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Technological Innovation of Automotive Steel Sheets Makers through the Early Vendor Involvement

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<목 차>

<요 약>

본 연구에서는 신차개발 과정에서 공급업체의 조기참여 프로그램을 통한 자동차용 강판 제조업체의 기술혁신에 대해 고려하기로 한다. 먼저, 치열한 경쟁 하에 놓인 자동차용 강판 공급업체의 생존전략으로 자동차업체와의 기술적 파트너십의 중요성과 함께 시장을 둘러싼 대내외 경영환경을 분석하고자 한다. 자동차산업의 신차개발 프로세스 단계별 기술적 목표를 명확히 제시하고 차체의 수명사이클에 근거한 최적 소재를 선정하기 위한 조기참여 활동의 필요성을 강조하고자 한다. 또한 자동차용 강판 공급업체의 최적 기술전략 수립 및 방향을 설정하기 위해 자동차용 소재시장에서의 철강재 위상을 제고하고, 핵심 기술목표를 도출하고자 한다. 마지막으로 자동차용 강판 제조업체의 핵심 기술로 고성형성 · 고강도강판 및 내식성이 우수한 도금강판에 대해 공급업체의 조기 참여를 통한 기술혁신 과정을 살펴보고자 한다.

Key Words : Technological innovation, Automotive industry, Automotive steel sheets, Supplier, Early involvement, Safety, Environment, Anti-corrosion

핵심어 : 기술혁신, 자동차산업, 자동차용 강판, 공급자, 조기참여, 지식, 강판, 안전성, 환경, 내식성

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I. INTRODUCTION

At the end of 19th century, fierce competition among steam engine, electric and gasoline engine vehicles was taking place in the automobile market. At that time, unsolved technical problems in a vehicle still existed in regard to matters of fuel, road infrastructure and high price. Key industries in a country, such as automotive and steel industries, began to rapidly develop around the beginning of 20th century. The market share of gasoline engine vehicles was increased overwhelmingly with the establishment of an infrastructure for the supply of oil fuel. With the rapid increase of automobile accidents in the late 1960s, the U.S. government established laws with safety regulations applying to vehicles.

Generally, industrial development causes serious social problems such as energy deficiency, air or environmental pollution. Issues of energy and the environment have emerged with the oil shocks of the 1970s and massive emissions mainly in the most vehicle-consuming countries such as the United States, Europe and Japan. It is known that oil accounts for about 38% of the world's energy consumption and 42% is utilized for road transportation (Breuer et al. 2000). Furthermore, about 84% of total energy consumed in the life time of a vehicle is used during driving and about 86% of CO2 causing global warming is emitted during driving (梶川義明 2000). In order to reduce emissions of CO2, Basel Convention in 1989 and United Nations Framework Convention on Climate Change in 1992 have been introduced as international conventions.

In these circumstances, the goals of automakers are to improve the safety of passengers and pedestrians and fuel efficiency, and at the same time to reduce the environmental load with low production costs, which are in a mutual trade-off relationship. In addition, functional performances and amenity quality such as driving agility, engine power, flexible transmission, and cornering, etc. are also pursued. World-leading OEMs deploy the technology management activities of planning, acquiring and exploiting technological capabilities in the perspectives of total systems in the corporate value chain. OEMs join in co-development projects in pursuit of new generation vehicles or engines such as fuel cell or hybrid vehicle engines and direct injections and alternative energy sources such as LPG and compressed natural gas.

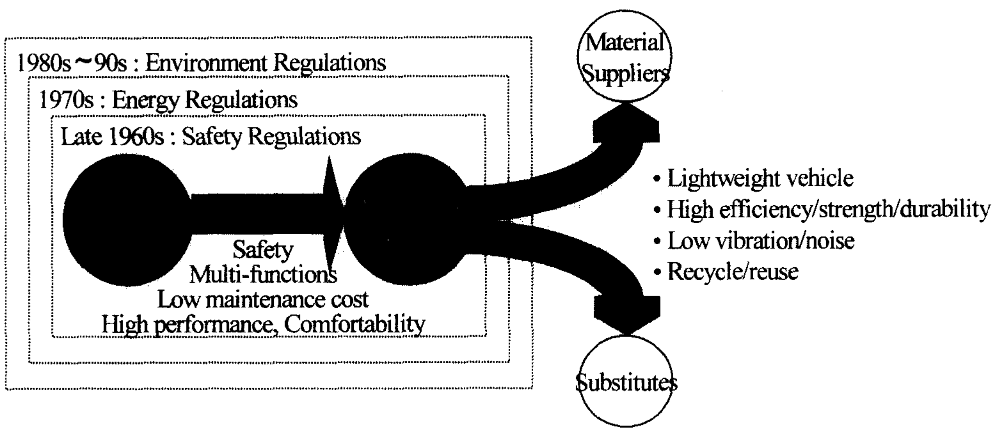
Potential factors having influence on the fuel consumption are the efficiency of components or vehicles, driving speeds, acceleration speeds, energy sources and utilization related matters such as driving infrastructure, traffic systems, driving attitudes, etc. The inertia resistance in the acceleration speed is directly related to the weight of a vehicle, and therefore, light materials, the optimal design of a model, and manufacturing techniques as influential factors should be considered for reduction of overall weight.

