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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

CANADA

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Ottawa, January 4, 1947.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2163.

Metallurgical Examination of a Broken Vane Casting.

(Copy No. 6 .)

Bureau of Mines

Mineral Dressing and
Metallurgy Division

Physical Metallurgy
Research Laboratories

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Mines and Geology Branch

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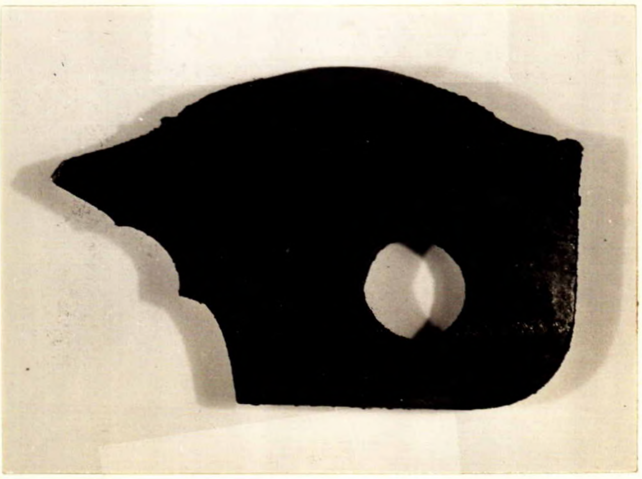
Origin of Material and Object of Investigation:

On December 16, 1946, Mr. W. K. MacLeod, President of Lynn MacLeod Metallurgy Limited, Thetford Mines, Quebec, submitted a broken vane casting to these Laboratories for investigation. It was stated that this casting was an experimental one cast out of an alloy steel in an endeavour to replace manganese steel which had been employed for this casting previously. The vane runs inside of a cylindrical-type machine and is bolted solidly to the frame. Three-quarter-inch rock falls through this machine and the vanes primarily break up this rock by means of pressing it against a liner. It was claimed that there was no shock encountered. Care must be taken, however, that the casting does not break. The casting which was submitted is reported to have broken in service. Figure 1 illustrates the piece of broken casting which was received by these Laboratories.

(Origin of Material and Object of Investigation, cont'd) -

Figure 1.



SAMPLE AS RECEIVED.

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Chemical Analysis:

Drillings were taken from the sample for chemical analysis. The analysis gave the following results:

		Per Cent	
Carbon	-	0.90	
Manganese	-	1.26	
Silicon	-	0.68	
Nickel	-	0.75	-.60 - .80
Chromium	-	2.10	
Molybdenum	-	0.36	.30 - .40
Vanadium	-	Nil.	

Hardness:

A Rockwell hardness test was made on the casting. The result was 45 Rockwell "C". (Brinell Hardness 422)

Microscopic Examination:

A sample was cut from the casting and examined under the microscope after polishing. In the unetched condition a random distribution of the inclusions was observed. No grain boundary eutectoid inclusions were evident. The specimen was etched in 2 per cent nital. Figure 2 (at X1000) illustrates the structure obtained. It consists of tempered martensite with a large number of free carbides in varying sizes dispersed throughout. In order to definitely

(Microscopic Examination, cont'd) -

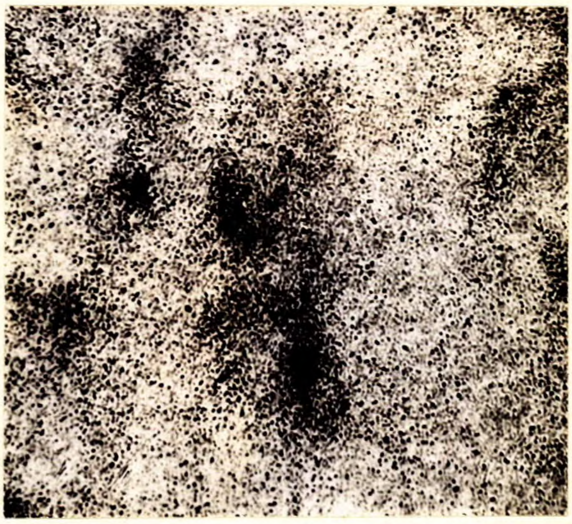
establish that these were carbides a selective etch was used. The specimen was repolished and etched in a hot solution of alkaline potassium ferricyanide. Figure 3 (at X300) shows the presence of carbides (black nodules).

