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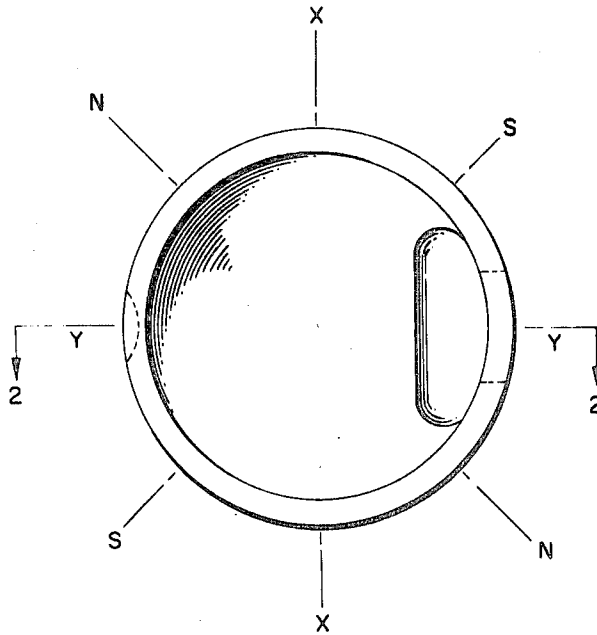
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[31]		41/69550

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[54] HEAT RESISTANT ALLOY STEEL
1 Claim, 2 Drawing Figs.

[52]	U.S. Cl.	75/126 C, 75/126 F
[51]	Int. Cl.	C22c 39/20
[50]	Field of Search	75/126 C, 126 F, 126

ABSTRACT: A heat-resistant alloy steel composed of 0.05 to 0.40 percent by weight of carbon, 0.5 to 1.0 percent by weight of silicon, 0.2 to 1.0 percent by weight of manganese, 20.0 to 23.0 percent by weight of chromium, 0.5 to 2.5 percent by weight of molybdenum, 0.5 to 3.5 percent by weight of tungsten, 0.5 to 3.5 percent by weight of niobium, and the balance iron and unavoidable impurities, the tantalum content in the niobium being not more than about 10 percent by weight.



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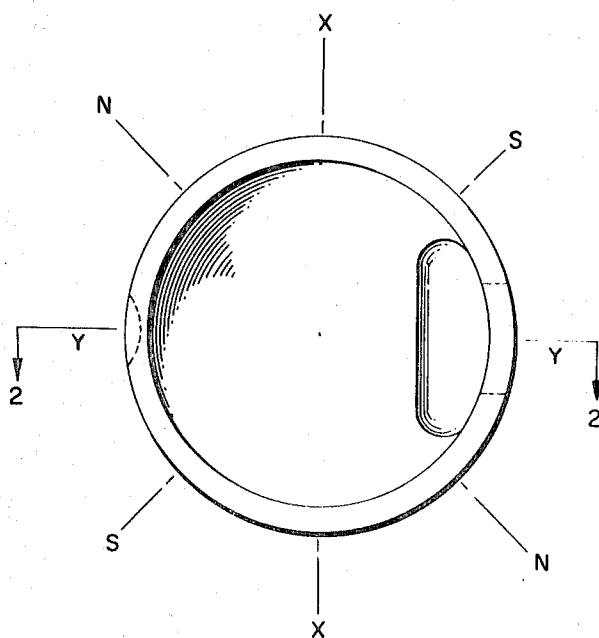


FIG. 1

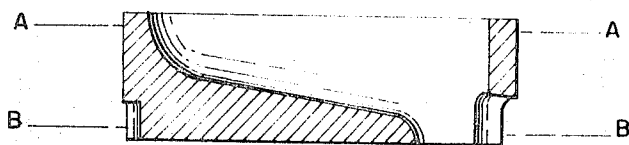


FIG. 2

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HEAT RESISTANT ALLOY STEEL

The present invention relates to a heat-resistant alloy steel. It also relates to a heat-resistant ferritic alloy steel which is excellent in resistance to corrosion, deformation and cracking under high temperature and corrosive environments. It further relates to an insert for the precombustion chamber of a Diesel engine which is made of the said alloy steel.

