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INVESTIGATION OF A FAILED CHAIN LINK FROM AN AUTOMOTIVE ASSEMBLY PLANT

EXAMPLE REPORT

Modified from Original Report

OVERVIEW & OUTCOME

The analysis found that the conveyor chain link failure was due to abnormally high loading. Failure was not the result of an abnormal quality issue. Other links within the chain likely also comprised of cracks.

To prevent continuous failure, two steps must be performed:

1) Replace the chain because other links are already likely cracked.
2) Reduce the loading on the chain to within design levels.

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INVESTIGATION OF A FAILED CHAIN LINK FROM AN AUTOMOTIVE ASSEMBLY PLANT

SUMMARY

The chain link failed due to abnormally high cyclic loading during operation. It was recommended that the chain operator further investigate the origins of the elevated loading, beginning with (a) evaluating the line tension and/or (b) looking for conditions applying elevated, repetitive loading.

It was probable that other links on the chain have already initiated cracks and unless replaced, the chain will continue to experience link failures even if the service loading is reduced.

1.0 INTRODUCTION

Two chain links, including a fractured link, from a paint conveyor line at an OEM Automotive Assembly Plant. The second link was a new link to be used as a benchmark for a metallurgical comparison. Steel Image was requested to determine the nature of failure and assess if the material had degraded during service.

The failed link was from a chain which had been in service for several years. During that speriod, fifteen link failures had occurred, the first link having failed after two years of service. Link failures were reported to consistently occur on the inside of the turn in the ovens. A portion of the paint line goes through an oven operating at a temperature of 400ºF (204ºC).

In addition to this line, there are eight other conveyor chains. Of these eight, Lines D and C have experienced one link failure each, both failures having occurred recently. The colour booth ovens can go up to 440ºF (227ºC) in temperature.

2.0 EXAMINATION

2.1 Visual and Macroscopic Examination

Figure 1 displays the two links in the as-received condition. The failed link was covered with baked grease and some portions of the link exhibited white paint. The fractured ligament displayed moderate yet superficial wear along its centerline. The link was ultra-sonically cleaned using various solvents. **Figure 2** displays the link before and after cleaning.

The fracture of one ligament had occurred at mid-length. Except for the formation of fine shear lips on the outer diameter surface, no deformation had occurred within the vicinity of fracture. The crack had opened up slightly due to deformation of the remaining ligament. **Figure 3** displays the fractured ligament.

The link was cut in order to open up the fracture surfaces. One fracture surface exhibited a significant amount of white paint. The second surface comprised of less paint as illustrated in **Figure 4a**. This half of the fracture was ultra-sonically cleaned for fractography. **Figure 4b** displays the cleaned fracture surface.

The fracture features were consistent with fatigue fracture. Fatigue crack initiation had occurred at a single location along the inner diameter surface. **Figures 4b and 5a,b** indicate the location where the crack had begun from. The crack had initiated at a forging flaw. The forging flaw was measured to extend 0.10 inches (2.6mm) into the fracture. Further examination would find that only the initial 0.016 inches (0.4mm) portion of the flaw had contributed for crack initiation.

The first third of the fracture surface exhibited a flat morphology with crack arrest marks typical of high-cycle fatigue (ie. repetitive low-to-moderate stresses). At this point, the fracture gradually transitioned and the remaining two-thirds of the fracture exhibited bands from low-cycle fatigue low crack growth. Low cycle fatigue indicated the loading experienced by the fractured ligament had been relatively high compared to the material strength. The outer perimeter of the fracture exhibited shear lips from final failure.

2.2 SEM Fractography

The cleaned fracture surface was examined at high magnification using a scanning electron microscope (SEM). Examination of the initiation region confirmed that the fatigue fracture had begun at the forging flaw. Crack initiation had occurred at the 0.016 inches (0.4mm) deep mouth of the flaw (**Figure 6b,c**). Note that such a small flaw would not have provided a significant stress concentration effect.

Crack initiation and initial propagation had occurred by high-cycle fatigue cracking as indicated by the fatigue striations (**Figure 6d**).

