EXECUTIVE SUMMARY

ULSAB-AVC

Advanced Vehicle Concepts

January 2002

Executive Summary

Figure 1: European C-Class

The ULSAB-AVC (Advanced Vehicle Concepts) Program is a study undertaken by the global steel industry to showcase the latest high-tech steel grades for automotive applications—Advanced High-Strength Steels (AHSS). This study reveals that use of new AHSS grades in vehicle architectures will provide an unprecedented high level of crash safety performance at no cost increase. At the same time, use of these steels will enable automakers to reduce the environmental impact of their vehicles through increases in fuel economy, significant source reduction, and steel's inherent ease of recycling.

Figure 2: North American Midsize-Class

ULSAB-AVC demonstrates high volume, steel-intensive concepts, Figures 1 and 2, for the popular. European C-Class and the North American Midsize-Class (referred to as the PNGV-Class). These designs represent just one possible approach for applying the unique properties of AHSS steel, providing engineering insight into their broad use in vehicles. The resulting concepts provide the foundation to develop vehicles that:

- Meet crash safety requirements anticipated for 2004 -
  - Five star crash performance in both the United States and Europe for:
    - full frontal (US-NCAP),
    - frontal offset (Euro-NCAP),
    - side impact (US-SINCAP), and
    - side pole crash.
- Can be manufactured affordably -
  - Manufacturing cost estimates ranged from $9,500 for the 4-door midsize sedan (PNGV-Class) with a gasoline engine to $10,200 for the same vehicle with a diesel engine. The body structure costs less than $1,000.
- Reduce the automobile's environmental footprint -
  - Gasoline engine version would achieve 52 mpg in U.S. combined driving cycle (48 mpg city/60 mpg highway), and the diesel variant would achieve 68 mpg in U.S. combined driving cycle (62 mpg city/78 mpg highway).
  - Made from steel, the most recycled material in the world.
  - Apply AHSS, using less steel to make improved, high-strength vehicle components.
- Are manufacturable –
  - AHSS's high strength and high formability result in increased component quality and strength.
  - Processes used to optimize the concept body structures, such as hydroforming and tailored blanks, are known, accepted technologies already in use by the auto industry.
- Use a common platform -
  - Two vehicle-class concepts sharing over 50 percent of components, totaling 22 percent of vehicle mass.
  - Additional ten percent of parts made from common dies.
- Are mass efficient –
  - Curb weights in the range of 1,000 kg (2,200 lbs.)
- Support consumer confidence –
  - Consumers believe steel is synonymous with safety. ULSAB-AVC offers steel-intensive vehicle designs.

Two important program drivers, which provided references for ULSAB-AVC target-setting, were:

- U.S. Partnership for a New Generation of Vehicles (PNGV)
- EUCAR (The European CO_2 reduction program).

AHSS - Key Enablers

Advanced high-strength steels are key enablers to the achievements realized in these vehicle concepts. These newly available high-tech steel grades exhibit a superior combination of high strength, crash energy management, excellent formability and dent resistance. They offer vehicle designers more freedom in how they address crashworthiness, packaging, styling and mass reduction.

The principal difference between AHSS and conventional high-strength steel (HSS) is in their microstructure. Conventional HSS is formed by adding certain alloys to the microstructure, whereas AHSS is formed by controlling the cooling rate of the steel. The resultant steel: (Figure 3)

(Continued)

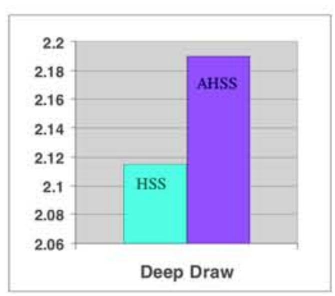

Figure 3: AHSS are highly formable steels

HSLA 350/450 DP 350/600

- Is highly formable while attaining high strain hardening capacity, which results in higher strength steel and excellent part forming.

- Can achieve even higher strengths through increased work hardening (i.e., stamping of a part) and bake hardening effects (i.e., post part-forming bake treatment or post paint-operation baking - Figure 4).

- Can be more easily applied to a broader range of component designs, with excellent forming while increasing component strength.

- Can often be substituted for thicker gauge, lower strength steels used in existing component designs with potentially no change in tooling dies.

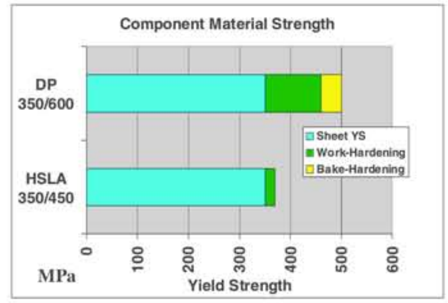

Figure 4: Component material strength comparison AHSS vs. conventional HSS

Crashworthiness

Since the ULSAB-AVC Program focused on steel vehicle applications for the year 2004 and beyond, the Program set crash requirement standards that, in some cases, are as much as 60 percent more severe than current U.S. and European crash requirements.

