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Mr. Ganesh, Volunteer
Ultra Surface Finishers
Mr. Sreenivasan, Volunteer
INDWEL Heat Treaters
Mr. S. Srinivasan, Volunteer
Ashok Leyland Ltd.
Mr. Sajikumar, Volunteer
Maxwarm Engineering

Message from Chairman

ASM International Chennai Chapter has performed well during 2014-2015 with multifaceted activities. We are able to establish fruitful collaborations with the other professional societies in and around Chennai and organized technical talks of significant interest. These technical evenings enabled us to develop a deeper understanding with other professional societies and also to foster friendship amongst the members.

The chapter also organised a few courses such as one-day course on heat treatment and also a two-day conclave on Steel technology, both of these have received from both industry and academia. Members of the chapter have worked hard in organizing these events, which is worthy of appreciation.

Chapter, the Chairman organised a symposium on “Innovation in Processing of Light Metals for Transportation Industries: A Symposium in Honor of Prof. C. Ravi Ravindran”, as a part of Materials Science and Technology 2014 in Pittsburgh, USA during October 12-16, 2014. A few members of the Chapters attended this event and felicitated Prof. Ravindran, President, ASM International (2014), who is a well-wisher of the Chapter and has been a constant supporter for all its activities. The proceedings of this symposium has been brought out as a special issue in Journal of Materials & Engineering Performance.

The Chapter has also conducted an outreach program for school children in Hosur together with Madras Metallurgical Society. This Chief Guest for this program was Mr. Muthuraman, Ex. Vice Chairman, Tata Steel. A number of students participated in this program.

The Materials Advantage Student chapters at IIT Chennai have also performed well. They have organized Materials Quiz along with IIM Chennai Chapter. They are also Co-organizers of 8th International Symposium for Research Scholars (ISRS-2014) during Dec. 11-13, 2014 along with Indian Institute of Metals Chennai Chapter and the Dept. of Metallurgical and Materials Engineering of IIT Madras.

All these activities were made possible because of the excellent teamwork of the executive committee and wholehearted support of the enthusiastic members. With the collective participation of its members, the chapter has initiated action on the upcoming major event, Heat Treatment and Surface Engineering Conference and Exhibition that is planned during May 12-14, 2016.

Chapter will always be looking forward to receive innovative ideas from its members to increase the number of activities of the Chapter.

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Vice Chairman
Wheels India Ltd.

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Ultra Surface Finishers
ASM Chennai Chapter Recognition Awards

**Industry Excellence Award**
- Microlab, Inspection & Testing Services
- Chennai Metco Pvt Ltd, Laboratory Equipment Suppliers

**Emerging Professionals Achievement Award**
- Mr. Fanish Tiwari, Engineer-Steel, Advanced Materials Technology, Caterpillar India Pvt Ltd.

**Young Professionals Achievement Award**
- Mr. R. Arumugakumar, Manager-Materials-SQA, Tractors and Farm Equipment Ltd.

**Outstanding Professionals Achievement award**
- Mr. G.S. Shankar, Division Manager, Advanced Materials Technology, Caterpillar India Pvt. Ltd
- Mr. S. Srinivasan, Senior Manager CQ-SQ, Ashok Leyland Ltd.
- Mr. K. Thirugnanam, Deputy General Manager – Corporate Quality, Tractors and Farm Equipment Limited
- Mr. D. Ravikumar, AGM- Metallurgical Services, Stanadyne Amalgamations Pvt. Ltd.

**Distinguished Professionals Achievement Award**
- Mr. V.P. Parthasarathy, General Manager- Engg. R&D, Brakes India Ltd.
- Prof. M. Kamaraj, Head, Dept. of Metallurgical and Materials Engineering, IIT Madras

**Outstanding Contribution Award**
- Dr. U. Kamchi Mudali, Associate Director, CSTG & Head, RRDD, IGCAR, Kalpakkam
- Dr. Srinivasa Rao Bakshi, Asst. Professor, Dept. of Metallurgical and Materials Engineering, IIT Madras

The Awards were presented during Annual General Body Meeting held on 13th September 2014 in Hotel Radha Regent
Activities of ASM Chennai Chapter

Technical Lectures

• A Technical Presentation on "New technologies in Heat Treatment Control" was delivered by Mr. Stefan Heineck, Head of Process Engineering, Stange-Elektronik GmbH, Germany on 7th June, 2014. The talk was jointly organized with Indian Institute of Metals Chennai Chapter and Madras Metallurgical Society.