Note that after initiation at the forging flaw tip, the remainder of the forging flaw had not influenced crack growth. **Figure 6e,f** shows the flaw having had no effect upon the behaviour of crack propagation. This was due to the orientation of the flaw being longitudinal to the ligament whereas the crack had propagated in the transverse orientation.

2.3 Optical Microscopy

The new and failed links were transversely cross-sectioned through the ligaments and prepared for metallographic evaluation in accordance with ASTM E3. The cross-section on the failed link was taken ~6mm (~0.25 inches) from the fracture. Optical examination found both links to comprise of a tempered martensitic structure typical of a hardened alloy steel. The failed link appeared slightly more tempered than the new link however, it was still within the typical condition expected for such an application. **Figure 7** displays the core structure of the two links.

As observed on the fracture surface, the cross-section of the failed link consisted of a large forging flaw. **Figure 8** displays the forging flaw and **Figure 8b** displays the location corresponding to crack initiation.

2.4 Chemical Analysis

The composition of the failed link was determined in accordance with ASTM E1479 and E1019. **Table 1** lists the obtained results. The composition conformed to an SAE 8640 and 8642 steel alloys.

Table 1: Chemical Analysis Results

Composition (wt%)							
C	**Mn**	**Si**	**S**	**P**	**Ni**	**Cr**	**Mo**
0.407	0.83	0.27	0.010	0.013	0.58	0.46	0.18

2.5 Mechanical Testing

Tensile testing of both the new and the failed links was conducted in accordance with ASTM E8. **Table 2** displays the obtained results.

Table 2: Tensile Test Results

Sample	Yield Strength (ksi)	Tensile Strength (ksi)	Elongation (%)	Reduction in Area (%)
New Link	222.5	246.5	8.0	31
Failed Link	195.1	206.9	8.5	33

2.6 Hardness Testing

Rockwell hardness testing was performed on material from both links in accordance with ASTM E18. **Table 3** lists the obtained hardness results.

Table 3: Hardness Test Results

Sample	Hardness Measurements (HRC)	Avg. Hardness (HRC)
New Link	49.0, 49.0, 49.0	49
Failed Link	43.0, 43.5, 43.5	43

3.0 CONCLUSIONS

The chain link fatigue failure had been due to abnormally high cyclic loading during service. The applied loading was well above what the chain link could have been expected to withstand. Although a minor forging flaw had been present, the chain link was deemed of reasonable quality and, had it not been overloaded, would not likely have failed.

The fracture features indicated that the total stresses on the failed ligament had been quite high. This was further supported by the remaining ligament having been slightly deformed, indicating the remaining ligament had been loaded above its yield strength (>195ksi). This would imply that the service stresses were in the order of 100ksi or greater which, considering geometrical factors, would be well above the fatigue limit of the part. As the material was deemed typical for this application, it was conceived that the loading was above the design limit of the link. Therefore, the chain had been subjected to abnormally high loading.

The loading experienced by the link would have been a summation of the (a) line tension and (b) additional, repetitive loading applied onto the link. It is recommended that the chain operator further investigate (a) whether the line tension was higher than required and/or (b) whether there is an issue along the line causing repetitive loading. The investigator should initially consider the size of the bend radii, potential issues with the chain drive, any repetitive noises, knocking, jolts or sudden link movements. Note that a high line tension alone could potentially cause repetitive link failures. It is recommended that the line tension be reduced if possible.

Note that since the entire chain had likely been overloaded, it was probable that other links had also initiated cracks. Therefore, even if the source of the elevated loading were eliminated or reduced, already cracked links may continue to fail. To reliably ensure repeat failure does not occur again, the source of the elevated loading would have to be reduced/eliminated and the chain would require replacement.

The presence of a small forging flaw was not considered a significant contributor to failure. Only the mouth of the forging flaw, measuring 0.016 inches (0.4mm) in depth, had provided a stress concentrator. Flaws of this size are common for forged links and the design safety margin would readily account for such small features. Therefore, this flaw was deemed as a convenient site for fatigue initiation to occur under elevated loading rather than the cause of failure.

The composition of the link conformed to an SAE 8640 and 8642 alloy steel. Tensile and hardness testing found the failed and reference links to have comparable properties. Although the failed link had a small, as discussed before, this was not deemed a significant contributor to failure. Overall, the failed link was of reasonable quality.

