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OTTAWA June 22nd, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1668.

Examination of Self-Tapping Machine Screws.

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(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 22nd, 1944.

REPORT

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Origin of Request and Object of Investigation:

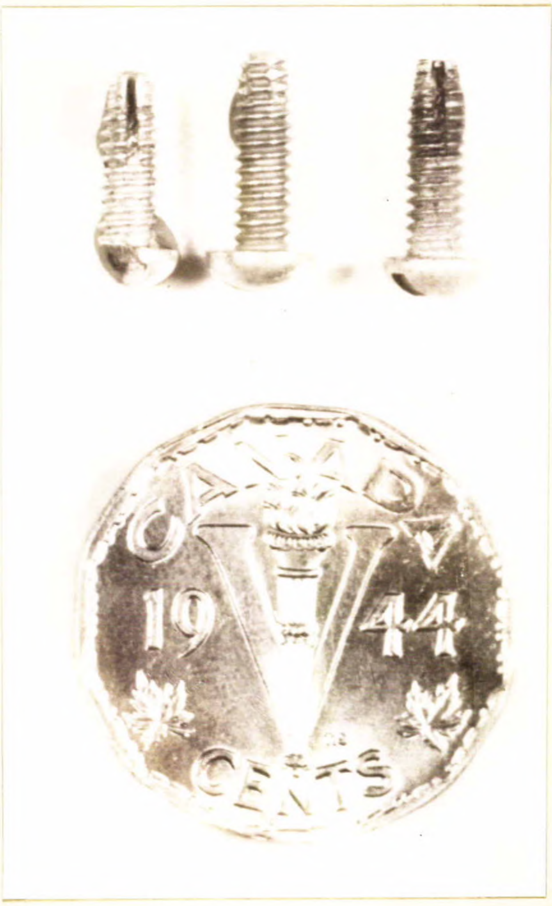
On May 31st, 1944, Major J. A. Loutit, Type Test Laboratory, D.E.C.D., Department of National Defence (Army), Ottawa, Ontario, submitted a request (File No. HQS. 9070-12-8) for an investigation into the cause of failure of some self-tapping machine screws. The request was accompanied by two sets of samples, one of satisfactory and the other of defective stock.

Macro-Examination:

The samples were given a careful visual examination. Some of the screws had failed by part of the head breaking away from the notch for the screw-driver, and others had broken part way down the shank. One of the screws had failed by stripping of the thread at the tip.

Two methods of notching the screws at the tip had been used. The defective screws had a single deep vertical cutting notch and the satisfactory screws had four shallow cutting notches. Figure 1 is an enlarged photograph showing two of the defective screws, with one of the satisfactory type in the middle. It can be seen that one of the defective screws has failed at the head and the other has failed by stripping of the thread at the tip. The five-cent piece is included for size comparison.

Figure 1.



Chemical Composition:

The amount of sample submitted was too small to permit a chemical analysis, but the carbon content, estimated from both the microstructure and the hardness obtainable, showed that at least two different types of steel had been used. The carbon content of the satisfactory screws and of the soft defective screw was found to be about 0.10 per cent. The carbon content of the hard defective screws was found to be 0.25 to 0.30 per cent.

Hardness Readings:

Vickers hardness readings were made on the core of the screws received. The material, with the exception of one of the defective screws, all had about the same hardness. Vickers hardness readings obtained were as follows:

		V.H.N.
Satisfactory screws	-	380
Defective screws, hard	-	392
Defective screw, soft	-	275

Microscopic Examination:

Microscopic examination disclosed that all the screws had been lightly case-hardened. The cores consisted of low-carbon martensite. Figure 2 is a photomicrograph of a typical core structure.

Figure 2.

X250, nital etch.

MICROSTRUCTURE OF CORE.

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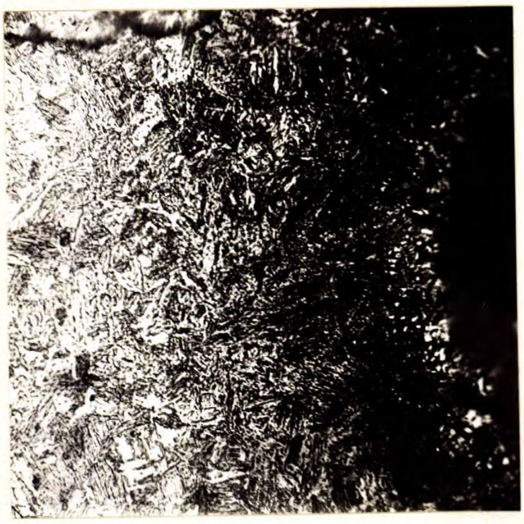
(Microscopic Examination, cont'd) -

The thickness of the cases varied considerably. The satisfactory screws had a case about 0.002 inch in thickness. The cases of the defective screws ranged in thickness from 0.002 to 0.0075 inch. Figures 3 and 4 are photomicrographs of two of the cases, taken at the base of the threads.

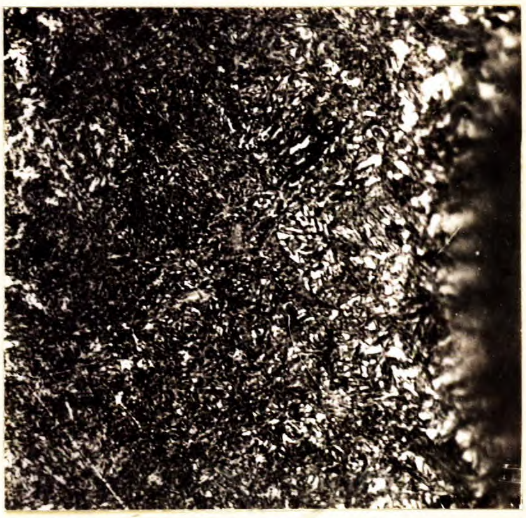
Figure 3.



X500, nital etch.

CASE OF SATISFACTORY SCREW.

Figure 4.



X500, nital etch.

CASE OF A DEFECTIVE SCREW.

Figure 5 shows a coarse martensitic structure observed in the thread of one of the defective screws.

Figure 5.

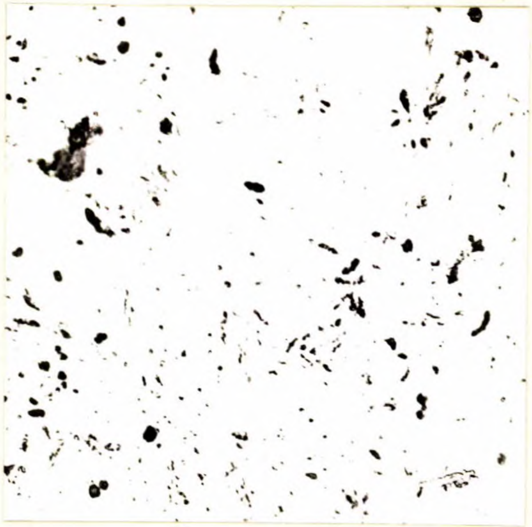
X500, nital etch.

COARSE MARTENSITIC STRUCTURE IN THREAD OF DEFECTIVE SCREW.

(Microscopic Examination, cont'd) -

The cases of the screws were examined for carbides. The good stock had no free carbides. Figure 6 shows the free carbides in the case of a defective screw.

Figure 6.



X500, basic ferricyanide etch.
FREE CARBIDES IN CASE OF DEFECTIVE SCREW.

-

Figure 7 shows the decarburized area below the case of a satisfactory screw. The hardness indentations of the Tukon tester show a hard case, a soft area of decarburization, and a hard core. Figure 8 shows how the hard case extends throughout the thread of one of the defective screws. It will be noted that the hardness indentations show a soft outer layer on the case in Figure 8.

Figure 7.

X100, nital etch.
DECARBURIZATION BELOW CASE OF SATISFACTORY SCREW.

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Figure 8.

X100, nital etch.
SOFT OUTER LAYER OF CASE ON DEFECTIVE SCREW.