• A Technical Presentation on "New Nitro-carburising Furnaces & Furnaces for Heat treatment in Protective Atmosphere" by Mr. Otto Hunold, Engineering and Sales Manager, Eliog, Germany was held on 1st July, 2014. The event was jointly organized with Madras Metallurgical Society.

• A Technical Presentation on "Vacuum Heat Treatment & Vacuum Carburizing " by Dr. Maciej Korecki, Vice President, Vacuum Furnace Technology, Seco Warwick Allied Pvt. Ltd. was held on 24th July, 2014. The event was jointly organized with Madras Metallurgical Society.

• A Technical Talk on "Advanced in Structural Light Weight Castings for Automotive Applications" was delivered by Prof. Sumanth Shankar, Braley-Orlick Chair in Advanced Manufacturing and Director of Light Metal Casting Research Centre (LMCRC) at McMaster University on 15th Nov. 2014. The event was organized jointly with Indian Institute of Metals Chennai Chapter and Madras Metallurgical Society.

• A Technical Talk on "Failure Modes in Welded Construction and Approaches to Mitigate Risk" was delivered by Mr. Marie Quintana, Chief Engineering and Technical Director, and Dr. Badri Narayanan, Director, Consumable Research & Development Group of Lincoln Electric, Cleveland, USA on 24th February, 2015. The event was organized jointly with Madras Metallurgical Society and Society for Failure Analysis, Chennai Chapter.
Courses Organized

• A One Day Course on Heat Treatment was organized on 9th August 2014. The program received a good response with 70 participants.

• ASM Chennai Chapter organized a Two Day Conclave on Steel Technology and its Applications on 13-14 February, 2015. This was well attended with 85 participants and highly appreciated by members of the industry.
“Automotive Light Weighting” – A Journey and Not a Destination

Dr. T. Sundararajan
Wheels India Ltd.

Over the past few decades “Light weighting in engineering applications” had been widely discussed and endorsed topic across various industries across the globe such as aviation, wind energy and most particularly in automotive sector. Automotive sector is undeniably the largest and most complex in industrial antiquity and in the current too. The very much evolved robust design methodology and state-of-art manufacturing techniques of the automotive segment has outstretched the same to a level to meet tauter demands of safety, price, performance, reliability and other needs. As known to all the field had witnessed several developments regarding light weighting and still paving way for further developments. What remains unknown is “How it is made possible? And what is the potential source behind the development?” The answer is simply “The Material”. This is a topic that remains important ever, as every kilogram you take away from your vehicle improves the vehicular performance, driving dynamics, vehicular agility and fuel economy, thereby reducing the emission level in automobiles. Studies say that for every 100 kg saving vehicular weight (unsprung mass), one can achieve fuel saving up to 3%. The above said, reasons out why OEM’s are investing more on carbon fibre and aluminium. Also other automotive giants are looking forward for industrial plastics for their components such as plastic fuel tanks and more. Due to higher capital to be invested in light weighting options and end user’s minimal interest to pay for light weighting in automobiles, light weighting did not take its place significantly. However the introduction of authoritarian environmental regulations and its enforced penalties has levered the light weighting targets in the automotive industry significantly.

Materials and Weight impact in a vehicle:

Reduction in vehicular mass paves way for mass de-compounding in vehicles, for example a vehicle with lighter weight will result in smaller brakes, and lighter drive trains will result in lesser support structures leading to still lesser vehicular mass / weight. As studied, to meet the light weighting targets of automotive industry there will barge out three imperative options as follows:

1. High Strength Steel on par with conventional steel is estimated to be used by over 60 % of the vehicles produced, mainly passenger cars (small and medium sized)

2. Another well recognised automotive light weighting option would be the use of aluminium and magnesium in alloy form. The estimated usage would be around to 30% of the executive class vehicles and battery run vehicles.

