The appearance of machining burr as a cracking failure on twistlock pin

Wahid Mohamad Fitri Mohd1*, Shamsudin Saiful Rizam1, Sanusi Mohamad Syazwan, Wardan Rajaselan1, Rahmat Azmi1

1Center of Excellence Geopolymer and Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis, 02600, Arau, Perlis, Malaysia

Abstract. The failure analysis of the twist lock pin made of alloy steel is presented. The pin was visually observed to have a cracking character at curvature area after 45,000 cycles. Some non-destructive inspections were previously done. However it failed to detect any crack defect. The twist lock pin sample was further macro and microscopic analysis. The analysis found that the surface discontinuities that were previously presumed as a cracking morphology was actually a machining burr and improper machining marks. There were some micro- and nano-sized pinholes dispersed over the metal matrix of the twistlock pin sample. The microstructure of the twistlock pin was tempered martensite structure.

1 Introduction

Twistlock is a standard fixing device, which locates in a corner casting, for securing container or a swap body to a road vehicle, rail wagon or attached to spreader for top lifting of containers. Generally, the semi-automatic twistlocks are comprised of a single-piece steel shaft (twistlock pin) encased in a steel housing. The shaft has an upper and a lower cone that are oriented in different directions and fit inside the corner fittings.

Twist lock pin is generally made of 36CrNiMo6 steel, which is equivalent to AISI 4340 alloy steel. This alloy is known for its toughness, ability to attain high strengths in the heat-treated condition and has very good fatigue resistance. Air-cooling from autenitizing temperature produces a bainitic structure. Oil quenching from autenitizing produces a martensitic structure with some possible retained austenite. The martensite of this steel consists of many laths of about the same orientation within packets.

Twistlock and its pin should have high tensile and shear strengths, high fatigue resistance. It carries concentrated load either in transverse or longitudinal directions. Proper maintenance and periodically check on the twistlock are important to avoid any sudden accident.

In July 2015, an incident occurred where several rail wagons were collided from container freight train. Investigation found that the twistlocks were in poor condition to be able for service [1]. Almost a year ago, 5-containers stack collapsed and crashed down from container ship onto deck of bunker tanker, moored alongside container ship.

* Corresponding author: fitri@unimap.edu.my
Twistlock failure is believed to be the cause of an accident, 40-foot container was to be lifted from container ship, but it didn’t go off smoothly and destabilized container below [2]. Burr forms during machining process. It involves large plastic deformation of work material. The type of burrs and their characteristics depend on the type of machining process, the process parameters, tool property, tool geometry, tool edge configuration, coolant, and workpiece material properties [3].

This paper presents the investigation of twistlock pin, which visually observed to have a cracking characteristic after 45,000 cycles.

2 Materials and method

As-received sample was cleaned to remove rust and some residual coating on the sample surface. The visual inspections were documented by D3100 Nikon digital DSLR camera to record the original condition of the sample (Figure 1). The sample was sectioned into 2 workpieces for chemical composition and metallographic analysis, respectively. The chemical composition was analyzed by using optical emission spectrometer, OES (Q8 Magellan, Bruker).

![As-received twistlock](image)

Prior to the analysis, the metal surface was ground using 80 grit SiC paper, and the chemical composition was examined at 5 different spots on the metal surface. The macroscopic analysis was done by stereomicroscope (SZX 16, Olympus). The samples were ground using 180, 240, 320, 440, 800 & 1200 SiC grit papers. Then, the samples were polished using 6- and 1-micron diamond solution. As-polished surface were examined to study the presence of defect or surface discontinuity such as cracks and pinholes. The as-polished samples were etched using 15 ml HNO₃ + 5 ml methanol solution to reveal the microstructural pattern on the samples. All the metallographic analyses were carried out by metallurgical microscope (BX41, Olympus).

3 Results and discussion

Quantitative analysis was done to inspect whether the material meets the specified composition limits of 36CrNiMo6 steel (Table 1). The nickel (Ni) element was found slightly below the range, thus the twist lock pin materials are not in compliance with 34CrNiMo6 steel. The lack of Ni content relatively reduces its special properties such as elastic limits, hardenability, fatigue and impact resistance.

| Element | 36CrNiMo6 steel (%) | Twist lock pin (%) |
|---------|----------------------|--------------------|
| C       | 0.30 - 0.38          | 0.371              |

![Table 1](image)
Si ≤ 0.40 0.298
Mn 0.50 - 0.80 0.596
P ≤ 0.025 0.015
S ≤ 0.035 0.024
Cr 1.30 – 1.70 1.538
Mo 0.15 – 0.30 0.153
Ni 1.30 – 1.70 1.148
Fe bal. bal.

