ROLES OF LIGHTWEIGHT MATERIALS AND ADVANCED HIGH-STRENGTH STEELS IN THE THAI AUTO-PARTS INDUSTRY

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ABSTRACT

To contribute to the environmentally friendly concept; trends and directions of vehicle manufacturing in the world automotive industry have focused on energy-saving vehicles and carbon-monoxide emission r

eduction. These affect Thai manufacturers to produce light and safe automobiles (the next generation) using lightweight materials and advanced high-strength steels (AHSS). The objectives of this study were 1) to study the readiness of enterprises in the Thai automotive-parts industry in producing automotive parts by using lightweight materials and advanced high-strength steels, 2) to gather their limitations in producing lightweight automotive parts, and 3) to seek recommendations from specialists in Thai Automobile industry to deal with the limitations. This study employed a qualitative methodology. The research instrument was an in-depth interview. The participants were 17 administrators of car-assembling companies, executives from Tier 1, Tier 2 and Tier 3 automotive parts companies/suppliers, and specialists from the automotive industry. The data gained were analyzed through content analysis. The results from this study indicated that small-sized companies in the automotive industry still lacked the knowledge and experience to produce their parts using lightweight materials, requiring external specialists to support them. On the other hand, big-sized companies and joint-venture companies are able to produce their parts with lightweight materials by themselves. In addition, the specialists recommended guidelines for the die design and production from the start to the end stage. The lightweight materials would be more widely used in the Thai automotive industry if their costs were approximately the same as the current materials.

Keywords: Lightweight Materials, Advanced High-Strength Steels (AHSS), Thai Auto-Parts Industry

INTRODUCTION

1. Introduction

To contribute to the environmentally friendly concept; trends and directions of vehicle manufacturing in the world automotive industry have focused on energy-saving vehicles and carbon-monoxide emission reduction. These affect Thai manufacturers to produce light and safe automobiles (the next generation) using lightweight materials and advanced high-strength steels

(AHSS). Weight reduction also leads to superior vehicle performance (e.g. fuel consumption, braking efficiency, and crashworthiness). Based on the Organization for Fuel Economy (CAFÉ) standards; original equipment manufacturers (OEMs) in the automotive industry have to follow the fuel economy targets by the vehicle's average weight and CO_2 emissions. In the past few years, the production of lightweight and fuel-efficient vehicles has been developed by using lightweight engineering materials such as aluminum (Al), magnesium (Mg), and advanced high-strength steels (AHSS) as shown in Table 1.

Table 1 Summary of representative lightweight materials for automobiles

Lightweight	materials	Typical components	Examples	
			Model	Application
Light alloys	Al	Shock absorber, brake, piston, tank, wheel rim, fender, roof, door, bumper, heat insulator, handle, piping, steering component, conrod, rotor, suspension component, bonnet, chassis, spoke, valve, gas cylinder, seat frame	Audi A8 Jaguar XE Mercedes AMG GT Ford F-150 Toyota GT86 Mazda MX-5 Nissan Leaf Tesla Model S	Chassis Monocoque Body Body panel Bonnet Bumper Battery case, sealing component Frame and heat exchangers
	Mg	Engine block, steering wheel frame, seat frame, instrument panel, wheel rim, cylinder head, clutch case, cylinder block, transmission case, lower crankcase, intake manifold, air intake system, steering link bracing, oil pump body, camshaft drive chain case, gear control housing, bracket	Ford Thunderbird Chrysler Plymouth BMW(MINI) Lexus LS430 Mercedes Roadster 300/400/500 SL Lexus LS430 Chrysler Jeep Audi A8 Toyota Century Toyota 2000GT Toyota Supra Alfa Romeo GTV Porsche AG 911 Dodge Raw Volvo Motors (LCP) Honda Motor Volkswagen Passat Audi A4, A6 Porsche AG 911 Mercedes-Benz S-class	Steering wheel frame Seat frame Instrument panel Wheel rim Cylinder head Transmission case Brake guide pin

