United States Patent

[11] 3,547,032

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[54] **STEEL ALLOY SHELL BODY**
2 Claims, No Drawings

[52] **U.S. Cl.** **102/67;** 75/123
[51] **Int. Cl.** **F42b 5/28**
[50] **Field of Search** ..... 75/123; 148/(C.C.); 29/180, (S.S.S.); 102/67

[56] **References Cited**

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ABSTRACT: A steel alloy consisting essentially of 1.0 percent to 1.2 percent carbon, 1.6 percent to 2.3 percent manganese, 0.5 percent to 1.1 percent silicon, balance iron and incidental impurities, and a shell body made therefrom. When exploded, the shell body exhibits high fragmentation characteristics, approximating or superior to those of pearlitic malleable iron.

STEEL ALLOY SHELL BODY

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 679,219 filed Oct. 30, 1967, now abandoned, for "Steel Alloy and Shell Body Made Therefrom."

BACKGROUND OF THE INVENTION

The field of the invention is that of steel compositions which can be formed into shell bodies having high fragmentation characteristics when exploded.

As herein used the term shell body means a hollow body intended to contain an explosive charge, e.g. an artillery shell body, a mortar shell body, a rocket body or a bomb body.

For certain applications shell bodies should desirably exhibit high fragmentation characteristics when exploded.

High fragmentation characteristics means the capability of breaking into a large number of fragments of small mass, in the approximate range of 2 to 25 grains, and ideally of a cubic or chunky shape.

Shell bodies manufactured from hypoeutectoid steels are generally too ductile to provide good fragmentation characteristics.

Shell bodies manufactured from pearlitic malleable iron fragment well but the poor hot working characteristics of pearlitic malleable iron necessitates casting to shape. The strength of this material is on the order of 60,000 p.s.i. which is insufficient for some shell bodies.

Shell bodies made from high carbon steels fragment well provided they have either a well developed carbide grain boundary network or extensive amounts of carbon in the form of nodular graphite. However, the attainment of a carbide grain boundary network requires a lengthy and precise heat treatment which varies with compositions. Shell bodies made from graphitic steels may produce elongated fragments, when exploded, if the graphite shape changes from nodular to stringer form as a result of the mechanical working operations needed to produce a shell body. In addition, graphitic steels must be forged at low temperatures and cold forming operations are difficult.

SUMMARY OF THE INVENTION

The principal object of this invention is to provide a steel alloy having high fragmentation characteristics when formed into a shell body and exploded, together with machinability, strength and ductility satisfactory for use in the manufacture of shell bodies.

This invention is directed to a steel alloy and to a shell body made therefrom having high fragmentation characteristics. The steel consists essentially of 1.0 percent to 1.2 percent carbon, 1.6 percent to 2.3 percent manganese, .5 percent to 1.1 percent silicon, balance iron and incidental impurities.

The amounts of carbon, manganese and silicon in this composition are such that standard fragmentation tests of shell bodies made therefrom have consistently achieved results approximating or superior to those achieved by shell bodies made of pearlitic malleable cast iron. Moreover these results can be achieved with a variety of easily produced microstructures and resultant strength levels, all at hardness levels (BHN 350 and lower) which are readily machinable. The carbon and manganese are believed to be the principal elements enhancing fragmentation in this alloy. The upper limits on the carbon and silicon are taken at 1.2 percent carbon and 1.1 percent silicon, to ensure that graphite is not formed during conventional heat treatment.

For economic reasons, elements other than carbon, manganese, and silicon, are kept to the residual levels which result from normal steelmaking practices. Slight changes in residual element content would not be expected to deleteriously affect the performance of the steel alloy of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the steel of this invention comprises:

	Percent
Carbon	1.0 to 1.2
Manganese	1.6 to 2.3
Phosphorus	.035 max.
Sulphur	.04 max.
Silicon	0.5 to 1.1
Nickel	.25 max.
Chromium	.20 max.
Molybdenum	.06 max.
Copper	.35 max.
Iron	Balance

As a specific example of this invention, a heat of steel was made having the following composition:

	Percent
Carbon	1.10
Manganese	1.78
Phosphorus	0.009
Sulphur	0.014
Silicon	0.83
Nickel	0.06
Chromium	0.04
Molybdenum	0.01
Copper	0.11
Aluminum	0.010
Iron	Balance

The steel was cast into ingots and rolled to 4 inch diameter bars in the usual manner. Individual pieces of these bars were heated to 1450° F. and formed into test cylinders by the warm cup-cold draw process. These cylinders were rough machined to within .010 inch—.020 inch of finish size, heat treated by various procedures as specified in table 1 if finish machined to 4.15 inches O.D. × 3.45 inches I.D. × 5 inches long, and then tested for fragmentation characteristics.

The fragmentation test consisted of exploding each cylinder with a charge of Composition B explosive, with the cylinder supported approximately 5.8 feet above a 3 feet by 4 feet opening in a water tank. The fragments entering the tank were collected, those having a weight of 2 grains or over were counted, and this count was multiplied by 12 to simulate a 100 percent recovery. For comparative purposes a cylinder of pearlitic malleable cast iron of the same dimensions was similarly exploded. The conversion factor of 12 results from the fact that the water tank collects only approximately one-twelfth of the total number fragments generated.

The results of these fragmentation tests are summarized in table 1 below.

TABLE 1

	Hardness, B.H.N.	Total fragments 2 grams and over
Pearlitic malleable cast iron steel of this Invention	217-235	4,288
Heat Treatment:		
(1) 1,700° F./1 hour, transfer to furnace at 1,400° F./1 hour, oil quench, 1,200° F./temper	321-341	5,053
(2) 1,700° F./1 hour, quench in salt pot at 1,400° F./45 min., air cool	277-302	4,895
(3) 1,700° F./1 hour, quench in salt pot at 1,150° F./45 min., air cool	277-321	3,757
(4) 1,450° F./30 min., oil quench, 1,100° F./temper	302-352	3,288

The fragmentation test results will vary with changes in heat treatment, in cylinder geometry and in test conditions. For example, the results summarized on table 2 were obtained with test cylinders 5 inches O.D. × 3.75 inches I.D. × 7 inches long, made from the same heat of steel above described, using Composition B explosive. These cylinders were exploded in a sawdust chamber and fragment recovery was accomplished by passing the sawdust across a magnetic roller.

TABLE 2

	Hardness, B.H.N.	Total fragments 2 grams and over
Pearlitic malleable cast iron steel of this Invention	255	5,850
Heat Treatment:		
(1) 1,750° F. for 2 hours, air cooled, tempered 1 hour at 900° F	331	8,355
(2) 1,700° F. for 30 min., quench in salt at 1,150° F. for 1 hour, air cooled	302	7,491
(3) 1,425° F. for 30 min., oil quenched tempered 1 hour at 1,100° F	331	5,779

The steel of this invention can be formed by a hot forge or warm cup-cold draw process.

This is the first time a steel which is relatively insensitive to variations in heat treatment has produced fragmentation characteristics approaching or superior to those of pearlitic malleable cast iron, and without the need for graphite or grain boundary carbide in the microstructure. Further the steel of this invention develops better fragmentation for the same hardness level than other steels against which it has been tested.

While certain optimum conditions of heat treatment have been established for the steel of this invention, as shown in tables 1 and 2, other heat treatments are possible. For example, shell bodies made from this steel have better fragmentation characteristics than other steels when tested in the cold-drawn and stress-relieved condition. Shell bodies of this composition have also been found to fragment reasonably well when tested in the spheroidized annealed, cold-nosed and stress-relieved condition.

Thus, a variety of simple, readily reproducible heat treatments produce shell bodies exhibiting consistently good fragmentation unaffected by minor variations in microstructure. At the same time these treatments produce a wide range of mechanical properties ranging from 60,000 to in excess of 140,000 p.s.i. yield strength and tensile elongations of 5 percent or more. Toughness of this steel is superior to that of cast iron. Machinability has been found to be superior to that of steels with ferrite-martensite microstructures for the same fragmentation results.

All references herein to percentages are weight percentages.

I claim:

1. An explosive shell body having high fragmentation characteristics formed from a steel alloy consisting essentially of 1.0 percent to 1.2 percent carbon, 1.6 percent to 2.3 percent manganese, .5 percent to 1.1 percent silicon, balance iron and incidental impurities.

2. The shell body of claim 1 wherein the amounts of the following elements are not in excess of the following:

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	Percent
Phosphorus	.035
Sulphur	.04
Nickel	.25
Chromium	.20
Molybdenum	.06
Copper	.35

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,547,032 Dated December 15, 1970

Inventor(s) Paul J. Horvath, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, and 2, Table 1:
"Pearlitic malleable cast iron" should be on a separate line; "Steel of this invention" should be on a separa line. Columns 3 and 4, Table 2 :
"Pearlitic malleable cast iron" should be on a separ line; "Steel of this invention" should be on a separate line.
Column 4, line 37, cancel "3,547,032".

Signed and sealed this 15th day of June 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
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