Figure 1: Photograph displaying the two links submitted for the investigation.

Figure 2: Photographs displaying the fractured link in the (a) as-received condition and (b) after cleaning.

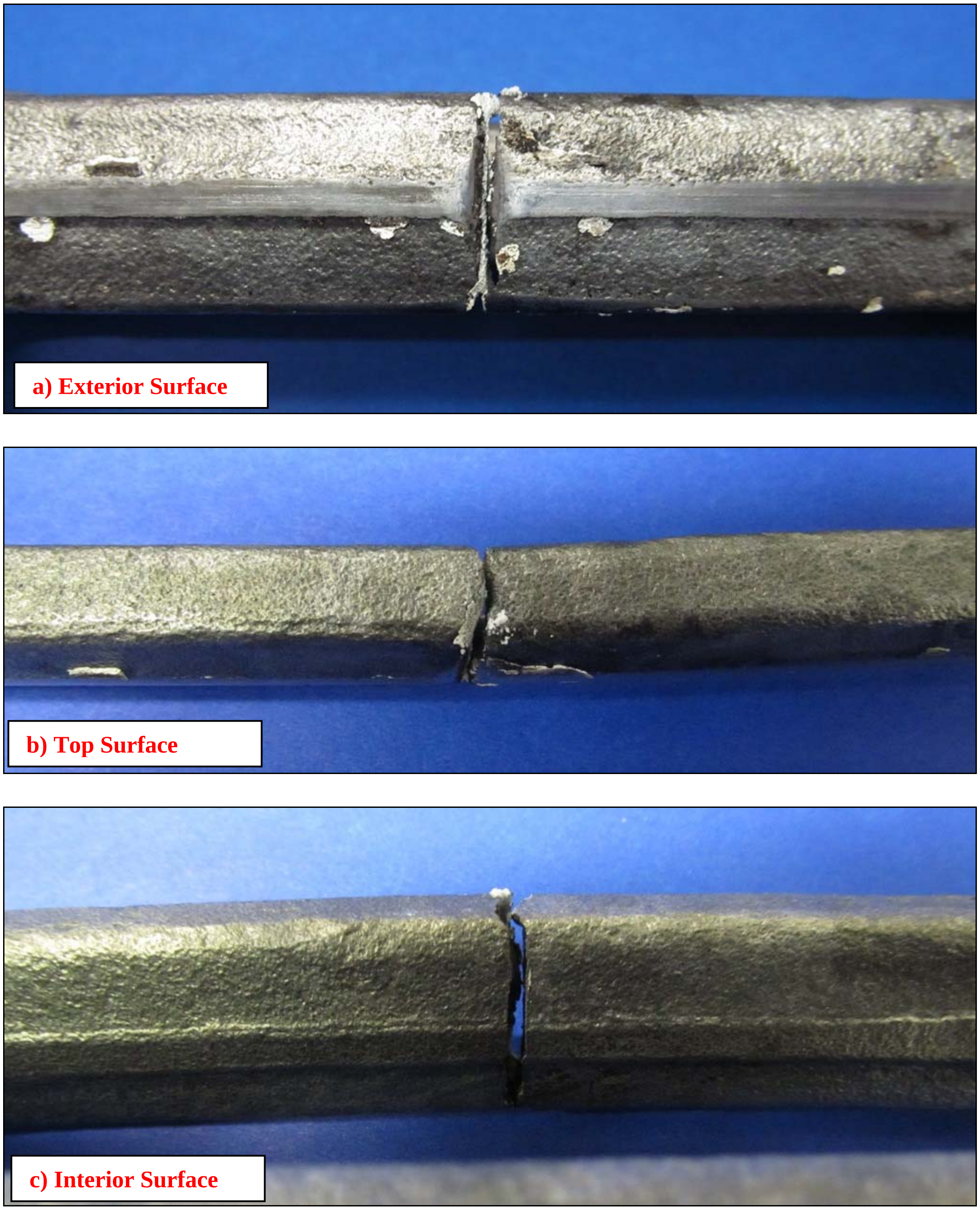
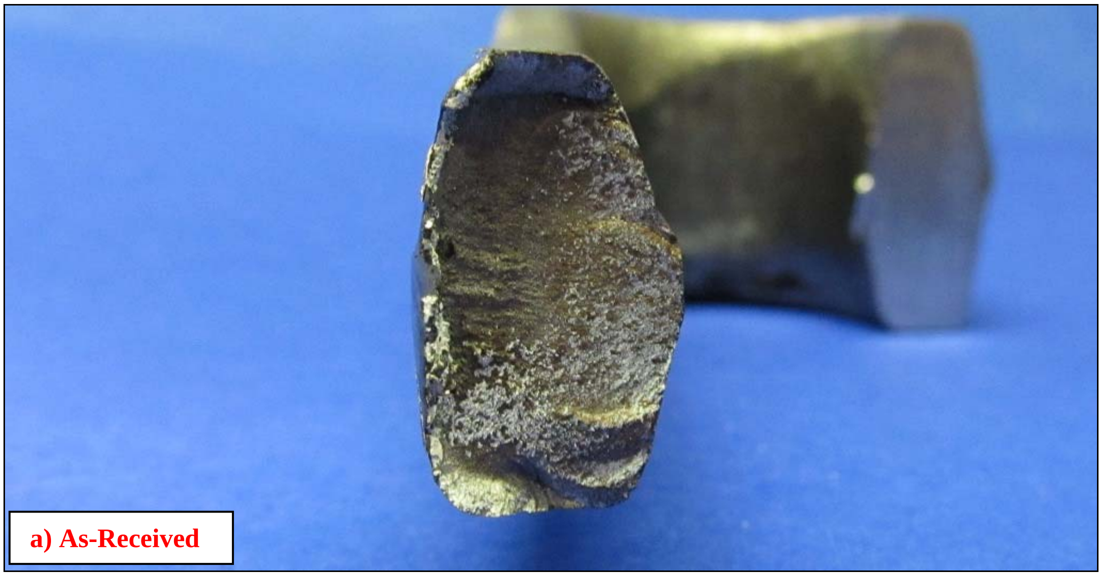


