Replacing Hot Stamped, Boron, And DP1000 With “Room Temperature Formable” Flash® Bainite 1500 Advanced High Strength Steel

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Abstract

Flash® Bainite Processing employs rapid thermal cycling (<10s) to strengthen commercial off the shelf (COTS) steel sheet, plate, and tubing into AHSS. In a continuous process, induction technology heats a narrow segment of the cross section in just seconds to atypically high temperatures (1000-1300°C). Quenching substantially immediately follows.

Flash® Processing utilizes inherent heterogeneity of steel creating multi-chemistry, complex mixtures of approximately 20% bainite and 80% martensite. Carbide dissolution and carbon migration are controlled by limiting time in the austenite temperature range. Unlike conventional heat treating to create advanced high strength steels (AHSS), homogeneity is intentionally avoided and non-equilibrium conditions are created. The leanest prior ferritic regions transform to bainite while prior pearlite forms martensite. A 7-10% higher yield/tensile strength product results with the beneficial ductility of the bainite constituent.

Flashed AISI1010 (1100MPa UTS) and AISI1020 (1500MPa UTS) have shown exceptional room temperature stamp-ability to 0T/1T bend radii. The 1500MPa formability of 3G-AHSS is achievable. Flash® Bainite offers simultaneous weight and cost savings.

Introduction

Problem Statement

It is well understood that reducing the mass of passenger vehicles will increase their fuel efficiency. Mass reduction of 10% is generally accepted to increase fuel efficiency by 6-8%. The automotive industry, driven by increasing CAFÉ standards, has focused on AHSS as a means to reduce vehicle mass. Working closely with the steel industry, many methods have been attempted to achieve stronger steel that can still form automotive components. Most of these methods involve costly alloying and capital intensive equipment with lengthy thermal cycles. Achieving limited success in the laboratory, difficulties remain in that heavily alloyed steels are costly, often difficult to roll into sheet, and weld poorly. In the future, these heavily alloyed steels will be difficult to recycle without either contaminating future heats of steel or simply losing the alloy content without financial recapture.

Proposed Solution

Dozens of COTS steels have been Flash Processed and evaluated. Flashing steel such as AISI1010 (1100MPa UTS) and AISI1020 (1500-1600MPa UTS) has shown unprecedented room temperature formability in stamping press operations. Flash® 1100 has fully formed to a 0T bend radius upon itself with no springback. Flash® 1500 has been stamped at room temp to form many difficult shapes to include B-pillars and complex seating components. Compared to leading boron steels, Flash® tubing has ~15% higher resisting force and ~20% more energy absorption during NCAP crash/impact simulation. Given the alloy-lean chemistry of plain carbon steels like AISI10## as the Flash Processing input material, the Flash product is readily weldable with all methods used in the automotive industry.

The 1500MPa form-ability desired of 3G-AHSS is now achievable. OEMs/Tier1s predict simultaneous weight and cost savings. Flash® Bainite Processing is the proven method to achieve elemental heterogeneity, the New Frontier in Steel.

Discussion

To reduce America’s dependence on oil imports, the Department of Energy (“DOE”) is pursuing multiple strategies for making vehicles more fuel efficient, primarily focusing on weight reduction. DOE estimates a 10% reduction in vehicle weight can increase fuel economy by 6 to 8%. To date, most of the agency’s efforts to reduce vehicle weight have focused on technologies to replace steel with low density metals like aluminum (Al) and magnesium (Mg), or carbon fiber composites. However, these materials are more expensive than low alloy steel (Al $2.00/lb, Mg $4.00/lb, and carbon fiber composites $15.00/lb vs. steel at $0.50 to $0.70/lb) and their use requires billions of dollars of investment to retool factories.

Curiously, much confusion remains on what exactly a “lightweight” material is. To amplify the matter, one’s frame of reference causes even more difficulty. For example, an empty soda can leads many to think that aluminum is a light weight material. One could then question whether the density of granite (thought to be heavy) is more similar to steel or aluminum’s density? Most do not realize that their “heavy” granite kitchen countertops and supposedly lightweight aluminum cans are the same density, near 0.1 pounds per cubic inch. Simply stated, at the same solid volume, “heavy” granite and “light” aluminum have the same mass.

