Emerging technology in heat treatment and surface engineering of automotive components

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Heat treatment and surface modification are the key technology to enhance effective use of materials applied for Automobile components, through the utilization of optimum properties to solve socials needs we are facing. In the past century, the advancement of industrial materials technology left various social demerits which should be solved in this century. Simultaneously, the materials and processing technology have to contribute to the advancement of industrial technologies through the more effective use of materials to increase efficiency by improvement in specific strength, reduce friction, and saving of energy and natural resources. Present article presents a short overview of automotive key materials and selected aspects of heat treatment and surface modification technology applied for automotive components. Especially, several topics in case hardening and surface engineering technologies contribute to enhance the properties of materials, and the relative scientific features and the future technical possibility are discussed.

INTRODUCTION

Automobiles are one of the typical industrial products that are produced using various categories of materials. However, metallic materials are fundamentally important in their application for heavily stressed components that require high durability with their degree of functionality and component performance being strongly tied to the effectiveness of the processing technology deployed within the given application. Body shell is usually produced from steel sheets that have been rolled and thermally processed to create the desired properties. The heaviest body part components migrate through a process traditionally characterized by stamping, welding and coating which lead up to the assembly process.
Automotive gears represent another important category of components that are heavily stressed and require high levels of performance in the areas of both fatigue and wear resistance. Effective and appropriate heat treatment and surface modification represent the cornerstones to optimizing properties of virtually all types of metallic components with durability featuring prominently in a great number of applications.
Heat treatment processes impart the required strength or hardness properties as dictated by the given component application. Other processes involved in metal processing may include forming, machining as well as quench and tempering, carburizing and hardening, and nitriding for the final steps of production. Surface modification, when properly applied, yields optimum surface properties enhancing corrosion and wear resistance while also improving frictional properties.
In support of further enhancing the properties and performance of components going into automotive passenger cars, it is very important to improve process efficiency and advance the fundamental industrial technologies that have been developed and applied to date while additionally building upon these further based on new concept and challenges. Even hybrid and electric vehicles contains components that require heat treatment and surface modification engineering as important parts in the production of reliable and durable vehicles in these new categories. Naturally, these emerging technologies will play more of a crucial role as traditional processes to enhance the processing efficiency and the final performance.

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1. TRENDS IN MATERIALS USED IN AUTO VEHICLES

In spite of various challenges to develop vehicles made of all aluminum auto body, still Iron and steels have (70 %) share. To fulfill the fuel economy targets, it is necessary to reduce vehicle body weight while also improving engine performance and reduction of friction losses. These improvements are in progress through the use of high strength sheets and/or in conjunction with even greater increased usage of aluminum, magnesium and titanium alloys having lower specific weights compared with iron and steels. [1]
As shown in Table 1, recent challenges to reduce the weight of auto "bodies in white" so called have proven the promise and possibility of weight reduction via the use of ultra high tensile strength sheet steels. These ultra-high-tensile strength steel sheets are produced using advanced steel mill technologies characterized by controlled rolling and cooling technologies that include heat treatment processing within the continuous processing of these steel sheets.
Challenges in body design and fabrication technology to optimize weight saving have been studied as a world wide development program as Ultra Light All Steel Body –ULSAB- program by utilization of all available technologies is essential, and such as the use of all types of materials including MMC and new powder metallurgical methods, joining and welding with high energy density and weld bonding which are commonly applied to steel and light alloy body construction.

1.1. Iron and Steels

Iron and steel was the main materials compose auto vehicles. However, the social and market needs forced the decrease in percentage of heavy materials like Iron and Steel share to reduce car weight to increase fuel mileage. It is an important change that the percentage of structural steel parts showed increase to satisfy crash worthiness, strength of car body and durability as shown in Table 1 [1].
Most of auto body components have complicated shape and usually formed by stamping operation. However, strong steel is difficult to deform to produce complicated components, while soft and