For such purposes as mentioned above, there have been used (1) "Nimocast PE-10" (2) a nickel-based ultra-heat-resistant alloy steel, (3) "Inconel-610," (4) a highly carburized heat-resistant austenitic alloy steel, (5) a heat-resistant austenitic alloy steel, and (6) a heat-resistant "21-chromium" ferritic alloy steel. However, these are not satisfactory in deformation and crack resistant properties. Further, they are disadvantageous in that they are expensive owing to the large content of such costly elements as nickel, niobium tungsten, molybdenum and the like.

Accordingly, a fundamental object of the present invention is to provide a new heat-resistant alloy steel. Another object of this invention is to provide a new formulation of a ferritic alloy steel. A further object of the invention is to provide a steel which is deformation and crack resistant at an elevated temperature. A still further object of the invention is to provide an insert for the precombustion chamber of a Diesel engine which is made of the heat-resistant alloy steel. These and other objects will be apparent to those conversant with the art to which the present invention pertains from the foregoing and subsequent descriptions, taken with the accompanying drawing, in which:

FIG. 1 is a plan view of a precombustion chamber insert; and

FIG. 2 is a section on line 2—2 of FIG. 1.

The alloy steel of the present invention is composed of 0.05 to 0.40 percent by weight of carbon, 0.5 to 1.0 percent by weight of silicon, 0.2 to 1.0 percent by weight of manganese, 20.0 to 23.0 percent by weight of chromium, 0.5 to 2.5 percent by weight of molybdenum, 0.5 to 3.5 percent by weight of tungsten, 0.5 to 3.5 percent by weight of niobium, and the balance iron and unavoidable impurities, the tantalum content in the niobium being not more than about 10 percent by weight.

In the alloy steel of the present invention, an excess amount of carbon results in deficiencies owing to the formation of carbides of chromium, molybdenum, tungsten and the like. Further, it decreases the solid solubilities of those metals in

weight does not affect the crack-stopping property, because the alloy is constituted by a sole ferrite form. But, the upper limit of the chromium content is to be at the most 23.0 percent by weight, because of the cost and the balance between the austenite and the ferrite forms under a carburizing condition.

Molybdenum and tungsten are each required for the deformation resistance, and the content should not be less than 0.5 percent by weight. Since excess amounts of them affect unfavorably the crack-resistance, the molybdenum and tungsten contents should be restricted to at the most 2.5 percent by weight and 3.5 percent by weight, respectively.

Niobium provides crack-resistance and gives a fine-grained steel. This effect is attributed not to niobium per se, but to niobium carbide. According to the experiments, a combination of 1 percent by weight of niobium and 0.1 percent by weight of carbon or of 3 percent by weight of niobium and 0.3 percent by weight of carbon produces the most excellent effect on the fineness of the grain. Thus, with a content of 0.05 to 0.40 percent by weight of carbon more than 3.5 percent by weight of niobium results in high cost instead of increasing crack-resistance, and a fine-grained steel can not be formed with a content less than 0.5 percent by weight of niobium, that is to say the niobium content has to be within the range to 0.5 to 3.5 percent by weight. It should be noted that less than about 10 percent by weight of tantalum may be contained in the said niobium. It is confirmed by the experiments to determine the effects of each carbon and niobium per se that when carbon was increased to 0.4 percent from 0.04 percent and niobium by weight and was increased to 30 percent from 0.5 percent, respectively, the absolute heat deformation value was increased by 33μ (corresponding to the carbon increment) and 30μ (corresponding to the niobium increment), respectively and the number of cycles before the occurrence of cracks was also increased by 20.0 (corresponding to the carbon increment) and 12.0 (corresponding to the niobium increment).

Silicon and manganese are added as the deoxidation agents. The deoxidation can be sufficiently achieved with 0.5 to 1.0 percent by weight of silicon and 0.2 to 1.0 percent by weight of manganese without any decrease of the strength of the objective alloy steel.