Some believe that low density materials are always the best lightweight solution. However, that is very often not true. After it is determined that a material can be formed into the configuration for necessary performance, the strength per unit mass becomes paramount in finding the lightest weight
(lowest mass) solution. The material that can form the component to function to specification at the least mass is the lightweight solution regardless of the material’s density.

Contrary to the notion that “steel is heavy”, advanced high strength steels (AHSS) with leading strength to weight ratio actually enables structural loads to be borne by less mass material than all other weldable metallic solutions. This strategy has the advantage of using low cost steel and avoids the near billion dollar expense of retooling factories. Significant effort has been expended over the last 30 years to develop high strength steels. Unfortunately, they have either required high levels of expensive alloying elements or tend to be brittle and unsuitable for automotive applications. Developing low cost, 1500MPa ultimate strength, room temperature form-able (RTF) steels with suitable formability and weldability for automotive applications has long been a goal of the steel and automotive industries. The desire for 1500MPa cold stampable steel demands the need for a paradigm shift in ferrous metallurgy development.

Flash Bainite, located in Metro Detroit, Michigan, has a 21 year history of forming COTS steel from CAD data to finished parts. Working through springback, cracking, and high cost concerns of existing AHSS, the Flash team began a quest to produce a steel more friendly to manufacturing processes based on commercial off the shelf (COTS) steel chemistry. Flash Bainite has developed an innovative steel heat treating process that requires less than 10 seconds to transform inexpensive and readily available mild steel into AHSS. With this process, steel is heated to over 1000°C in a few seconds, and then rapidly quenched to room temperature a few seconds later. Known as Flash® Bainite Processing, this globally patented variant of the heat and quench method is the first process capable of producing steels that combine extreme strength (1100 to 2100MPa), adequate ductility, component “form-ability” at room temperature, and weldability. The Flash Process favorably controls carbon migration, carbide dissolution, and heterogeneous microstructures to create ductile and weldable AHSS that is ideally suited for fabrication of many automotive components, impact beams, and even armor plate. In addition, Flash Processing can be performed at steel service centers and small scale component manufacturers because the compact equipment used in the process requires a minimal fraction of the capital investment needed for the continuous annealing lines currently used to heat treat steel ($1 to $5 million vs. $400 million).

Comparing Traditional Heat Treat and Flash Processing

Decades of research and many billions of dollars have been invested in the development of steels and other metallic materials that combine high strength with high ductility. Additional alloying elements such as manganese, nickel, chromium, molybdenum, boron, titanium, vanadium, and niobium, and specialized thermal mechanical processing can be used to modify the characteristics of steel, but the fundamental tradeoff between strength and ductility persists, even with the most advanced alloys and production processes. To create AHSS, most often a $400M, seven story tall continuous annealing line (CAL) draws a kilometer of steel through a maze of rollers carefully maintaining the sheets temperature for many minutes prior to quenching. Due to the roller system, thicknesses of 3mm are not possible in the only the handful of CALs in operation around the world. As a result, the search for a cost effective iron alloy and energy efficient process to produce steels with high strength and ductility has remained a challenge.

When iron alloys are heated to temperatures generally above 800°C, a crystalline structure of iron known as austenite is formed. This crystalline structure can contain more carbon than the crystal structure present at lower temperatures. As the iron alloy cools, carbon diffuses from the crystals and austenite converts into a matrix of various microstructures. Depending on the time and cooling rate used to cool the steel, ferrite, pearlite, bainite, martensite, and other microstructures can form. Ferrite and pearlite are relatively weak but ductile. Bainite is a strong yet relatively ductile microstructure, while martensite is a harder, stronger, less ductile microstructure. The rate of cooling and alloy content of the steel determine the relative proportions of the microstructures, which in turn determine the mechanical properties such as hardness, tensile strength, and ductility of the processed steel. Traditional steel heat treating is designed to produce a uniform, homogeneous distribution of microstructures and chemistry. This is accomplished in sheet and plate products with lengthy exposure times of several minutes or hours to elevated temperatures in the range of 850 to 950°C.

Contrary to current steel processing technologies, Flash Bainite has discovered that the mechanical properties of steel can be improved by maintaining a varied and random distribution of microstructures and carbon concentrations. With Flash Processing, induction heating is used to rapidly increase the temperature of an iron alloy to over 1000°C to form austenite and quenched substantially immediately to control and limit carbide dissolution and carbon migration. Rapidly reducing the temperature controls the formation of martensite and bainite from the heterogeneous austenite. The entire process requires less than 10 seconds.

Flash’s rapid thermal cycle preserves heterogeneous microstructures because kinetically sluggish processes do not have time to homogenize the chemistry of the austenitic microstructure. The result is a heterogeneous, composite metal matrix of chemistries that each provides a different advantage. The low carbon regions are readily weldable and ductile while the high carbon regions are strong and hard. In particular, Flash Processing of commercial available chrome-moly (AISI41XX series) steels produces especially strong composite microstructures while plain carbon (AISI10XX series) steels produce highly form-able microstructures.

Flash Processing can be controlled to produce a matrix of approximately 75-80% martensite and 20-25% bainite. Since the 1980s Academia has known this 80/20 or 75/25 ratio will yield what is considered “maximum strength” steel for a given iron alloy, but a process to consistently produce this microstructural mixture from lean alloy steel has not been available. Flash Processing is the first process capable of producing cost effective steels that combine extreme strength, form-ability, and weldability. While martensite does constitute
the majority of the result, bainite is the unexpected constituent from which the Flash technique receives its name.

Transmission electron and scanning electron microscopy analyses of Flash® processed AISI8620 sheets revealed the presence of an evenly distributed mixture of an estimated 20% bainite within a martensite matrix [1]. A transmission electron micrograph of typical bainitic sheaves in the Flash® processed sample is shown in Figure 1. Details of this microstructure have been published elsewhere by Lolla et al [1]. Traditional continuous-cooling-transformation (CCT) and time-temperature-transformation (TTT) diagrams suggest that such a bainitic microstructure cannot be attained during such rapid quenching conditions. The cooling rates measured during Flash® processing are much faster than the allowable critical cooling rate to nucleate bainitic microstructure when considering the bulk chemistry of the steel.

Fig 1: TEM showing AISI8620 bainitic sheaves

To rationalize this discrepancy, Lolla et al have proposed a mechanism for the formation of mixed bainite and martensite microstructure. This theory suggests rapid heating of steel with ferrite and pearlite initial microstructure leads to an austenite with inhomogeneous carbon concentration. In specific, a paraequilibrium condition exists in which prior ferrite becomes carbon lean austenite while prior pearlite becomes carbon enriched austenite. Minimal carbon diffusion occurs during a several second duration above the upper austenitization temperature thus carbon homogenization does not occur. Later work has shown that austenite grains with a 0.02%wt C and 0.3%wt Cr chemistry can transform to bainite at cooling rates exceeding 1000ºC s⁻¹. The carbon-enriched austenite in prior pearlite regions will be of comparatively much higher carbon content. During quenching, the bimodal carbon distribution in the austenite transforms into the two distinctly different microstructures of bainite and martensite. The bainite and martensite regions are homogeneously distributed completely through the steel thickness. This is not just a surface treatment with samples up to 9.5mm thick able to be through hardened.

Figure 2 and Table 1 provide a detailed profile of the typical Flash Process. The thermal cycle induced in the steel and “through thickness” strengthening are the significant advantages of Flash Processing compared to existing induction heat treatment technology and oven processes. The success of the process requires precise control of temperature variations during the thermal cycles to produce the desired microstructure in the final material.

