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FAILURE OF ROAD GRADER CHANNEL MEMBER

by

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ABSTRACT

The samples forwarded were inadequate for a complete appraisal of the reason for failure. The fracture samples were too small for the preparation of mechanical test specimens, and were heat affected by the flame cutting procedure. Microscopic examination was of little use, but visual examination of the specimens revealed a typically brittle fracture.

Sections taken from another channel conformed chemically to the ASTM A 7 specification, although the mechanical requirements of the specification were not quite met. The material of the broken member was of a similar classification, but analysis of the samples showed a higher carbon content than for the channel sections.

Impact tests on samples prepared from the channel section material showed a transition temperature of 70°F and a Charpy V-notch impact strength of 3 ft/lb at the service-failure temperature. The higher carbon content of the broken channel would accentuate the tendency to low temperature brittleness. The chemical and mechanical characteristics would combine to make this steel prone to brittle failure under the loading and temperature conditions which occurred.

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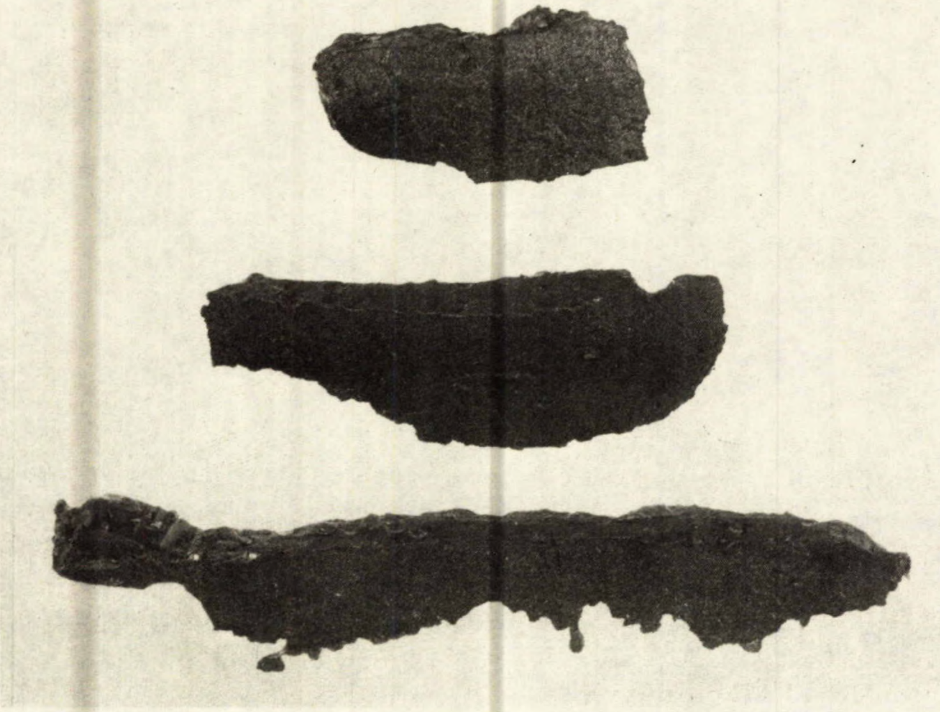
(2 tables, 3 illus.)

INTRODUCTION

A sample of a weld, two channel sections, and three samples taken from the fracture were submitted, following an enquiry dated January 12, 1959 from Mr. H. Bosnell, Director of Purchasing, The Dominion Road Machinery Company Limited, Goderich, Ontario, concerning the failure of a channel member of a Road Grader. The samples of the fracture were flame-cut from the broken frame prior to repair. The channel sections were from another channel, the material of which was presumed to be similar to that of the broken frame. The weld sample was intended only as an illustration of weld quality, as it was not from the broken member.

A photograph of the samples of the fracture is shown in Figure 1.



(Approx.X1)

Figure 1. - Samples of the fracture

Careful visual examination of the middle sample shown above revealed traces of a chevron pattern typical of brittle fracture. A faint indication of this pattern is seen at the right of the picture.