Model year	Weight	Total Iron & steels	Sheet steels	Construct steels	Cast Iron	Non Ferrous	Plastics	Rubbers	Glasses, & Ceramics	Miscellaneous Materials
1968	1020	75.0	46.9	14.3	13.8	6.0	3.6	3.6	3.0	7.4
1978	1144	75.7	44.1	20.2	11.4	7.8	5.0	5.0	2.4	3.4
1988	1300	73.7	42.5	20.8	10.4	7.2	7.1	7.1	2.6	5.4
1992	1290	71.7	37.5	23.9	10.3	9.2	7.5	7.5	3.1	4.3
1996	1313	69.8	35.5	23.7	10.2	10.4	9.2	9.2	2.9	3.6
2000	1371	68.7	36.6	23.9	8.2	10.6	9.0	9.0	2.6	4.1
2000 / 1978	1.198	0.908	0.830	1.183	0.719	1.1359	1.1359	0.911	1.083	1.206

Vehicle model Toyota Mark II, weight in kilograms.

Table 1 – Past trend in weight and materials of passenger car.

Tensile Strength (MPa)	Designation	Yield Strength (MPa)	Type of High Strengthening
~450	Misc.	-----	
	BH 210/340	210	Bake Hard.
	BH 260/370	260	Bake Hard.
	IF 300/420	300	Interstitial Free
	HSLA 350/400	350	HSLA
500~600	DP 280/600	280	Dual Phase
	DP 300/500	300	Dual Phase
	DP 350/600	350	Dual Phase
700~800	DP 400/700	400	Dual Phase
	TRIP 450/800	450	TRIP
	DP 500/800	500	Dual Phase
	CP 700/800	700	C Precipitate
1000	DP 700/1000	1000	Dual Phase
1200 ~ 1500	Mart 950/1200	950	Martensite
	Mart 1250/1520	1250	Martensite

Bake Hard: Bake Hardening . HSLA: High Strength Low Alloy C Precipitate: Precipitate Hardening

Table 2 – Steel sheets used in ULSAB-AVC. [3]

weak steel sheets can not sustain heavy weight and has low fatigue strength.
Production technology needs to improve formability and productivity, and requests were indicated to steel producers.

1) Bake hardening steel sheets: Low yield strength and good formability steel sheets is necessary for stamping and forming operation. However, body panels needs stiffness and strength to increase crash worthiness and fatigue strength. Both of those needs at first were fulfilled by "Bake Hardening" steel sheets they are formable during stamping operation, but hardened by baking after painting. The baking condition can improve strength level from less than 30 kg/mm^2 to about 45 kg/mm^2. This technology contributed greatly to the improvement in productivity and body strength and durability of vehicle body, simultaneously enabled the production of high fuel mileage vehicles, and additionally contributed to the improvement in crash worthiness.
2) High tensile strength steel sheets: Strength of steel sheets is improved by optimization of chemical composition, rolling and cooling condition. Further increase of High tensile strength sheet – HITEN- usage seems necessary to satisfy crash worthiness and durability while reduce its weight to attain optimum fuel mileage. The results of world wide technical program ULSAB and ULSAB-AVC made a contribution to the weight reduction of body shell. [2, 3]
3) Corrosion resistant coated steel sheets [4, 5]: Body panel sheets needs coatings to prevent perforation caused by salt splash during winter. Various types of coating such as Zinc dip coating, Zn-Fe alloy coating, Zn-Fe plating and Ni-Zn plating are used for panels. Also Al coating and Al-Zn coating are used for exhaust line pipes and mufflers similar to some types of stainless sheet and pipes.
Fuel tank also needs corrosion resistant coating like Lead, but is no longer applicable to reduce hazardous scraps. [4]

1.2. Constructional steels

Various types of construction steels are used to fabricate high performance components in engines, suspensions and power train components that need strength and durability. Strength of components is introduced by the selection of appropriate steel grade and appropriate heat treatment to give necessary strength, wear and fatigue durability. While the weight reduction is necessary to improve fuel mileage, steel components have to maintain strength. Additionally, various types of fasteners and screws used to assemble body, transmission, chassis components and auxiliary parts are mostly made of steels. However, a gradual transition toward conversion to lighter fastening mechanism will proceed further. The competition with such materials transition may necessitate the development of the more effective component design with durability by effective use of the structural steel products with optimum heat treatment.

