Report on the Importance of Steel in Future Automobiles

Overview
AISI conducts research with its member companies and automotive customers to advance the use of steel in future vehicles through its business unit, the Steel Market Development Institute (SMDI). SMDI places a high value on the automotive market for steel. Today, the average vehicle in North America contains about 60% steel. Remarkably, the types of steels used in new models are considerably different from the steels used only a decade ago to build light vehicles. It is this continuous change in steel technology that enables steel to respond to the ever-increasing demands of vehicles such as the escalating crashworthiness and fuel economy requirements. Advancing steel technology within our North American steel companies and car companies is key to the health and growth of two industries vital to our economy – autos and steel. In fact, over the last 10 years vehicles have changed dramatically in how they are built and how they perform. One important contributor to the increased safety and ever-increasing fuel economy is the growth of new advanced high-strength steels (AHSS) that have made today’s modern vehicles into high-strength cars and trucks.

Manufacturing Competitiveness – North American Steel and Automotive
The average American is unaware of the relative state of technology of U. S. steel and automotive companies. When it comes to steel, a prevailing opinion by many U. S. citizens is that the U. S. steel industry is non-competitive in a global sense. Nothing could be further from the truth. One index of manufacturing technology is the state of automation of North American steel mills versus the rest of the world. North American steel mills operate at less than 2.0 man-hours per ton, a common index of labor productivity, and a measure of the level of automation and technology in the manufacturing process. This productivity level is among the best in the world. The energy intensity per ton for North American steel has been reduced by over 60 per cent in the last 25 years and by over 33 percent since 1990. In fact, if every sector of the U. S. economy had achieved this level of energy improvement, the U. S. would have exceeded the targets of the Kyoto protocol.
On the automotive side, one measure of technology is the usage of the latest steels in building crashworthy and fuel-efficient vehicles. A recent industry survey by Ducker Worldwide showed conclusively that the North American carmakers (Detroit three and New Domestics including Toyota, Honda, Nissan, Hyundai, Mercedes, BMW and others) are incorporating the newest high strength grades so fast so that these new steels are the fastest growing material in today’s vehicles. The rapid growth of AHSS (advanced high-strength steels) and UHSS (ultra high-strength steels) are shown in Figure 1.

Steel-intensive vehicles are well established as the lowest cost material to provide all the structural requirements of today’s vehicles. It is in the best interest of both industries to encourage collaborative work among companies and industries to ensure that North American steel and automotive manufacturing can remain competitive. This collaboration can occur in several ways. Of course, the normal supplier-customer relationship between steel companies and car companies allows technical transfer of steel technology to occur in the normal course of business. Another pathway that is more cost-effective is to conduct cooperative work on pre-competitive issues in order to reduce the cost of solving such problems as individual companies. Programs like the Auto/Steel Partnership (A/SP), which has been in existence for more than 20 years, have undertaken projects that represent common challenges among all car companies and steel companies. Past issues which have been addressed effectively by this group have included welding practices for high-strength steels, stamping guidelines, and uniformity of steels, for example. Current members of A/SP today are Chrysler, Ford, GM, ArcelorMittal, Nucor, Nucor, Severstal NA, and U. S. Steel.

Changes in Automotive Steels Now and for the Future

Figure 1  The average amount of UHSS and AHSS in North American light vehicles in 2005, 2007 and (estimated) in 2009, from Ducker Worldwide.
Automotive steels are often referred to as a “commodity.” They are anything but. In fact, automotive steels are among the most engineered materials on the planet. Over the last 40 years automotive steel grades have been invented and re-invented repeatedly as the requirements for newer, safer, more fuel-efficient vehicles have gotten more and more demanding. One illustration of the types of steel that have been applied to body and chassis structures over these years is shown in Figure 2. Each field represents a particular grade or type of steel, each with its characteristic strength, microstructure, formability, and role to play in optimizing vehicle structure. Steels in the upper left corner of the chart are traditional mild steels. As steels are added to the chart progressing to the right, the strength and mass reduction capability of the steel grades improve. The best steels for reducing vehicle mass are those at the right of this diagram (high strength). More parts can be made from these steels the higher up (more formability) they appear on this chart. Developing these many grades has required over 30 years of development by the steel industry and the work is not yet complete. Because of this progress, however, steel remains the most used material in today’s vehicle, representing about 60% of the weight of the average vehicle on the road today.