Figure 3: Photographs displaying the fractured ligament.



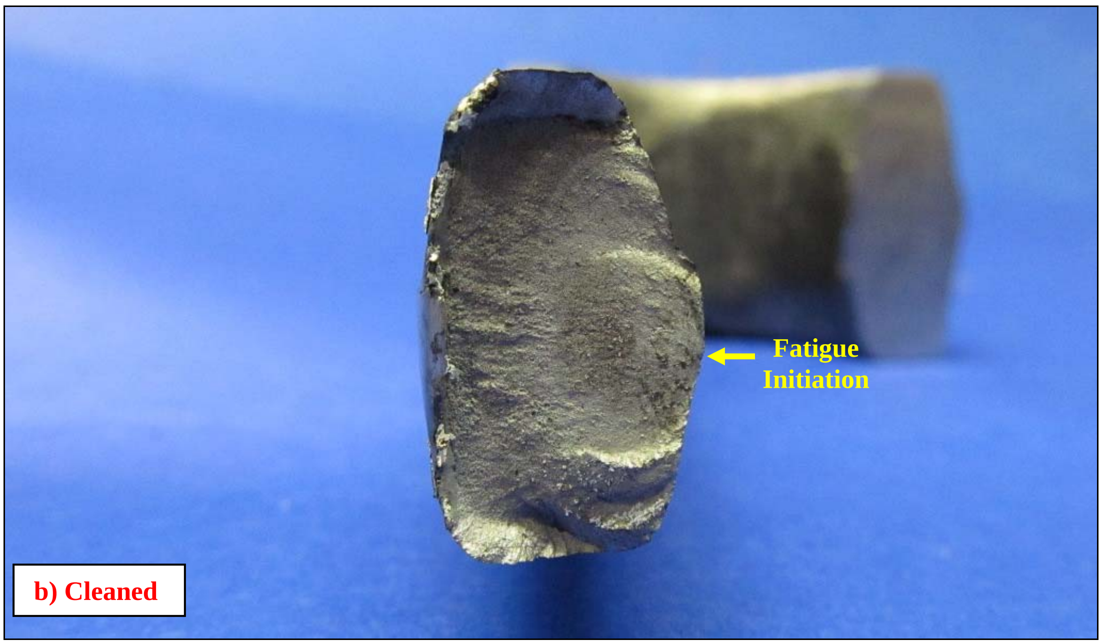


Figure 4: Photographs of the fracture surface in the (a) as-received and (b) cleaned conditions. The fracture exhibited fatigue features radiating from a single point.

