FILE COPY

O T T A W A    September 7th, 1940.

# R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 890.

An Examination of a Broken Front Axle Housing.

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

O T T A W A September 7th, 1940.

# R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 890.

## An Examination of a Broken Front Axle Housing.

---

### Origin of Material and Object of Investigation:

On August 23rd, 1940, the office of the D.C.I.A.(G), Department of National Defence, Ottawa, Ontario, sent in a broken front axle housing which had failed when in service in a military vehicle. An examination of the housing was requested in order to determine, if possible, the reason for the failure.

Macro-Examination:

The housing failed just before it expanded into the ball joint portion through which the king-pin runs. Figure 1 shows the fracture on the ball joint section, while Figure 2 shows the fracture as viewed along the housing in the direction of the differential. Both photographs are approximately to size. It may be seen that the fracture is of the duplex type, all but a small smooth area being coarse-grained. The location of the greasing connection in the ball joint and the position of the king-pin bearings indicate that the centre of the smooth area was at the top of the housing.

The inner surface of the casting showed a sand or slag hole at the flange end of the casting. There appeared to be a very heavy tool mark at the outer surface of the housing adjacent to the smooth portion of the fracture.

Chemical Analysis:

The steel in the housing was found to be of the following composition:

| Carbon, per cent | Manganese, per cent | Silicon, per cent | Sulphur, per cent | Phosphorus, per cent |
|---|---|---|---|---|
| 0.49 | 1.95 | 0.41 | 0.030 | 0.031 |

Hardness Tests:

Hardness tests were made (using the Vickers method and a 30-kilogram load) on the housing steel and on housing steel that had been given a variety of heat treatments. The following table shows the nature of

(Hardness Tests, cont'd) -

these treatments and the results obtained:

| Sample. | | Vickers Hardness |
|---|---|---|
| As received | - | 274 |
| Furnace cooled from 1550° F. | - | 260 |
| Normalized from 1550° F. | - | 602 |
| Normalized from 1400° F., drawn at 1200° F. | - | 210 |
| Normalized from 1650° F., drawn at 1100° F. | - | 274 |

Tensile and Impact Tests:

Impact tests were made on standard Izod test specimens cut from the housing steel and from housing steel that had been normalized at 1400° F., drawn at 1200° F., and quickly cooled after the draw. A tensile test specimen was also machined from the broken housing and tested in an Amsler Universal testing machine. This specimen broke in the head; consequently values obtained from it may not be correct. The following table gives the results obtained:

| Specimen | Ultimate strength, p.s.i. | Impact, foot pounds. |
|---|---|---|
| As received | 80,700 | 2.5 |
| Heat treated | -- | 5.0 ⊗ |

---

⊗ Value may be low, as steel showed flaw at point of fracture.

No elongation or reduction of area values were obtained in the tensile test as the specimen broke outside

(Tensile and Impact Tests, cont'd) -

the gauge length. However, the test specimen broke with no perceptible elongation, so these figures would have been very small.

Both impact specimens broke with coarse-grained fractures. Samples which had been normalized but not drawn broke with fine-grained fractures.

Microscopic Examination:

Samples of the steel, both in the "as received" and heat treated conditions, were polished and examined under the microscope. The steel was found to contain a fair number of inclusions, which appeared to be manganese silicate. A wavy crack was also found near the smooth portion of the fracture. This crack and a few of the inclusions are shown in Figure 3 (X200 magnification). A fairly large number of internal shrinkage cavities were also noted. An area close to the fracture, containing a number of these cavities, is shown in Figure 4 (X100 magnification).

The samples were then etched in a 2 per cent solution of nitric acid in alcohol and re-examined. Figure 5 (X200) and Figure 6 (X1000) show the structure of the steel in the broken housing. The structure shown in Figure 6 is finely spheroidized, the small particles being iron carbides and the background being ferrite, the iron constituent. The vague dark lines shown in Figure 5 have the same structure as the lighter portions of the

(Microscopic Examination, cont'd) -

sample. It is thought that they indicate the location of former austenite grain boundaries. The sample that had been furnace-cooled was made up of free ferrite and lamellar pearlite, while the air-cooled sample had a troosto-martensitic structure. The structure of the "as received" sample was duplicated in the specimen that had been normalized and then drawn at 1100° F.