AHSS		Frame, body, crash zone, pillar, roof rail, door beam, seat frame, front side member, bumper reinforcement, roof bow, rocker, cross member, seat track	Jaguar XF Dodge Caliber Ford Fusion Porsche Cayenne Volvo XC90 GM Cadillac ATS GM Chevrolet Sonic	Inner reinforcement Body-in-white (BIW) structure Seatback, door panel, lining

Choosing aluminum as the basic material for the production of automotive parts of the world was first established in 1888. Later, it was developed and improved for better properties for automotive parts manufacturing. In the generation of electric cars, 'Aluminum' plays the role of advanced material, unlocking the automotive industry to move forward while reducing carbon dioxide emissions. The advantages of aluminum are not only limited to weight reduction, it can also almost 100% be recycled and reused. For this reason, many products made of aluminum are recycled materials. The most widely used aluminum alloy in die casting is an aluminum-silicon alloy (Al-Si alloy). This is because it is easily cast and perfectly supports corrosion-resistant welding. This grade of aluminum alloy is often mixed with copper or magnesium to improve its properties. The percentage of aluminum used in automotive parts is increasing, as shown in Figure 1 and Figure 2.

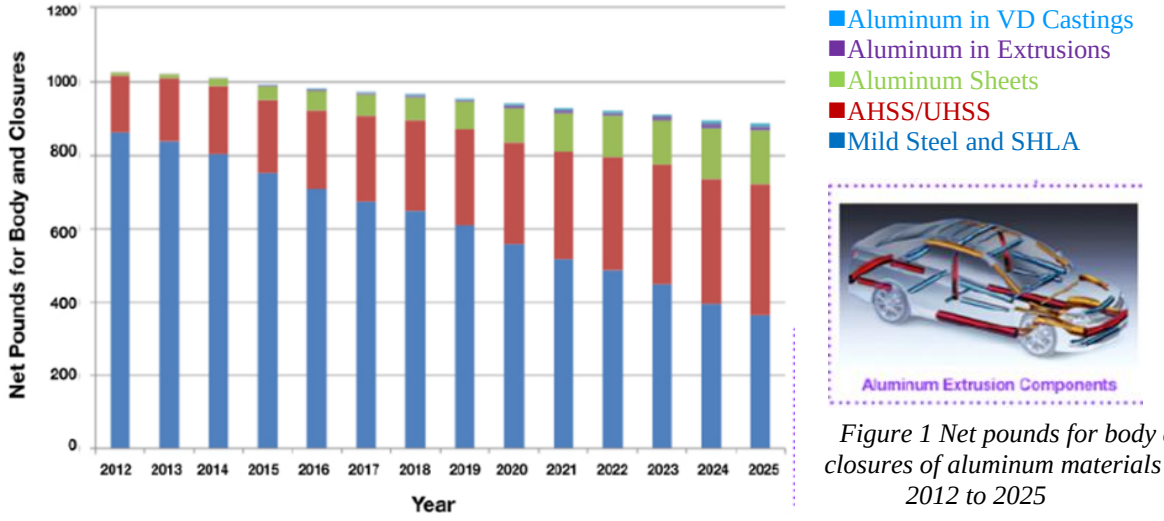

Figure 1 Net pounds for body and closures of aluminum materials from 2012 to 2025

