



UKRO

New Materials And Vehicle Construction Workshop

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University of Stirling Scotland

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CHIEF FIRE OFFICERS ASSOCIATION



1. Introduction

Road Traffic Collisions (RTC's) are still the biggest killer of people in the UK. The Fire Service Act now places a duty on Fire & Rescue Services not only to train and respond to such incidents, but also to work in partnership with others to reduce death on our roads.

The aim of the UKRO 'Extrication Challenge' is to bring together teams of rescue personnel who are committed, not only to displaying their ability, but also to expanding their practical skills by learning from and teaching others involved in the same field. This is where the UKRO 'Workshops' come into their own.

This workshop aims to give you answers to the following questions:

1. What considerations are being made by vehicle manufacturers?
2. New material considerations
3. The location of such new materials
4. The implications of new materials
5. The future development of tackling new vehicle constructions

The information contained within this handout, as part of the workshop, is a small amount of the information which is being made available through the UKRO and its partnership organisations. Should you wish to receive further information please contact Cameron Black or Seth Armstrong who are part of the UKRO Education Committee (cblack@ukro.org or sarmstrong@ukro.org)

2. New Technologies and Construction

What considerations are being made by vehicle manufacturers?

Market forces and current legislation are the key drivers for modern day vehicle design considerations. Manufacturers must meet safety requirements and they must also meet the demands of the customer, e.g. aesthetics, practicalities, fuel efficiencies and occupancy safety. Their ability to do this to the highest standards makes their vehicles highly appealing to the vehicle market audience and as such drives sales.

What considerations are being made for New Materials?

So what exactly goes into a modern day vehicle in order to meet all of the above requirements? Manufacturers are increasingly turning to new materials to give a wider range of vehicle construction options. These materials are utilised in a range of combinations to add impact strength, compartment integrity, crush areas, reduction of lateral twisting and increased stability, and allow aesthetically pleasing designs and

curves which maximise safety. The key attributes of such material as we have said is strength to weight, so what exactly is material strength?

The main category of strength that we will observe as rescuers when tackling vehicle rescues is **Tensile Strength** and is the amount of stress applied to a material at its breaking point or the point at which it fails.

The tensile strength of a material is the point at which a material, under the stress of an applied force, snaps, breaks or can no longer maintain its structural integrity. It is, in other words, the amount of force the material can withstand without breaking. Tensile strength is an intensive property and, consequently, does not fluctuate when the amount of test material is increased or decreased. However, it is dependent on the preparation of the specimen and the temperature of the test environment and material. Tensile strength is an important measure in the field of vehicle construction.

Tensile strength can be further categorised into three subcategories, Yield strength, Ultimate strength and finally Breaking strength, these are the strengths from deformation, to max deformation then to where the material finally breaks and fails. The measurement we use for this strength is megapascals (MPa) a metric unit of pressure, one megapascal is also equal to 145 psi or 0.145 ksi..

Now that we know what strength is we can now look at different categories of metals and get an idea of comparison between metal performances. It is of note that if you are dealing with a late model vehicle, it is more likely that the steel is either mild steel, conventional high-strength steel, or one of several strength variations of high-strength steel commonly referred to in the industry as advanced-high-strength steel (AHSS).