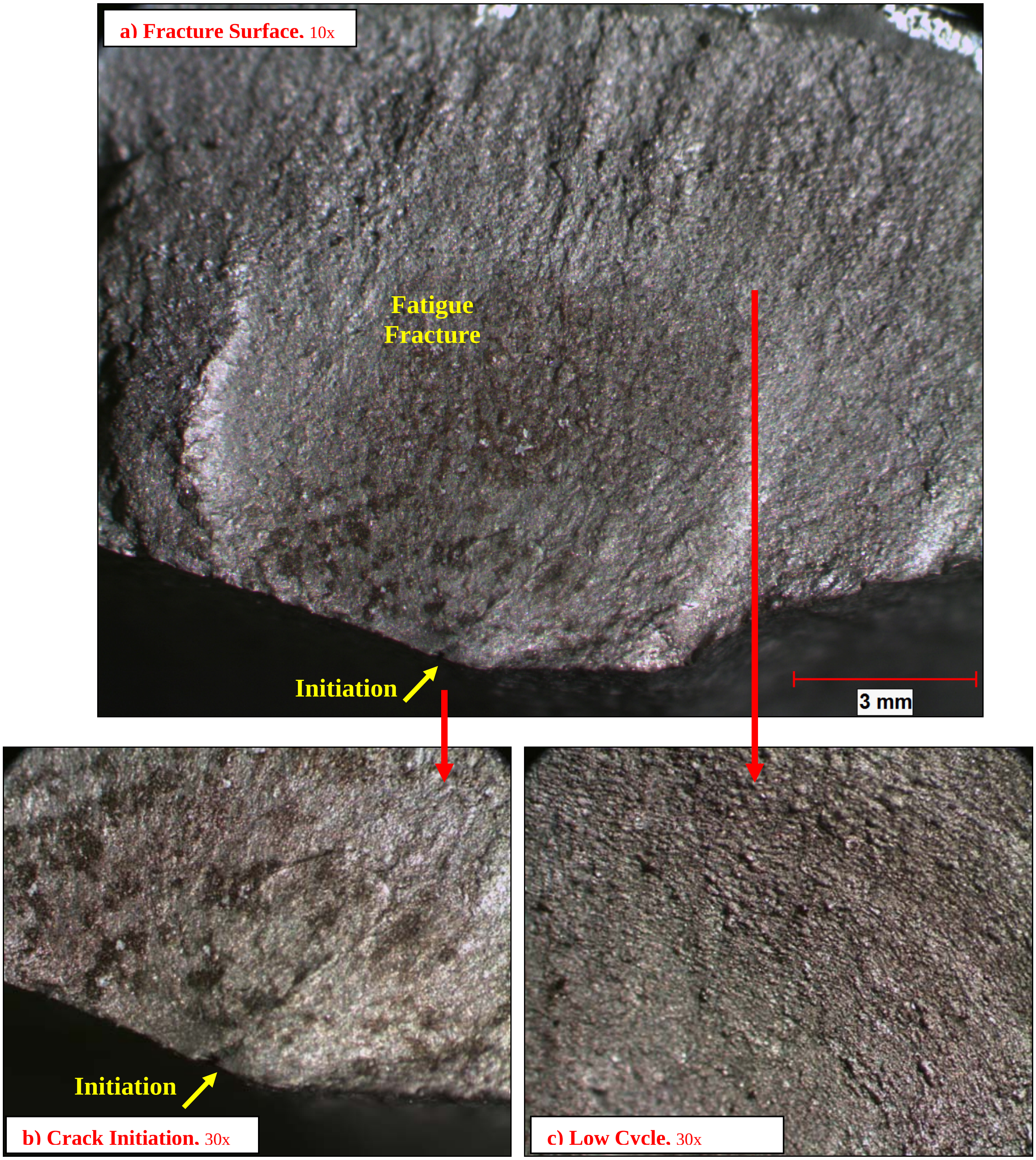


Figure 5: Macrographs displaying the fracture surface. The fracture features were consistent with fatigue failure from repetitive loading. Crack initiation had begun at a forging flaw yet further analysis would find that this small feature had not been a significant contributor to failure.