-

(Microscopic Examination, cont'd) -

As an additional check on this decarburization, further hardness readings were made, using the Tukon machine. Knoop hardness readings, from the case inwards (right to left on photomicrographs), were as follows:

Satisfactory Screw (Figure 7)	Defective Screw (Figure 8)
741	329
494	610
208	421
235	427
353	318
438	329
	274
	281

Discussion:

Nature of Failure -

No definite information was given as to the nature of failure. However, the use of the word "crystallize" in the letter requesting the work indicates that failure may be in service, but certain samples submitted had fractures which seem to have occurred in installing the screws. In this report we will assume that both types of failure have been encountered.

Composition -

The fact that the screws which fractured on installation had a higher carbon content than those which proved satisfactory is very significant. The carbon content of this steel, 0.25 to 0.30 per cent, is higher than is recommended for case-hardening steels. The explanation for some of the failures may be in the use of this non-carburizing-grade steel in a carburizing operation, which would tend to produce a brittle article.

Method of Notching -

The difference in the method of notching the screws may well be the main cause of failures occurring on installation. Four notches, cut on a bias, as observed on the satisfactory

(Discussion, cont'd) -

screws, should distribute the tapping stresses more evenly throughout the revolution than would a single notch cut vertically. The shallower cut possible with the four notches would also contribute to better stress distribution.

Heat Treatment -

A thick case is not needed on the screw, as the case has performed its function after one tapping operation. A thick case, as observed on some of the defective screws, lowers the shock resistance of the part.

The coarse martensitic structure observed in some of the defective screws (see Figure 5) is caused by quenching from too high a temperature. This would definitely impair the toughness of the screw.

The decarburized area below the surface of the satisfactory screws (Figure 7) may act as a cushion for the case, and increase the toughness.

The soft surface of the case of one of the defective screws which failed by stripping of the thread is the result of either a partial decarburization or the presence of retained austenite. Both would be expected to lower the fatigue strength of the part. The case on this particular screw (Figure 8) is deeper and softer than that on the satisfactory article. Although thickening the case definitely leads to brittleness, it is thought that for this screw the effect would be cancelled out by the lower case hardness. Certainly, brittleness was not a factor in this thread stripping failure, which definitely occurred in installation. Low strength, probably brought about by decarburization, must have been responsible for this failure.

Free carbides in a case, such as those shown in the case of a defective screw (Figure 8), are very detrimental, as

(Discussion, cont'd) -

they lower both the impact and the fatigue strength of the part. Free carbides are caused by the rate of carburizing exceeding the rate of diffusion (from use of too active a carburizer, too high carburizing temperature, etc.).

CONCLUSIONS:

1. The cause of failure of the screws may lie in the use of an unsuitable grade of steel, in the design, in the heat treatment, or in a combination of these factors.

2. Some of the unsatisfactory screws were made from a non-carburizing grade of steel, which may account for their brittle behaviour.

3. The fact that a single tapping notch is used in the defective screws may be the chief cause of installation failure, as the screws with four tapping notches proved satisfactory.

4. The difference in the depth of case of some of the defective screws indicates that the heat treatment was not uniform.

5. The coarse structure observed on some of the defective screws indicates high quenching temperature, which would cause brittleness.

6. The presence of free carbides in the case of some of the defective screws is a serious defect, from both the impact and fatigue standpoints.

7. There is evidence of a partial decarburization of the surface of the case of some of the defective screws, which would be detrimental to fatigue strength and also might lead to thread stripping on installation.

8. Decarburization below the case of the satisfactory

(Conclusions, cont'd) -

screws may help them to better resist the tapping forces.

Recommendations:

1. Use a carburizing grade of steel.

2. Investigate the relative merits of single-notch and four-notch screws.

3. Keep the depth of case on screws uniform. A depth of 0.002 inch was observed on the satisfactory screws.

4. Adhere to carburizing practice recommended for the steel.

5. Adopt a practical test in determining whether the screws are satisfactory. Holes of appropriate size could be drilled in an iron block and the test made by driving screw samples into these holes.

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