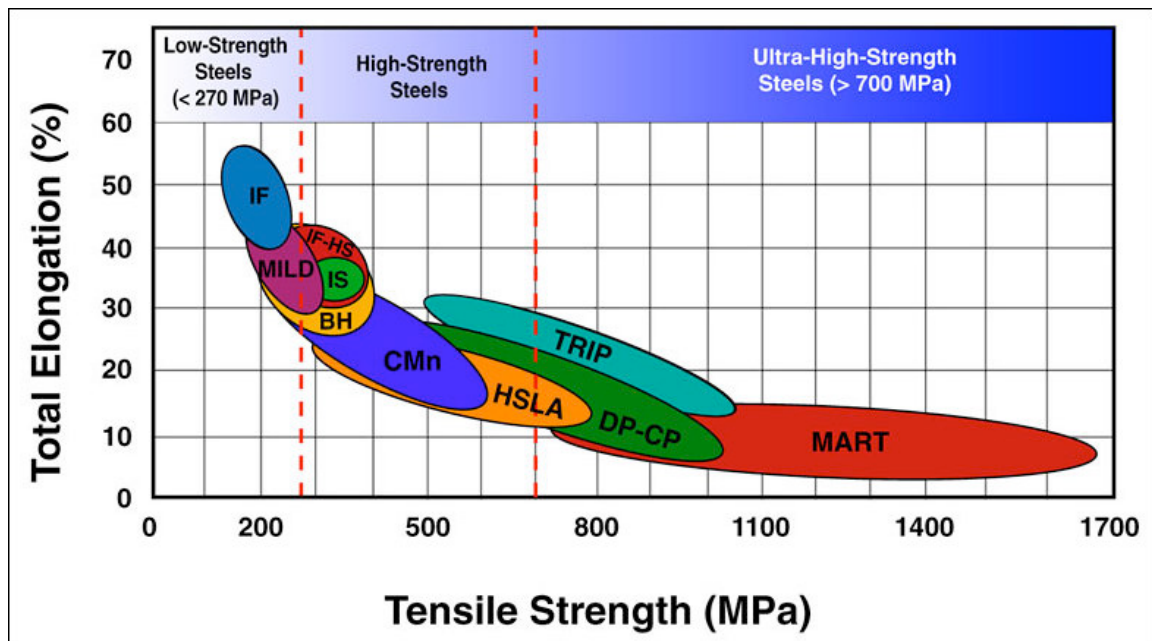


Mild Strength Steels: Generally seen as <280 MPa, such steels are still widely used in vehicle construction, predominantly in filler areas such as boot lid skins, floor pan areas and rear seat/boot separators'. Such steels are being replaced in modern vehicles as a greater balance of energy distribution is understood by manufacturers and different characteristics are required.

High Strength Steels: These steels are again widely used in modern vehicle construction and have a strength rating of >280 <700 MPa. Its use is widespread in modern vehicles, ranging from structural coverings and skins as well as high strength components e.g. seat hinge brackets, internal cross members. Such steels have limited mouldability but depending on the vehicle requirement can have some mouldability characteristics added through the introduction of micro-alloying elements such as niobium, vanadium and titanium.

A further advancement of the High Strength Steels is the HSLA (High Strength Low Alloy) This material is predominantly used in the construction of the vehicle posts e.g. A, B and C, vehicle cross-members and items requiring a high level of strength to weight. It has the capacity to add greater rigidity, minimise flexing and ultimately maintain occupancy compartment areas. Cars within the last 20 years have made use of this material as part of their impact reduction systems and as such it can be found within doors, side and cross members and within the roof construction.

Extra High Strength Steels and Ultra High Strength Steels: Such materials are used to provide large amounts of rigid strength into a vehicle and their strengths range from >700 MPa up to 1700 MPa although 1700 MPa materials in vehicles is extremely rare. Such UHSS material exists through the introduction of raw Elements such as Boron during the molten metal stage (alloying), and developed new processes and quenching techniques and post formed heat treatment phases.



Ultra High-Strength Steels include the classes of Dual Phase (DP), Complex phase (CP), Transformation induced plasticity (TRIP), Martensitic (MART) and UHSS alloyed with boron (BOR). With metals based around the Martensite structure (named after the German metallurgist Adolf Martens who developed the structure) it should be noted that such metals are extremely fragile and brittle.

To put all these metal types in some order and to give you an idea of the material strengths you as rescuers will be dealing with we have the following chart:

Steel Grade	Yield Strength	Ultimate Tensile Strength
BH 180/300	180 MPa (26 ksi)	300 MPa (44 ksi)
HSLA 350/450	350 MPa (51 ksi)	450 MPa (65 ksi)
DP 300/500	300 MPa (44 ksi)	500 MPa (73 ksi)
TRIP 350/600	350 MPa (51 ksi)	600 MPa (87 ksi)
CP	700 MPa (102 ksi)	800 MPa (116 ksi)
MART	1250 MPa (181 ksi)	1700 MPa (247 ksi)
BOR	1350 MPa (196 ksi)	2482 MPa (260 ksi)

The ultimate goal which the steel and vehicle industry aims for is a hot rolled steel with very high maximum elasticity, mechanical resistance and good moulding characteristics, to produce parts by stamping, profiling and hydroforming.

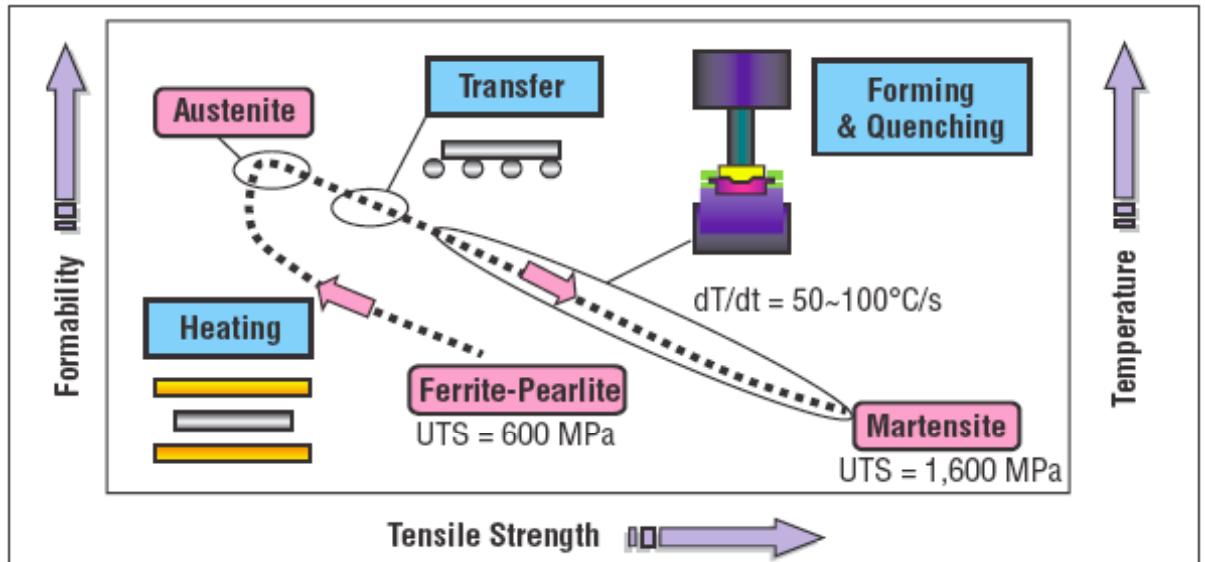
It is of note that we as rescuers are just coming to grips with such UHSS, there is a new process being developed which will once again increase metal characteristics without the great trade off in flexibility. The latest production invention involves Bainite steels which will allow flexibility of material >700 MPa and a yield strength >1000 MPa and make the use of harder steels much more commonplace as greater flexibility is introduced.

The Location of New Materials Used in Vehicle Construction

Considerations by manufacturers as to the materials they use in vehicle locations has with it a number of complications. These can range from – what processing techniques will allow me to form the part I need with such material, if processing techniques are too expensive how else can I utilise the characteristics of such material, and if such material is used how will it interact with other metals located nearby within the vehicle.

To understand why materials are incorporated as they are we must look at some of the production techniques available.

Stamping of material: In order to stamp shaped forms for the automotive industry manufacturers make use of the Hot Stamping process. This is where boron alloyed metal that is in the hot formed process, then gets stamped into shape and then is quenched so that the martensite structure is formed, thus creating the very hard stamped piece of metal which the vehicle manufacturers require.

