Moly-cop Comsteel Wheels

PUBLIC RECORD VERSION

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Contents

Introduction

This report summarises the incidents of broken and cracked wheels at BHP Western Australian Iron Ore's railway division since January 2016. Eight instances have been recorded, all of which are Moly-cop Comsteel wheels. No broken or cracked wheels were recorded in this period from other manufacturers.

Material Risk Management

Derailment is a material risk to BHP Western Australian Iron Ore's railroad division. Due to having level crossings over major public roads and a number of bridges on the rail network, this constitutes a fatality risk. There is also a significant cost impact due to the operational interruptions caused by derailments.

Wheel defects such as broken wheels are a potential cause of derailment events. Broken wheels create impact loads that propagate through the wheel structure and into the axle bearings; and also into the rail structure. Derailments can occur through:

- Cracks in broken wheels propagating through to the wheel hub and effectively separating the wheel (or sections of the wheel) from the axle. This will allow the matched wheel to travel off the rail (no longer constrained through the flanges).
- Impact loads due to discontinuities in the wheel running surface (due to shelling / missing wheel sections) can break the rail. This can result in the wheels no longer being constrained within the rails.
- As a secondary effect, impact loads may induce damage to the wheel bearings. This can result in numerous bearing issues which can lead to 'burn off'. This effectively means that the bearing locks up but the axle continues to spin. The heat created melts the axle and the bearing is thus separated.

As such, controls have been put in place to prevent or detect such occurrences.

Track side condition monitoring is employed to detect failures in service. This includes video imaging and wheel impact load detectors. These systems are monitored 24/7 by a dedicated team who respond to identified issues immediately.

Component manufacturing requirements are also specified by BHP. With respect to wheels, this includes considerations such as:

- Material cleanliness to reduce the chances of subsurface defect formation
- Residual stress requirements to retard crack growth should cracks form
- Mechanical properties to ensure compatibility with rail types and meet minimum requirements for wear

Manufacturers are required to complete a suite of tests and provide evidence of compliance to BHP specification requirements. BHP also audit suppliers of critical components periodically.

History

Broken Wheels

Since January 2016, BHP has investigated eight broken ore car wheels. The table below summarises these occurrences:

#	Date	Ore Car	Wheel Manufacturer	Wheel Diameter [mm]	Key findings

[information in table redacted due to confidentiality]

As part of the investigation process, BHP engages an independent metallurgical laboratory to conduct testing on failed wheels. Findings are shared with the manufacturers in order to provide feedback on product performance.

Causes

Manufacturing Issues

5 of the last 8 wheel cracks originated from subsurface defects. These occur when small inclusions in the steel grow through cyclic loading until they break out onto the tread and rim surfaces.

When the wheel diameter is small, contact stresses are higher due to reduced contact area with rail. Stiffness is also reduced due to reduction of cross-sectional area of the rim. If a small wheel tracks off-centre, bending forces are also increased. Small inclusions are thus subjected to cyclic loads in multiple planes and can grow into shells, eventually breaking through the tread and rim surfaces.

The presence of these inclusions is a result of the feedstock and manufacturing process employed by Moly-cop Comsteel (MC). MC melt down scrap steel and utilise an ingot casting method to manufacture the bloom used to forge the wheel. Scrap steel has inherent impurities present that are usually reduced in the bloom through dilution and treatment of the molten steel before casting. The ingot-casting process entails casting the molten steel into an ingot mould. The method of casting, the cleanliness of the steel and the control over the cooling process in the mould will determine how impurities are distributed through the ingot (segregation), Figure 1. The factors that will determine the quality of the wheels are the cleanliness of the steel poured into the ingot, the control over the solidification process and the amount of discard removed from the ends of the ingot. A high degree of care during the ingot casting process is required to ensure acceptable wheel quality.

The modern alternate process of wheel making employs a continuous casting method to manufacture blooms to be used as feedstock. Because of the continuous process there is less issues with end effects and the need to remove discard material from the ends of the bloom cut from the continuous cast strand. The same care in the steel melting process is required as in the ingot process, but the control over cooling rate and segregation of impurities is much more controllable. Magnetic stirring in the continuous cast mould and spray cooling of the mould ensure that the material quality, particularly the material that will end up in the wheel rim, is of high quality. The hot metal stream is protected during casting so contact with the atmosphere is eliminated.