ULSAB-AVC vehicles incorporate unique steel design innovations to achieve five-star crashworthiness, including:

- Bodies-in-white (BIW) comprise more than 80 percent AHSS, with the remaining 20 percent high-strength steels. (Figure 5)
    - Components employ advanced technologies such as hydroforming and tailored blanks for optimized part design and reduced part count.
    - Combination of AHSS and manufacturing technologies results in body structures that contain just 81 major parts, contributing to structural efficiency and lower costs.

Figure 5: ULSAB-AVC Bodies-In-White; top shows C-Class (mass = 202 kg/445 lbs.); bottom shows PNGV-Class (mass = 218 kg/481 lbs.)

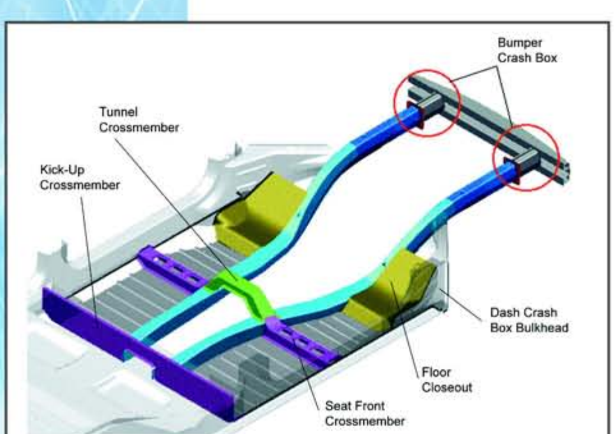

Figure 6: ULSAB-AVC floor pan with hydroformed longitudinal rails in blue

- Specific body structure examples of AHSS use are:
    - AHSS steel tailored tube front rails combining 1.3 mm and 1.5 mm thickness materials to optimize efficiency, mass and front crash performance. (Figure 6)

(Continued)

- Dash crash box structure, designed primarily to absorb energy in full frontal and 40 percent offset crash events. AHSS in this structure ensures that crash loads are widely distributed through the vehicle at reduced mass. (Figure 7)
- Fixed seat concept using AHSS seat crossmember and crossmember extension, providing the strength and rigidity needed to maintain passenger compartment integrity in side crash.

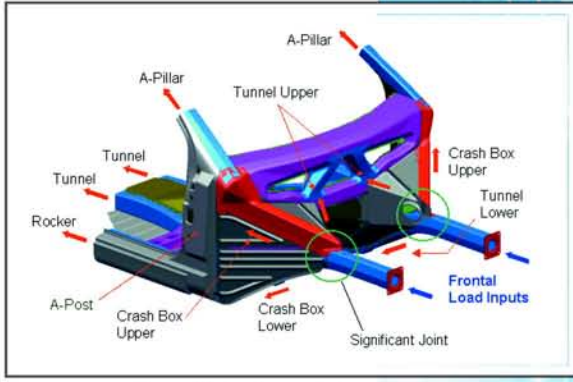

Figure 7: Dash crash box structure

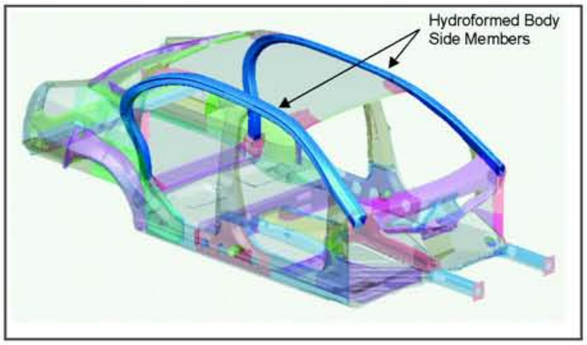

Figure 8: Hydroformed side roof rails

- AHSS hydroformed side roof rails that effectively disseminate crash energy along the roof at a reduced part count. This component, combined with an AHSS rocker section, creates the stable body side ring needed for side impact protection. (Figure 8)

Reducing Vehicle Environmental Footprints, Affordably

AHSS applications in automobiles yield significant benefits to the environment, while maintaining affordable manufacturing costs. ULSAB-AVC vehicles feature dramatic increases in fuel efficiency and reduction in CO_2 emissions. According to calculations using the U.S. Combined Driving Cycle (combination of city and highway driving) requirements. (Table 1)

U.S. Driving Cycle	PNGV-Class	
	Gasoline	Diesel
CO_2 emissions (Combined)** [g/km]	108	92
Combined** [mpg]	52	68
City [mpg]	48	62
Highway [mpg]	60	78

** Average automatic & manual shift modes

Table 1: Fuel Economy Results

ULSAB-AVC vehicles use either a gasoline or diesel engine and manual transmission with automatic gearshift actuator.

AHSS means less impact on natural resources:

- AHSS can be applied at thinner gauges than conventional steels for reduced overall vehicle mass, while actually improving component strength and maintaining crash performance. (Figure 9)
- Thinner gauges mean less steel tonnage is needed for high-volume manufacture.
- AHSS has the same recyclability attributed to conventional steel.
- Steel's recycling rate is far higher than that of any other material, capturing more than twice as much tonnage as all other materials combined.
- Steel's established recycling loop and the ease with which steel scrap is magnetically reclaimed helps today's designers make end-of-life total vehicle recycling a vital part of product planning.