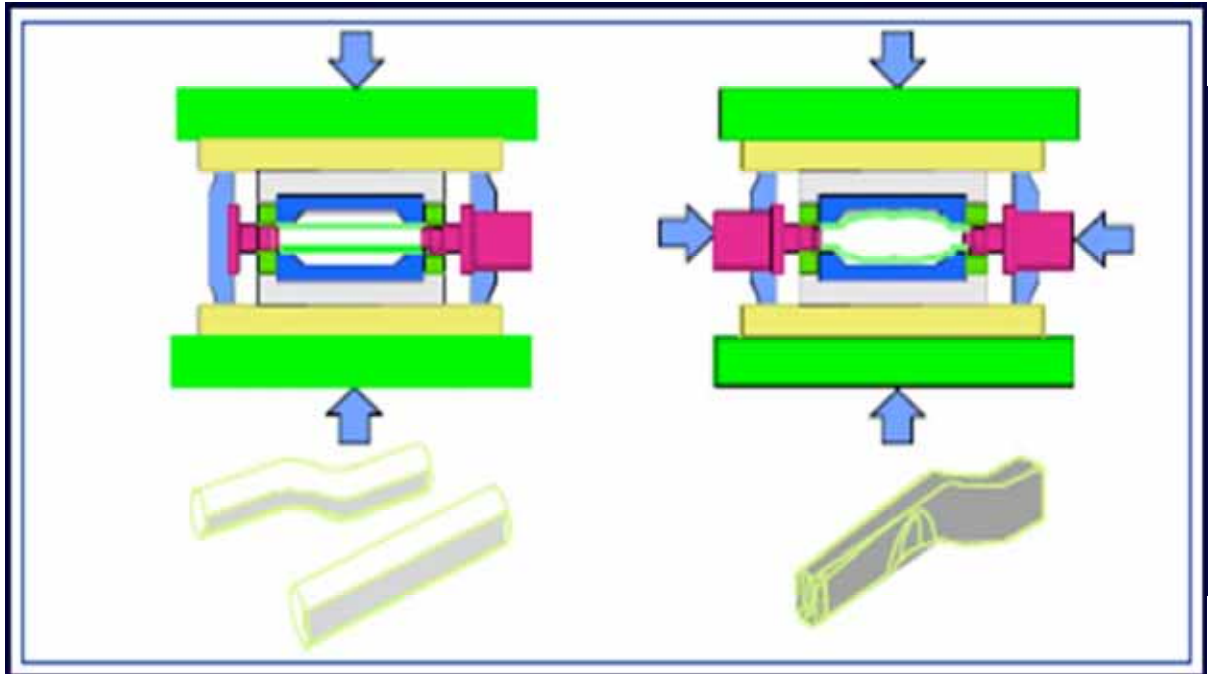


Stamped sections can appear in many different parts of the vehicle, an example of this is a modern B post which can have from 3 to 8 main structural components. These parts with tolerances of $<0.2\text{mm}$ are put together and laser welded, long gone are the days of spot welding and folding of edges. This layering and welding of sections should be noted by rescuers as layering often hides the true composition of structures within a vehicle.

Where a manufacturer wishes to make use of a single formed insert, e.g. a boron A post, roof support and C post insert or where parts need to have an economical yet complicated design the use of Hydro Forming is common.



This involves a mould which is in two halves which the metal is placed between and then filled with liquid. When the two halves of the mould are pressed together the liquid maintains the volume of the part and the metal takes up the shape of the mould.



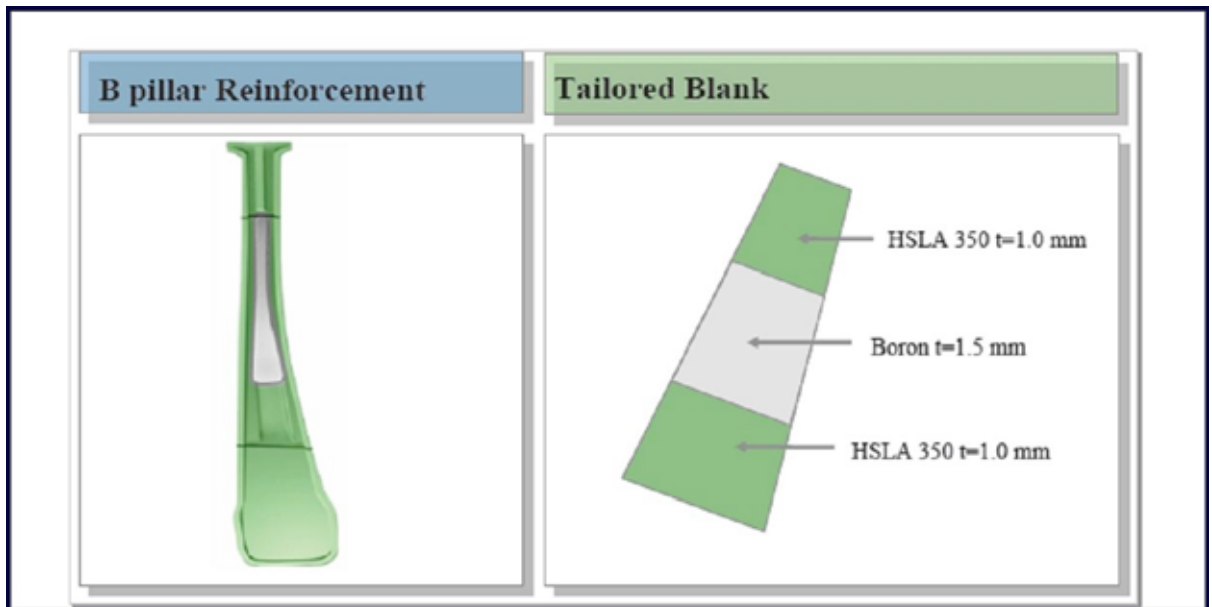
Hydroforming allows complicated designs to be made utilising very strong MPa metals, so looking at vehicle construction just because its complicated doesn't mean that the metals used are soft metals.



As we can see above inserts have been placed within the B post that take up the shape of the vehicle design. Such inserts will have alloying with Boron and present huge energy considerations for the rescuer, tool technician and casualty.

A key consideration for rescue professionals is the use of tailored blanks within vehicles. What are tailored blanks ? if you can visualise very precise tailoring of

different types of metal brought together to create a part then these are the blanks which manufacturers utilise. Tailored blanks are steel sheets of different grade, gauge and finish, joined together by laser-beam welding. They are mainly used in lightweight vehicle construction and can be tailored precisely to the manufacturers requirements. In the carmaker's stamping plant, tailored blanks are processed into function- and weight-optimized components.

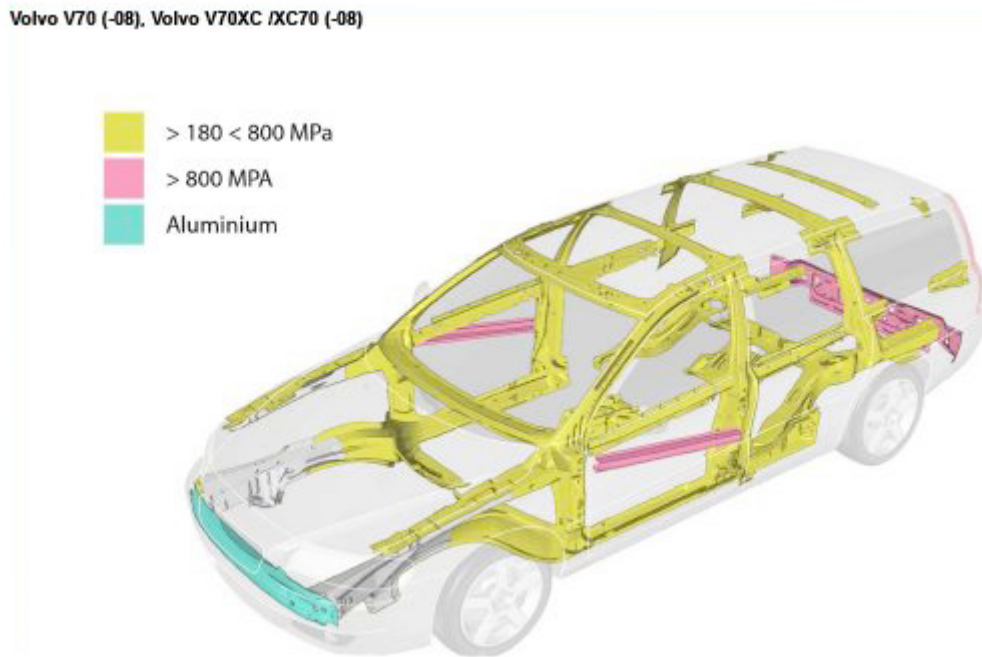


The main advantages of the use of tailored blanks are reduced weight, improved crash performance due to the targeted use of material, a lower parts count, optimized component tolerances and reduced production costs. The use of tailored blanks allows manufacturers to mix a large amount of metal types within the vehicle construction economically by prefabricating large sections that will then be brought together to give the vehicle its ultimate performance characteristics.

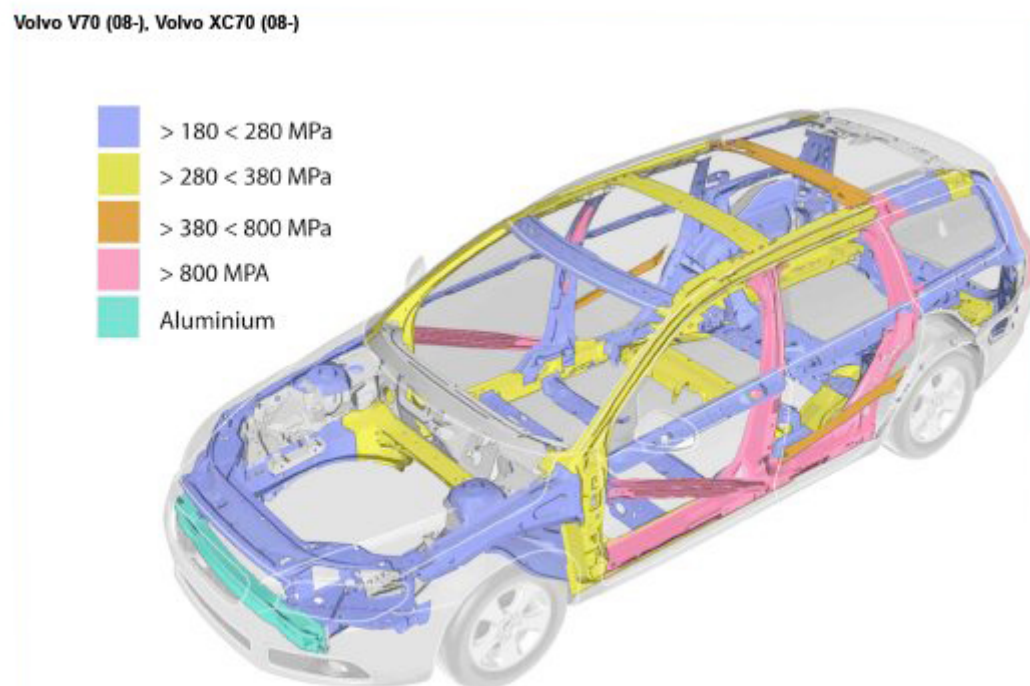
As we will see the variety of metals used can change over age ranges as also product categories to transfer energies as required. An example of this is if you were to look at two different models from the same manufacturer you may very well find that metal choices are vastly different.

The location and choices of the metals we discussed above also are related to the year of manufacturer of the vehicle, again you will see vast differences in metal choices for the same model vehicle over different time periods.

Here we have a Volvo V70 prior to 2008 showing the range of materials choices made.

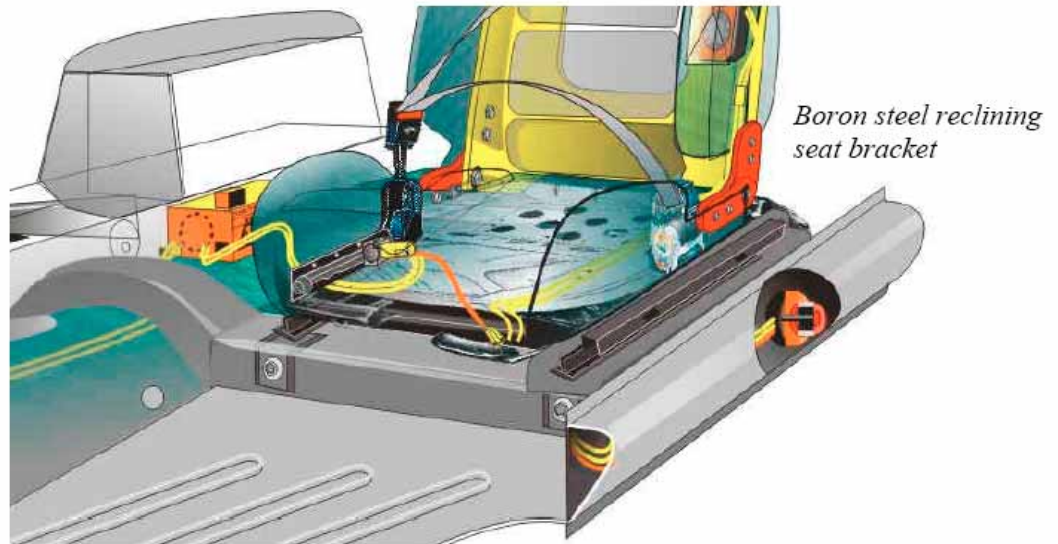


The revamped 2008 onwards model as we can see has a vastly different material choice as part of its construction.

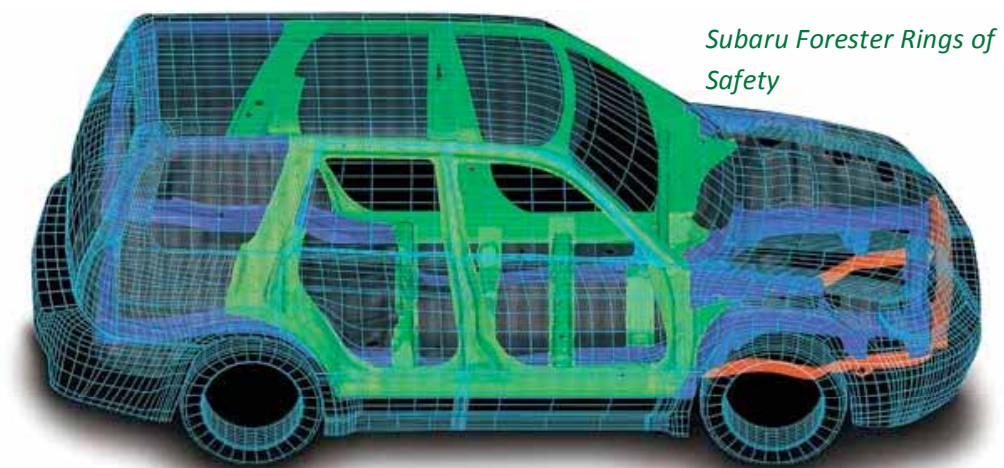


As you can see for modern vehicles there is a large increase in the use of >800 MPa UHSS steels e.g. Boron. Such metals provide great strength for the thickness, lightness and size however can prove problematic for the technical rescuer.

Consideration should not only be given to the structure of the vehicle for the use of Boron but also for internal constructions e.g. seat brackets to prevent seats breaking where a rear occupant is thrown forwards.