Table 1: Description of Structural Changes in a Metal during Flash Processing

<table>
<thead>
<tr>
<th>Process Steps</th>
<th>Structure Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region I: Preheat</td>
<td>Steel is preheated to about 200°C due to thermal convection.</td>
</tr>
<tr>
<td>Region II: Rapid</td>
<td>The rapid increase to a temperature of over 1000°C promotes the formation of</td>
</tr>
<tr>
<td>Temperature Increase</td>
<td>austenite.</td>
</tr>
<tr>
<td>with Induction Heating</td>
<td></td>
</tr>
<tr>
<td>Region III: Controlled</td>
<td>Austenite forms with multiple carbon</td>
</tr>
<tr>
<td>High Temperature</td>
<td>concentrations present in grain sizes from 5 to 7 microns.</td>
</tr>
<tr>
<td>Exposure</td>
<td></td>
</tr>
<tr>
<td>Region IV: Water</td>
<td>The rapid, controlled cooling rate limits carbon diffusion leading to the formation</td>
</tr>
<tr>
<td>Quenching for Rapid</td>
<td>of a complex heterogeneous mixture of low carbon</td>
</tr>
<tr>
<td>Reduction to Room</td>
<td>ductile bainite and high carbon strong</td>
</tr>
<tr>
<td>Temperature</td>
<td>martensite.</td>
</tr>
</tbody>
</table>

The cost effective Flash Process shown in Figure 3a is compared to a seven story tall continuous annealing line, shown in Figure 3b. Flash Processing does not require time consuming thermo-mechanical production processes or capital intensive equipment to achieve its unparalleled results. While the Flash Process line will need added material handling equipment to the shown depiction, it is obvious that less physical equipment is required to perform the Flashing. Flash Processing uses recent innovations in induction heating and computer modeling to define the parameters for a particular grade of steel and desired mechanical properties.
Figure 4 is an enhanced US AMP #LM080 strength/elongation chart. Flash Processed steel grades have a unique combination of high strength and form-ability that is well suited for forming many automotive parts. Flash Processing contradicts the long held assumption that as steel becomes stronger, because of its increased martensitic content, it becomes more brittle (i.e. less ductile) and thus more susceptible to fracture. In the case of Flash Processed steels, higher strength does not come at the expense of reduced ductility. At strengths from 1100 to 2100MPa Flash steels maintain 9 to 11% total A50 elongation. The highest strength Flash steels are as ductile as other steels that are only 60 to 70% of Flash’s strength. In addition, Flash processed steels at 1900 to 2100MPa are more than twice as ductile as limited production martensitic steels of the same strength.

Welded steels typically fail where the steel has been reheated during welding, an area known as the heat affected zone (“HAZ”). A typical HAZ in AHSS is shown on the right as performed by Edison Welding Institute. The left side of Figure 5 shows the HAZ for a weld between pieces of Flash Processed AISI4130. The colors depict hardness within the weld with red representing the harder areas and violet representing the softer areas. The bulk steel outside of the HAZ (not shown in the figure below) is predominately orange.

In AHSS steel on the right of Figure 5, the interface between the bulk metal and the weld, known as the “fusion line”, is very hard as depicted by the deep red color. The extreme hardness of the fusion line is caused by a homogenous martensite structure which is very brittle and the primary source of weld failure. The blue/violet area in the center of the HAZ of the AHSS weld is softer than the bulk material and not the source of embrittlement. As a result, AHSS welds can separate and fail because the central blue/violet area remains on one steel part, while a hole is created in the other steel part upon weld separation.

Flash Processed steel has a unique HAZ because it does not develop a fusion line hardened into brittle martensite. As can be seen in the hardness mapping on the left side of Figure 5, the Flash Processed steel is softest in the center of the HAZ and gradually increases hardness moving outward into the bulk Flash steel being welded. This leads to welds on Flash Processed steel that are more ductile and less prone to brittle trimming, remain unchanged, if not less intense. Flash® steels up to 0.40wt% carbon have been found to be readily weldable at room temperature, not requiring any preheating or post tempering. Welding tests have found no signs of embrittlement after weld bending tests were performed. The proposed reason that a steel with a bulk chemistry of 0.40% wt C is readily weldable is that the prior ferrite areas being very low in carbon initially would likely remain with concentrations of less than 0.20%wt carbon after processing. A majority of the prior austenite grains are lean, low carbon steel alloy similar to AISI1010 or 1018, both known to be readily weldable.

As Flash® Bainite is made from COTS lean alloyed steel, manufacturing processes such as welding, painting, and laser
failure under high loading conditions when compared to other AHSS steels.