Using the thus-composed alloy steel, an insert for the precombustion chamber of the Diesel engine as shown in FIGS. 1 and 2 is cast by a conventional method, e.g. a lostwax process.

To examine the crack and a deformation resistances of the alloy steel of the present invention, the test pieces in the form

TABLE 1

Number	Composition (percent by weight)								
	C	Si	Mn	Cr	Ni	Mo	W	Nb	Fe
1	0.04	0.79	0.33	19.12	Balance	2.65	2.60	6.39	1.25
2	0.09	1.70	0.80	13.14	Balance	1.31	1.11	3.38	12.50
3	0.11	2.57	0.93	15.64	Balance	-----	-----	1.00	11.25
4	0.70	1.70	0.76	23.93	14.24	1.89	-----	1.32	Balance
5	0.06	1.94	0.91	24.28	20.00	-----	-----	1.95	Balance
6	0.12	0.79	0.64	21.19	-----	-----	-----	-----	Balance
7	0.14	0.66	0.61	20.15	-----	1.62	1.03	0.92	Balance
8	0.09	0.68	0.32	21.46	-----	2.29	3.13	1.01	Balance
9	0.37	0.58	0.33	21.28	-----	2.00	2.86	3.29	Balance
10	0.07	0.73	0.31	22.67	-----	1.00	0.90	1.11	Balance

NOTE.—Nos. 1 to 6 are the previously known compositions and Nos. 7 to 10 are the compositions of the present invention.

the alloy base, and also prevents the dispersion of nitrogen during a Tuffride process (i.e. soft-nitriding process) to make thin the layer of the mixture of iron carbide and iron nitride. Taking these facts into consideration, it has been decided that the upper limit of the carbon content should be 0.40 percent by weight. It is necessary for good strength of the alloy steel that the carbon content should not be less than 0.05 percent by weight.

At least 20.0 percent by weight of chromium is required to make the alloy steel corrosion and crack resistant, especially under an oxidative environment at an elevated temperature. An increased chromium content more than 20.0 percent by

of the above mentioned insert were cast in six kinds of known alloy steels and four kinds of the present alloy steels, having compositions shown in Table 1.

Three pieces were cast in each of ten compositions; and directly subjected to the testing and another three pieces of all but the fifth composition, a heat-resistant austenitic alloy steel, were cast and subjected after heat treatment or a surface treatment by the Tuffride process. In the heat treatment, the formation of solid solution was executed at 1,100° C. for 2 hours and the crystallization of the alloy at 750° C. for 2 hours. The Tuffride surface treatment was carried out at 560° C. for 2 hours.

The test was carried out by heating each of the 57 test pieces intermittently and repeatedly so that they were treated substantially under the same condition as in the engine. That is, each test piece was placed in a metal holder which was cooled by running water. Any oxygen-acetylene burner was provided to heat the upper surface of the test piece. A rotating cam was used to successively move the nozzle of the burner forwards to direct the flame onto the test piece at an angle of 65° for 24 seconds (whereby the temperature of the reverse side of the piece was elevated to 1,015~1,045° C.) and rearwards, away from the test piece for 30 seconds (whereby the temperature of the reverse side was lowered to 350~360° C.), and the cycle was repeated 500 times.

Deformation values for each set of three test pieces were measured during each cycle, along equiangularly spaced axes X—X, Y—Y, N—N and S—S (shown in FIG. 1) in the region A—A (shown in FIG. 2), and along axes X—X, N—N and S—S in the region B—B (FIG. 2). In the table 2, under the heading "Deformation values (**)" the averages of the deformation values in the regions A—A, B—B are listed in appropriately marked column. The averages in the A—A column are found by adding the deformation values along the 4 axes for each of the 3 test pieces and then dividing by 12. The averages in the B—B columns are found by adding the deformation values along the 3 axes for each of the 3 test pieces and then dividing by 9. The values listed in the columns marked "Average" are found by multiplying the appropriate A—A and B—B averages respectively by 4 and 3, adding the products and then dividing by 7.

