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EXAMINATION OF BROKEN ELEVATOR PART

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

An investigation was carried out on a broken elevator part in an attempt to determine the cause of the failure. The examination indicated that a combination of poor design and improper heat treatment was responsible.

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(12 pages, 1 table, 8 illus.)

INTRODUCTION

A broken assembly from a construction elevator was submitted for examination by Mr. J. R. Waterman of Sarnia Scaffolds, Limited, P. O. Box 67, St. Catharines, Ontario. A sketch of one-half the assembly is given in Figure 1, showing how it was held rigid by means of plates fitted into notches in the pins. The ends of the pins, which in normal service would carry very little load, broke at the notches.

It was requested that an investigation be carried out to disclose any metallurgical evidence of the reason for failure.

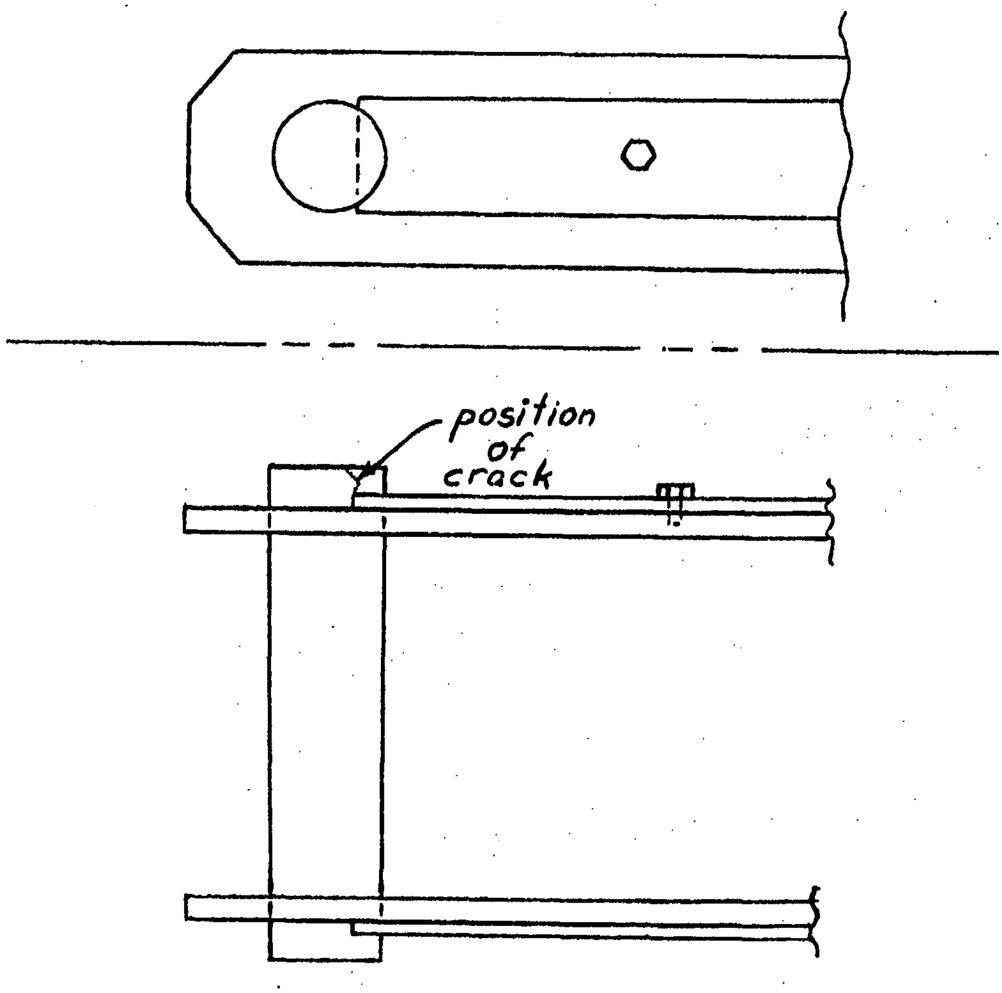

Figure 1. - Sketch of one-half the elevator assembly. The path of the fracture is indicated.

VISUAL EXAMINATION

Inspection of the fractured surface of one of the broken pins showed a brownish-red oxide discolouration on a portion of the fracture (at the end of the arrow in Figure 2).