OEMs strongly urge tier-1 major suppliers to develop innovative technologies with gradual reduction in costs. Since the advent of automobiles, steel has played a major role in automotive body sheets with excellent functional properties such as strength, recyclability, formability, weldability, paintability, etc., as well as the merit of low cost. However, the automotive body sheets market is now completely open to all kinds of competitive substitutes satisfying the market requirements and regulations. In particular, light materials such as aluminum, magnesium, and plastic are highly focused as competitive materials for the luxury class of passenger cars.

As the survival strategy of automotive steel sheets suppliers in a fierce competition, this study considers the technological innovation of automotive steel sheets makers through early vendor involvement activities in a new model development. Firstly, managerial environments of automotive steel sheets suppliers are considered with the matters of partnership with automakers from a technological point of view. Then, based on the processes of a new vehicle development, technological objectives in the automotive industry are clarified and the selection of optimal materials based on the life cycle assessment is emphasized through the early-involvement activities. For the technology strategies of automotive steel suppliers, the status of steel in the automotive sheets market is reviewed and then, their key technological objectives are defined. Finally, the technological evolution in automotive steel mills is described in high strength steel with formability and coated steel for anti-corrosion through the early vendor involvement.

II. MANAGERIAL ENVIRONMENTS OF AUTOMOTIVE STEEL SUPPLIERS

OEMs continuously pursue both low costs of production and high performance and quality. As one their technological strategies, OEMs devote their best efforts to the adoption of optimal materials in each part of a new model. As time passes, vehicles are up-graded, and legal and social regulations in the safety and environment become stricter. Figure 1 shows some important characteristics of automotive body sheets required by automakers according to the environmental changes; that is, lightweight, high efficiency, strength and durability, and recyclability and reusability.



<Figure 1> Material Characteristics of Automotive Body Sheets

In the field of automotive materials, OEMs perform various technological activities such as developing innovative substitutes and new application parts by using conventional materials, improvement of physical and mechanical properties in conventional materials, processing technologies such as hydroforming and tailor welded blanking, etc. Expected effects may be fuel saving, improvement of comfort, expansion of life span and durability, crashworthiness, lower costs and high productivity, as shown in Table 1.

<Table 1> Material Development Activities of OEMs with Expected Effects

[redacted]	[redacted]
• New materials as substitutes	• Fuel saving by using lightweight materials
• Improvements of material characteristics and manufacturing technology	• Improvement of comfort and output of power - absorption of collision energy and noise
• Improvements of physical and mechanical properties	• Corrosion resistance, durability, safety
• Simplification and integration of manufacturing processes	• Low production cost and high productivity

During the 1990s, strategic alliances including mergers and acquisitions between global automakers, have increased the birth of 5~6 mega-mergers in order to achieve the economy of scale and overcome both trade and non-trade barriers in regional markets. As a purchasing strategy for raw materials, OEMs induce complete competition among material suppliers as well as substitutes so that they are positioned with a strong bargaining power against suppliers. Furthermore, they prefer the intensive purchasing from a fewer suppliers in the long-term contract system. In Table 2, the concentrations of raw material industries are compared, based on global market shares of the top 10 makers. The aluminum industry is more concentrated than the steel industry, where aluminum is a powerful substitute for steel in the automotive body sheets market. Note that iron ore is one of major raw materials for the steel industry and its top 10 companies dominate the global market with about 97% of market share. Thus, iron ore makers have strong bargaining power against steel mills. As a consequence, automotive steel suppliers are in a situation of tension between automakers and raw material suppliers.

<Table 2> Comparison of Industrial Concentration for Top 10 Suppliers

Industry	Platinum	Iron ore	Nickel	Copper	Aluminum	Steel
Market share(%)	98	97	95	50	49	27