3. The third widely spoken and attractive option would be the use of carbon fibre in concept cars or most advanced high end sports cars and forte luxury cars.

The following table describes the Percentage Usage of materials in current road vehicle application

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>43.7</td>
</tr>
<tr>
<td>HSLA Steel</td>
<td>8.2</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>1.4</td>
</tr>
<tr>
<td>Other Steel</td>
<td>1.5</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>13</td>
</tr>
<tr>
<td>Plastics / Composites</td>
<td>7.8</td>
</tr>
<tr>
<td>Aluminium</td>
<td>5.6</td>
</tr>
<tr>
<td>Rubber</td>
<td>4.3</td>
</tr>
<tr>
<td>Glass</td>
<td>2.8</td>
</tr>
<tr>
<td>Copper</td>
<td>1.4</td>
</tr>
<tr>
<td>Powder Metal</td>
<td>0.8</td>
</tr>
<tr>
<td>Lead</td>
<td>0.8</td>
</tr>
<tr>
<td>Die Casted Zinc</td>
<td>0.5</td>
</tr>
<tr>
<td>Fluids / Lubricants</td>
<td>6</td>
</tr>
<tr>
<td>Other Materials</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

There are still varied light weighting options in the automotive industry such as Austempered Ductile Iron and Titanium whose usage will be discussed too.

Various light weighting options are into consideration, but the use of a particular material is fully application adapted. For example one particular material may offer superior strength, while the other may offer higher toughness. Also the major constrain in the use of these materials is their cost. Cost of light weight material worsens its application but as said earlier the environmental regulation forces the use of light weighting option into automotive engineering forcing a trade-off between the application and cost. The below plots describes the material weight and cost of the same as compared to steel for various materials of light weighting options.

Not all the vehicular parts can witness light weighting in them. The major vehicular parts that can expect material change or the parts where hands can be laid on are the Power train and Chassis followed by exteriors and interiors. The following table describes the expected material usage in automobiles.

<table>
<thead>
<tr>
<th>CURRENT MAJOR OCCUPANTS</th>
<th>FUTURISTIC OCCUPANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Train</strong></td>
<td><strong>Chassis</strong></td>
</tr>
<tr>
<td>Iron, Steel, Aluminium</td>
<td>Steel, HSS</td>
</tr>
<tr>
<td></td>
<td>HSS, AHSS, Composites</td>
</tr>
<tr>
<td><strong>Exteriors</strong></td>
<td><strong>Interiors</strong></td>
</tr>
<tr>
<td>Steel, Aluminium, Plastics</td>
<td>Steel, Aluminium, Plastics</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>High Strength Steel and Crash Worthiness</strong></th>
</tr>
</thead>
</table>
| Steels with yield strength of not more than 360 MPa has met the industrial usage for long. However the usage of High Strength Steels in automotive industry can be dated back to more than 3 decades for light weighting and its very properties of formability and weld ability with strength ranging to 1400 MPa. Domineering automotive safety standards in automotive sector, particularly the crash resistance in automobiles stood for employment of HSS in the same. Some of the developed steels where even able to absorb energy in axial crash test to more than 90% of the imparted. Henceforth cold rolled HSS and AHSS have been into automotive light weighting applications because of their crash resistance and impact resistance. There are various methods to produce such steels such as: 1. Strain Hardening, 2. Thermo-mechanical treatment 3.Alloying, and 4.Grain Refinement.

_Hood outers and frames in some automobile application employ aluminium in its construction_
Aluminium and Magnesium in Automotive Application

Aluminium has already crept in automotive applications years back. The average usage of aluminium in passenger cars has reached 144 kg by 2000. Since 2010 the share on aluminium in automotive application did not find any significant increment. The main challenge in the usage of aluminium is where the component’s cyclic loading is predominant. To achieve on par fatigue life with steel, aluminium did not yield any light weighting, for example the wheels used in passenger cars made of aluminium as well as steel possessed similar mass. The above said phenomenon can be very well reasoned out by the lower fatigue life of aluminium alloys and their manufacturing process such as casting possess inherent defects such as porosity and dendrites, which warrants higher factor of safety. Aluminium has took a good position in automobiles and its components for the very reason of light weight, high specific strength, energy absorbing characteristics, corrosion resistance and easier recyclability of the metal. Aluminium cannot replace steel directly, it has to be engineered or alloyed to make it usable in automotive application. Pure aluminium has also been employed for luxury cars and other niche cars. Magnesium is another light metal that has found its way into automotive application. One of the major advantages of magnesium over aluminium is that due some peculiar material properties, magnesium primarily pressure die casted paving way to produce complex structures and geometries.