## Discussion of Results:

### Macro-Examination -

The duplex type of fracture exhibited by the broken casting is the type usually associated with failures produced by the action of changing bending stresses, the smooth surface showing where the gradual failure occurred, as the two faces in this zone had a chance to wear smooth on each other. The coarse-grained portion of the fracture reveals the portion of the housing that failed at the time of accident. Fatigue cracks usually start at points that are locally more highly stressed as a result of changes in section or because of the presence of surface imperfections. It is significant that there appears to be a heavy tool mark on the outer surface of the housing at the point where the fine-grained portion of the casting starts.

The sand or slag hole on the inside of the casting is enough to condemn it, as it indicates faulty foundry practice.

(Discussion of Results, cont'd) -

Chemical Analysis -

The following table gives the composition of S. A. E. steel T 1350:

| Carbon, per cent | Manganese, per cent | Phosphorus, per cent | Sulphur, per cent |
|---|---|---|---|
| 0.45-0.55 | 1.60-1.90 | 0.040 max. | 0.050 max. |

With the exception of its slightly higher manganese content the composition of the housing steel is within the above limits. Such a steel is often used in place of medium alloy steels because of its cheapness and fairly good physical properties. The steel, however, has a tendency to temper brittleness on slow cooling from the draw, is liable to have a low grain coarsening temperature, and may be quite brittle when high in carbon and manganese.

Hardness Tests -

The hardness tests show that the steel is air hardening and indicated that the housing was normalized and then drawn at around 1100° F.

Tensile and Impact Tests -

As the housing broke with a coarse-grained type of fracture, it was thought that it might have been made brittle by cooling from too high a temperature. The impact tests showed, however, that the steel was quite brittle but that its impact properties could not be much improved even when the steel was given a low-temperature normalizing followed by a high-temperature

(Discussion of Results, cont'd) -

(Tensile and Impact Tests, cont'd) -

draw. The tensile tests showed that the steel had poor properties, as it possessed only medium strength and practically no ductility. Inasmuch as the normalized samples all broke with fine-grained fractures and the normalized and drawn samples all exhibited apparent coarse-grained breaks, it would appear that the type of fracture in the housing is not due to actual coarseness of grain but is rather caused by some effect the drawing had on the structure.

Microscopic Examination -

The dirtiness of the steel and the number of shrinkage cracks present indicate poor foundry practice. The jagged crack shown in Figure 3 is the type usually produced by the action of changing stresses and indicates that the housing fatigued at this point. The major fracture also was undoubtedly produced by a similar mechanism.

The absence of free ferrite from the housing steel shows that it was cooled fairly rapidly, as the furnace-cooled specimen contained this constituent. The steel may have been quenched in oil but as it is air-hardening it was more likely normalized. The finely spheroidized structure of the steel indicates that it was drawn at around 1100° F. after this normalizing treatment. The microscopic examination, then, confirms the findings of the hardness tests.

Conclusions:

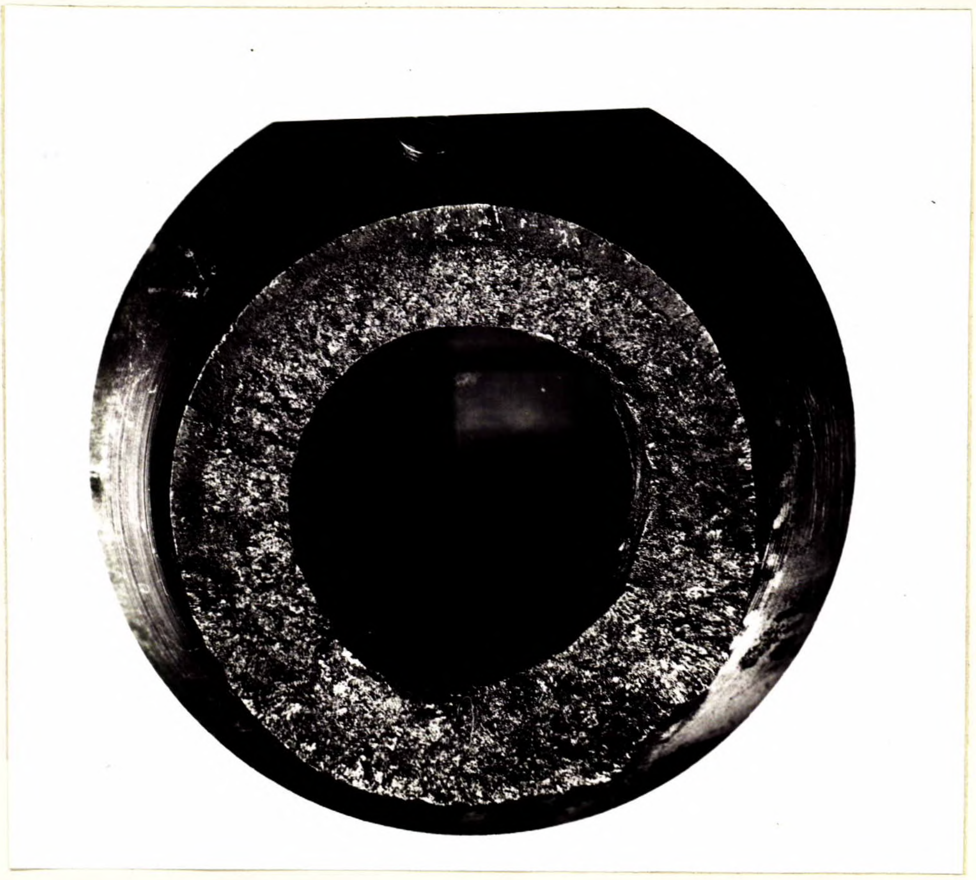
The presence of dirt and shrinkage cavities in the steel, and the sand or slag hole on the inner surface of the casting, all definitely indicate poor foundry practice. The natures of the fracture and of the crack near the fracture indicate that failure occurred as the result of the acting of changing bending stresses. These stresses are naturally concentrated at the top of the housing where failure started. The heavy tool mark at the point of failure, however, would serve to increase this stress concentration and must be regarded as a defect.

The physical properties of the steel were quite poor, as the material lacked ductility and was quite brittle. Heat treatment improved the impact properties to some extent but it is thought that in view of the heavy service likely to be encountered a front axle housing of a military vehicle should be made from a medium alloy steel rather than from high carbon - medium manganese steel, as the former material for the same strength is considerably tougher, more ductile, and more reliable.