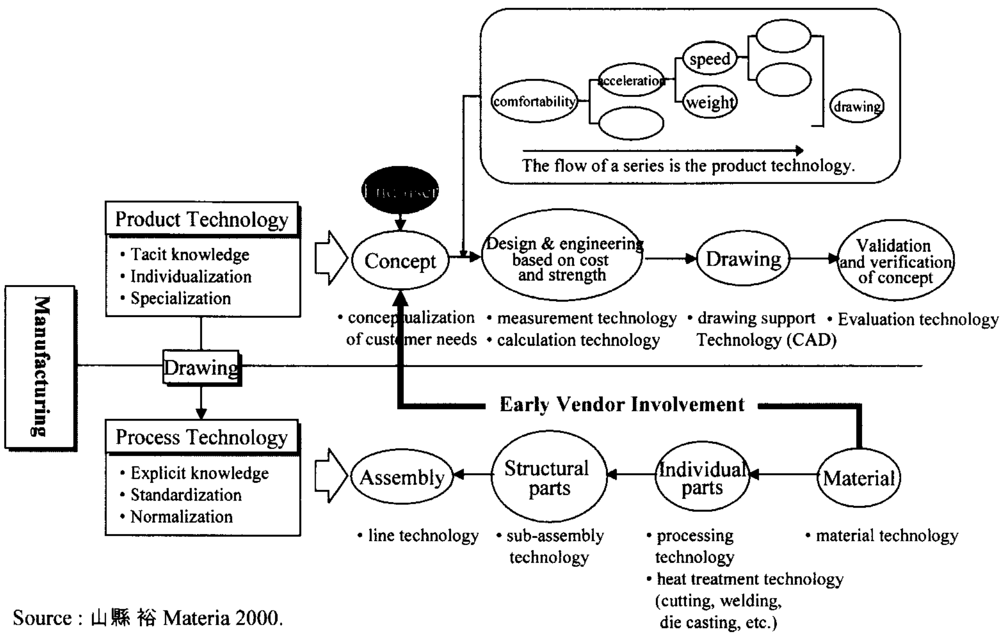
Source: Exane 2003, CRU 2003

In order to maintain the strong and stable supply chain network with the most steel-consuming industry, steel mills pursue the partnership with their major automakers. For mutual success through the win-win strategy, the automotive and steel industries in the United States pursue since the establishment of the Auto/Steel Partnership(A/S P) in 1987, in order to share the burden of R&D. Furthermore, the U.S. government organized a consortium of partnership for a next generation of vehicles including Big 3 U.S. automakers, components suppliers, national research institutes and steel mills in 1992 for the research and development of new vehicles technologies that are safer, stronger, and lighter 3 times more fuel efficient (www.pngv.org). This has been achieved nationally, in order to reduce the dependency of foreign crude oil imports and vehicle emissions. Furthermore, the competitiveness of the automotive industry was also pursued in order to recover their market share lost to foreign competitors.

III. TECHNOLOGICAL GOALS OF AUTOMOTIVE INDUSTRY

1. Processes of New Vehicle Development

Dr. Peter Wells in the Centre for Automotive Industry Research of University of Wales says that the Father of the modern automotive industry is Edward Gowan Budd, not Henry Ford as the general public may think. Since Budd developed monocoque manufacturing skills using steel, the mass production system of Dodge model with steel was developed first in the United States in 1914 (Steel Times 1997). In Figure 2, the procedure to develop a new model in the automotive industry is shown with product and process technologies. Product technology is generally composed of tacit knowledge in individualization and specialization. In contrast, process technology is composed of explicit knowledge in standardization. According to basic and engineering designs, appropriate materials for each individual or structural part are selected.

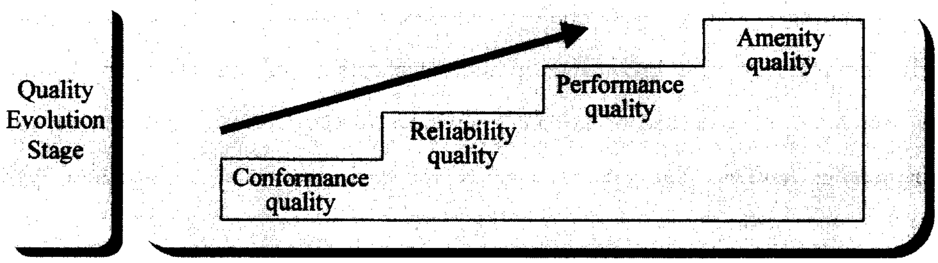


Source : 山縣 裕 Materia 2000.

<Figure 2> New Model Development in the Automotive Industry

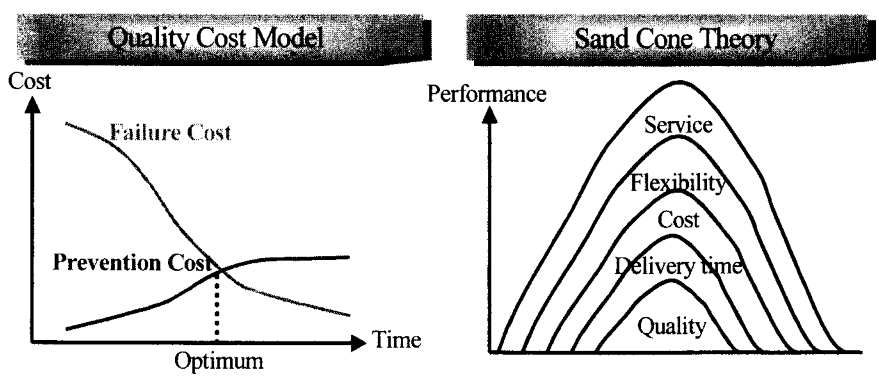
2. Technological Objectives in the Automotive Industry

According to the theory of a quality evolution for a product or service (Kim 1999), when the conformance quality is satisfied, a manufacturing company usually moves to improve reliability, and then the performance quality. Finally, it proceeds to the amenity quality, as shown in Figure 3. In length of time, a company in the automotive or steel industry moves to pursue upper stages such as performance and amenity qualities according to the industrial advancement and high level of customer needs.



<Figure 3> Evolutionary Progress of Quality in a Product or Service

In order to reach the conformance or reliability quality, technology standards in design and manufacturing processes are focused on for the satisfaction of engineering specifications. According to the failure decrease by the improvement of conformance or reliability quality, the failure costs like reimburse decrease while the costs to prevent failures increases, as shown in the left side of Figure 4. When the performance or amenity quality is achieved, the price of a product goes up due to the invested capital. That is, there exists a trade-off between the price and additional function. However, it improves the corporate value with the product differentiation. This is the ultimate goal of world-leading OEMs - to simultaneously pursue the performance and amenity quality of a vehicle in the minimum cost. In order to share the economical and technical burdens, OEMs try to achieve cost reduction as well as technological innovation through the partnership with their major suppliers.