1.3. Powder metallurgy products

Powder compaction and sintering technologies are widely applied for production of engine and transmission components. They are mostly Iron base and Cupper base alloys and Titanium alloy is used for a limited applications. Iron base powder alloy parts are such as ; Crank timing sprockets or gears, Cam shaft timing sprocket or gears, Transmission clutch hubs, Powder forged connecting rods, ATM planetary ring gears, Cam robe of Composite Cam shafts, Door lock strikers and etc. Non-Ferrous alloy powder metallurgy products are such as; Plane bearings Cu-Pb, Plane bearings Al-Sn, Valve seat inserts, Exhaust valves Ti-TiB2 and etc.

Table 3 – Automobile components made of Magnesium alloys.

Company Name	Components
Mazda	Transmission case, Clutch housing, Engine front cover, Oil pan. Etc
Toyota	Steering column upper brackets, Steering wheel cores, Brake pedal brackets, Cylinder head cover, Disc wheel, Instrument window frame & etc
North America & Europe	Clutch housing, Manual Transmission case, Steering column bracket, Cylinder head cover, Intake manifold, Accessory drive brackets, Instrument panel frames, Wheels, brake and clutch pedal brackets, Seat frame, Oil filter adapters, EGR valve covers, A/T stators, and pistons, Decorative nameplates, Window motor housings, Radio housing & covers, Mirror brackets, Head light retainers and etc.

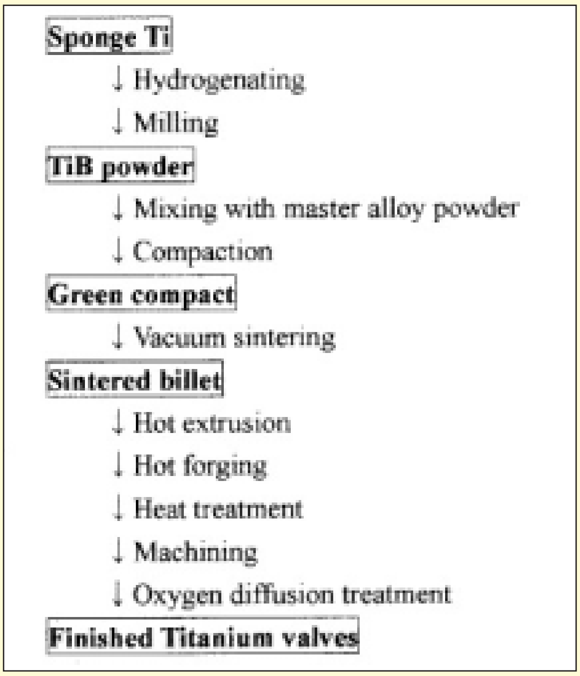

Fig. 1 – Fabrication flow chart of Titanium valves [14]

1.4. Light metals and alloys

The use of light metals is increasing every year and various types of research and development efforts are devoted to improve their strength and wear properties.

1) Aluminum alloys: Typical products made of Aluminum alloys are cases such as transmission, differential and steering gear boxes. Recent materials technology contributing to cut vehicle weight is the use of aluminum sheets that is expanding to panels such as engine food, trunk rid cover, body panels and suspension components. [9]: Bake hardening technology used for steel sheets was applied to develop new aluminum alloy applicable to body panels. [10]
2) Magnesium alloys: The Magnesium alloys are very effective to reduce components weight, but their stiffness, strength and corrosion properties are poor to increase application in vehicles. However, Mg alloy had been used for old Volkswagen since 1950's utilizing lightest metal property. Even the expensive materials cost of Mg alloy can extend fare weight strength ratio and gradually increasing applications in automotive components. Corrosion resistance of the alloy was not sufficient to satisfy application needs, and new grade of low impurity alloy grade was developed for automotive applications. [11]
3) Titanium alloys: Titanium and alloys have quite excellent specific rate - weight /strength ratio- but the high materials cost is the biggest hazard to the expansion of Titanium applications. Candidate components fit for Ti alloy use are such as, Valve spring retainers, [12] Suspension coil springs [12] and Connecting rods [13].
The biggest hazard of Ti alloy usage was solved by the development of new production method via the use of powder metallurgy process. Toyota developed a process start from sponge Titanium powder to fabricate valves with competitive economy even compared with heat resistant steel valves. Figure 1 shows the main production steps that enabled the mass production of light weight Titanium valves for passenger car. [14]

1.5. Composite materials technologies

Soft and weak materials can be strengthened by reinforcement of fibers or particles. Glass fiber rein- forced plastics are used for roof panels and many other plastic products.