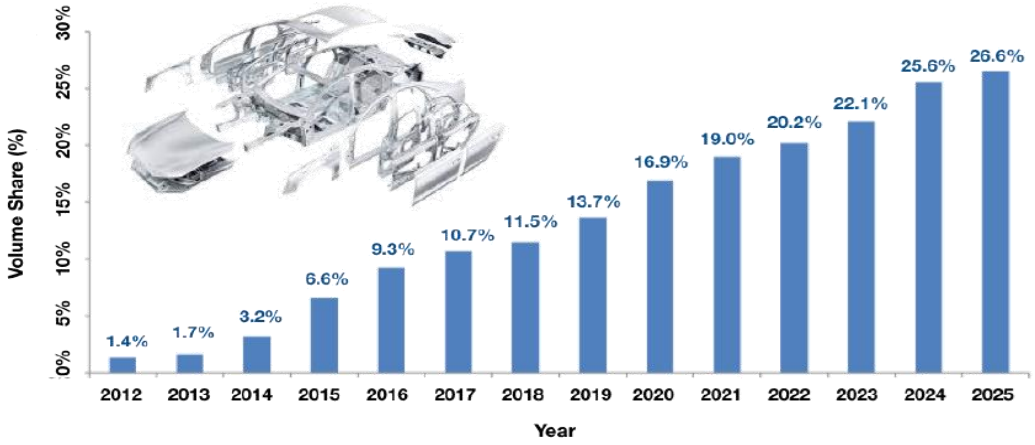

Figure 2 Aluminum volume share of body and closure components from 2012-2025

At present, producing low-cost and higher-performance cars with outstanding formability and recycled capability is increasingly demanded. Although other lightweight materials have been extensively used; steel is still the most advanced automotive material. This continuously becomes an essential driving force for developing and innovating new steel grades- low-carbon steel. The microstructure and strength range of AHSS grades in each representative grades of AHSS includes dual-phase (DP) steel, complex phase (CP) steel, lightweight steel with induced plasticity (L-IP), transformation-induced plasticity (TRIP) steel, and twinning-induced plasticity (TWIP) steel. In the light of strength and elongation performances, existing grades of AHSS can be divided into the first and second generations (See Table 2)

Table 2 Microstructures and strength ranges of the first and second generations of AHSS

Generation	AHSS grades	Microstructures	Strength (MPa)
1st	Dual-phase (DP)	Ferrite + martensite	400–1000
	Complex phase (CP)	(Ferrite + bainite) matrix + small amounts of pearlite, martensite, and retained austenite	400–1000
	Martensitic (MS)	Martensite	700–1600
	Transformation-induced plasticity (TRIP)	Ferrite + martensite/ bainite + austenite	500–1000
2nd	Twinning-induced plasticity (TWIP)	Single-phase retained austenite	1100–1650
	Lightweight induced plasticity (L-IP) austenitic stainless steel (AUST SS)	Single-phase retained Austenite	850–1150
		Single-phase retained austenite	900–1150

Presently, steels for automotive manufacturing are classified into many types. The first type is low-carbon steel. This steel grade has high formability and low tensile strength of around 270 MPa. Applications of low carbon steels are used to form car bodies, suspension parts, brackets, control arms, and many more. The second class of steel is high-strength steel (HSS). The HSS has more tensile strength, up to 700 MPa, than the low-carbon steel. However, the formality also reduced with the increase of tensile strength. Most of the applications of the HSS are safety-related components such as cross members, impact door beams, A-pillars, and so on. Dual-phase (DP) steels, for example, are composed of ferrite and 5-20% martensite. The presence of the martensite phase improves the tensile strength of the steel. Transformation-induced plasticity (TRIP) steel is another type of HSS. Retain austenite microstructure of the TRIP steel can transform into martensite when deforming, as suggested by the name. For advanced high-strength steels (AHSS), the tensile strength is improved to more than 700 MPa. The steel grade can is a ferrite-based microstructure composed of a multi-phase microstructure and extremely fine grain. Some DP and TRIP steels and complex phase (CP) steels, martensitic (ms) steels, and hardening press steel (PHS) are classified as AHSS or also known as the first generation of AHSS. The second generation of AHSS includes twinning-induced plasticity (TWIP) having an austenite-based microstructure. The steel has high tensile strength and formability. Third-generation steel is the improvement of first-generation steel and is presently under consistent development. These multi-phase steels rely on retained austenite in a bainite or martensite matrix and some ferrite and/or precipitates to improve their formability and tensile strength (See Figure 3).

