OTTAWA November 28th, 1940.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 927.

An Examination of a Cracked Military Vehicle Universal Joint Part.

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BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Material and Object of Investigation:

On November 1st, 1940, the office of the D.C.I.A.(G), Department of National Defence, 479 Bank Street, Ottawa, Ontario, sent in a cracked universal joint part that had failed when in service in a military vehicle. It was stated that many other parts of this same design had been subject to exactly similar failures. An examination of the part was requested in order to determine, if possible, the reason for these failures.

Macro-Examination:

Photographs of the cracked part are shown at about four-tenths size in Figure 1 and to size in Figure 2. The crack may be seen at A. A small piece of the steel has also chipped off at this point. The pin shown at B holds a spacing ball in place. This ball serves to keep apart two larger balls which work against the shiny surfaces C and D. The pin is at the centre of a crater-like depression, the crack apparently starting at the edge of the "crater". With the exception of the surfaces C and D and the splined portion of the part, the surface is in the "as forged" condition. There are, however, no major surface imperfections at the point where failure occurred.

Chemical Analysis:

The part was found to have the following composition, the case being removed by grinding prior to sampling:

C, %	Mn, %	Si, %	P, %	S, %	Ni, %	Mo, %	Cr, %
0.21	0.57	0.20	0.014	0.014	1.81	0.27	0.04

Hardness Tests:

Hardness tests were made at various points on the surface shown in Figure 2. In addition, hardness tests were also made across the section of the part. The Rockwell method was used for the first test work and the Vickers method for the second. The part was found to have been case-hardened, with the case having an average Rockwell "C" hardness of 60 (627 Brinell) and the core a Vickers

(Hardness Tests, cont'd) -

hardness of 285 (285 Brinell).

Tensile Test:

A standard 0.564-in. diameter tensile test bar was machined from the core of the splined portion of the part and then broken in an Amsler Universal testing machine. The following results were obtained:

Tensile strength, p.s.i.	Yield point, p.s.i.	Elongation in 2 in., per cent	Reduction in area, per cent
102,400	81,200	16.0	67.4

Microscopic Examination:

A sample cut from the part so as to include the crack was polished on a section at right angles to the surface and examined under the microscope. The steel was found to be quite clean, only a very few inclusions being located. The sample was then etched in a 2 per cent solution of nitric acid in alcohol. The etch revealed clearly the core and case material. The case depth as measured under the microscope was found to be 0.063 inch. Figure 3, a photomicrograph at X1000 magnification, shows the structure of the greater part of the case. A crack may be seen running through the centre of the field. This crack parallels the main crack. It may be seen that the material surrounding this crack has the same structure as the remainder of the case. The same is true for the material around the main crack. Figure 4, a photomicrograph at X1000 magnification, shows the structure of the core. The dark

(Microscopic Examination, cont'd) -

etching material is a low-carbon pseudo-martensite; the white etching material is ferrite, the iron constituent. In order to check on the method of heat treatment a portion of the part was quenched in oil from 1500° F. This specimen was found to be identical in structure and hardness with the "as received" material. All of the case did not have the structure shown in Figure 3, as the extreme outer edges were higher in carbon. Figure 5 shows the structure of this outer zone at X1000 magnification, the print shown being over-developed in order to bring out more clearly the white carbide particles. It may be seen that these carbide stringers are practically continuous in places. The background area if developed less fully would show a structure similar but somewhat darker than that shown in Figure 3.

DISCUSSION:

Macro-Examination -

The material in which the crack started would undoubtedly be high in carbon, because its wedge shape allows for a carburizing from two sides. As a result of this, there would probably be little core material to support the case on the wedge. The crack appears to have been formed by the action of alternating stresses. It is not surprising that a fatigue failure would occur at such a place, for hardened high carbon material is liable to such failures in the absence of perfection in surface finish. Even if the surface were perfectly finished, the shape of the part

(Discussion, cont'd) -

would probably allow for sufficient stress concentration to cause failure.