1.4.1. Metal Matrix Composites –MMC- is not popular, but this technology is a quite useful method to increase local strength where components needs stiffness or creep strength of such as Magnesium and contribute to increase light metal applications. Toyota is the only company using "Metal Matrix Composite Engine pistons" since 1981.[15] The Diesel engine piston started production by the successful development of quite simple Alumina-Silica fibers perform that is squeeze- cast into the top portion of Al alloy piston. Since 1981 various technical improvements have been accumulated and one of recent MMC piston is reinforced by porous Nickel perform around the ring grove. [16~18] Several MMC components such as; Diesel engine piston [15~18], Engine cylinder block bore portion [19], Crank Dumper pulley shaft hole [20], and Connecting rod. [21]

1.6. Miscellaneous materials

Fabrics and Leather products are continuously used for interior seats and linings. Beside the main materials consisting auto vehicle various solution such as water and oils are necessary to operate vehicle share considerable percentage of the weight. That means, not only the properties of materials, but also everything composing vehicles is concerned with the weight, performance, durability and total life of a car.

2. HEAT TREATMENT

2.1. Types of heat treatment

Almost all types of heat treatment are used for production of automotive components. In this section only some typical topics are discussed.
The selection of steel type, grades and appropriate heat treat methods are very important to produce reliable quality components. Properties of manufactured components are affected by chemical composition and microstructure of mate-

Hybrid types	1st heat treatment	2nd heat treatment or surface modification
Plural Heat Treatments	Carburizing & hardening	Surfurizing, Nitriding, Induction hardening
	Nitrocarburizing, Nitriding	Induction hardening, Oxidizing, PVD
Sintering base	Sintering and brazing	(simultaneous H.T.)
	Sintering	Forging, Extrusion
Quenching and tempering + Surface Coating	Quenching and coating (Simultaneous)	Rust proof, COF control coat, Solid lubricant coatings, Rolling fatigue strength
	Tempering and blackening	Surface Oxidation, (Simultaneous H.T.)
Coating + Heat treatment	Iron plasma spray	Phosphate coat
	Plating	Diffusion treatment
PVD- Physical Vapor Deposition COF- Coefficient of Friction		

Table 4 – Various types of Hybrid heat treatments [28].

rials that results from refining, casting, rolling and cooling methods. And, it is quite important to be cognizant of these factors throughout the fabrication steps and to ensure that appropriate methods are applied.

2.2. Topics in processing technology in heat treatment

Since the advent of gas carburizing processing, various improvements in furnace, atmosphere and their control methods have been are achieved and hundreds of continuous furnaces are utilized to in the production of automotive vehicles. Improvements in furnace design have enabled considerable savings in energy and gases to be achieved while considerable improvements have occurred in moving toward the application of reduced pressure controlled processing methods. Vacuum carburizing and nitriding methods are gradually increasing in usage and plasma assisted technologies have further advanced the capabilities of these processes.