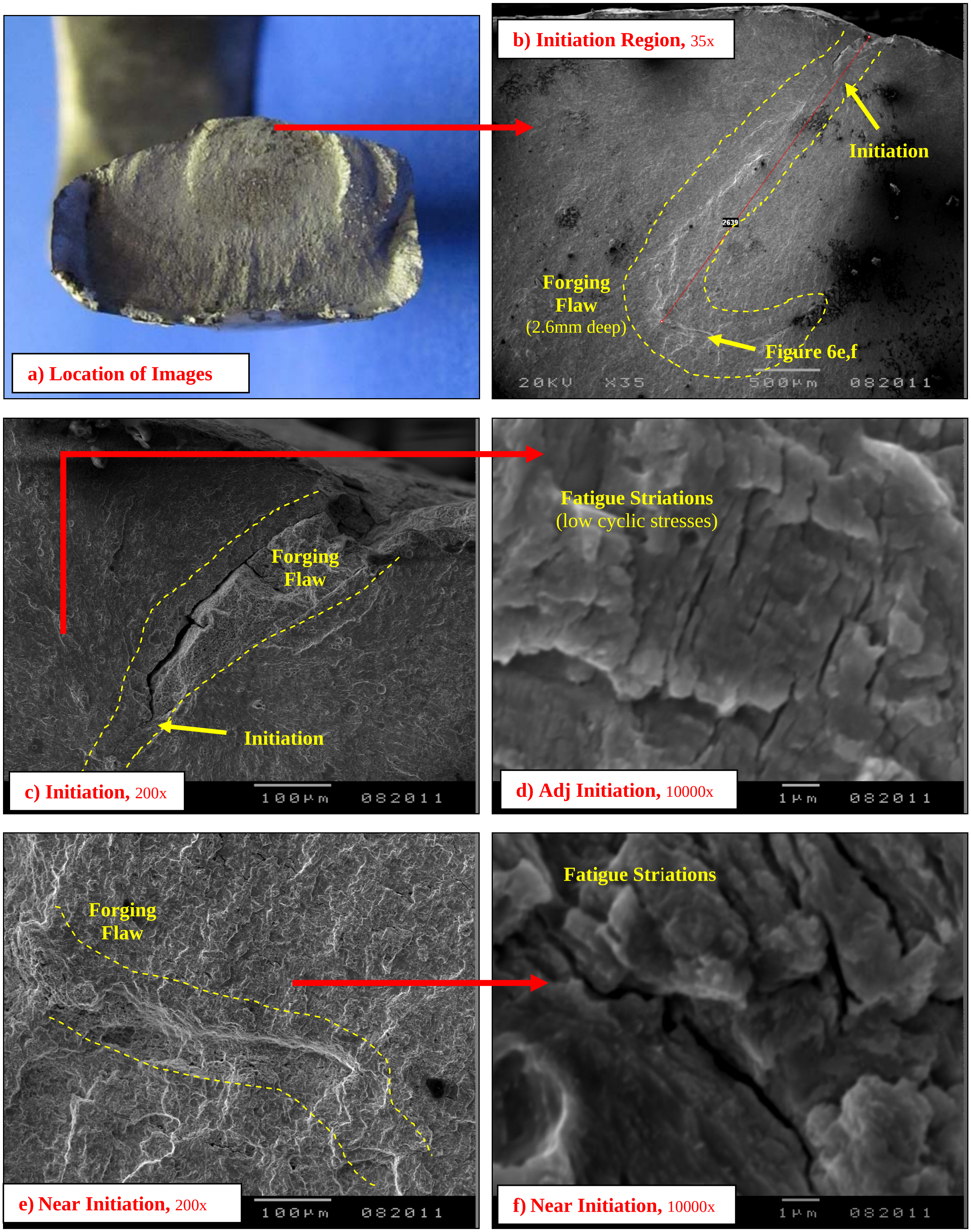


Figure 6: SEM images displaying fatigue striations classic for fatigue failures. Crack initiation had occurred at the 0.016 inches (0.4mm) deep mouth of a forging flaw. SE1, 15kV.