DESCRIPTION OF MANUFACTURE AND FAILURE

The Road Grader frames are made by welding two channels to form a box section. Prior to welding, the toes of the flanges are chamfered so that when matched together they form a 90° "V" approximately 1/4 in. deep (i.e. about 1/2 of the flange thickness). A longitudinal, manual arc weld is then deposited in a single pass using 7/32 in. diameter E6024 welding rod. The scarifier mounting is welded to this frame. (Figure 2).

At the time of the failure, the Grader was being used to scarify ice and frozen snow at a temperature of about -5 °F. It was reported that the scarifier teeth hit some solid object, causing the Grader, which weighs about 14 tons, to come to a dead stop.

The fracture occurred at right angles to the longitudinal weld and close to the scarifier-mounting welds. It was 3 in. from, and parallel to, the scarifier mounting plate weld on the top flange, and approached to within 2-1/2 in. of the side welds (along the webs) (see Figure 2). The bottom flange (loaded in compression) did not break, but bent so as to leave a displacement of about 3/4 in. at the top flange. When the frame was bent back into shape no deformation was apparent at the crack. Three fracture samples (Figure 1) were cut, the frame was repaired, and the grader was put back into service.

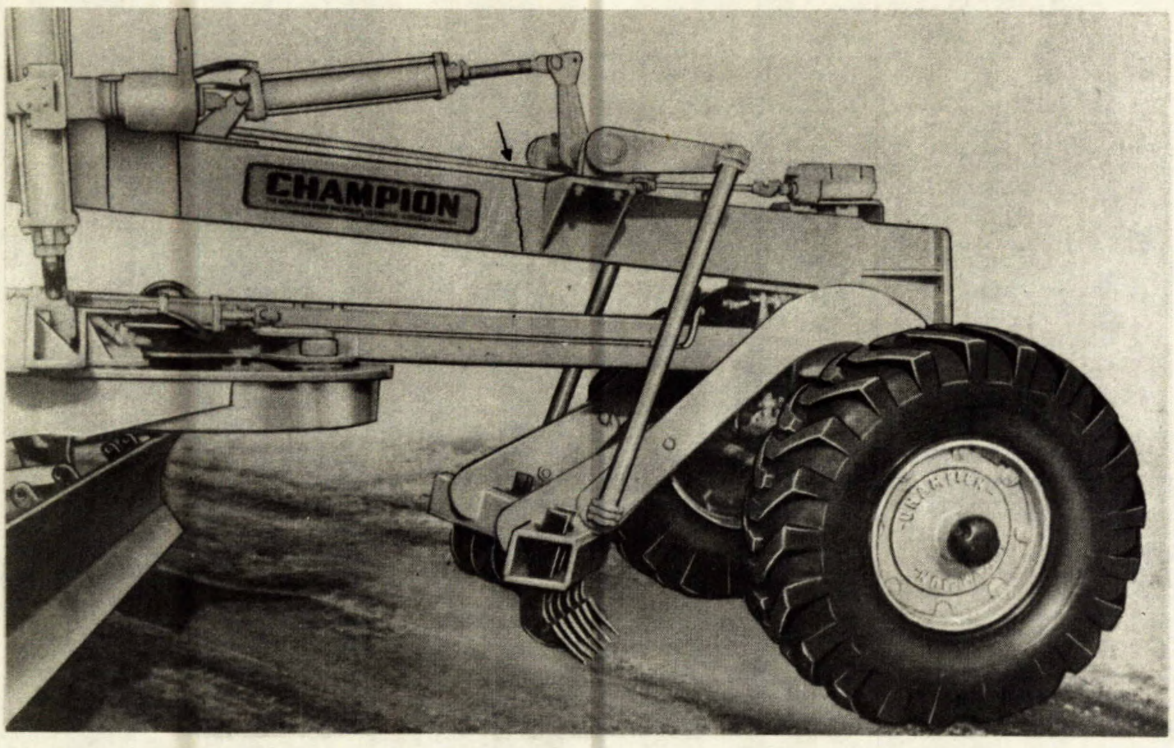


Figure 2. - The position of the crack along one web was as indicated above (at arrow). The crack on the other web was parallel to this, and the crack in the top flange was parallel to, and 3 in. away from, the scarifier mounting plate.