1) Forge and direct heat treatment processes: The forge and direct quench method can reduce nearly eighty percent reduction of thermal energy compared with traditional heat treatment processes which needed repeat heating and cooling. However, this technology is not yet distributed well to fabricate energy efficient automotive components. The thermal energy of forged components should be fully utilized to create the desired microstructure through the deigned controlled cooling methods such as air blasting, water spray cooling or quenching and typically yield the same strength levels as compared to traditional quenched and tempered products. [6]
2) Carburizing and Carbonitriding: Carburizing is the most popular case hardening methods widely used for automotive gears. However, observing from actual carburizing operation at production floor, optimum condition that give the highest quality in hardness, residual stresses and fatigue and wear resistant are not fulfilled satisfactory. [22] The upcoming vacuum carburizing technology is still in the development stage and needs further R &D efforts to satisfy mass production needs. Carbonitriding is increasing that diffuses carbon and nitrogen additionally, or set wise to yield a hardened case with higher softening resistance through the influence of diffused nitrogen. [23]
3) Nitro-carburizing, Nitriding: Nitrocarburizing have been used widely, since 60's. Salt bath nitrocarburizing processes have made a great contribution to the improvement in components durability in wear and fatigue properties. However, due to the process used Cyanide salts, the environmental issue results in decrease of their uses. And various gas nitrocarburizing methods have been developed and expanding their applications. [24] The iron nitride layer at the surface gives excellent wear and seizure resistance, and nitrogen diffused into sub-surface area increases fatigue resistance by quenching to prevent precipitation of iron nitride and containing nitrogen within the ferrite matrix. [25] Nitriding technologies are moving toward reduced pressure Plasma technology because of environmental needs, but the difference of surface nitride compound layer and the processing time should be re-evaluated conjunction with energy and time efficiency.

3. SURFACE MODIFICATION AND HYBRID HEAT TREATMENT

In accordance with the required advancement in automotive technology and social environmental responsibility needs that companies participating in this industry must recognize and adhere to, the operating condition and durability of automotive components have become more strict and severe. And variety of surface modification technologies is playing very important role to enhance components properties and are listed in Table 6. [26] This has necessitated the use of plural processes to fulfill the needs of this category of components. Duplex heat treatment or heat treatment and additional surface modification methods are applied to special applications. Most specifically, there are many popular combinations of surface modification such as phosphate treatment, vapor deposition and or solid lubricant coatings that have potential to satisfy unique combined property needs. A unique economical coating available with heat treatment is a coat quench technologies. [27] There are few types of coat quench methods, one of which have been used to improve surface friction coefficient more than thirty years, and other few methods to prevent rusting by forming surface oxide film during cooling into aqueous solutions.

4.EMERGING TECHNOLOGIES IN MATERIALS, HEAT TREATMENT AND SURFACE ENGINEERING

4.1. Materials

Social needs toward global environment, climate and energy conservation are the key factors decide the way to proceeds R & D along with green technology in automotive materials and their processing technologies.

Additional design trends are increasing needs of fossil energy saving via new vehicle such as Hybrid power, fuel cell and Electric cars partially on market since 2001, by the breakthrough made by mass production of Toyota Hybrid powered vehicles. This trend will change the balance of materials balance used for production of auto-vehicles and processing technologies. And the R & D in direction to light and stronger materials such as light metals and plastics, while special steels will become the more important to maintain durability and comfort simultaneously.

Table 5 – Surface modification methods applied for automotive components. [28]

Methods	Modification type	Thickness (μm)	Property	Typical application
Electrolytic plating	Cr, Cu, Ni, Zn-Fe, Zn-Ni Ni-P-SiC BN Fe, Sn Ni-P-B	100~300 10~100 5~20	Corrosion resistance, outlook, low COF, resistance to wear, scuff and micro-welding	Bumper, Ornaments, Body component panels Cylinder bore, Piston
Electro-less, Conversion	Ni-P-SiC Phosphate coat	3~20	Wear resistance	Brake cylinder pistons
Electrolytic deposition	FeS, Fe_2S Phosphate coat	3~8 20~50	Reduce friction Lubrication	(Developing) Cold forming blanks
Coat quench	Gr, Phosphate, MoS_2 etc x PIA, PE etc	4~7	Prevent rusting, Adjust friction coefficient	Fasteners, W spring retainers, etc.
Solid lubricant coat	MoS_2, Graphite, PTFE, hBN x PAI, Epoxy	3~100	Reduce friction Dry lubrication	Piston rings, Carburetor shafts, Gears, Pistons,
Painting	Color paints	30~500	Outlook, Corrosion resistance	Body and panels and various components
Plasma spray	Fe, Cr, Al, Mo, Ceramics, W, WC, Cu, Cu-Zn,	100~400	Wear resistance, Thermal insulation	Piston ring, Lifter periphery, O_2 sensor, (Cylinder bore),
PVD Physical vapor deposition)	TiN, CrN, TiAlN, TiAlCN	4~20	Wear, Seizure resistance	Lifter shim, Piston rings, Tools & dies for Machining & forming
CVD	DLC,	2~10	Reduce wear and friction	(Piston rings)
Dip coating	Zn, Zn–Ni, Zn-Al	50~300	Corrosion resistance.	Body sheet panels Fuel tank