It is suspected that the darkened portion of the fracture is part of a quench-crack, but this could not be definitely proved since no unused samples were available. A part of the fracture on the other pin had a similar appearance, but little or no oxide discolouration could be seen on it. The presence of oxide indicates that a crack was present for some period of time prior to the final complete failure of the section. While it could not be definitely established that the initial areas of the fracture surfaces were due to quench-cracking on the basis of the samples supplied, it should be noted that the design used, featuring a sharp notch, would be very susceptible to quench-cracking.

(X2.5 magnification)

Figure 2. - Shows view of fractured end of pins. Arrow indicates pre-existing crack darkened by oxide. A similar crack can be seen on the other pin, but little or no oxide is evident.

CHEMICAL ANALYSIS

Chemical analyses were carried out on drillings taken from the core material of the pins. These are reported in Table I. A qualitative spectroscopic check showed no alloying elements in amounts greater than residual quantities.

TABLE I

Percent Chemical Composition

	C	Mn	Si	S	P
Sample	0.10	0.57	0.31	.009	.014
SAE 1010	.08 - .13	.30 - .60	-	.050 max.	.040 max

HARDNESS TESTS

The surface hardness of the two broken pins was taken using the Rockwell Superficial Hardness Tester (30N scale). The pin which had little or no oxide discolouration on the fracture surface is referred to as Sample 1; the sample with oxide on the fracture is named Sample 2. The hardnesses of the samples were:

	30N	Rc (converted)
Sample 1	81	64
Sample 2	79	62

Pieces were cut from the pins, mounted in bakelite and polished. Hardness surveys were carried out on these samples from the surface inwards using the Tukon Hardness Tester with a 1000 gm load. The results of these surveys are indicated in Figure 3.

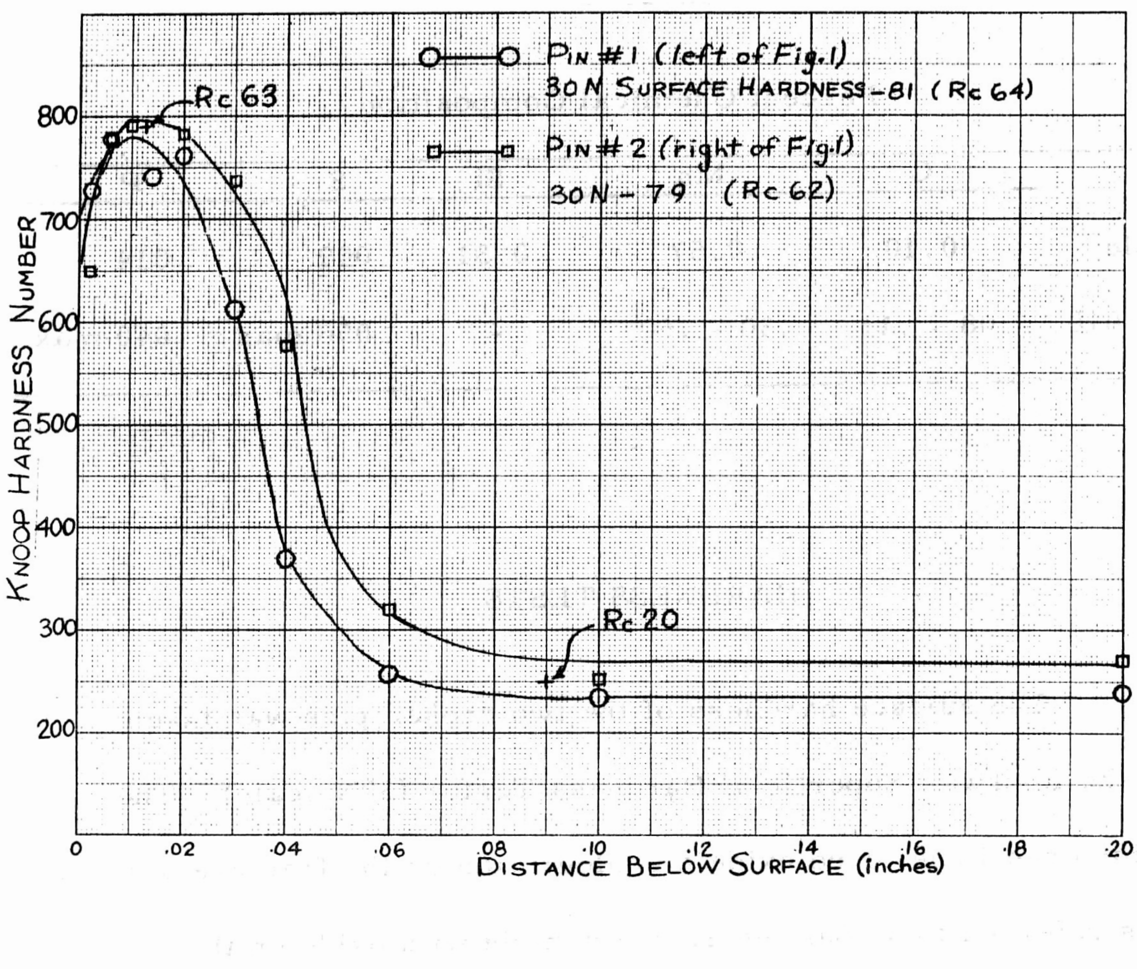

Figure 3. - Results of Tukon Hardness Surveys.