Figure 2.

X1000.

Etched in 2 Per Cent Nital.

Figure 3.



X300.

Etched in Alkaline Potassium Ferricyanide.

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Discussion:

The analysis of the steel and the photomicrographs both indicate that a hypereutectoid air-hardening steel was used for this casting.

The hardness is somewhat low for this type of steel, since a higher hardness is readily obtainable. The draw temperature was probably too high. This analysis is used when high hardness (550 Brinell and over) is required for wear resistance.

It is, of course, well known that a high-carbon nickel-chrome-molybdenum steel heat-treated to a high hardness has very low impact properties. Consequently, this

(Discussion, cont'd) -

steel should never be used in this condition where any impact is likely to be encountered in service. In substituting for manganese steel it is advisable to proceed with caution. Manganese steel is 180-220 Brinell. If manganese steel is being employed where no impact is involved, it does not work-harden and consequently gives the same wear as any steel of similar hardness (180-220). It might be advisable to first try a low-carbon nickel-chrome-molybdenum steel for the vane, heat treated to 350-400 Brinell. This steel, having 0.30-0.40 per cent carbon and 0.90-1.30 per cent chromium (with the nickel and molybdenum remaining in the same quantities as for the high-carbon type), has intermediate impact properties and is a tougher steel than the high-carbon type. If satisfactory service is obtained with this steel and further increased wear is desired, then the high-carbon steel should be tried.

In producing either type, low carbon or high carbon, of nickel-chrome-molybdenum steels, a number of precautions must be taken in the foundry. Casting and cooling stresses are high in air hardening steels. Severe strain, or micro-cracks (not large enough to be easily observed), might readily exist in the casting. When placed in service these propagate and the casting fails.

After the castings have been poured, they should not be allowed to cool down to room temperature in the mould (especially if they are light castings). They should be shaken out while still hot, placed immediately in a furnace, and normalized. The air cool should be as slow as possible. If knock-off risers are used, the castings (after they have cooled to room temperature) can have the risers removed. The grinding should then be carefully carried out since grinding checks might occur. After grinding, the

(Discussion, cont'd) -

castings should be renormalized at the proper temperature (over 1600° F.) in order to dissolve the sluggish carbides. The final draw should be at 350°-400° F.

If knock-off risers are not used, care should be taken to flame-cut the risers while the casting is still hot. This can be done immediately after shaking the casting out of the mould. After flame cutting, the casting (while still hot) should be placed into the furnace for the normalizing treatment. This is then followed by grinding, renormalizing and drawing. For all nickel-chrome-molybdenum steels the practice should be to keep the casting hot throughout the foundry process (if knock-off risers are not used) until it has been completely heat treated.

Conclusions:

1. A high-carbon nickel-chrome-molybdenum steel has been used.

2. The casting was heat treated to 45 Rockwell 'C', which is too low a hardness for this type of steel.

3. The structure consists of tempered martensite and free carbides.

Recommendations:

Since manganese steel is wearing too quickly and the high-carbon nickel-chrome-molybdenum steel failed in service, it is recommended that a low-carbon nickel-chrome-molybdenum steel be used. This steel should have 0.30-0.40 per cent carbon and lower manganese and chromium (no change in the nickel and molybdenum contents) and should be heat treated to 350-400 Brinell. This Brinell will give

(Recommendations, cont'd) -

better wear than manganese steel (when not work hardened) which has a Brinell of 180-220.

If after using the low-carbon steel successfully, further increased wear is desired and experience definitely indicates no impact to be present in service, the high-carbon type may be installed after taking all the proper precautionary measures in production.

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