![Figure 2](image)

**Figure 2.** Many types of steels, like those shown in each field in this diagram, have different strength-formability (elongation) combinations for use in various automotive applications. Source: AISI and National Science Foundation.

The work of developing these grades has expanded to include current research support by the National Science Foundation and U. S. Department of Energy in the area of the figure enclosed by the red ellipse. This field represents the promise of new metallurgical steel grades now under research at leading universities in the United States that will further increase the ability of steels to take mass out of cars and trucks.
History of Lightweighting of Vehicles and Steel - U.S. and Global Programs

During the Clinton-Gore administration the US Government encouraged car companies to develop fuel-efficient vehicles. In the 1990’s this encouragement took the form of support funding in the program entitled Partnership for a New Generation of Vehicles (PNGV). This time period saw aggressive research into lightweighting of vehicles in order to help to achieve a target of 80 miles per gallon. The research explored low density materials, and steel was excluded from the program. In the end, concept vehicle were produced that indeed achieved high mileage, but there was a problem. The technologies identified for the program were not affordable or feasible with known large-volume manufacturing methods.

During this same period, from early 1990s through 2002, the North American steel industry together with its global partners did not sit idly by. In fact, in order to prove that steel technology could be used to make affordable lower-mass vehicles, a project was initiated to study steel in lightweight bodies. This project, Ultra-light Steel AutoBody (ULSAB), was completed in 1998 through the work of Porsche Engineering Services and showed conclusively that high-strength steels could be used in a holistic design to significantly reduce the mass of car bodies. Additional studies were done on suspensions, closures (doors, hoods, etc.) and this work culminated in a lightweight vehicle concept program called ULSAB-AVC (advanced vehicle concept). This vehicle concept program examined what could be done with steel to improve the efficiency of an entire vehicle. This work showed that a steel-intensive vehicle could be produced with twice the fuel economy of benchmark vehicles of that time, at no increase in cost, and at equivalent or higher crashworthiness.

Today the global steel industry, with the assistance of AISI, has organized a new project under WorldAutoSteel to continue this work on future electric drive vehicles. This new global program called Future Steel Vehicle is now underway and will focus on making new vehicle architectures with steel suitable for electric drive cars and hybrids of the future. The steel industry is committed to answering the needs of one of its biggest customers, the automotive industry, by developing steels and steel technology to answer these future needs.

Interestingly, the U. S. Government now includes steel in its current work on FreedomCAR through the U. S. Department of Energy. AISI member steel companies part of the Auto/Steel Partnership (A/SP) conducting current research on high-strength steels through the administration of the U. S. Automotive Materials Partnership (USAMP), alongside manufacturers of composites and of low density metals. It is now well recognized throughout the world and in the U. S. government that meaningful improvement to vehicles can be achieved through the creative use of steel technology. By reinventing steels we are helping to reinvent the automobile. Partnerships such as A/SP (steel and auto), AISI (North American Steel), and
WorldAutoSteel (global steel) dramatically reduce the costs of such important engineering developments. The sequence of the global projects is shown in Figure 3.

![Figure 3](image_url)

Figure 3. Global steel projects establishing that high strength steels plus holistic design can save significant mass in vehicles.