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VISUAL AND MICROSCOPIC EXAMINATION

Visual observation of the fracture surfaces revealed the chevron pattern and apparent lack of deformation typical of a brittle fracture. The weld sample appeared to be of good quality, but no sample of welding from the failed frame was available. Microscopic examination of the fracture samples revealed little, since the structure had been affected by the flame cutting. The microstructure of one of the channel sections is shown in Figure 3.

(X100 - Etched in 2% nital)

Figure 3. - Microstructure of channel material

This figure shows the fine pearlite-ferrite structure normal for material of this type.

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To investigate the possibility of decarburization or carburization during the flame-cutting, a sample was vacuum-sealed in a quartz tube and annealed. Microscopic examination of this specimen revealed the carbon content to be uniform out to the flame cut. Thus the higher carbon content reported for the fracture samples is probably a true value for the sample.

CHEMICAL ANALYSIS

Drillings for chemical analysis were taken from the two channel sections and from the fracture samples. The fracture samples were not of sufficient size for a full analysis. The results obtained are shown in Table 1.

TABLE 1

Chemical Composition of Channel Samples (Percentage of Elements)

Sample	C	Mn	Si	S	P
Channel Section #1	0.20	0.61	0.04	0.033	0.014
Channel Section #2	0.22	0.61	0.05	0.032	0.011
Fracture Sample	0.28*	0.58	0.05	-	-

*Higher carbon content referred to later.

MECHANICAL TESTING

Tensile bars and Charpy V-notch impact bars were machined from the channel samples. The results of the mechanical tests are given in Table 2.

TABLE 2

Mechanical Properties

Sample	Tensile Tests				Impact Results		
					Energy absorbed (ft/lb)		
	Ultimate Strength kpsi	Yield Strength kpsi	Elongation in 2 in. %	Reduction in Area %	+72°F	+32°F	-5°F
1	58.0*	27.8	35.0	56.7	14	5	3
2	58.2	26.7	33.0	56.7	18	6	3

*ASTM A7 specification calls for a minimum of 60 kpsi ultimate strength and 33 kpsi yield strength (minimum).

DISCUSSION

The investigation showed that the channel sections conformed chemically to the ASTM A 7 specification, but did not quite meet the strength requirements. The particular samples tested were transverse samples, and another test result from the same heat of steel indicated a strength sufficient to meet the specification. The broken member was a similar material, but had a carbon content higher than the channel sections. No details of the material specifications were forwarded. Impact tests showed that the channel material had a high ductile-brittle transition temperature (about 70 °F for the 15 ft/lb level appropriate for this material), and a very low impact strength at a testing temperature equivalent to that at which the failure occurred. The higher carbon content reported for the broken frame indicates that it probably had a higher transition temperature and lower impact strength at the temperature of failure.

Under the load and temperature conditions applied to the grader, once the fracture began, little energy would be required for the complete failure, and the fracture of such material would be of the brittle type. The failure of the channel member was probably related to the presence of a notch, either metallurgical (relating to the steel quality), or mechanical, such as would be caused by the accidental striking of an arc on the frame during welding. On the basis of the samples supplied there is no way of determining at what type of notch the crack initiated. It is possible that even in the absence of a notch, such extreme low-temperature impact loading would result in failure due to the very low impact resistance.

In general, killed steels (fine-grained) have better mechanical properties at low temperatures than the semi-killed steels presently used, but the former are considerably more expensive. If such failures are frequent, it would be desirable to incorporate into the design a less critical and easily changed component which will fail due to such accidental overload in preference to the main frame member.

SUMMARY

1. Chemical analyses showed the channel materials to be semi-killed stock. The channel sections supplied conformed chemically to the ASTM A 7 specification, but the tensile results showed slightly lower strength values than are specified. The fracture samples were similar material, but had a higher carbon content.
2. Such steels in the presence of a notch are very susceptible to low temperature brittle failure.
3. Examination of the fracture surfaces revealed a typical brittle failure.
4. The notched impact strength of the channel section was only 3 ft/lb at a temperature equivalent to the temperature

of failure.

5. It is very likely that some metallurgical or mechanical notch contributed to the failure.

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