COF: Coefficient of Friction hBN: Hexagonal Boron Nitride DLC: Diamond Like Carbon

4.2. Heat treatment

The time and energy conservation via the utilization of all the possible technologies to minimize heating energy and elimination of re-heating processes via the improvement of heating methods and designs of burners and furnaces. Also, investigation and use of technology at lower processing temperature, reduce processing time become the more important. Those tasks should be performed via the collaborative efforts between material manufacturers; automotive e engineers and heat treating engineer's t optimize the results.

Surface modification technology will become more important to enable maximum use of materials properties with optimum combination of base materials property, heat treatment and final surface modification technologies over the traditional threshold of materials science. Ferrous, light metals plastics and glass and ceramics materials should be used in optimum combination to introduce new grade of specific weight strength ratio to satisfy new century needs.

4.2.1 Carburizing and carbonitriding

1) Vacuum (Reduced Pressure) Carburizing needs additional technology to reduce processing time during heating and cooling by convection thermal technology and which should be named as "The controlled Pressure Processing" [29-30]
2) High temperature reduced pressure carburizing with gas quench needs further technological advancement to increase cooling power without increase in distortion.
3) Necessary technologies are development of grain growth controlled steel by dispersed TiN, AlN and NbN precipitates and thermo-mechanical process control.[31]
4) RE influence seems to be important to reduce carburizing under reduced pressure and further investigation is requested. [32-35]
5) Processing time for specified effective case depth is directly influenced by carbon potential of the carburizing atmosphere even with reduced pressure methods, and standardization of process parameter should take carbon potential into account to enable reliable and efficient carburizing. Therefore the development of the more precise Carbon potential control methods is necessary not depend on traditional LBE control measures by utilizing applicable atmosphere measurement methods.
6) Increase in processing efficiency is important to increase surface activity with new concept to such as catalytic or REDOX (Reduction-Oxidation) reaction.
7) Carbonitriding technology has new possibility by the effective use of nitrogen influence beside the use of dispersed carbide particles for the improvement of sever wear and rolling fatigue strength. [36]

4.2.2. Low temperature nitriding and nitrocarburizing technologies

1) Nitriding technology have to introduce new possibilities via the development of nitriding steels and improvement in processing technologies as operating temperature, N and C- potential control at low temperature processes to reduce processing energy. The optimization of relative influence of Carbon and Nitrogen in steels seems to enable reduce in processing time compared.
2) Low temperature nitrocarburizing and oxy-nitro-carburizing: For more than thirty years the low temperature (570 ~ 580 _) cyanide salt bath nitriding process has been widely used in the automotive industry. Salt bath nitriding, which uses Cyanate instead of cyanide, was developed in the late 1960's to eliminate toxic and hazardous disposal problems. Also, operating temperatures widened from up to 630 _ down to 430 _ to meet application needs and to optimize component properties. Stainless steels can be nitrided without deteriorating corrosion resistance while also increasing surface hardness up to Micro Vickers hardness (Hv) 1000 or higher. [37] The salt bath and gas processes have differences in N and C concentrations depending on the process used. Also, treatment times of these process yield different results as a function of N, C and O concentrations. [38]
3) Active Screen Plasma: A new Plasma nitriding technology was developed in Europe and expanding mainly there. New "Through cage" or "Active Screen Plasma: ASP" nitriding processes have

yielded excellent results and may open a new market thus expanding the low temperature nitriding market. [39]

