

The Effects of Repairing High Strength Steels

The Importance of Considering the Repairability of High Strength Steels



Supporting New Zealand's Repair Certification Industry

About RepairCert NZ Technical Bulletins

These Technical Bulletins have been developed to provide 'Best-practice' guidance for Repair Certifiers, to assist them in ensuring that autobody repairs are carried out safely and correctly. It is also intended that these Technical Bulletins can be used by the wider autobody repair industry.

Purpose

To provide information about the adverse effects that repairs, both with and without heat, can have on safety-critical structural components which are manufactured from High Strength Steel (HSS). This is particularly relevant to those structural sections which form part of a motor vehicle's occupant protection system, including chassis rails or subframe sections, and critical cabin structure elements.

This Technical Bulletin is centred around summarising, and highlighting key points from, a material analysis and test report prepared by Hayes Laboratories after analysing a damaged and repaired High Strength Low Alloy Steel (HSLA) rear chassis rail section provided by RepairCert NZ. Hayes Laboratories is a respected industry leader which has provided analytical services to the manufacturing, metallurgical, and foundry industries since 1946. The testing process and the report (the Hayes Report) was commissioned by RepairCert NZ, and should be read in conjunction with this Technical Bulletin.



Image 1: In the photograph above left, the rear chassis rail section of a 2018 Holden Captiva is shown in its impact-damaged state. The damaged rail section, which is made from HSLA steel, should have been replaced, however it was (incorrectly) repaired.

Image 2: In the photograph above right, the impact-damaged rail section is shown after the completion of the (incorrect) repair process.

This Technical Bulletin significantly expands upon the information relating to repairing critical safety components contained in the NZTA Light Vehicle Repair Certification Vehicle Inspection Requirements Manual (Repair VIRM).

Background

Repairability of High Strength Steel

Falling within the general umbrella of High Strength Steels (HSS) is 'Advanced High Strength Steels' (AHSS), which in turn includes Ultra High Strength Steel (UHSS), Transformation Induced Plasticity Steel (TRIP), Twinning Induced Plasticity Steel (TWIP), Complex Phase Steel (CP), Dual Phase Steel (DP), and Boron-alloyed Steel.

It is generally accepted within the collision repair industry that in modern motor vehicle structures, these steel types have very limited repairability due to the potential for the characteristics of the materials to change during the repair process. This, in turn, can change the way that the materials perform when subjected to a load. Of particular relevance are chassis rails or subframe sections which are designed to progressively deform and absorb impact energy during a collision, thereby reducing the deceleration rate of the vehicle occupants.

What is less well known however is the extent to which the material's behaviour during impact-energy and post-impact repair changes from the way in which the vehicle manufacturer originally designed the material to perform.

Sample Damaged and Repaired Chassis Rail Section

Earlier in 2024, a 2018 Holden Captiva was damaged during a rear collision. The Repair Certifier involved was engaged post-repair of the damaged vehicle, and determined, during his repair certification inspection that the right-side rear chassis rail had been damaged in the collision (*see Image 1*), and had been repaired (*see Image 2*) by the collision repairer. The repair involved pin-pulling to facilitate the dent removal process.

The Repair Certifier failed the repair due to the severity of the kinks, requiring the damaged and repaired section to be removed and replaced with a new part, in line with the vehicle manufacturer's recommendations, and best-practice guidance.

RepairCert NZ supported the Repair Certifier during his repair certification inspection, and also took the opportunity to take possession of the damaged and repaired chassis rail section (*see Image 3*), and have the section analysed and tested by Hayes Laboratories to learn what effects the repair process had on the HSLA material the rail is made from.



Image 3: The removed damaged and repaired rail section, prior to fitting a new part. The 'slot' cut from the removed section enabled a preliminary inspection of the material to take place.

Vehicle Manufacturer's Specifications

The General Motors Body Repair Manual (BRM) 'Structure Identification' section for the 2018 Holden Captiva lists the chassis section as a 'Rear Rail' (*see Image 4*) and specifies the material as 'High Strength Low Alloy Steel'. It also specifies that the correct repair procedure for kinked steel is 'part replacement'.