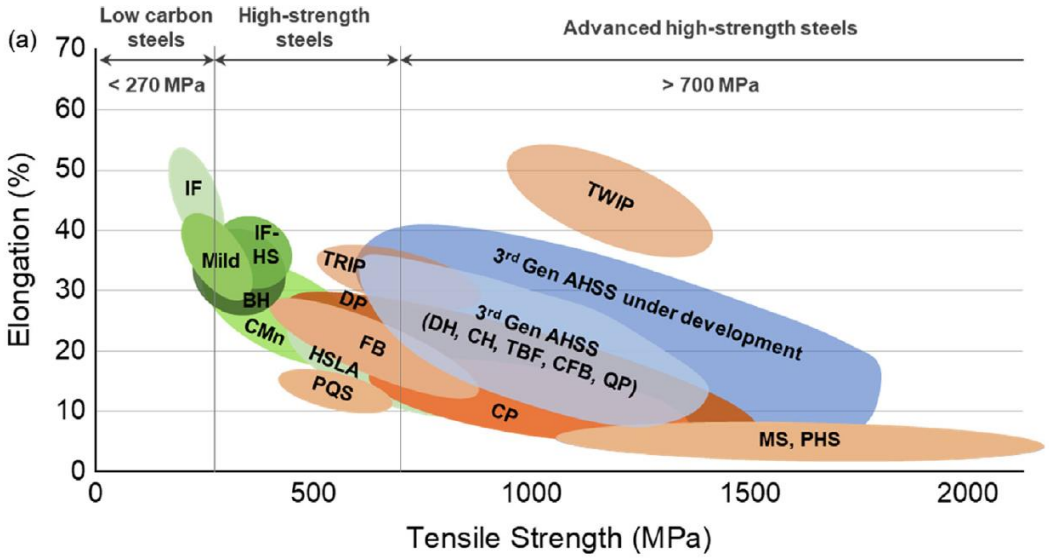

Figure 3 Mechanical Properties of Steels

Selecting materials for automotive parts and for their structural design could offer a new direction for lighter, safer, and more environmentally friendly vehicles. Therefore, the production of new cars focused more on the safety of the driver. Therefore, the load-bearing and safety-related parts are developed by applying lightweight materials and high-strength steels, as shown in Figure 4.

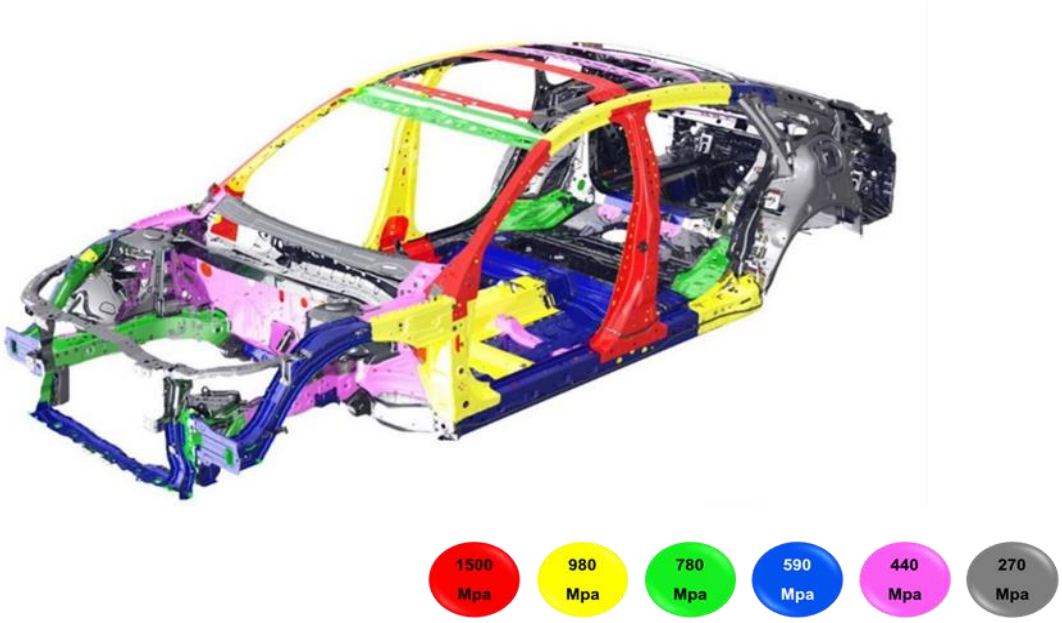

Figure 4 Lightweight Materials and Advanced High-Strength Steels (AHSS) for Body Structure

