catalysts. Obtained results have significantly contributed to the studies on the impact of changes of active surfaces to the total ammonia recovery coefficient in the nitric acid production process.

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