Columns marked "A—A," "B—B" and "Average" are provided under subheading "Subtractive values" and "Absolute values." The averages listed under the first of these subheadings are found by "qualitative" addition of the deformation values, that is to say, by adding expansions and subtracting contractions. The averages listed under the second of these subheadings are found by "qualitative" addition of the

deformation values, that is to say, by adding the amounts of deformation without regard to the nature of the deformation as expansions or contractions.

The average number of cycles taken before cracking took place were also determined and noted in Table 2.

From the results in listed in Table 2, it is apparent that the alloy steels Nos. 7 to 10 of the present invention are significantly superior to those Nos. 2 to 6 of the previously known compositions in combined crack and deformation resistant properties when merely cast. It is also noted that the deformation-resistance of the alloy steels according to the invention is remarkably improved by the surface treatment, although the crack-stopping property is affected somewhat unfavorably. Heat-resistant alloy steels of the present invention are also economical, because the amounts of expensive metal are decreased, and are therefore superior to the known alloy steels such as "Nimocase PE-10" in general engineering properties.

The test results of Table 2 can be confirmed by the continuous working trials for 1,000 hours, where the insert made of the present alloy steel is actually assembled in the Diesel engine.

As disclosed above, there is provided a heat-resistant ferritic alloy steel which is deformation and crack-resistant at elevated temperatures, and this material is especially suitable for use in the precombustion chamber of a Diesel engine.

What is claimed is:

1. A heat-resistant alloy steel the provision "for use as an insert in a diesel engine combustion chamber" consisting essentially of 0.05 to 0.40 percent by weight of carbon, 0.5 to 1.0 percent by weight of silicon, 0.2 to 1.0 percent by weight of manganese, 20.0 to 23.0 percent by weight of chromium, 0.5 to 2.5 percent by weight of molybdenum, 0.5 to 3.5 percent by weight of tungsten, 0.5 to 3.5 by weight of a material which is at least 90 percent by weight-pure niobium and the rest tantalum, and the balance iron and unavoidable impurities.

TABLE 2

Number	Deformation values (μ)						Cycle Nos. to cause cracking	Preparation
	Subtractive values			Absolute values				
	A-A	B-B	Average	A-A	B-B	Average		
The known compositions:								
1.....	{ -40	-82	-58	86	101	93	158	Casting.
	{ -15	-7	-12	73	53	65	23	Heat treatment.
2.....	{ -197	-327	-253	197	327	253	130	Casting.
	{ -156	-215	-181	156	215	181	88	Surface treatment.
3.....	{ -180	-423	-284	180	423	284	170	Casting.
	{ -287	-607	-425	289	607	425	103	Heat treatment.
4.....	{ -130	-68	-103	161	95	133	40	Casting.
	{ -93	-42	-71	135	75	109	28	Surface treatment.
5.....	{ -181	-445	-294	181	445	294	264	Casting.
	{ -175	-497	-313	185	497	319	165	Casting.
6.....	{ -107	-327	-201	107	327	201	123	Surface treatment.
The compositions of the invention:								
7.....	{ -59	-265	-148	84	265	160	370	Casting.
	{ -48	-79	-61	84	91	87	96	Surface treatment.
8.....	{ -79	-134	-103	82	134	105	140	Casting.
	{ -8	-15	-11	70	39	57	75	Surface treatment.
9.....	{ -52	-89	-67	77	105	89	175	Casting.
	{ -9	-7	-3	64	34	51	50	Surface treatment.
10.....	{ -73	-160	-110	90	167	123	260	Casting.
	{ -25	-35	-30	83	59	72	50	Surface treatment.

Note: Casting refers to casting without heat- and surface-treatments. Heat treatment refers to soaking in air at 1100° C. for 2 hours and at 750° C. for 2 hours. "Surface treatment" refers to "Tufftriding" at 560° C. for 2 hours.