The True Meaning of A “Lightweight” Solution is NOT Low Density Metal

There is significant undocumented confusion when the topic of metallic strength and the term “lightweight” is discussed. The only true method to determine a metallic’s functional strength to failure is to review its “specific” strength. Specific strength is a metallic’s tensile strength divided by its density. This methodology normalizes all metallics to produce a strength to weight ratio. Jones and DeLorme point out in Figure 4 of their work that “specific” strength is more important than an individual metallic’s strength per unit area, typically measured in MPa [2]. They determine that magnesium AZ31B is, on a per mass basis, is stronger than 5083 aluminum even though the 5083 aluminum has 33% higher strength measured in MPa. Comparing the specific strengths of Automotive HSLA at 570MPa, aluminum at 370MPa, martensitic M1300 (MPa), Hot Stamp 1500 (MPa), Flash 1550(MPa), titanium-6Al-4V at 1000MPa, Flash® AISI4130 at 1850MPa, and Flash® AISI4140 at 2050MPa shown in Figure 6, long held notions of what a “lightweight” metallic is are proven to be incorrect.

Crash Member Automotive Applications

Development of AHSS for automotive applications falls into two general categories. The first developmental focus is for increased formability in the range of 15-30% A50 total elongation while maintaining strength from 1000 to 1500MPa. These applications usually rely on a retained austenite constituent to increase formability. The austenite will work harden to martensite during the stress of forming parts in a stamping die to gain ultimate strength. Fully hardened Flash Bainite does not possess a large retained austenite constituent but alloys have been cast to investigate such a possibility. The second developmental focus is for maximum strength with reasonable ductility. At present, the Steel Industry produces dual phase steels up to 1180MPa with guaranteed elongation of about 10% in the rolling direction. While typical elongation is usually more, it is not near the 15% aforementioned. When fully martensitic steels are considered, strengths can range from 1400MPa to 1900MPa but guaranteed elongation drops to about 4 to 5%. Many of these steels have boron included in the chemistry, hence called boron steels. These steel offerings are of limited use due to their reduced ductility. There is limited availability of martensitic steel above 1200MPa due to mill capacity and demand.

To improve automotive crashworthiness in side impact events, boron tubing has been used by many Auto OEMs. Hyundai Motor Group, in its quest to ever increase automotive performance, has sought out higher performing steels as well. Hyundai researchers had interest in testing Flash® Bainite at 1800 MPa against the performance of boron steels as car door impact beams [3]. To fully compare other OEMs work, Hyundai disassembled door beams from five other highly rated current production cars.

A testing regimen was developed using the US Side NCAP pole test. Maximum displacement was limited to 200mm. This could represent 75mm of door thickness reaching to the door inner decorative panel and then 125mm of further intrusion into the passenger compartment. The OEM door beams were tested in the sizes that other OEMs had selected to use as shown in Figure 7. Resisting force is plotted against the displacement as the tubing is deformed during impact. Various diameters of Flash® Bainite tubing were selected between 25 and 32mm. Tubing wall thickness was varied from 1.6mm to 3.0mm. Figure 8 shows the Flash tubing performance at various diameters and wall thickness compared to OEM #1’s 32mm diameter tubing at 2.2mm wall.
Based on the displacement versus resisting force findings, relationships were plotted showing the different diameters tested for each wall thickness. Figure 9 (left) clearly illustrates that 32mm diameter Flash tubing has higher resisting force than the boron tubing for a given wall thickness. Approximately 15% or more resisting force is provided by the Flash tubing for the 32mm diameter tubing size at the exact same mass per unit length. As well, 32mm and 28mm Flash tubing have higher total energy absorbed for a given wall thickness than 32mm boron tubing as shown in Figure 9 (right). More than 20% or more total energy absorbed is provided by the Flash tubing size at the exact same mass per unit length.

It is well understood that a larger diameter tube should be stiffer than a smaller diameter when both tubes have the same wall thickness. Based on this data, Flash Bainite tubing has the ability to absorb notably more energy than boron tubing even when the Flash tubing is 12% smaller diameter than the boron tubing, i.e. 28mm vs 32mm. The boron tubing was tested to have about 8% total elongation while the Flash® tubing has tested at 9-10% total. This increase in elongation is credited with the improve crash performance of Flash® Bainite tubing.