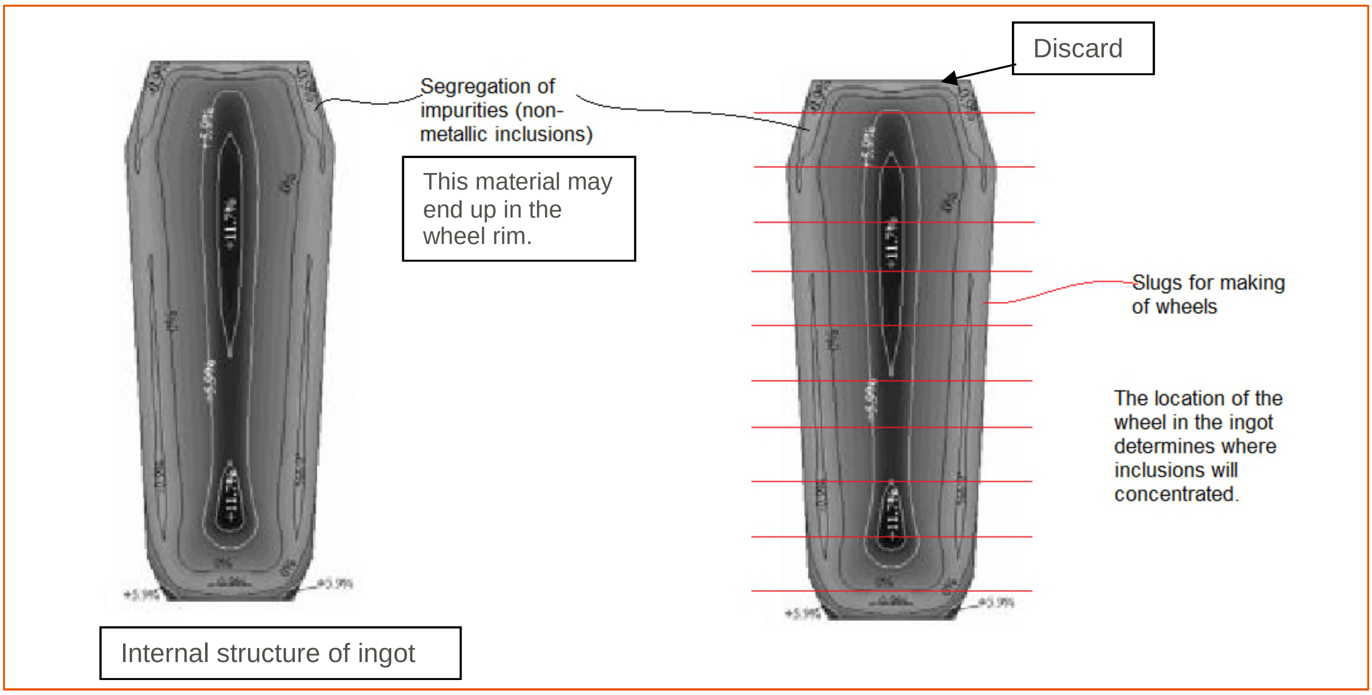

Figure 1: Schematic of steel slugs for wheel forgings taken from ingot feedstock.

Operating Conditions

2 of the last 8 wheel cracks originated from operating conditions and were not directly related to manufacturing issues. The key reason for these was thermal cracking. Thermal cracks occur due to cyclic heating and cooling of the wheel (due to braking) coupled with cyclic contact stresses. Increased heat input from braking can occur due to dragging brakes (incorrect set up / valve failure / deviations from train driving strategy). These failures are not attributed to wheel manufacturing processes.

Other Considerations

In 2015, a small number of brand new (~970mm diameter) Ma Steel wheels were detected with thermal cracks on the rims. This was attributed to the brake blocks dragging on the wheel inducing thermal loads as described in the Operating Conditions section above. This failure mode is not attributed to any manufacturing considerations but rather operating conditions.

No broken wheels due to sub-surface defects have been detected on Ma Steel or Valdunes wheels. Ma Steel wheels have only been in service for ~7 years however, Valdunes wheels have been utilised at BHP since the mid 1990's.

Operational Impacts

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Other Considerations

Wear Performance

A key driver for wheel replacement is wear. Wheel profiles must be maintained within specified tolerances to ensure:

- Derailment risk is managed
    - Dynamic instability may occur if wheel treads become hollow which can induce 'hunting'
    - If flange angle is not sufficient the possibility of a flange climb derailment is increased
- Satisfactory steering performance (reduce wear on the wheel and the rail)
- Contact band between the wheel and rail is maintained to manage induced stresses and associated failure risks

As such, the wear rate of the wheel material is a key performance indicator. Wheels are designed to wear in preference to the rail, so hardness must be maintained within a certain range to ensure this occurs. Once a wheel is worn beyond the specified operating limits, it is removed from service and re-profiled.

The rate at which a wheel wears is thus directly proportional to service life and lifecycle cost. Below is the aggregated wear rates of all wheels in the BHP Western Australian Iron Ore railroad fleet broken out by manufacturer as of May 2018.

[Chart showing wheel wear rates for each supplier]

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX [conclusion on relative wear rates].

Strategy

A number of quality issues with Moly-cop Comsteel wheels in the 1990s / early 2000's were experienced by BHP. These include:

- Small number had rolled lap defects which caused wheels to break in half causing derailments
- Wheels supplied with microstructure variation on the tread surface making them prone to flats – required a machining campaign to remove affected tread material
- Wheels supplied with hydrogen embrittlement (leading to cracks)
- Epidemic of wheel defects due to steel cleanliness at manufacture

Due to these ongoing quality issues, an alternate vendor was sought to supply wheels (Valdunes). As noted in the preceding sections, wheel quality has a direct bearing on derailment risk, exposure of BHP personnel to rolling stock vs person material risks, wheel lifecycle costs and BHP production impacts.

Conclusion

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XX [conclusion on wheel qualities of the respective suppliers and impact on sourcing decisions].

Appendices

[Photographs of two wheel failures]