<Figure 4> Quality Cost Model and Sand Cone Theory

According to the Sand Cone Theory in the right side of Figure 4 (Kim 1999), the performances such as delivery time, cost, flexibility and service can be accumulated on the basis of the quality competitiveness. Then, the effects can be maximized when the quality level of a product or service in a company is accurately identified with the most appropriate activities such as the 6 Sigma program and global quality management.

OEMs pursue the reduction of development time and production cost as well as high quality. Table 3 summarizes the objectives of automotive industry with detailed schemes at the main phases such as conceptual design, engineering and manufacturing, as shown in Figure 2. The corresponding roles of steel mills as one of the major material suppliers are also described. Based on this table, it is obvious that the early involvement activities of steel mills make a great contribution towards the automotive industry technically and economically.

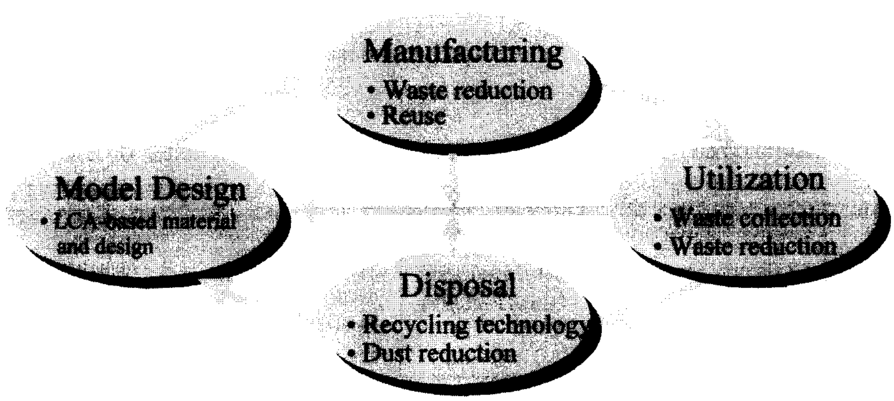
<Table 3> Technological Objectives of Automotive Industry with Roles of Steel Industry

Phase	Main Goals of Automotive Industry			Roles of Steel Industry
	Quality Improvement	Time Reduction	Cost Reduction	
Conceptual Design	• Performance/amenity quality - Size/style - Intelligent telematics - Advanced materials/parts	• Market trend search - Design forecasting system • CAD program	• Development time reduction • Optimal program/tool • Early vendor involvement	• Joint design through early involvement • Knowledge acquisition on markets and products • System understanding
Engineering	• Reliability quality • Legal/social regulations - Crashworthiness - High fuel efficiency - Low air pollution	• C3P program - CAD/CAM/CAE • Global specification	• Utilization of knowledge and know-how • Early vendor involvement • Concurrent engineering	• Joint engineering • Selection of optimal materials • Joint development of processing technology
Manufacturing	• Conformance quality - Optimal tool/process • Advanced technology - Tailor welded blanking - Hydroforming	• Modularization • Platform unification • Simplification and integration • Short-distance supply	• Unification/simplification of parts/platform/process • Concentrated purchasing with long-term contract • Outsourcing expansion	• Optimal logistics • Quick response for claims • Field support of engineers • Defect reduction

3. Life Cycle Assessment based Material Selection

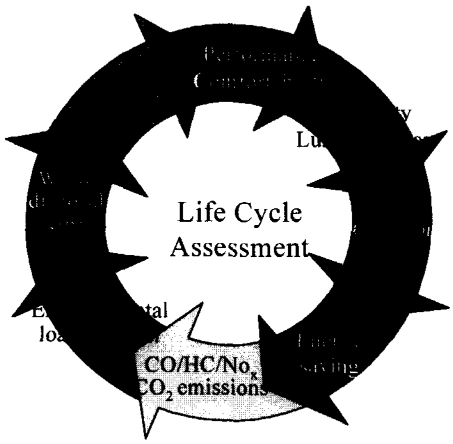
The earlier optimal materials are selected, the more production cost and development time are reduced. If critical failures or corrections caused by materials occur during manufacturing processes, basic and detailed engineering designs might be reworked, even with fundamental changes such as the conceptual design. Recently, automakers adopt the early vendor involvement (EVI) program in order to induce the participation of tier-1 suppliers in the beginning stage of a new model development through the concurrent engineering and value engineering. Therefore, it is desirable that materials suppliers are involved in the concept of Figure 2, no later than detailed engineering design.

The selection of optimal materials should be considered based on the end-of-life vehicle (ELV) from model design to disposal, as shown in Figure 5. Recently, the phases of utilization and disposal are emphasized according to the adoption of the law of product liability.