![Fig 9: Flash® and Boron Tubing Resisting Force vs Wall Thickness (left) and Total Energy Absorbed vs Wall Thickness (right)](image)

Flash Bainite tubing has been made in round, square, rectangular, and custom geometries. Such geometries lend themselves to many transportation related components. In passenger vehicles, bumpers, roll bars, roof members, pillars, frame rails, hitches, and many other parts have been made with tubing and could be made with Flash Bainite. While the energy absorption capacity of Flash Bainite tubing is further documented, the formability of Flash Bainite tubing will lend itself to making tubing components that are considered impossible today. Hydroforming of tubes is currently limited to dual phase steels at a strength of 1000MPa known as DP1000. Flash® Bainite at 1500MPa has been shown to form the same components in the same tubing geometry as DP1000. This will lead to more robust, lighter structures with a 1/3 mass reduction.

**Cold Stamping of Flash® Bainite Sheet**

In thinner gages, most sheet steel will have less total elongation than the same alloy and microstructure of that steel in thicker sections. This phenomenon holds true in Flash Bainite as well. While 2 to 3mm thick samples will have total A50 elongation of 8 to 10%, a 1.2mm thick sample will only have 6-7% total elongation. Conventional wisdom would lead one to believe that 6% is not enough elongation to room temperature form components of difficult complexity in a stamping die. At 1100MPa to 1600MPa UTS, Flash Bainite sheet has been found to be highly formable to Zero-T and 1T bend radii, unexpected based on the 6% total elongation.

To date, development of ductile, highly formable 3rd Generation Advanced High Strength Steel at 1200 to 1500MPa has focused on the need for a retained austenite phase to increase the initial ductility of the steel during room temperature forming. Upon completion of the forming of the part, the retained austenite would transform to martensite due to the deformation stresses induced in the steel. To achieve 3G-AHSS with retained austenite, costly additions of manganese, nickel, and other elements have been alloyed in the steel chemistry during testing at the university laboratory scale. Additionally, capital intensive thermo-mechanical processing requiring typically more than five minutes has been proposed to bring 3G-AHSS to realization. Performed in a continuous annealing line, three to five minutes of just austenization would be used to homogenize the steel prior to quenching. As the austenization occurred, the alloying elements including carbon and manganese would be homogeneously distributed in the austenite. After quench initiation, attempted processes require even more minutes to complete. Historically it has been believed that a homogeneous chemistry down to the micron scale is needed to develop uniform properties in steel.

The development of Flash Bainite occurred at the near-meter scale in the form of tensile, welding, ballistic, and forming tests. It is proposed that since steel is formed, welded, and used in hundreds of millimeters, not microns, that uniform properties tested at a scale four orders of magnitude larger is sufficient. Only after a desirable product was developed was the transformation mechanism identified to explain the performance of Flash Bainite.

The lean-ness of the majority prior ferrite constituent of Flash Bainite has led to further product optimization. While other 3G-AHSS increases alloy content and dislocations in the steel, Flash Bainite obtains desirable results with leaner steel and thus fewer dislocations. With plain carbon steels such as AISI1010 and AISI1020, it is believed that few dislocations, once Flashed, create a previously unknown high level of formability.

Starting with Flash® 1500 (at 1550MPa) made from COTS AISI1020, numerous parts have been room temperature formed (RTF) using conventional stamping equipment. Conventional “two piece crash forming” dies were CNC machined at increasing levels of complexity. Generally speaking, the tooling was for prototype quantities and thus made of only AISI1018 steel blocks or hot rolled plate. Figure 10 shows the tooling being CNC machined and mounted in a 350 ton hydraulic press to stamp a B-Pillar. The B-Pillar was scaled to 3/4 of its original size and had five reinforcing darts added at the top of the part to increase difficulty. At 3/4 scale, the male forming radii were tighter and more difficult to form.
(ie 4mm bend radii became 3mm bend radii upon scale-down). Figure 11 showing the plan and side views of the 200mm x 1100mm laser trimmed B-Pillar. It is believed that this is the first ever room temperature formed steel B-pillar at 1550MPa from a 98%wt Fe alloy.