The following vehicles employs a minimum of 10% aluminium in their curb weight since 2012

<table>
<thead>
<tr>
<th>Car Model</th>
<th>aluminium %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiat 500</td>
<td>10.5</td>
</tr>
<tr>
<td>Chrysler 300</td>
<td>10.6</td>
</tr>
<tr>
<td>Ford Explorer</td>
<td>9.9</td>
</tr>
<tr>
<td>Hyundai Elantra</td>
<td>9.6</td>
</tr>
<tr>
<td>Merc-Benz ML Class</td>
<td>11.6</td>
</tr>
<tr>
<td>Ford Escape</td>
<td>10.9</td>
</tr>
<tr>
<td>Ford Focus</td>
<td>9.8</td>
</tr>
<tr>
<td>Saab 9-4X</td>
<td>11.6</td>
</tr>
<tr>
<td>Honda Civic</td>
<td>10.4</td>
</tr>
<tr>
<td>Honda CR-V</td>
<td>10.9</td>
</tr>
<tr>
<td>VW D-Sedan</td>
<td>9.10</td>
</tr>
<tr>
<td>Chrysler/Fiat C-Sedan</td>
<td>11.3</td>
</tr>
<tr>
<td>Dodge Viper (ZD)</td>
<td>10.7</td>
</tr>
<tr>
<td>Merc-Benz GL-Class</td>
<td>9.6</td>
</tr>
<tr>
<td>Ford Fusion</td>
<td>10.2</td>
</tr>
<tr>
<td>Lincoln MKZ</td>
<td>11.3</td>
</tr>
<tr>
<td>Cadillac XTS</td>
<td>10.3</td>
</tr>
<tr>
<td>Honda Accord</td>
<td>11.2</td>
</tr>
<tr>
<td>Nissan Altima</td>
<td>10.7</td>
</tr>
<tr>
<td>Toyota Avalon</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Some of the auto components that use aluminium in raw or alloy form is the automotive body, exteriors, engine blocks and more. Similarly magnesium in automobiles exists as transmission housings, doors components and bonnets. Magnesium applications doesn’t stop with housings it also extends to fuel cells, engine parts and hybrids, even taking over aluminium in some cases. Some of the intrinsic application of magnesium include valve covers, intake manifolds and casings. Magnesium is 30% less dense than aluminium and solidifies faster which makes manufacturing easier.

Austempered Ductile Iron (ADI) in Automotive Application

Austempering heat treatment process produces ferrous materials which has superior properties than those which are processed in conventional methods, and hence are used in widely in automotive applications. Austempering in Ductile Iron is a process where Austenitizing is done followed by rapid quenching to a temperature above Martensite start temperature. ADI with hardness magnitude of up to 550 BHN were produced and employed where high wear resistance in of importance in automotive engineering. Softer ADI (275 – 325 BHN) can transform in to martensite when subjected to physical strain, hence in application such as transmission gears worn out regions can be freshly replaced by strain hardened ADI thereby increasing product life. Transmission gears and crank shafts find themselves built with ADI for higher wear resistance. Knuckle joints such as in steering systems are a potential auto component to be built with ADI to meet the safety standards. There are varied application of ADI in Heavy Trucks as well as Passenger cars. Heavy trucks employ ADI for suspension components and power trains and light vehicles employ them for engine parts.

Cast steel replaced with ADI in truck suspension support
Engineered Automotive Plastics:
Plastics in automotive sector did not find its way until 1950, when thermoplastics played a major role. Polymers in various structures were engineered to make way for plastics in automotive industry. