File

FILE COPY

OTTAWA June 20th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1666.

Examination of "Toughard" Weld Metal.

(Copy No. 10)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA June 20th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1666.

Examination of "Toughard" Weld Metal.

Origin of Material:

On May 15th, 1944, Dr. R. E. Jamieson, Director General, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, through the Director of Metallurgy, submitted for examination samples of a new weld metal known as "Toughard". The samples consisted of (a) a cast bar approximately 3/8 inch square and (b) what was said to be the same metal, deposited on a piece of mild steel by the oxy-acetylene torch.

The following are copies of the correspondence received with the samples:

"CRUCIBLE STEEL COMPANY OF AMERICA
SALES DEPARTMENT
405 Lexington Avenue,
New York 17, N.Y.
April 19th, 1944.

Mr. A. N. Orsher,
Toughard Metal Sales Co.,
Graybar Building,
New York, N.Y.

Dear Sir:

The sample of Toughard metal has been given a preliminary test and has been found to show a Rockwell hardness in its present form of 60-C. We took this same piece and melted it down on mild steel using an acetylene torch. The weld metal Rockwelled 58-C. the weld appeared most satisfactory and did not show any signs of blow holes or porosity.

The structure of the piece as cast appears very good, it having a good grain structure and good clean metal. The excellent hardness indicates that it would be most suitable for use as a cutting tool and for machining applications. We intend to make further tests to determine the characteristics of this metal, particularly with regard to impact and shock.

We hope to have further information for you very shortly.

Yours very truly,
CRUCIBLE STEEL COMPANY OF AMERICA,
(Signed) W. B. Downes."

..

(Origin of Material, cont'd) -

"Richard Rice,
20 Commerce Street,
New York 14, New York.
April 19, 1944.

Major Marlow, Military Representative,
Canadian Consulate General's Office,
Suite 410, 620 Fifth Avenue,
New York, N.Y.

Dear Major Marlow:

Herewith I submit copies of reports on the metal alloy of which I spoke today, and also a sample of the metal. This metal combines three important qualities heretofore unobtainable, to wit: extreme hardness, abrasion and wear resistance, and ability to withstand severe impact and shock.

The hardness of this metal can be brought up to 78 Rockwell C without impairing its other qualities. It is made from scrap material or metal in abundance in Canada, combined with graphite and a sand abundant in Canada which has been treated chemically prior to being included in the melt. I have arranged to have this business housed in a major steel plant in New Jersey. The U.S. Arsenals and many large corporations have purchased this material before it was perfected at from $4.50 to $6.50 per pound. The raw material cost here 11¢ a pound mixed and ready for melt. This metal can be drawn into wire and will withstand temperatures in excess of 3,000 F. It is an excellent material for hard surfacing soft metal of any kind and is applied with an electric or gas arc or torch. It likewise can be used to repair tanks and other equipment in the field. It can be made in bulk and will then be an excellent impact resistant armor for any army or navy purpose. This material, because of its workability and three above-mentioned qualities is in my opinion highly necessary in the war effort, both for repair, maintenance, and in the construction of armament capable of withstanding shock and impact and wear. If applied in a heavy layer or as a basic material it will be of great advantage in my opinion in armoring ranks against mines and explosion.

Very truly yours,
(Signed) Richard Rice.

P.S.: I had this metal tested for 'shock' 'percussion' and 'impact.' It is tops. Your experts can easily apply this metal on a hard surface by electric arc or gas weld and check this factor."

..

The heat histories give no information as to the constituents of the furnace charges. The additions are referred to only as "rod" with the exception of an electrolytic manganese addition as a deoxidizer.

Object of Investigation:

To examine the cast Toughard metal and the welds with a view to assessing its usefulness as a weld metal, armour plate and hard surfacing material.

Procedure:

(1) The samples submitted were subjected to a careful visual examination. Figure 1 shows the samples in the "as received condition.

(2) A chemical analysis sample was machined from the welds and mixed with grindings from the cast bar. The table

(Procedure, cont'd) -

below lists the results of the analysis:

Toughard Weld Metal.

		Per cent
Carbon	-	2.82
Phosphorus	-	0.023
Sulphur	-	0.013
Manganese	-	0.16
Silicon	-	1.86
Chromium	-	10.87
Nickel	-	0.61
Molybdenum	-	0.33
Copper	-	0.46
Vanadium	-	Not detected.
Titanium	-	Not detected.
Boron	-	Not detected.

(3) Samples for microscopic examination were machined from the weld and the cast bar. Figure 2 reveals the structure of the fusion line between the weld and the mild steel plate. Note that there has been a carbon migration from the weld metal into the plate sufficient to produce a lamellar pearlite structure. Figure 3 shows the structure of the weld metal remote from the fusion line. Note the profusion of massive carbides.

The microscopic examination of the cast bar revealed structures not frequently encountered. Figure 4 shows the dendritic type of structure towards the outside of the bar. Figure 5 shows the same structure at considerably higher magnification. In both cases the structure consists of pro-eutectic cementite (carbides) in a matrix which consists of the eutectic of cementite and austenite (with some products of austenite decomposition). Figure 6 shows the structure at the centre of the bar where the cooling rates have been slower than those at the outside of the bar. There the structure consists of, mostly, the eutectic of cementite and pro-eutectic cementite in a matrix of the eutectic of cementite and austenite. The arrow in this

(Procedure, cont'd) -

figure points to a group of carbides which are shown at higher magnification in Figure 7. Note the geometric regularity of shape of these carbides. When etched in Murakami's reagent, the carbides take on an orange-yellow colour characteristic of iron-chromium carbides.

(4) Hardness tests, using a Vickers machine and a 50-kilogram load, were made on the above microspecimens. The following table lists the results secured. Each hardness number is the average of six readings.

		Vickers Hardness Number	Approximate Rockwell Equivalent
Mild steel plate	-	160	'C' 5
Fusion zone	-	179	'C' 8
Weld metal	-	715	'C' 58
Cast bar - outside	-	1018	'C' 67
Cast bar - inside	-	792	'C' 61

(5) Insufficient material was available to conduct impact or abrasion resistance tests. As a crude impact test, one end of a piece of the cast bar was clamped in a vise and the opposite end tapped with a hammer. The piece fractured at the first blow. A second piece accidentally dropped to the floor from a height of 3 feet also broke.

Discussion:

A visual examination of the samples submitted revealed that the welded sample had been subjected to Rockwell hardness tests. The cast bar showed nothing unusual other than a central pipe indicating that it was cast in an upright mould. All welds were irregular, one being cracked. It is possible that the welded piece is that referred to in the report from the Crucible Steel Company.

The chemical analysis of the weld metal is unusual. The material is approaching the type used for valves in internal

(Discussion, cont'd) -

combustion engines because of its high strength and corrosion resistance. There is also a similarity between this composition and that of high carbon, high chromium tool steels of the oil-hardening type. In general the analysis is such as to be subject to carbide segregation and consequent brittleness. It would be reasonable to expect excellent wear-resisting properties and low movement in hardening. The small amount of molybdenum present would be of slight effectiveness in reducing the inherent brittleness of the metal.

The tendency to carbide segregation is well shown in the microscopic examination and it is to this characteristic that good wearing properties may be attributed. This type of segregation is, however, responsible for brittleness, and crude tests indicate that the metal has low impact resistance. This being the case, the use of this metal as armour plate, or as additional protection for armoured vehicles against land mines, cannot be recommended. The claim that the metal retains its properties at a temperature of 3000° F. is false. Alloys of this type at 3000° F. are completely liquid. The statement that the metal can be drawn into wire is impossible to accept, in view of the hardness and brittleness of the material. This would be akin to trying to draw white iron.

The excellent hardness of the case bar and deposited weld metal indicate that the most promising field of application for this metal would be in hard surfacing and tool manufacture. In addition, it could be effective if used to manufacture articles subject to severe wear with little or no impact, such as nozzles for sandblasting machines.

The statement that this metal is made from scrap material or metal, sand which has been chemically treated, and graphite may mean much or nothing. A price of 11 cents per pound for the furnace charge ready to melt is just possible. The chromium content could be obtained from the cheaper, high-carbon

(Discussion, cont'd) -

ferrochrome, and the remaining alloys mainly picked up from selected scrap. However, specialty alloys of this kind usually sell for a considerably higher price.

CONCLUSIONS:

1. The chemical analysis of "Toughard" weld metal is such as to render its use as armour plate, or for armouring purposes, of little value.

2. The best fields of application are hard surfacing, tools, and wear-resistant castings.

3. The claims as to retention of properties at temperatures in excess of 3000° F. are completely unacceptable.

4. The quoted cost of ready-to-melt material is difficult to believe for high-alloy metal of this type.

ooooooooooo
ooooo
o

HJN:GHB.

Figure 1.

SAMPLES AS RECEIVED: LEFT, CAST BAR; RIGHT, WELD ON MILD STEEL PLATE.

Note crack in deposited weld metal.

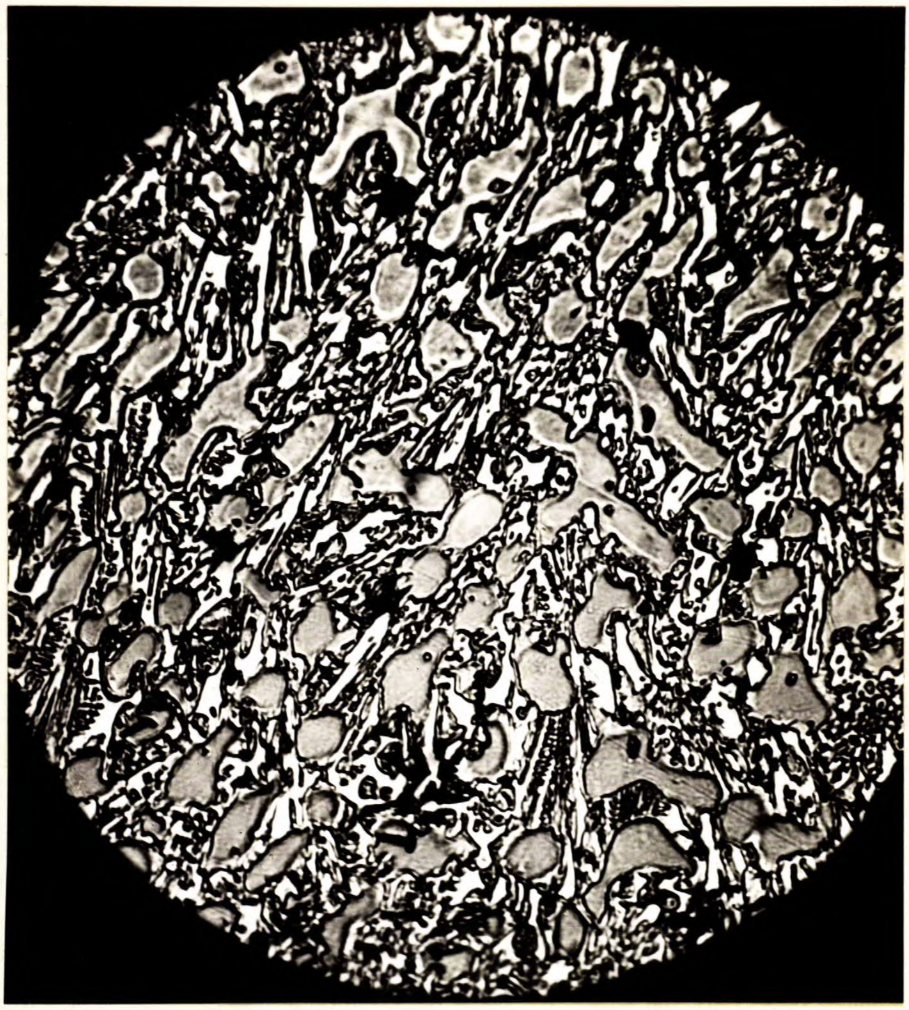
Figure 2.

X1000, etched in 1 per cent HCl and 4 per cent picric acid in alcohol.

FUSION LINE--WELD METAL ABOVE; MILD STEEL PLATE BELOW.

Note carbon migration into mild steel plate, producing a lamellar pearlite structure. Note also the massive iron-chromium carbides in the weld metal.

Figure 3.



X1000, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

STRUCTURE OF DEPOSITED WELD METAL
REMOTE FROM THE FUSION LINE.

Pro-eutectic cementite (carbides) in a matrix which consists of the cementite and austenite (with some products of austenite decomposition).

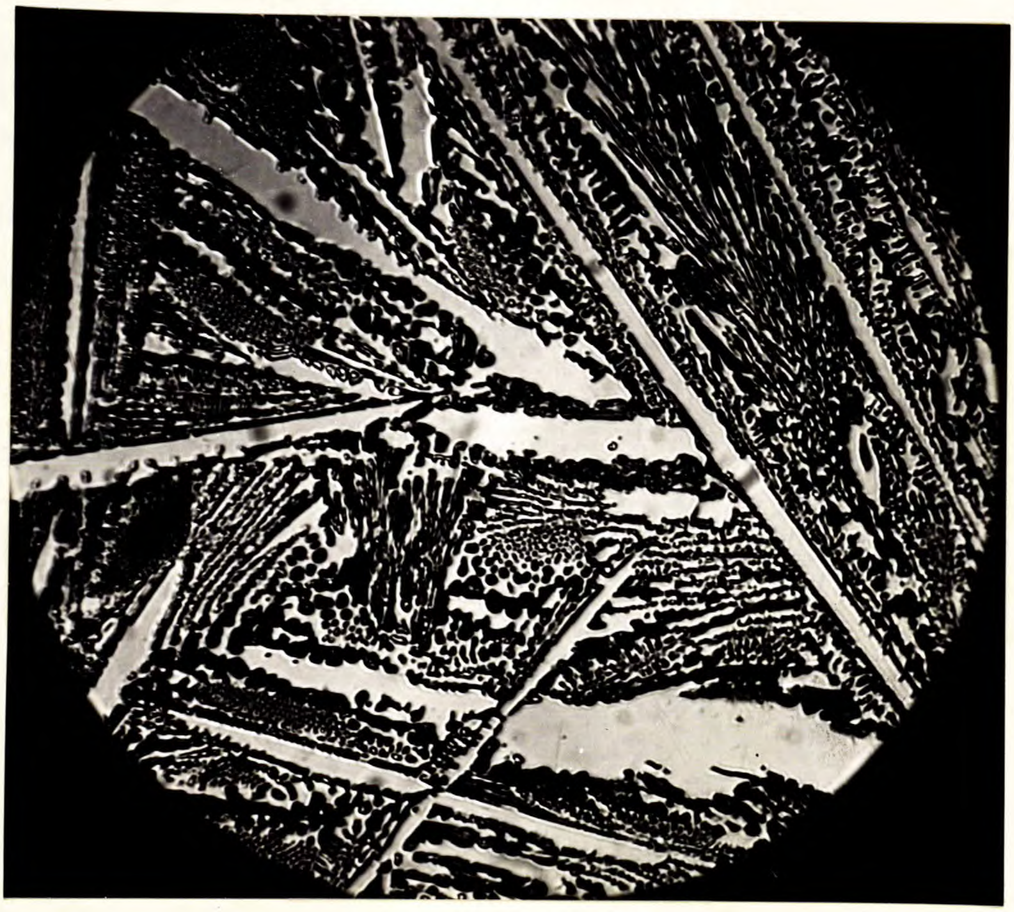
Figure 4.

X100, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

STRUCTURE OF CAST BAR TOWARDS OUTSIDE.

Pro-eutectic cementite in a matrix
of the eutectic of cementite and austenite.

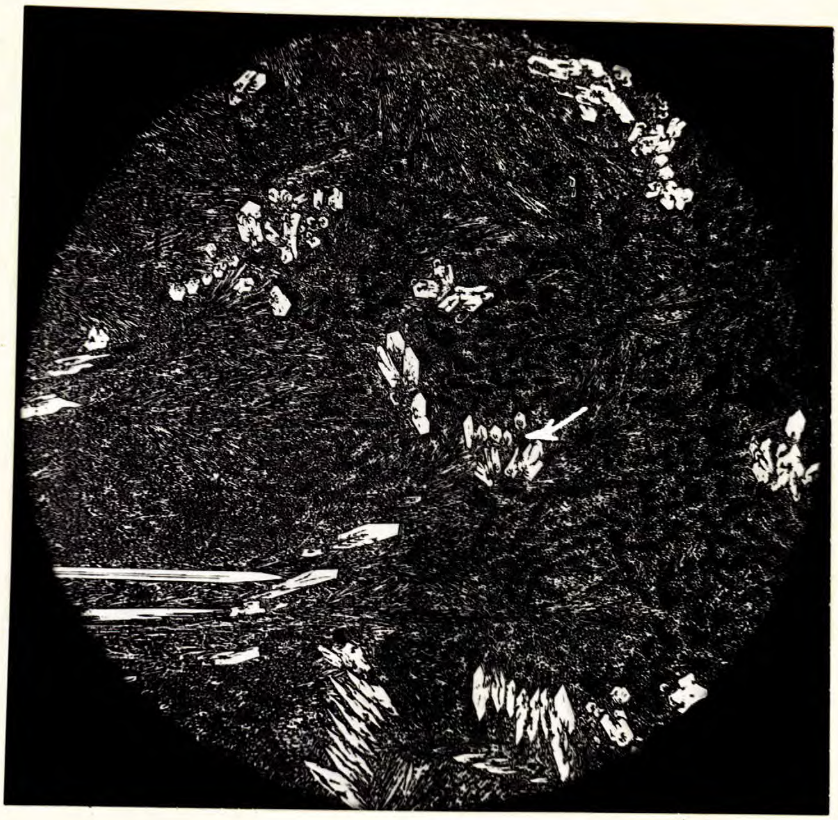
Figure 5.



X1000, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

SAME GENERAL AREA AS FIGURE 4.

Figure 6.



X100, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

STRUCTURE OF CAST BAR TOWARDS CENTRE.

Pro-eutectic cementite in a matrix of the eutectic of cementite and austenite. Arrow points to carbide shown in Figure 7.

Figure 7.

X1000, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

IRON-CHROMIUM CARBIDES.

Note tendency to regular geometrical shape.

HJN:GHB.