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MANUFACTURE OF ARTICLES FROM STEEL ALLOYS

Friedrich Karl Naumann, Essen, Germany, assignor to Fried. Krupp Aktiengesellschaft, Essen-on-the-Ruhr, Germany

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This invention relates to the manufacture of articles that by their nature are subjected in use to, and must withstand the attack of, gases that attack and remove carbon, such as apparatus and parts thereof which are used in the destructive hydrogenation of oil and coal, or in the synthesis of ammonia, and with which hydrogen or mixtures of gases containing hydrogen come into contact at high temperatures and pressures.

In my co-pending application for Letters Patent, filed 22nd November, 1933, Serial Number 699,300, I propose to manufacture articles of this class from steel alloys which contain titanium and if desired one or more of the elements silicon, manganese, nickel, cobalt, chromium, tungsten, molybdenum and vanadium, the steel alloys suitably containing up to 1% carbon, up to 5% titanium, and if desired up to 30% of one or more of the elements silicon, manganese, nickel, cobalt, chromium, tungsten, molybdenum and vanadium.

It has now been found that besides titanium also the other elements of the IV group of the periodic table, as far as they form carbides in the steel, viz. zirconium and thorium, have the property of rendering steel resistant to the attack of gases that attack and remove carbon. Therefore, according to the present invention use is made for the manufacture of the articles in question of steel alloys which contain at least one of the elements, forming carbides in the steel, of the IV group of the periodic table and if desired one or more of the elements silicon, manganese, nickel, cobalt, chromium, tungsten, molybdenum and vanadium.

Besides titanium, the elements of the IV group of the periodic table which form carbides in the steel are zirconium and thorium. Preferably the content of these elements amounts to not over 5% and the carbon content to not more than 1%, while the total content of the elements Si, Mn, Ni, Co, Cr, W, Mo, V may amount about up to 30%. In general, however, a total content of not more than 15% of these elements is found desirable.

The high resistance of the steel alloys employed according to the invention to the attack of hydrogen is evident from the tests indicated hereinafter for which the following steel alloys were used:

Steel	Percent C	Percent Si	Percent Mn	Percent Cr	Percent W	Percent Mo	Percent Zr
A	0.05	1.66	0.55	-----	-----	-----	1.81
B	0.10	0.38	0.51	1.96	-----	-----	-----
C	0.10	0.38	0.55	-----	2.08	-----	-----
D	0.13	0.23	0.52	-----	-----	1.22	-----

Tensile test pieces prepared from these steel alloys were exposed at a temperature of 600° C. for 100 hours to the attack of hydrogen which was under a pressure of 300 at. The effect of this treatment on the test pieces appears from the following table:

Steel	Yield point kg./mm.²	Tensile strength	Extension 5Xd	Reduction in area	Hardness 5/750	C-content percent
A *a*	42	55.5	23.0	51	188	0.05
b	41	54.3	20.7	49	191	0.05
B *a*	67	73.6	22.0	78	211	0.10
b	-----	27.4	0	0	127	0.007
C *a*	86	90.0	20.7	73	252	0.10
b	34	45.9	12.7	13	141	0.008
D *a*	107	107.9	14.7	60	302	0.13
b	-----	35.1	0	0	129	0.007

In this table *a* denotes the condition of the alloy when supplied, A in forged state and B, C, D after heat treatment. *b* denotes the state after the test.

It appears from this table that the steel A alloyed with zirconium has preserved its full strength and tenacity as well as its original carbon content, whilst the remaining steels have lost their carbon nearly completely and show serious loss of strength and especially of tenacity.

The steel alloys which besides the carbide-forming element of the IV group contain further additions of elements, show likewise a resistance to carbide-removing gases which far exceeds the effect of these additional elements, as the following test shows:

From two steel alloys E, F of the following composition

Steel	Percent C	Percent Si	Percent Mn	Percent Cr	Percent Zr	Percent Mo
E	0.10	1.43	0.48	1.22	0.95	-----
F	0.10	1.07	0.58	1.19	-----	0.58

tensile test pieces were prepared and likewise heated 100 hours at 600° C. in hydrogen under pressure of 300 at. The test pieces treated in this manner showed the following data of strength:

Steel	Yield point kg./mm.²	Tensile strength	Extension 5Xd	Reduction in area	Hardness
E *a*	44	53.8	24.5	59	169
b	42	51.2	23.0	57	162
F *a*	41	53.4	33.3	78	149
b	26	32.7	13.7	16	110

wherein by *a* is marked the state when supplied and by *b* the state after the test.

This table shows that the steel marked E re-

mained practically unaltered, whilst the steel F suffered a considerable deterioration of its properties of strength.

Steel alloys have been found particularly suitable for the purposes according to the invention, which contain about up to 0.4% carbon, up to 2% zirconium, up to 3% molybdenum or vanadium, separate or mixed and if required up to 10% chromium.

What I claim and desire to secure by Letters Patent is:—

1. Articles which in their normal use are subjected to the attack of hydrogen at high hydrogen partial pressure and high temperature, said articles being composed of a steel alloy containing an effective amount not over 5% of one or more elements selected from the group zirconium and thorium, and not over 1% of carbon, the remainder substantially all iron.

2. Hydrogenating apparatus having its parts which are subjected to the attack of hydrogen at high pressure and temperature composed of a steel alloy containing an appreciable amount not over 5% of one or both of the elements zirconium or thorium, the remainder substantially all iron.

3. Articles which in their normal use are subjected to the attack of hydrogen at high hydrogen partial pressure and high temperature, said articles being composed of a steel alloy containing an effective amount not over 5% of zirconium and not over 1% of carbon, the remainder substantially all iron.

4. A process which comprises subjecting a material to be hydrogenated to the influence of hydrogen at high hydrogen partial pressure and high temperature in a container composed of a steel alloy containing an effective amount not over 5% of one or more elements selected from the group zirconium and thorium, and not over 1% of carbon, the remainder iron containing up to 1.7% of silicon and up to 0.55% of manganese.

5. A process which comprises subjecting a material to be hydrogenated to the influence of hydrogen at high hydrogen partial pressure and high temperature in a container composed of a steel alloy containing an effective amount not over 5% of zirconium and not over 1% of carbon, the remainder iron containing up to 1.7% of silicon and up to 0.55% of manganese.

FRIEDRICH KARL NAUMANN.