Aluminum is a lightweight metal with a density that is three times less than steel, so aluminum is easy to form and can be formed in many ways. However, aluminum is a material with a low melting point, making it easy to tear or crack in the cold stamping process. In addition, the welding line in the heat effect zone tends to crack easily.

Presently, AHSS is used to develop the production of automotive parts to better withstand high tensile strength up continuously to 1800 MPa. This is to strengthen the car body structure such as bumpers, and door beams. The increased high tensile strength, results in a lower percentage of elongation, resulting in higher surface hardness causing a lot of spring back of the workpiece. This makes it difficult to form workpieces with complex shapes.

Purpose of the study

The objectives of this study were: 1) to study the readiness of enterprises in the Thai automotive-parts industry in producing automotive parts by using lightweight materials and advanced high-strength steels, 2) to investigate their limitations in producing lightweight automotive parts, and 3) to seek recommendations from specialists in Thai automotive industry to deal with the limitations.

RESEARCH METHODOLOGY

2. Research methodology

This study employed a qualitative methodology. The research instrument was an in-depth interview, both a ‘face-to-face’ interview and an ‘online’ interview. This study employed a qualitative methodology. The research instrument was an in-depth interview. The participants were 17 administrators of car-assembling companies, executives from Tier 1, Tier 2 and Tier 3 automotive parts companies, and specialists from the automotive industry. The interview schedules were administered to 1) assess the readiness of the automotive companies and Thai automotive-parts manufacturers in producing automotive parts by using lightweight materials and advanced high-strength steels, and 2) investigate their limitations in producing lightweight

automotive parts. and 3) seek recommendations from specialists in Thai automotive industry to deal with the limitations. The data analysis was conducted through content analysis.

RESULTS

3. Results

3.1 The readiness of enterprises in the Thai automotive-parts industry in producing automotive parts by using lightweight materials and advanced high-strength steels (AHSS)

The data revealed that there were 3 types of automotive-parts companies/suppliers: Tier 1, 2, and 3. Automotive-parts companies and automotive-assembling companies could be Thai companies, joint-venture companies, or international companies. Their sizes could be categorized into 4 classes: small-sized, medium-sized, big-sized, and large-sized companies, with the numbers of personnel at less than 200, 201-500, 501-999, and more than 1000 respectively. (See Tables 3, 4, and 5.)

Table 3 Types of Automotive-parts Suppliers

Automotive-parts Suppliers	**Capability of producing with lightweight materials**	
	Aluminum (Al)	Advanced High-Strength Steels (AHSS)
Tier 1 Suppliers	Yes	Yes
Tier 1 and Tier 2 Suppliers	Yes (*)	Yes (*)
Tier 2 and Tier 3 Suppliers	No	No
Tier 2 Suppliers	No	No
Tier 3 Suppliers	No	No

(*) Yes with the condition: Be able to produce parts under the guidance of outside experts

Table 4 Sizes and Numbers of Personnel of Automotive-parts Companies

Sizes and Numbers of Personnel	**Capability of producing with lightweight materials**	
	Aluminum (Al)	Advanced High-Strength Steels (AHSS)
Small-sized companies (less than 200 personnel)	No	No
Medium- sized companies (201-500 personnel)	No (*)	No (*)
Big-sized companies (501-999 personnel)	Yes (*) but not all parts	Yes (*) but not all parts
Large-sized companies (more than 1,000 personnel)	Yes	Yes

(*) Yes with the condition: Be able to produce parts under the guidance of outside experts
(*) No but be able to produce parts under the guidance of outside experts