Chemical Analysis -

The composition of the steel is within the limits specified for S. A. E. 4620 steel as listed in the following table:

C, %	Mn, %	Si, %	P, %	S, %	Ni, %	Mo, %
0.15 - 0.25	0.40 - 0.70	0.15 - 0.30	0.04 max.	0.04 max.	1.65 - 2.00	0.20 - 0.30

This is a first-class carburizing-grade steel. The low sulphur and phosphorus contents indicate that the steel was properly made.

Hardness Tests -

The case hardness is such that the part should have good wear-resisting properties. The core hardness is higher than would be expected in a conventionally double- or single-quenched steel of the analysis, as in ordinary practice the steel is usually finally quenched from around 1425° F. However, when additional strength of core is required to resist brinelling action, the part is usually finally quenched from 1500° F. It is evident that this part has been so treated.

Tensile Test -

The physical properties of the core are very satisfactory.

(Continued on next page)

(Discussion, cont'd) -

Microscopic Examination -

The low inclusion content of the metal shows that the steel making operations were carefully conducted. The case is quite thick, but no doubt the designers considered such thickness necessary for the service. The crack shown on Figure 3 is probably of the fatigue type. The similarity in the structures of the case material surrounding the crack and the remainder of the case indicates that the cracks were formed in service rather than in the manufacturing operation, although if heat treating operations were carried out under perfect atmosphere control a case cracked in manufacture would have a similar appearance. The amount of ferrite present in the core and the result of the heat treatment experiment definitely show that the final heat treatment given this steel was an oil quench from around 1500° F. This is a recommended heat treatment for this steel when high core strength is desired. Apart from the extreme outer edge the case structure is satisfactory. The material at the edge, however, is too high in carbon, as material which has carbide present in practically continuous envelopes is very liable to crack. The presence of such a large amount of free carbide indicates that too active a carburizing medium was used, although it is difficult to avoid the presence of some free carbide when such a thick case is applied.

Summary and Conclusions:

The crack, apparently of the fatigue type, started at the edge of the spacing ball cavity. The part was case-hardened so as to give good resistance to wear and good resistance to a brinelling action of the ball parts, the case being quite thick and hard and the core hardness relatively high. The core was found to have a satisfactory structure and good physical properties. The case structure, apart from the very high carbon outer edge in which free carbides were present in practically continuous envelopes, was satisfactory. It was pointed out that high carbon material, such as was present at the outer surfaces, cracks easily and that the condition probably could be remedied if a less active carburizing medium were employed or if the case thickness were reduced.

Apart, then, from the high carbon areas in the case, the part is in good condition. Even if the case were free from excess carbide, however, the part would be likely to fail as the case is supported by very little core material at the point where the crack occurred. The shape of the part would also allow for a certain stress concentration at this point. Under these conditions it would be much better if this portion of the part were not case-hardened, as the softer core material, being more subject to plastic flow and consequently less notch-sensitive, would be much less liable to crack. Certainly, if the shine on the part is any indication, only the areas marked C and D on Figures 1 and 2 need a wear-resistant case-hardened surface. It is thought, then, that if the part had been

(Summary and Conclusions, cont'd) -

selectively carburized by copper plating before carburizing all areas but those requiring wear resistance, it would probably have given satisfactory service.

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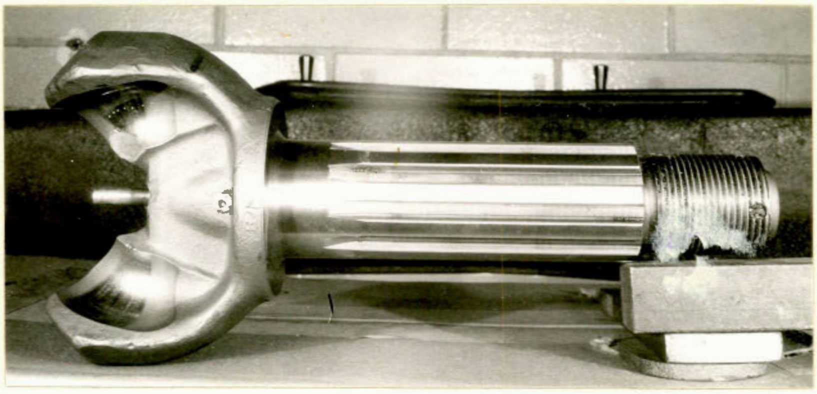
GSF:PES.