MICROSCOPIC EXAMINATION

Microspecimens were cut at the fractured and unfractured ends of the pins, and these were examined microscopically. An open crack could be seen with the unaided eye at the unfractured end of Sample 1 (the pin having no oxide on the fracture surface). No crack could be seen macroscopically on the unfractured end of Sample 2, but microscopic examination did reveal a fine crack. Views of these cracks are shown and explained in Figures 4, 5, 6 and 7.

(X75 - As polished)

Figure 4. - Shows open crack at the unfractured end of Sample 1 and also a fine, parallel crack which was not visible to the naked eye.

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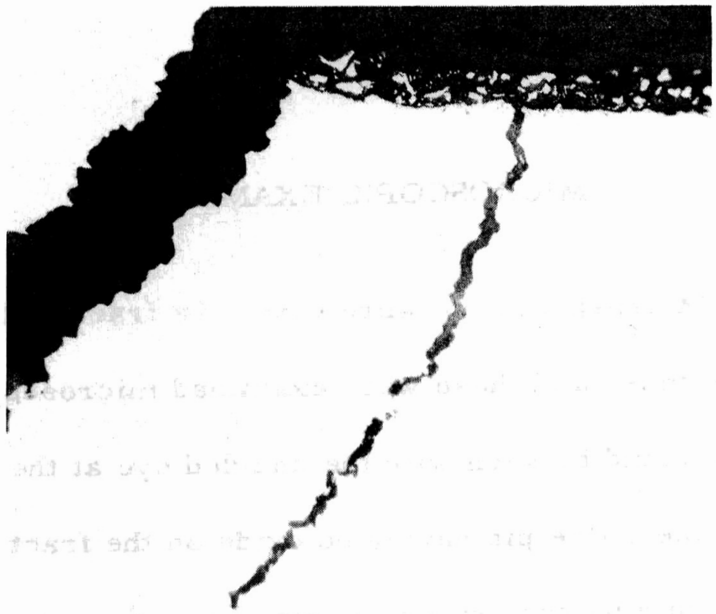

(X250 - As polished)

Figure 5. - Shows same field as in Figure 3 at a higher magnification. The oxide seen in the fine crack is indicative that the crack had been present for some time, and it is suspected that it was a quench-crack.

(X500 - As polished)

Figure 6. - Shows fine crack (not visible to the naked eye) which was present at the unfractured end of Sample 2. Note the presence of a thin layer of grain boundary non-metallics, presumably oxides, at the surface. Such inclusions are occasionally found at the surface of carburized parts, and their presence at the grain boundaries might have aided the crack formation.