<Figure 5> Material Selection based on the End-of-Life Vehicle

In order to satisfy environmental regulations in domestic and global markets, Toyota pursues 3R - recycle, re-use, and reduce - environment technology strategies to suppress waste and hazardous materials. Life cycle assessment (LCA) based model design is performed, including easy decomposition, material unification as much as possible, and reduction of dust. Through the feedback of results at each stage, material selection systems in a vehicle development can be developed under the consideration of constraints such as functional performance, comfort, durability, luxuriousness, collision safety, fuel saving, reduction of emissions, hazardous materials and waste disposal, recycle and reuse, which is shown in Figure 6.



<Figure 6> Constraints in the LCA-based Material Selection

Ⅳ. TECHNOLOGICAL DIRECTION OF AUTOMOTIVE STEEL SHEET SUPPLIERS

1. Status of Steel Material in the Automotive body Sheets Market

The parts in a vehicle can be divided into the engine, powertrain, chassis, body, and closure and the weights of each part are different according to the vehicle types. Generally, body, closure and chassis occupy about 70～80% of vehicle weight; steel is the major material in these parts (河合 洋 2000). The automotive body sheets are generally composed of thin panels with 0.6～1.2mm thickness and 2g to more than 10kg weight. The chassis supports the body, and composed of more than 1.2mm thick sheets. The body accounts for about 20% of total weight on the criteria of Ultra Light Steel Automotive Body (ULSAB) project, and high strength as well as weight reduction is always sought.

After the first oil crisis in 1973, the U.S. government established the Corporate Average Fuel Economy (CAFE) regulations in 1975, in order to control the average fuel consumption of vehicles. As a result, the goal was achieved through this downsizing strategy. Since the early 1990s, the average vehicle weight began to increase with the requirements of performance and safety. Particularly, the rate of weight increase in European and Japanese vehicles was distinctive, compared with the situation in the United States. The major vehicles in these regions are small-sized. In Table 4, the trends and differences in the average vehicle weight of Japanese passenger cars is shown, along with the composition of materials. From 1973 to 1997, the average weight increased by about 41.3% for the enhancement of collision safety and luxuriousness of customers. At the same time, lightweight materials were gradually substituted for steel, in which non-ferrous metals such as aluminum and magnesium and plastics increased by about 9.1% from 7.9% while steel decreased by about 10.6%.

<Table 4> Change of Weight and Constituent Material in Japanese Passenger Cars

(unit : %)

	1973	1980	1986	1992	1997
Weight*	100	105.9	106.8	136.8	141.3
Ferrous	81.4	78.0	74.4	72.3	70.8
Non-ferrous metal	5.0	5.6	6.1	8.0	9.6
Plastics	2.9	4.7	7.3	7.3	7.5
Robber/Glass	9.7	8.6	8.0	7.4	7.8
Others	1.3	3.1	4.2	5.0	5.3

Source : Takita & Maruta FISITA 2000, * base year = 1973

The American Iron and Steel Institute (AISI) said that aluminum is unsuitable as a replacement for steel due to the price, although it is competitive in performance. Note that LME(London Metal Exchange) official price of aluminum in February 13, 2004 is US$1,695 per tonne while Western Europe export price of cold rolled coil is US$455 per tonne (www.metalbulletin.com). According to the analysis results of AISI for General Motors, Ford, and DaimlerChrysler, steel consumption of the North American automakers is about 13.5 million tones per annum and about 1,752 pounds per vehicle, which is approximately 55% of vehicle weight. It is known that this trend was maintained during the last 40 years, and expected that steel will be in the center of the automotive body sheets market as the most consumed material for the time being.

2. Technological Objectives in Automotive Steel Sheets

Porter defines 5 forces driving industry competition, such as industry competitors, potential entrants, substitutes, suppliers and buyers (Porter 1985). Five forces in the automotive steel sheets market are defined as suppliers of raw materials, such as iron ore and coking coal, rival competitors, suppliers of substitutes such as aluminum and magnesium, new entrants, and major customers such as OEMs. World-leading steel mills in the global automotive steel sheets market are Nippon Steel Co., JFE Holdings in Japan, ThyssenKrupp Stahl in Germany, Arceler in Europe, International Steel Group and AK Steel in the United States, POSCO in Korea, etc. They are always threatened by new entrants such as Boasteel in China and Tata Iron and Steel Co. in India, with relatively easy entrance with lower technological barriers and investment capital. In the survival war, some world-leading steel mills share the burden of R&D with their rivals through strategic alliances or collaboration in technology.

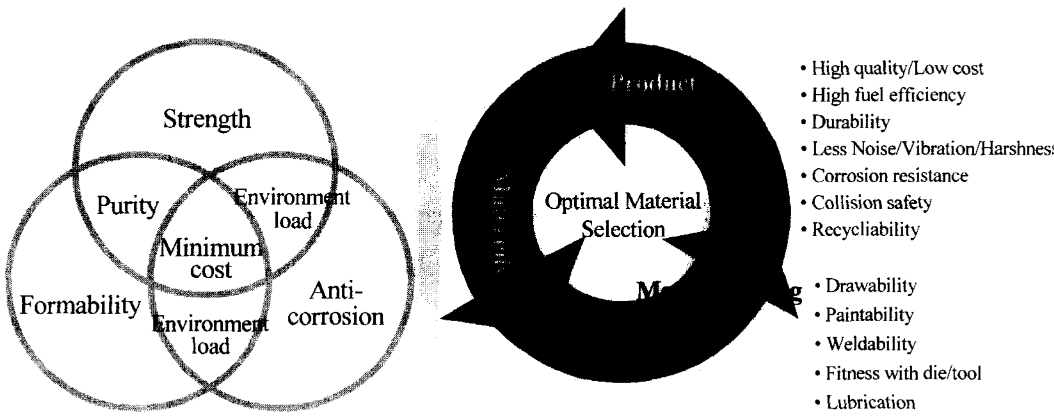
In the perspective of Pan-global steel industry, the International Iron and Steel Institute has established the ULSAB consortium with 35 steel mills of 18 countries in 1994 in order to develop light vehicles with high strength steel and advanced processing technologies. And, the projects of ULSAS (Ultra Light Steel Automotive Suspension), ULSAC (Ultra Light Steel Automotive Closure) and ULSAB-AVC (Ultra Light Steel Automotive Body - Advanced Vehicle Concepts) have been followed as shown in Table 5.

