AFTER THE CHAIN BREAKS

Ray Hensley, Renold Jeffrey, discusses causes and remedies for premature chain failure.

Introduction

Renold Jeffrey is often called to survey chains and analyse the chain components to better understand the reason(s) that a chain has failed. One of the more common factors that contributes to premature chain failure is excessive service loads. Renold Jeffrey presents two case studies that its in-house quality laboratory conducted, determining excessive loads to be the primary cause for chain failure.

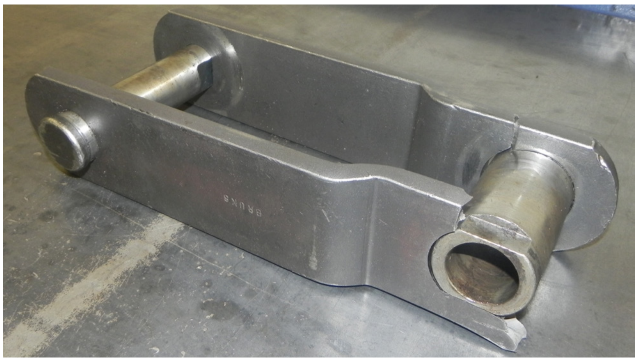

Figure 1. Sample as received.

Figure 2. Fractured area on the head end offset bar (left); fractured area on the cotter end offset bar (right).

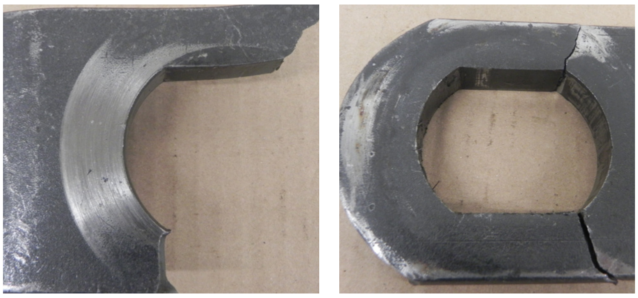

Figure 3. Rubbing wear from the roller on the inner surface of the head end sidebar (left); rubbing wear from contact with the adjacent sidebar on the outer surface of the cotter end sidebar (right).

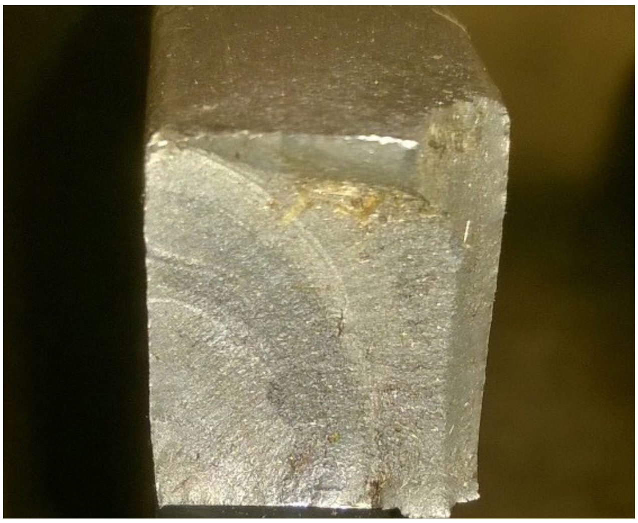

Figure 4. Evidence of long cycle fatigue followed by a fast fracture observed on the fracture surface of the head end sidebar.

Case study 1

Sample received

One link of 5202-PB chain was received for analysis (Figure 1).

Inspection

The returned link was visually inspected for any unusual wear conditions and points of failure. Both of the sidebars had cross sectional failures occurring in the area of the bushing (Figure 2). The inner surface of both sidebars had rubbing wear marks from the roller, but heavier wear was observed on the head end offset sidebar (Figure 3: left). The outer surface of the cotter end offset sidebar had some rubbing wear observed from the adjacent link (Figure 3: right).

The fracture surfaces of both sidebars were cleaned and examined. There was evidence of long cycle fatigue observed on the fracture surface of the head end sidebar at the pitch hole, beginning on the outer surface of the pitch hole and progressing inward through the cross section (Figure 4).

Wear measurements

Measurements were taken across the bearing surfaces of the pin and bushing received. Minimal wear was present on the pins and bushings with areas of localised galling on the bearing surfaces (Figures 7 and 8). Table 1 summarises the results from this evalutation.

Metallurgical analysis

Surface and core hardness readings were taken from each of the broken sidebars. Hardness readings were consistent where tested and were found to be within the specified tolerances.

The bars were scanned by means of XRF analysis and were confirmed to be carbon steel as specified.

Summary

1. The plate failures appear to have originated on the head end offset bar at the pitch hole. There was evidence of long cycle fatigue beginning at the edge of the pitch hole on the outer surface of the bar and progressing inward through the cross section, followed by a rapid fracture.
2. The fractured cotter end offset bar appears to be a secondary failure condition.
3. The inner surface of the head end sidebar had rubbing wear present from the roller. In addition, rubbing wear from the adjacent sidebar was present on the outer surface of the cotter end sidebar. These conditions would suggest that the link was being forced to one side, which may have caused unusual stresses, resulting in failure of the sidebar through fatigue.

Figure 7. Localised galling on the head side of the pin was present on the bearing surface.

Figure 8. Localised galling on the ID of the chain bushing on the head side of the chain.

Table 1. Wear measurement.