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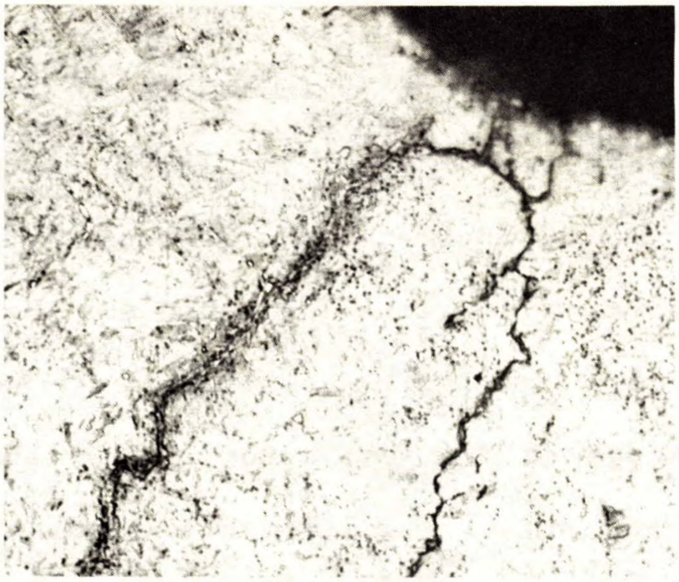
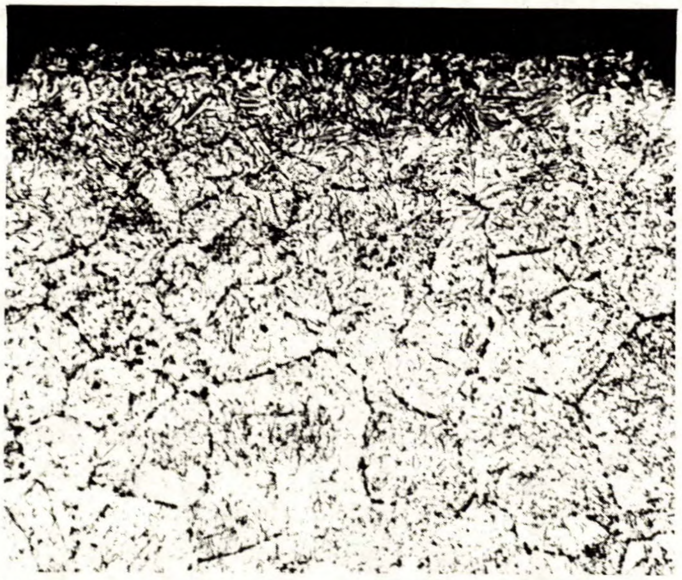


(X1000 - Etched in 2% Nital)

Figure 7. - Same field as in Figure 5, but etched, and at double the magnification. Matrix is very hard, brittle martensite.



(X500 - Etched in Alkaline Sodium Picrate for 5 min to darken carbides, followed by a 20 sec etch in 2% Nital)

Figure 8. - Photograph taken at the surface of Sample 2. Shows the surface carbide network that could be seen at most of the surfaces of the samples. Note that such carbides were not found at the points of origin of the cracks, since these points were internal angles which had been carburized to a lesser degree than the more accessible surfaces.

Figures 4, 5, 6 and 7 show cracks which appear to have been present for a considerable period of time before the failure occurred. The presence of oxide in the cracks supports this supposition. It is possible that these are quench-cracks, but no unused samples of similar parts were available for inspection to confirm this opinion. A thin layer of grain boundary non-metallics, presumably oxides, could be seen at most of the carburized surfaces, and their presence might have aided in the formation of cracks in the hard, martensitic case.

The microstructure of the case of the pins is shown in Figures 7 and 8. The matrix is a high-carbon martensite. The high hardness (around Rc 63) is indicative that no tempering operation had been carried out. (While untempered martensite should not etch, it should be noted that the samples shown were mounted in bakelite, which in effect gave them a short temper at about 300 °F). In most areas, a large number of grain boundary carbides were present. None was seen in the areas of crack initiation because the degree of carburization at these areas was less than average (since cracking started at internal angles).

The microstructure of the core was carbide in a ferritic matrix. It was the type of microstructure that would be expected in the core of low-carbon steel following quenching.

DISCUSSION OF RESULTS

Chemical analyses and microscopic examination revealed that the pins had been made of SAE 1010 steel and had been case hardened by carburizing and rapid cooling. The very high surface hardness (around Rc 63) indicated that no tempering had been carried out after the parts had been hardened. The presence of undesirable grain boundary carbides showed that either the quenching temperature had not been high enough to allow solution of all the carbides, or that the diffusion time was too short to allow proper dispersion of the carbon. The combination of high surface carbon content and the presence of a notch gave ideal conditions for the development of a quench-crack at the point of initiation of the fractures. Oxide-filled cracks, which are suspected of being quench-cracks, were found at the notches at the unbroken ends of the pins. A quench-crack, which would constitute a very sharp notch, combined with the very high hardness over most of the fracture path in the case, would allow the pins to hold only a very small load relative to their normal capacity without breaking.

CONCLUSIONS

The failure was due to the presence of a notch in hard, untempered martensite. An even more efficient stress-raiser than the notch present in the design was the pre-existing crack which had formed at the notch, probably when the part was quenched or shortly after.

RECOMMENDATIONS

1. Any similar parts should be checked for quench-cracks by means of magnetic particle inspection, or some other suitable means.

2. If possible, the design should be altered to eliminate the notch.

3. Quenched pins should be given a stress-relieving tempering treatment, at not lower than 400°F.

4. It is believed that the end of the pins which broke had no bearing contact in this application which implies that wear resistance is not important. If this is the case, these ends could be masked before carburization to prevent the formation of the brittle high-carbon martensite in these areas on quenching.

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