<Table 5> Global Projects for Ultra Light Steel Automobiles

	ULSAB	ULSAC	ULSAS	ULSAB-AVC
Time	July '94 ~ March '98	May '97 ~ Dec.'99	May '97 ~ April '99	Feb. '99 ~ Jan. '01
Main results	• 25% body weight reduction • high strength steel : 90% to its mass	• Up to 32% weight reduction for door, hood, decklid, hatch	• Up to 34% weight reduction for suspension • 30% cost benefit	Structural platform • crash safety • fuel efficiency • environmental performance • affordable cost
# of countries & companies involved	18 countries 35 companies	18 countries 35 companies	15 countries 34 companies	21 countries 32 companies

Source : www.iisi.org

Individually, steel mills try to make a contribution toward optimal steel selection appropriate for design and manufacturing dies or tools, based on the complete understanding of new model development processes in the early involvement activities. In considering product characteristics required in the market and mechanical properties required in manufacturing processes quality, technological strategies in automotive steel sheets have to be directed to pursue high formability, strength and anti-corrosion with low environment load and production cost. This is shown in Figure 7.



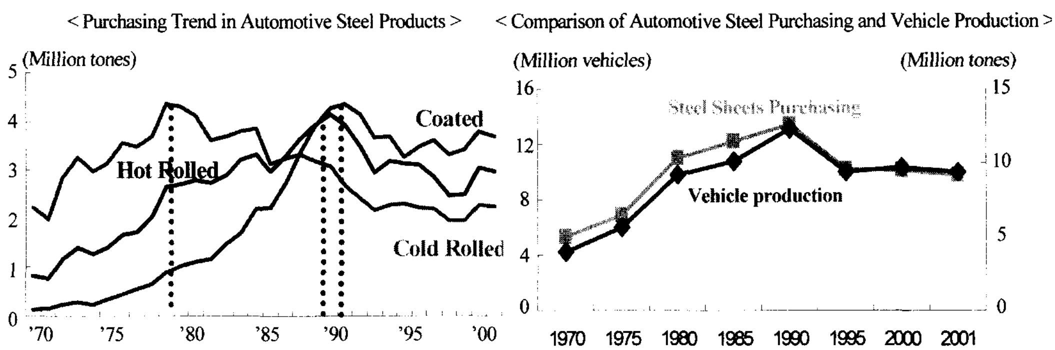
<Figure 7> Technological Objectives in Automotive Steel Sheets

By adopting advanced material processing technologies such as hydroforming and tailor welded blanking (TWB), the production costs and productivity can be improved as well as the reduction of weight. Since processing technologies can be well-developed in the mutually supplementary relationship of users and material suppliers, the partnership of OEMs and steel mills for technological innovation is necessary.

V. TECHNOLOGICAL INNOVATION IN AUTOMOTIVE STEEL SHEETS

Automotive steel products are mainly composed of hot rolled, cold rolled and coated sheets.

As shown in the right side of Figure 8, the purchasing trend for these products is proportional to the growth of vehicle production. The purchasing reduction of steel products in 1990s was caused by a decrease in vehicle production in Japan according to the expansion of foreign direct investment. The left side of Figure 8 shows the S-curves of purchasing for these products in Japan during the last 30 years. Compared with these three curves during the 1970s to 1990s, cold rolled steel began to decrease around 1979 while hot rolled gradually increased with the development of thin sheets technology and coated steels increased sharply with galvanizing technology. Here, hot and cold rolled sheets are replaced by cold rolled and coated products, respectively.



Data : Handbook for Iron and Steel Statistics 1971 ~2002, World Motor Vehicle Statistics 2002.