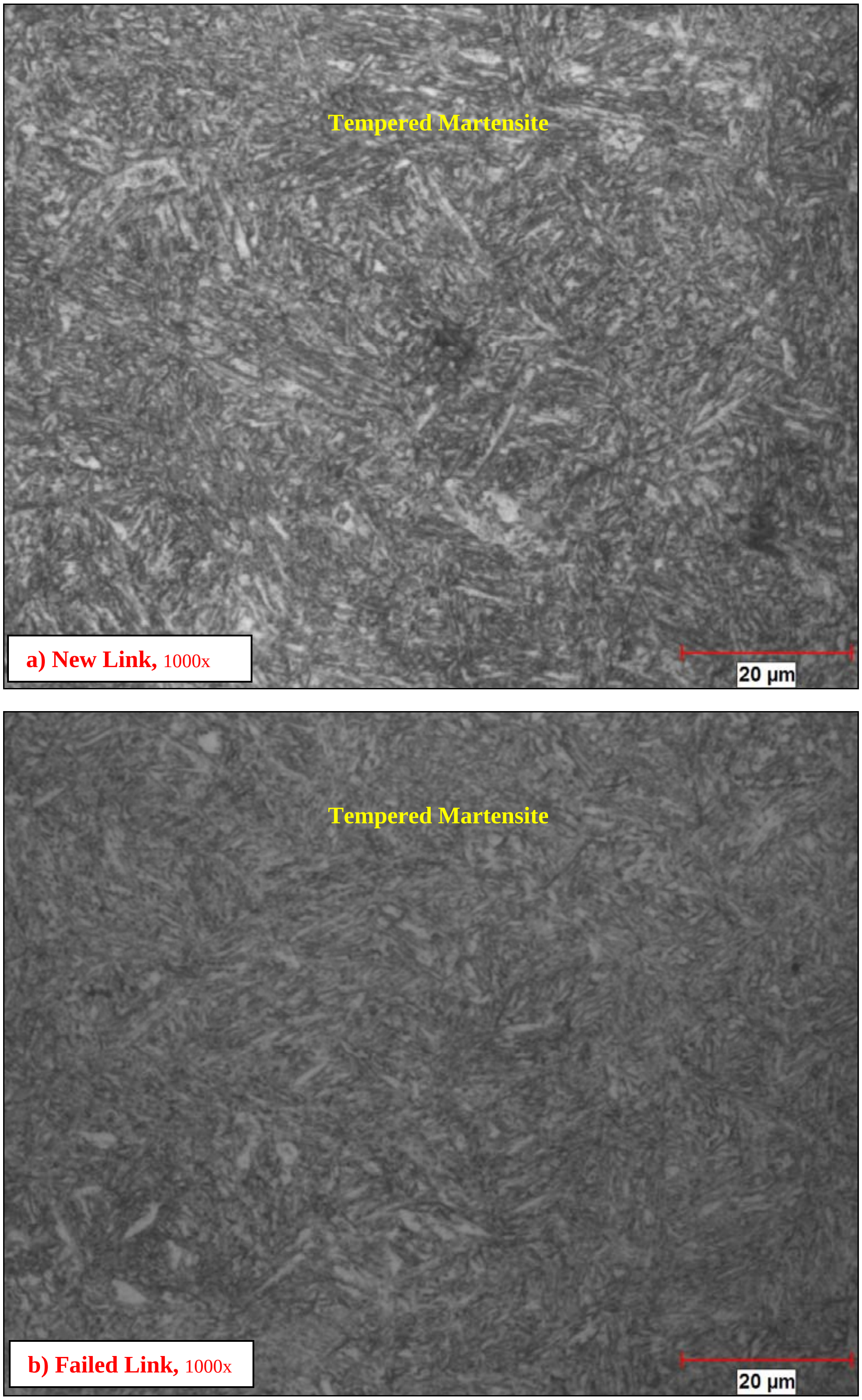


Figure 7: Micrographs displaying the core structure of (a) the New Link and (b) the Failed Link. Both links exhibited tempered martensitic structures typical for such links. Etched using 3% nital.