Component	Average wear measurement	Nominal measurement	Total wear
Pin	1.617 in.	1.624 in.	0.007 in.
Bushing OD	2.366 in.	2.375 in.	0.009 in.
Bushing ID	1.649 in.	1.641 in.	0.008 in.

Figure 9. Sample as received.

4. The bearing surfaces of the pin and bushing had localised galling present on the head end side of the link. This condition may indicate uneven load on the chain, which could have caused unusual stresses to one side of the link and, over time, contributed to the sidebar fatigue failure.

The cross section of the initial failure progressed through a fatigued mechanism until approximately half of the section remained. While not 100% accurate, this provides an estimation of the load at time of failure, indicating that the sidebar was seeing loads equivalent to a tensile force in the magnitude of half of the breaking load of the sidebar. This would put the equivalent tensile load on the chain in excess of 100 000 lb, while this chain has an expected 29 000 lb working load based on bearing area. It should be noted that the equivalent load might not be delivered directly through a pure tensile load on the chain. For example, if side loads are applied to the chain in the reclaimer, then the chain length between top and point of contact is effectively a giant lever arm, meaning high loads can generate stresses on the chain.

The bearings did not indicate continuous overloading in tensile conditions, so a sensible conclusion would be that the load was highly impulsive in nature, or the stress was applied through some mechanism that generated an equivalent tensile load of this magnitude in the sidebar. Based on the small sampling, it is possible the fatigue initiation was the result of temporary overload due to misalignment and/or repeating unnatural loading.

Case study 2

Samples received

SJ102 chain sections (Figure 9).

Evaluation

Two small sections of SJ102 chain with broken pins were received for failure analysis. Some stiff joints were observed in the returned samples and both sections were heavily covered in application material.

Each of the sections received had one cross sectional pin failure in the shear zone area, with failures occurring on both ends of the pins (Figure 10). The fracture surfaces on one pin were in an angular direction, while the other pin fractures were even with the outer sidebars. Each of the fracture surfaces were covered in rust and application material (Figure 11).

The area of the chain sections where the pin failures occurred was disassembled for inspection. The internal joint areas of the sections were heavily packed with material from the application, which caused the stiff joints observed in Figure 12.

Figure 10. Pin broken even with the sidebars in the shear zone area.

Figure 11. Material from the application covering the outer surfaces of the chain.

Figure 12. Heavy build-up of application material within the internal joint areas.

Figure 13. Corrosion pitting on the surface of the sidebar and evidence of torsional fatigue observed on the pin fracture surface on the head side.

Figure 14. Typical condition of the pins tested showing sufficient ductility.

***Table 2.* Pin hardness.**

<table>
<tr><th>Pin</th><th>Specified hardness</th><th>Average surface hardness</th><th>Average core hardness</th></tr>
<tr><td>Broken pin</td><td rowspan="4">37 – 47 Rc</td><td>45 Rc</td><td>45 Rc</td></tr>
<tr><td>Unbroken pin no. 1</td><td>39 Rc</td><td>38 Rc</td></tr>
<tr><td>Unbroken pin no. 2</td><td>41 Rc</td><td>40 Rc</td></tr>
<tr><td>Unbroken pin no. 3</td><td>45 Rc</td><td>45 Rc</td></tr>
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***Table 3.* Pin bend test.**

Broken pin	Average load applied to pin	Bend angle
Unbroken pin no. 1	13 069 lb	11°
Unbroken pin no. 2	15 582 lb	17°
Unbroken pin no. 3	15 079 lb	14°

Each of the components removed from the chain were cleaned for inspection. The sidebars were pitted from corrosion and some localised areas of pitting were observed on the pins. There was evidence of fatigue present on the fracture surfaces (Figure 13).

Pin analysis

Samples of the pins were removed to confirm hardness levels and material grade. Each pin was also bend tested to confirm ductility. None of the broken pins were long enough to perform bend testing. However, one of the broken pins had sufficient length for surface and core hardness measurements.

Surface and core hardness readings were within the specified hardness ranges (Table 2). Each of the pins that were bend tested had good ductility (Figure 14; Table 3).

Summary

The broken pins that could be tested were found to be within the specified surface and core hardness ranges. A bend test of the broken pins could not be conducted due to the short length of the pins. Bend test results on the unbroken pins showed sufficient ductility.

The pin fractures occurred on both ends of the pins at or near the shear zone area. The outer surface of the sidebars had heavy corrosion pitting present. One of the broken pins had some very light pitting observed near the fracture area surface. This could have introduced some stress cracks in the surface of the pin in this high stress location.

Stress corrosion cracking is the growth of crack formation in a corrosive environment. It can lead to unexpected failures of normally ductile metals when subjected to tensile stresses.

The fracture surfaces had evidence of fatigue present. Pin fatigue failures result from service loads that exceed the rated working load of the chain, or due to incorrect sprocket and chain interaction such as the chain climbing or clinging to the sprockets, which can result in high abnormal load conditions. In addition, the internal joint areas of both samples were packed with material leading to the tight joints observed. This condition could have caused unusual stresses to the pins which ultimately lead to failure.

As both case studies illustrate, excessive loads and other factors greatly impact the chain service life. Corrosive environment and incorrect alignment can place abnormal service loads on your chain and cause it to fail prematurely. Fatigue is a mode of mechanical failure that can be avoided with proper maintenance.

About the author

Ray Hensley is the Director of Engineering Sales for Renold Jeffrey.