4) Nitriding of stainless and Maraging steels: Some of the reported results such as following nitriding technologies may worth notice for the high nitriding speed. A patent on gas nitriding of Maraging steel by controlled dissociation method has high nitriding speed compared with other processes. [28] Other technology to increase diffusion rate is as explained before by the alloying effects of rare earth elements. [32-35] These technologies may open a rout to develop the more efficient nitriding technology, that is not well understood now and needs further investigation. Reduction and oxidation phenomena are seems to be related with particular results observed in some cases will be a key to break through traditional processes. [40] Activation of reaction by atmosphere and plasma control is other possible methods to increase surface reactivity. [41]

5) Induction heating processes: Induction hardening is widely applied to automotive components that require locally hardened areas. Cam shafts, ball joint stud and miscellaneous components are induction hardened to yield high surface hardness by induction heating and quenching. Induction heating is also an energy efficient heat treatment process not only for hardening while also having the benefit of being able to soften selected area for improvement of toughness in case hardened components. Recent technology enabled hardening of gear tooth profile via the precise control of heating cycle and optimum coil design. This profile hardening process can introduce extraordinary high compressive residual stress at the surface layer compared with traditional carburizing and hardening processes. The combination of technologies to optimize case depth with the high residual compressive stresses seems to expand their application into gearing of transmission and machines. [25]

5. POWDER METALLURGY AND SINTERING

Powder compaction and sintering process is widening application. Transmission and Engine components such as clutch hub, timing sprockets and gears in are typical example made of Iron powder. The powder processing technologies are advancing further to introduce more powder metallurgy products. [25] Valve seats in cylinder head are excellent example of powder products that enabled the introduction of specially designed valve seat materials necessary to fit with severe engine operating condition. [42] Powder Forged Connecting Rods were developed and used in BMW Engines. [43] Toyota also developed powder forged connecting rods in engines. [44] Variable Valve Timing gears used for Engine are also made from Iron based powder alloy. [45] the most advanced powder metallurgical application is Titanium valve produced via compaction, sintering and extrusion, and swaging to form valve seat face as mentioned previously. [14]

SUMMARY

Challenge toward the development of design and production technologies of light and durability with driving comfort will proceed further and competition in materials seems to become the more severe. Additional force toward breakthrough in management of technology related with alternative power source such as Hybrid, Fuel Cell and Electric vehicles accelerate the change of materials balance in this century. In spite of existing well used heat treatment processes, there is possibility to increase energy and processing efficiency, and improve product quality by the development of advanced processing methods by utilizing following technologies.

1. Competition in materials to fit for new generation vehicle design necessitates collaborative R & D with basic science and industrial technologies in through-process design.
2. Steels will play important role to maintain strength and durability of vehicles and further investigation to fabricate reliable components via optimized alloy design and processing technology.
3. Increase of production efficiency with minimum energy is enabled by multiple reheat operations by hybrid heat treatment technologies such as FQ and DHT technology, coat quench.
4. Improvement of light metal property via the investigation in alloy design and processing technology should be stressed to cut vehicle weight and increase reliability.
5. Especially the reaction and dissociation control should be advanced further via the analyzing and monitoring technology and the development of sensors.
6. Additional measure to increase surface reaction activity is necessary to advance heat treatment technology via the use of catalytic and or reduction-oxidation reaction.

The advancement of both of heat treatment and surface engineering technologies are inevitable to meet the progress of application needs. Emerging technologies should fulfill requires as the higher efficiency, comfort, safety, and measures for environmental and global warming problems while also meeting the needs to reduce energy consumption and production costs.

Innovation of industrial technologies is not possible without advancement of materials and processing technologies to make a breakthrough. Especially, improvement in performance per weight is only possible through the strengthening of components which in turn, is achieved through the deployment of effective heat treatment and surface engineering technologies.

To meet and overcome these challenges, both scientific and industrial research and development should be continued not only through these entities own domestic efforts within their respective countries, but also international collaborative activities. IFHTSE, in particular, plays a particularly critical role in supporting this concept through their efforts in facilitating information and technology exchange to further increase the level of international understanding of the challenges that all global entities supporting and responding to the global mechanical and automotive industry face.

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