Another key manufacturer in the development of UHSS usage is Subaru with its World Rally connections. As you can see below they have developed a full cage made from UHSS which is surrounded by softer metals to take energy from impacts, and still maintain the integrity of the passenger compartment.



As part of the consideration for the positioning of all this new high strength material in vehicles, we should think back 10 years when our hydraulic rescue tools gave true professional benefits. Such tools although advancing now have to tackle materials four times stronger than average high-strength steels. The UHSS used on the Volvo car shown earlier has a yield point of about 1,350–1,400 N/mm² (196,000–203,000 psi) and has different characteristics which we as professionals need to understand and work with. One example is UHSS due to the extremely high heat process used to make it strong when it is formed takes away some of the steel's workability properties, such as being able to straighten it.

When UHSS is damaged in a collision, work hardening makes it too brittle to be restored to its original state. Attempts to straighten an UHSS part will usually result in a cracked part.

What are the true implications of such New Materials for professional rescuers?

The techniques we use as Professional Rescuers are relevant to the aims which we wish to achieve when undertaking a rescue involving vehicles. We have decisions to make on how we use such techniques and advance the way we work as we tackle different situations.

New vehicles will bring new challenges to professional rescuers, of that there is no doubt. Tooling options which have worked year after year will now prove very difficult, or impossible, and even with the most modern of tooling designs and strengths a host of new considerations will have to be made by rescuers.

So what considerations are there regarding tooling and tackling UHSS:

A reciprocating saw should not be used with a standard metal toothed blade. Boron steel will remove the teeth on a reciprocating metal saw blade. A consideration should be made for the use of Industrial Diamond coated reciprocating saw blades which were initially developed for Cast Iron applications but are being advanced for UHSS techniques.

*Old style B Post an
Newer Style B Post
with UHSS Inserts*



Rams should be used with great consideration when displacing boron steel parts. The great amount of energy which such steel requires to displace it means that rams

push points are likely to deform unless they themselves are made from UHSS. Where ramming does take place Boron is likely to fracture when it reaches its extremely high 'Breaking Point' resulting in large amounts of energy being released around the vehicle with potential issues for any casualty or rescuers within the vehicle.

All but modern day hydraulic cutters will fail if they try to cut Boron steel. Where such cutting is undertaken the brittle boron will eventually yield at extremely high MPa and where the vehicle has been involved in a collision and energy is again stored throughout the vehicles construction, a sudden and violent release could occur resulting in issues for both casualties and rescuers within the vehicle. The introduction of energies from the hydraulic tool should also be a consideration as they will be higher than historic requirements.

The use of battery powered and 110v cutting disks on grinders is growing in popularity as it holds a number of key advantages over hydraulic cutters. Making use of industrial diamond embedded disks the cutters do not introduce energy into the vehicle as it cuts through UHSS posts, and has a large benefit that cuts do not have to be exactly straight thus can go around items which would restrict the blades on hydraulic cutters. There are two obvious disadvantages which would need to be dealt with when using a cutting disk and these are sparks and additional noise creating a greater hazard to the casualty, medical staff and rescuers.

One thing is certain, we as rescuers need to be aware of. Vehicle construction. It is changing and we need to ensure that we keep ahead of the game with both our knowledge of vehicles and the tools that we choose or we will be left behind struggling to undertake effective rescues for those that we serve.

The future for tackling new vehicle development?

We should not be surprised if when we tackle newer vehicles, existing tools do not perform as they have historically done. We have seen throughout this document that technologies being utilised by vehicle manufacturers have advanced rapidly. It is up to each of us as professional rescuers to understand what tools are telling us when they are performing so that we can quickly judge if new techniques, different tools, or new strategies are required.

We should applaud the investments that vehicle manufacturers have made in reducing the likelihood of fatal injury and work with them to better perform when our services are required.

Through the UKRO's Education committee it is working closely with tooling manufacturers and vehicle manufacturers to ensure that the professional rescuers throughout the UK are better equipped to deal with different vehicle constructions, and this information will be provided to every UK Fire Service.