OOOOOOOOOOOOOO
OOOOOOOO
OO

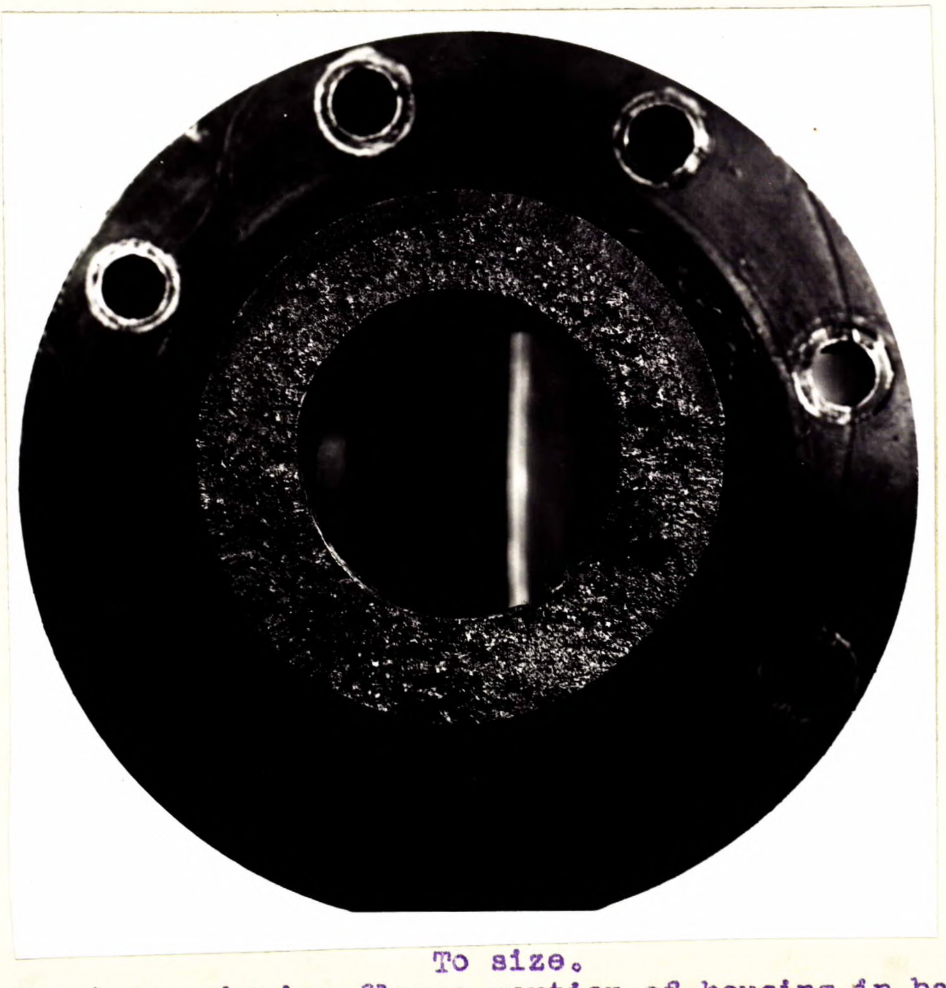
GSF:FES.

Figure 1.



To size.
Fracture, showing ball joint portion of housing in background.

Figure 2.



To size.
Fracture, showing flange portion of housing in background.

Figure 3.

X200.

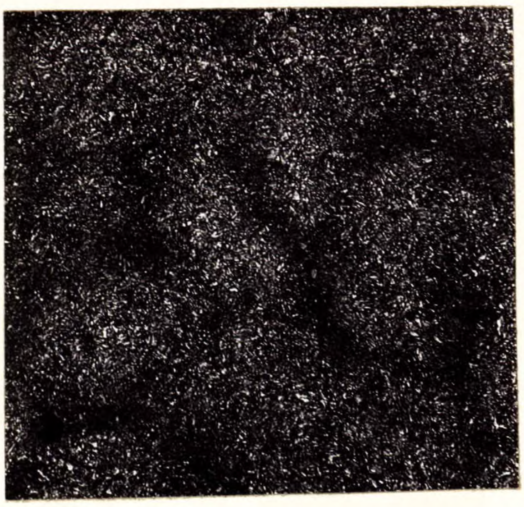
Showing inclusions and fatigue crack. Unetched.

Figure 4.

X100.

Showing internal shrinkage cavities. Unetched.

Figure 5.

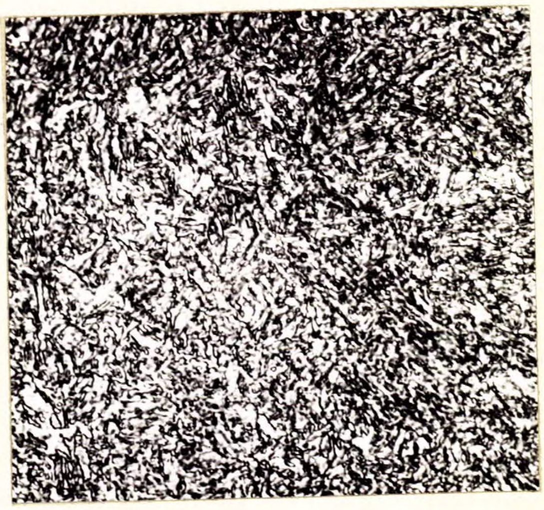


X200.

Structure of housing steel near point of failure.

Etched in 2 per cent Nital.

Figure 6.



X1000.

Structure of housing steel near point of failure.

Etched in 2 per cent Nital.

GSF:PES.