Steel as a Green Automotive Material

The domestic steel industry has made tremendous strides in improving its own manufacturing energy efficiency. Through investments in technology and the widespread application of recycling, the North American steel industry has reduced the energy to produce a ton of steel by 33% since 1990, as shown in Figure 4. This improvement is more than twice the improvement target that would have been established for our industry according to the Kyoto protocol.
Life Cycle Analysis (LCA)

When examining the role that materials like steel play in determining the carbon footprint or “greenness” of vehicles, it is important to consider the full life cycle of the vehicle. Clearly, improvements in fuel economy measured in miles per gallon over the driving phase, as defined in the new CAFE regulations, will directly reduce energy use and CO2 emissions for the driving or “use phase” of the vehicle’s life. However, by ignoring the carbon consequences from certain technologies (like mass reduction through materials selection) used by car companies in order to comply with CAFE, it is possible for higher-energy and CO2-intensive materials and processes to offset the benefits achieved in the driving cycle alone. The full life cycle of a vehicle including the materials and processes used to make it must be considered, as described in Figure 5, if we are to have a meaningful effect on the reduction of energy intensity and CO2 emissions.

![Energy consumption per ton of steel shipped in the U.S. steel industry](image)

**Figure 4** Reduction in manufacturing energy per shipped ton of steel in North America

![Automotive Product Life Cycle](image)

**Figure 5** Automotive Product Life Cycle
Energy Content of Steel and other Automotive Structural Materials

Figure 6 shows clearly that steel is the lowest energy intensive material of all materials being considered to build a vehicle. A comparison of the CO2 required to make these same materials as described in Figure 7 shows the same result. By the use of a life cycle assessment calculation it is possible to determine the material with the lowest carbon footprint and energy intensity. As vehicles of the future become more fuel efficient, it will become even more important to understand the energy and CO2 emissions associated with manufacturing vehicles from the various structural materials including steel, aluminum, magnesium, and composites. In that way the true environmental impact of a materials choice for vehicles can be determined.

Figure 6  Greenhouse gas emissions from the production of various automotive materials.
**Figure 7** Energy required for the production of various automotive materials

**Conclusions**

Historically, steel has been important to the development and improvement in vehicles over the years. The significant contributions to vehicle structural efficiency and crashworthiness have made possible by the work of the steel industry in reinventing the types of steel available to answer the ever-increasing demands of the automotive industry. The rapid assimilation of these new steels has been made possible by the collaborative work among steel companies and car companies in North America and, indeed, in global steel programs where North American steel companies provide leadership and direction.

Because of steel’s ability to adapt to the needs of future vehicles, it will remain an important contributor to the advancement of future fuel-efficient and safe vehicles. Additionally, steel’s relatively low energy intensity in comparison to other automotive structural materials and its complete recyclability make it an ideal contributor to the low life-cycle energy and CO₂ emissions that will be demanded of our future fleet of automobiles.
As vice president - automotive applications for the Steel Market Development Institute, a business unit AISI, Ron focuses on advancing the use of steel in the highly competitive automotive materials market. His responsibilities include leadership of the Automotive Applications Council, a group of member steel producers, in automotive research, education and technology transfer activities. He also coordinates the steel input to the Auto/Steel Partnership and other steel-related consortia.

Krupitzer has held various research and production positions within the steel industry. His steel industry experience includes product development, formability research, and implementation of steel mill processes including calcium injection, controlled rolling and continuous casting of new steel grades.

Krupitzer has also held both engineering and manufacturing positions at Chrysler. He managed sheet metal engineering and high tech steel development in the Chrysler Materials Engineering Department. As a manufacturing senior manager, he was responsible for production and quality at Chrysler’s Warren Stamping Plant. He directed the effort to obtain initial ISO 9002 registration for the facility. He headed a TPM (Total Productive Maintenance) integration team to improve maintenance practices throughout Chrysler’s stamping division.

Ron joined AISI in 2001. He has been active in ASM International, the Engineering Society of Detroit, and the Society of Automotive Engineers. Krupitzer earned BS and MS degrees from in Metallurgy and Materials Science from Case Western Reserve University in Cleveland, Ohio.