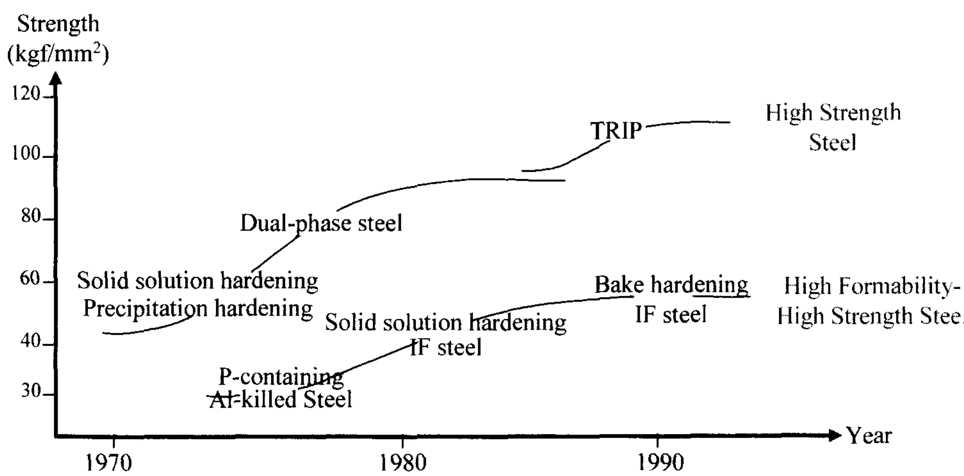
<Figure 8> Automotive Steel Sheets Purchasing and Vehicle Production in Japan

Generally, the advancement of technology in a firm is originated from the market needs. As mentioned in the previous section, automakers urge material suppliers to improve the strength, formability and anti-corrosion. These properties have direct influence on OEMs' processing and then, the earlier steel mills are involved in a new vehicle development, the more the production cost and development time can be saved. In this section, the technology progress in automotive steel sheets will be considered, based on three properties as the main concerns of automakers.

1. Technology Progress in High Strength Steel with Formability

Generally, technological innovation in steel is achieved from two perspectives; that is, gradual innovation like the increase of strength and formability in a product, and radical innovation like the creation of new high strength steel. In most cases, two innovations occur simultaneously. However, a time gap exists between the commercialization of a new technology and actual adoption in a product or service.

The birth of high strength steels originated from social needs. With the increase of vehicle accidents with the motorization in 1960s, the U.S. government established the Federal Motor Vehicle Safety Standard (FMVSS) in 1968. The automotive industry began to adopt high strength steels of solid solution hardening and precipitation hardening in some parts like bumpers, door reinforcement and brackets. Before the FMVSS, technology activities in automotive steel sheets were mainly focused on the improvement of formability for elegant surface and shape. Since the oil crises in 1970s, high strength steels to reduce the thickness of steel sheets in inner panels and outer panels have been developed. Figure 9 shows the sequential progress of high strength steel development.



※ TRIP : TRansformation Induced Plasticity, IF : Interstitial-Free

<Figure 9> Technological Innovation in High Strength Steel with Formability

As the amount of carbon in steel increases, the strength increases while the formability decreases. That is, the higher the strength of steel is, the lower its formability is. In 1970s, continuous annealing facility was commercialized first in Japan. This technological innovation marked a turning point in the improvement of productivity for automotive steel sheets with a wide range of strength and deep drawing quality.

As shown in Table 4, the average weight of vehicles increased slowly until 1990 through the active development activities in high strength steels during the 1970s to 1990s. However, according to the strict environmental regulations in advanced countries such as the United States, Europe and Japan, vehicle weights began to increase sharply by the addition of functional performances. Since the early 1990s, automakers have adopted high strength steels, and even required higher strength with formability.

2. Technology Progress in Anti-Corrosion Steel

By the middle of 1950s, thick steels as automotive body sheets were used and chemicals like NaCl or CaCl2 were not used in order to deice the snow on the road (Ostermiller et al. 1998). Therefore, the vehicle corrosion was not serious at that time. However, according to the industrial growth with the expansion of transportation infrastructure, the corrosion of a vehicle began to occur, especially in the regions with heavy snow like Canada in North America.

There are two types of corrosion in a vehicle; perforation and cosmetic corrosion. Perforation corrosion starts from lower interior parts such as rocker, panel, door and fender while cosmetic corrosion occurs at exterior surfaces which are easily damaged by the sand or pebbles. Furthermore, the lifetime of a vehicle with the corrosion problem has been issued on the aspects of the environmental protection. In order to guarantee the minimum life span in steel sheets, some countries or automobile companies defined the anti-corrosion warranty as shown in Table 6. In 1978, the Canadian government established the Canadian Anti-Corrosion Code of 3-year perforation corrosion and 1-year cosmetic corrosion. As time goes by, those requirements become stricter with the extension of warranty. Recently, GM Opel requires the warranty of 12-year perforation and 6-year cosmetic anti-corrosions. The consumption of coated steel sheets in the North American automotive industry has sharply increased during the 1994 to 1999, resulting from the anti-corrosion warranty of CAFE regulation in the United States.