From visual inspection performed on sample, it is observed that the line morphology along the curvature area A seems to have a cracking character on it (Fig. 2(b)). The cracking characters clearly appear to occur along the curved area as depicted by the red marked arrows. The visual appearance of such morphology like-crack creates anxiety to the user as it is inevitable will cause a catastrophic accident to happen.

The observation is focused on the cracking character adjacent to the curvature area, as the stress concentration factor is known geometrically increases here [5,6]. The line morphology closes to the curvature surfaces of A (Fig. 2(b)) shows the surface discontinuities as indicated by red arrow in Fig. 3. The surface discontinuities were clearly observed. However, macroscopically observation on B (not shown here) is believed not a cracking morphology. It is noticed that it just

![Fig. 2. Camera photographs of (a) as-cleaned sample, show the focusing spot; (b) along curvatures area A-B.](image)

![Fig. 3. Stereomicrograph image at curvature surface.](image)
a scratchy surface affected by the operation service condition. Therefore, the deficiencies observed in the curvature of area B are non-cracking morphology. The preliminary assumption by the user can be ruled out. The above stereomicroscope image, still inadequate to complete the investigation, therefore this twist lock was cross-sectioned to detect any crack presence in the sample. The suspected surface discontinuities were detected as shown by the red arrow bar (Fig. 4). There was no indication of crack detected at both cross-sectional curvatures areas. As-polished surface from the discontinuities that were previously presumed as a cracking morphology were actually a machining burr and improper machining mark as shown in Fig. 4. It was also observed that several pinholes scattered in the metal matrix near the curvature area.

As-polished metallographic images for metal matrix are shown in Fig. 5. There were some micro- and nano-sized pinholes dispersed over the metal matrix of the twisted pin sample. The presence of pinholes imperfection was due to many factors, some of them were attributed from the gas dissolved and/ or not properly degassed during steel making processes. The presence of pinholes is probably contributed to weaken the overall mechanical properties of steel.

As-polished samples were etched using HNO₃+ methanol to reveal its microstructure as shown in Fig. 6. Generally, the cross-sectional area that is close to the surface has a fully fine tempered martensite structure while forming bainite away from the surface.

![Fig. 4. Metallographs of surface discontinuities of (a) as-polished (b) etched curvature area.](image1.png)

![Fig. 5. As-polished micrograph image 10 mm from the curvature area.](image2.png)
4 Conclusion

The twist lock pins material is not in compliance to 34CrNiMo6 steel as Ni element was found slightly below the standard range of chemical composition. This is relatively reducing its special properties such as elastic limits, hardenability, impact and fatigue resistance. Upon observation there was no indication of cracking on the twist lock pins sample. There were surface discontinuities, especially on curvature area A. However, the surface discontinuities that were previously presumed as a cracking morphology were actually a machining burr. There are some micro- and nano-sized pinholes dispersed over the metal matrix of the twisted pin sample. The imperfection was originated during the steel making processes. The microstructure of twist lock pins was a tempered martensite structure.

The authors would like to thank School of Materials Engineering, Universiti Malaysia Perlis for giving the opportunity to perform field investigation on the above matter.

References

1. Australia Transport Safety Bureau, ATSB Transport Safety Report, Rail Occurrence Investigation, (2016)
2. https://www.heavyliftnews.com/containers-from-cscl-container-ship-fell-onto-tanker/
3. I. A. Choudhury, S. A. Lawal, Comprehensive Mater. Process., **11**, (2014)
4. ASM International: Properties and Selection: Irons, Steels, and High-Performance Alloys, ASM Handbook, **1**, (1990)
5. Mari Åman, Yuzo Tanaka, Yukitaka Murakami, Heikki Remes, Gary Marquis, Procedia Structural Integrity, **7**, (2017)
6. C. W. Springfield, H. Y. Jung, Engng. Fracture Mech., **31**, (1988)