Under the BRM's 'Rear Rail Replacement' section, a replacement procedure is provided for the rear chassis rail section.

When referring to General Motors' repair recommendations and general guidelines for HSLA steel, the specified tensile strength rating range is from 300 to 700 MPa.

General Motors' guidelines on HSLA steel state:

- 'cold repairs can be performed on this type of steel, unless the damage includes kinks. If the damage includes kinks, the part should be replaced'; and
- 'controlled use of heat can be used to repair damage, if the heat does not exceed 1200 degrees Fahrenheit (650 degrees Celsius)'.

It should be noted that the heat generated by the pin-pulling process is significant and can reach approximately 2000 degrees Celsius - almost double that allowed by General Motors' guidelines.

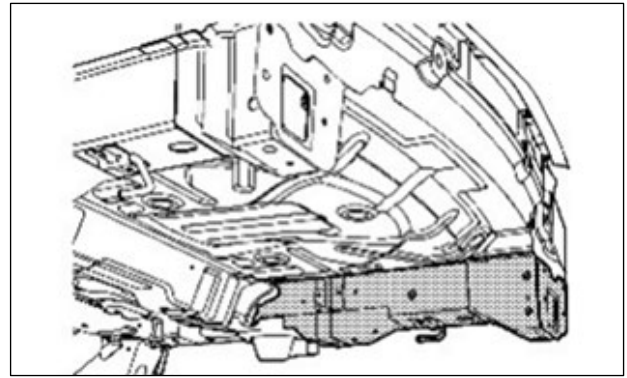


Image 4: The 'Rear Rail' from General Motors' BRM.

The Testing Process

The Inspection Samples

Once in the expert hands of the Hayes Laboratories technicians, two samples of material were cut from the chassis section, each approximately 60 mm x 175 mm in size. One sample (designated 'sample NR' - for 'Not Repaired') was cut from the side of the chassis rail section which had not been damaged and repaired, while the other sample (designated 'sample R' - for 'Repaired') was taken from the damaged and repaired side of the chassis rail section, and included an area which directly overlapped the repaired area of the rail (see Image 5).

After stripping the rear chassis rail section, multiple heat-affected areas from the pin-pulling process were found to be present on the damaged and repaired area. As detailed under 'Vehicle Manufacturer's Specifications' above, it is evident that the heat applied to the rear rail section significantly exceeds that allowed by the vehicle manufacturer.

Microscopic Analysis

Two sections were cut from the 'R' sample and one from the 'NR' sample, and were polished and etched to enable the laboratory technicians to examine the grain structure of the three sections under a microscope.



Image 5: This photograph shows the extracted samples cut from the chassis section, and marked 'R' (Repaired), and 'NR' (Not Repaired).

Tensile Testing

The other test conducted was a 'tensile test', which involves cutting precisely sized and shaped sections from the 'R' and 'NR' samples, and applying a tensile load to the sections, with the objective of comparing how their respective failures occurred. A tensile test was carried out on one section of material from the 'NR' sample, and on two sections of material taken from different areas of the 'R' sample.

The Testing Results

Microscopic Analysis

The microscopic analysis concluded that the grain structure of the 'R' sample has been significantly altered from that which could be viewed in the 'NR' sample. Specifically, the ductility of the 'R' sample has been substantially reduced from the level of ductility in the 'NR' sample.

The visual evidence of the altered grain structures between the analysed samples also strongly implied that a modification to a material structure through 'hot' or 'cold' repairs will affect the characteristics of modern high strength steels, to the extent that crash performance to critical components will be compromised. This was proven by the effect the cutting equipment had on the edges of the material when the samples were cut out.

It can be reasonably expected from this observation that even cold repairs, including hammering, pulling, stretching, stress relieving, and bending, are also likely to compromise high strength steels.

Tensile Testing

The tensile testing carried out showed a significant difference in the performance of the two sections from the 'R' sample compared to the section from the 'NR' sample (*see Images 6 and 7*). The loss of ultimate tensile strength in the 'R' samples was relatively minor at between 8% and 14% reduction.