<Table 6> Anti-Corrosion Warranty for Automotive Steel Sheets

Type	Canadian Code	Nordic Code	CAFE Regulation	GM Opel
Year	1978	1983	1994	-
Warranty (year)	• Perforation : 3 • Cosmetic : 1	• Perforation : 6 • Cosmetic : 3	• Perforation : 10 • Cosmetic : 5	• Perforation : 12 • Cosmetic : 6

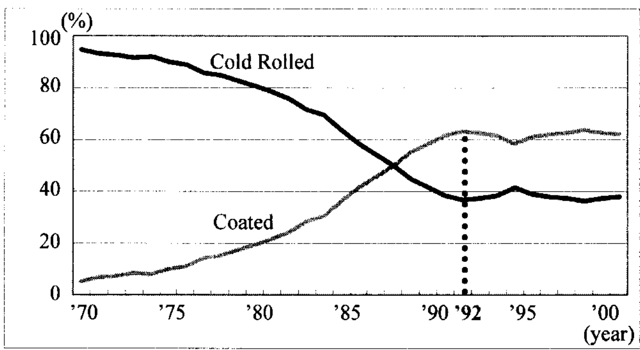
Table 7 shows the progress of technology in automotive coated steel sheets with their application parts. Perforation corrosion has considerably decreased during the last ten years, since the development of two-sided coated steel sheets (Goodwin et al. 2000). Some heavy metals such as lead, mercury, cadmium, and chrome are the objects of regulations in the European ELV standard, and nickel and copper has been mentioned as potential objects for regulation. The use of coated steel sheets using nickel is gradually decreasing.

<Table 7> Technology Progress in Automotive Coated Steel Sheets

Year	Type of Steel Sheets	Application Parts of Vehicles
1963~65	Two-sided hot-dip galvanized	Rocker panel, Wheelhouse
1968	Two-sided hot-dip galvanized	Tailgate
1975~1985	One-sided pre-coated	Fender, Hood, Door, Decklid
1977	One-sided electro-galvanized	Quarter panel
1980	Two-sided pre-coated	Structural members on front-wheel drive vehicles
1985	Two-sided pre-coated	Hood, Door, Inner decklid, Floorpan
1985~1986	Two-sided galvanized	Inner panel, Outer panel, Structural member
1990	Two-sided pre-coated	Exterior cosmetic/interior perforation corrosion resistance
1994~1995	Two-sided pre-coated	Exterior panel for exterior cosmetic/perforation corrosion resistance

Source : Ostermiller et. al. 1998

Figure 10 shows the substitution of coated steel sheets for cold rolled in the Japanese automotive steel sheets market. According to the revolution of galvanizing technology in Japan, the replacement rate during the late 1980s to the 1992 was significant. By comparing the technology development of Table 7 and the product purchasing of Figure 10, it is noted that some time gap always exists between the development of new technology and its commercialization in the market.



<Figure 10> Substitute of Coated Sheets for Cold Rolled in Automotive Steel Sheets

3. Future Direction in Automotive Steel Sheets Technology

Steel mills supply to automakers directly as tier-1 or to their subcontractors as tier-2 and so forth. If steel mills just stay in the existing roles as raw material suppliers, they will be threatened by the substitutes or processing businesses with value adding activities. Such endeavors of steel mills can be found in the areas of steel processing, such as tailored blanks welding and hydroforming. TWB is a revolutionary technology that composites steel sheets with different functional properties by using 3-D laser welding. TWB is also beneficial to automakers because their investment cost and processing time can be reduced. Furthermore, the TWB technology can reduce body weights by selecting optimal steel sheets for each composite with the effects of fuel savings and low emissions.

The other case is the development of pre-sealed or pre-painted steel sheets that simplify automotive manufacturing processes by skipping some painting processes. These sheets are not yet widely spread, but are becoming more prevalent in technically advanced Western Europe and Japan. European steel mills have already started the processing business for automotive component parts in order to provide total solutions as well as high added value for OEMs. It seems that most of OEMs manufacturing processes will be continuously outsourced and they will maintain only few key roles such as R&D, design and marketing. Therefore, steel mills have to extend their existing roles with value added processes through early vendor involvement activities, not just as a raw material supplier.

VI. CONCLUSIONS

In a fiercely competitive environment in the automotive industry, OEMs strongly urge tier-1 major suppliers to develop innovative technologies as well as the reduction of production cost. Since the advent of automobiles, steel has played a major role in automotive body sheets with excellent functional properties such as strength, recyclability, formability, weldability, paintability, etc., including the merit of relatively low cost. However, the automotive body sheets market is now completely open to all possible substitutes satisfying the market requirements and regulations. Wells says that the automotive industry will try to escape from steel-intensive vehicles because they are about 200～400kg heavier, compared to aluminum or plastic intensive ones (Wells 1998). The steel industry in the world devotes technological endeavors by establishing the global ULSAB consortium in pursuit of advanced mechanical properties and processing technologies.

This study considers the technological innovation of automotive steel sheets makers through early vendor involvement activities in a new model development. The technological goals in the automotive industry are to simultaneously improve the collision safety, fuel efficiency, and environmental load with the low production costs. As one of the major suppliers to the automotive industry, steel mills have to accurately understand processes of a new model development and then approach the optimal material selection in the total perspectives of design, material and manufacturing processes. Furthermore, in order to maintain or even expand their existing markets, technological innovations in steel material and its application have to be performed with the early vendor involvement activities in the new model development of OEMs.

According to the level of technological capability, Professor Jeffrey Sachs in Harvard University classifies three groups such as technological innovators, technological adopters and technological excluded. Technological innovators are about 15% of world population, who are leading the technology development. Technological adopters account for about 50%, who possess the capability to utilize technologies invented by technological innovators. In order to leap from a technological adopter to a technological innovator in the field of automotive steel sheets, a continuous technological innovation of automotive steel sheets makers is required, as well as strong partnerships with their major customers.

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