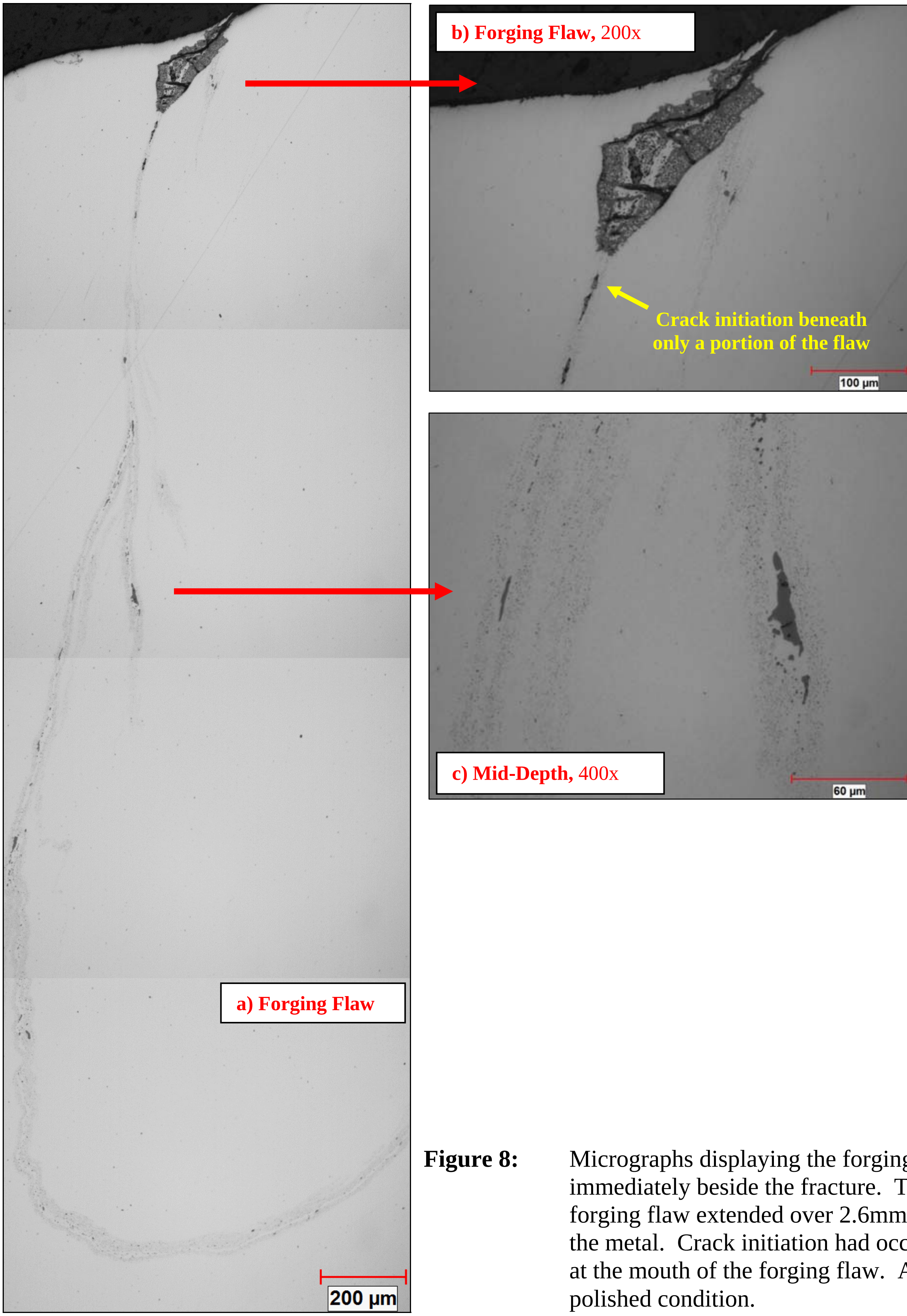


Figure 8: Micrographs displaying the forging flaw immediately beside the fracture. The forging flaw extended over 2.6mm into the metal. Crack initiation had occurred at the mouth of the forging flaw. As-polished condition.