However, the ductility (the material's ability to bend and stretch rather than fracture or shatter) of the chassis rail section was massively compromised as a result of the heating that had been applied to the material during the pin-pulling process. A tensile test was carried out on two sections of the 'R' sample, and one section of the 'NR' sample.

On the two 'R' sample tensile tests, the ductility was found to have been reduced, from the 'NR' sample test, by 92% and 70% respectively.



Image 6: The tensile strength sections have been roughly cut to shape from the 'R' and 'NR' samples.

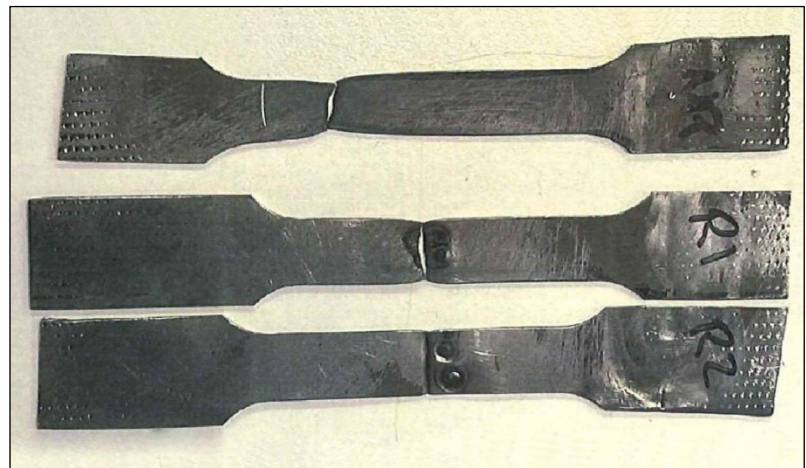


Image 7: The tensile test sections have been finished, and clamped, and had a load applied until the sections have failed, with the load information telling the story.

The significance of this result can't be understated because the ductility of the material is crucial to the chassis rail's collision performance. Had the vehicle (still fitted with the damaged and repaired chassis rail section) been involved in another rear collision, the material would almost certainly have collapsed in an uncontrolled manner instead of doing its important job of progressively deforming, and thereby reducing the impact energy on the occupants. This is particularly relevant on this vehicle, because of the proximity of the third-row seats and associated seatbelt anchorages to the repaired rear chassis rail section.

Remember that these same changes in physical properties (increased hardness, reduced tensile strength, and significantly reduced ductility) were, as previously noted, also clearly visible when the grain structures of the samples were examined under a microscope.

While no one can realistically estimate the extent of the effect on the occupants in a crash had the vehicle continued with the incorrectly repaired chassis rail section, without question, the structure of the vehicle would not have performed in the same way the vehicle manufacturer designed it to.

In Summary

The Hayes Report concludes that the reduction in performance of the damaged and repaired HSLA steel would also occur to an equal, if not greater degree, on other high strength steels.

Importantly, the Hayes Report provides the following general conclusion on the matter of repairing, by any means, safety-critical components or sections made from modern high strength steels:

'It is reasonable to conclude that any repair effort that involves heat sufficient to melt steel, or mechanical action to restore the shape of bent or kinked areas of modern automotive steel is going to impair the designed level of safety of that part, justifying industry and regulatory expectations that modern steel chassis sections must be fully replaced, not repaired, in the event of damage.'

Based on this reinforcement of what we've always understood to be 'Best-practice', RepairCert NZ strongly urges Repair Certifiers to exercise diligence when considering the repairability (or non-repairability) of components which the vehicle manufacturer lists as being made of HSS materials, especially in safety-critical areas of a motor vehicle - and even more so where they form part of the vehicle's occupant protection system.

By following this Technical Bulletin, a Repair Certifier's decisions will be aligned with OEM requirements, guidelines, and/or recommendations.



RepairCert NZ is appreciative of the assistance in developing this Technical Bulletin, of Hayes Laboratories, Onehunga, Auckland (email info@hayeslabs.co.nz).



FOR FURTHER INFORMATION PLEASE CONTACT REPAIRCERT NZ.

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