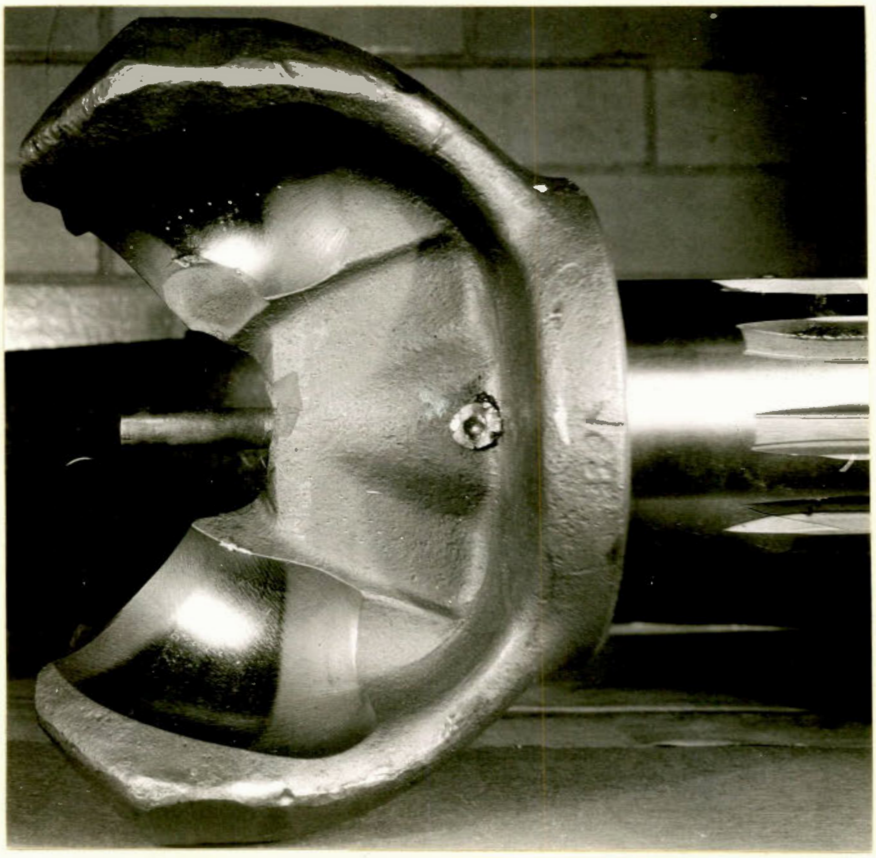
Figure 1.



Four-tenths size.

Cracked Part.

Figure 2.



Full size.

Cracked Part.

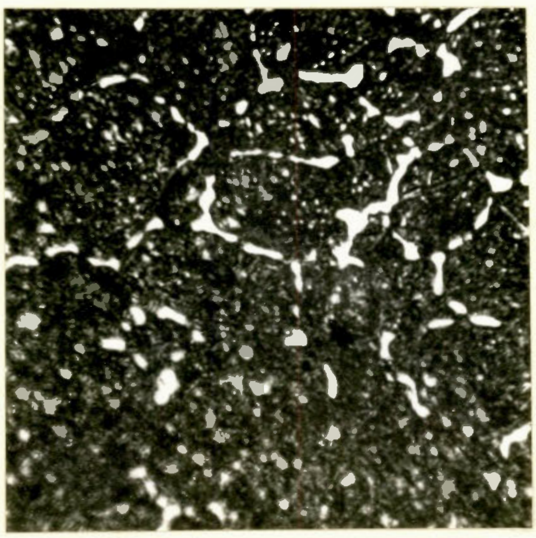
Figure 3.

X1000.
Case Structure, Showing Crack.

Figure 4.

X1000.
Core Structure.

Figure 5.



X1000.
High Carbon Area at Outer Edge of Case.

NOTE: All specimens etched in 2 per cent Nital.

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