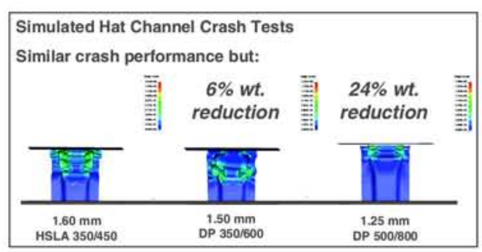

Figure 9: Dual Phase AHSS substitution for conventional HSS yields up to 24% mass reduction in this part example

ULSAB-AVC vehicles are steel-intensive designs, including suspensions, seat structures and wheels, as well as the BIW. Consequently, these vehicles offer the benefits of steel's well-known recycling heritage.

Big Benefits, Little Cost Impact

AHSS use has little impact on manufacturing costs, while offering high-tech advantages of higher strength with excellent formability. Table 2 compares:

- ULSAB-AVC PNGV-Class AHSS vehicle body structure investment with
- UltraLight Steel Auto Body (ULSAB), a high-strength steel body structure
- Reference Structure vehicle, representing current body structure costs.

Tooling investment is perhaps the most interesting evidence of ULSAB-AVC's affordability, with a cost savings of about 40 percent over a conventional vehicle.

Body Structure Cost, $	ULSAV-AVC PNGV	ULSAB	Reference Structure
Steel Cost	468	416	369
Forming Cost	213	250	282
Assembly Costs	291	281	328
Total Body Structure Costs	**972**	**947**	**979**
Tooling Investment Cost	**40.3 M**	**51.2 M**	**68.0 M**
Parts Count (Major Parts Only)	**81**	**96**	**135**

Table 2: Body Structure Manufacturing Cost Assessment

Table 3 summarizes the total vehicle manufacturing costs:

System	Gasoline, $	Diesel, $
Parts Fabrication Cost	8,123	8,863
Assembly Cost	1,375	1,375
Manufacturing Costs	**9,538**	**10,238**

Table 3: Vehicle Manufacturing Costs

These manufacturing costs include:

- $1,400 BIW manufacturing cost.
- $580 approximate BIW steel material cost.

For as little as 15 percent of the total vehicle cost, the BIW concept designs offer optimized body structures that meet considerably more aggressive safety requirements than applied in any other vehicle structures and are fully recyclable.

Affordability Comparison

An analysis (Figure 10) comparing ULSAB-AVC PNGV-Class diesel-powered vehicle variant (in accordance with PNGV criteria) with other PNGV-related concepts, as well as current Midsize vehicles, revealed manufacturing costs that are:

- One-third to one-fifth the projected selling prices of PNGV diesel hybrids.
- One-half the projected selling price of current Midsize gasoline vehicles.

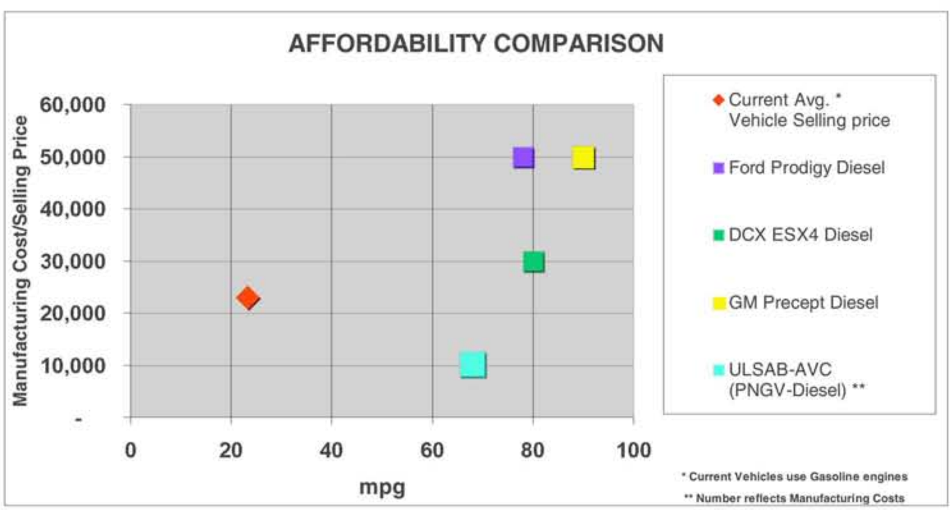

Figure 10: Affordability Comparison

The ULSAB-AVC PNGV-Class vehicle offers design options for achieving improved fuel economy and superior crash performance in high volume production vehicles that can be sold profitably at competitive prices.

ULSAB-AVC

Advanced Vehicle Concepts

ULSAB-AVC offers near- and long-term solutions for affordable, safe and environmentally responsible vehicles. AHSS and related manufacturing technologies provide the means to develop vehicle architectures that are safe and efficient at reduced mass and affordable costs.

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