Table 5 Types of Automotive-assembling Companies

Types of Companies	**Capability of producing with lightweight materials**	
	Aluminum (Al)	Advanced High-Strength Steels (AHSS)
Small- sized companies (Thai Companies)	No	No
Large-sized companies (Thai Companies)	Yes	Yes
Joint-Venture companies	Yes (*)	Yes (*)
International companies	Yes	Yes

(*) Yes with the condition: Be able to produce parts under the guidance of outside experts

3.2 Limitations in producing lightweight automotive parts

The data from administers and executives from automotive-parts companies and automotive-assembling companies indicated that Thai enterprises with the potential to make dies from lightweight materials, Advanced High-Strength materials (980-1180 MPa) and ultra-high tensile steel materials (more than 1200 MPa) are mostly international companies or joint-venture companies. This was because to do this, engineers mainly required simulation software (engineering technology) to analyze the design of automotive parts. For Thai small-sized enterprises, even though the technicians possessed experience in producing their parts with materials such as mild steel (270-340 MPa) or high-strength steel (590-780 MPa), those experiences did not have sufficient knowledge, skills, and experience to produce lightweight workpieces according to the time specified by the automobile manufacturer. Thái enterprises with the potential to make dies from lightweight, advanced high-strength (980-1180 MPa) and ultra-high tensile steel materials (more than 1200 MPa) are primarily international companies and joint-venture companies with foreign countries.

The findings also indicated that the key problems to creating dies from lightweight materials and advanced high-strength steel materials (980-1180 MPa) were the spring back, wrinkle, cracking, and twist. These problems resulted from selecting imprecise values in the simulation process.

3.3 Recommendations of Specialists in the Thai automotive industry to deal with the limitations

The specialists in the Thai automotive industry discussed that a lack of understanding of the materials' properties was not the only reason for manufacturing lightweight automotive parts. They advised applying appropriate simulation software and new technologies in the design and production stages. (Wutipong Janmuangthai, et al., 2021)

They recommended guidelines for the design and production from the starting point to the end stage as follows:

1. Production planning and production design:

Engineers can predict problems that may occur by using simulation software to assess and find problems that may occur along with finding solutions to such problems. The simulation software will be used such as forming simulation analysis software, welding simulation software, or plant simulation software. This software can help reduce problems in the production process, decrease the time for producing parts, and build customer trust.

2. Appropriate die design:

Designing an appropriate die includes creating the strong die- structure, selecting the correct materials, selecting the surface heat treatment process, and determining the right stamping process by confirming the results from the simulation result.

3. Quality checking in each step of the die-making process:

If the try-out result does not match the simulation result, it does not mean that the simulation software has a problem, but the errors may be from entering incorrect values in the program.

4. Preparation of personnel with knowledge and competence in material technology and production:

This preparation is to have a better understanding of the problems of the materials used in the manufacture of lightweight vehicles and to efficiently use them.

5. Utilizing new technologies and innovations:

To solve the mentioned problems of material limitations, new technologies, and innovations will be utilized to create values, control costs, increase performance and appropriately save energy.

Additionally, the specialists recommended that lightweight materials such as aluminum and advanced high-strength steels would be more widely used to produce the vehicle body parts if their costs were approximately the same as the current materials.

CONCLUSION

4. Conclusion

Regarding the current generation of the world automotive industry, producing light and safe automobiles and concerning carbon-monoxide emission reduction have been emphasized. To compete on the world stage, all parties in the Thai automobile industry are aware of this trend and have continuously adjusted and developed the efficiency of their products by using lightweight and AHSS materials. To reach this goal, however, Thai medium-sized companies require effective simulation software, new technology, and external specialists to support them. In contrast, Thai big-sized and joint-venture companies can successfully produce their products by themselves. Unfortunately, small-sized companies cannot reach this goal at this time. They still need some time to research and develop their knowledge and experience together with preparing efficient technology and innovation to produce automotive parts that are accepted by the world standard. The lightweight materials would be more widely used in the Thai automotive industry if their costs were approximately the same as the current materials.

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