Figure 13 shows a proposed automotive “crush can” application for Flash® 1500 that is part of an ongoing research project. Tubing of 63mm diameter and 1.2mm wall thickness has been formed into two different configurations. The first was a 50mm x 60mm rectangle at a length of 140mm. The second rectangular shape of 40mm x 70mm collapsed straighter in initial testing. The photo at right is of the crush can Wire EDM-ed in half to reveal the 0T to 1T bend radii made during the crushing of the tube from 140mm in length down to 50mm. It should be noted that typical auto crush cans are made of either DP780 steel or aluminum tubing and hydroformed into shape. Further investigation is underway to confirm energy absorbing properties.

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Multiple other seating components have been RTF stamped in piece crash form prototype tooling. Figure 12 shows five different seating components stamped with Flash® 1500.

Figure 11 showing a 3/4 scale B-Pillar laser trimmed to a size of 200mm x 1100mm

Figure 12: Five different seating components stamped with Flash® 1500

Figure 14 shows an example seating component known as a seat track foot. The foot is typically welded to the seat track rail and bolted to the floor of the vehicle. In this case, 3mm thick Grade 60 steel at 420MPa was called out for use by the OEM for the prototype study. In comparison, separate tooling was made for a 1.2mm thick Flash® 1500 variant of the foot. The Flash® 1500 foot is only 40% the mass yet 50% stronger than the Grade 60 foot. It should be emphasized this was only a formability study and no fatigue or other performance characteristics have been tested to date.

Figure 13 shows a research project for an automotive “crush can” made of Flash® 1500.

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Flash® 1100 at 2.1mm thick can be formed to a 90 degree bend with a 3T radius, then closed to 180 degrees at a 2T bend radius, and then ultimately hemmed closed to a 0T bend radius as shown in Figure 15. Flash® 1100 has potential for use in “progressive” forming dies. A typical “progm die” could consist of 3 to over a dozen forming stations, all mounted on the same die shoe, that a strip of steel is fed through. Typical feed stock for Prog Dies has been of notably lower strength due to the work hardening experienced in the AHSS. Problems would arise during the multiple “hits” in the Prog Die in which the
AHSS needed to be formed to its final shape in the first forming operation, which does not occur in Prog Dies. Flash® 1100 appears to overcome this.

![Image](image.png)

**Fig 15**: 2.1mm thick Flash 1100 formed to 90° 3T bend, closed to a 180° 2T bend, then hemmed in a Press

**Conclusions**

Because steel is widely used in the automotive industry, the use of ductile and readily weldable Flash® 1500 can significantly reduce the lifetime energy consumption of millions of vehicles. Flash Processing can reduce costs to automotive OEMs, because the small increase in the per pound cost of Flash Processed steel is more than offset by the fact that less steel is required to produce a component. Flash Processing equipment uses induction heating technology made by dozens of manufacturers across the United States. Flash Processing can be performed with compact, low capital cost equipment which will significantly expand the number of US entities that can produce 1100 to 2100MPa AHSS. Finally, Flash Processed steel will also benefit other industries, including construction, where low cost high strength steel can reduce material requirements.

In summary, the key benefits of the Flash® Bainite Process in steel manufacturing are:

- Simultaneously combines high strength and high formability in the material
- Enhances welding characteristics with less severe heat affected zones
- Performance benefits can be achieved with a wide range of existing grades of steel
- Can eliminate the need for expensive alloying elements
- Does not require time consuming thermal mechanical production processes
- Simple process reduces complexity of production equipment and capital intensity
- Suitable for direct conversion to AHSS by small and medium scale industrial facilities
- Process is well defined and readily available for immediate deployment

When designing automotive structural applications, it is paramount to fully understand the specific structural strength of all potential solutions to design, per mass, the lightest, most robust vehicles. Flash® Bainite has surfaced as the leader in specific strength surpassing all other readily weldable metal solutions. Impact testing to determine crashworthiness has found Flash® Bainite to outperform the best boron steels available to Industry today.

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**References**


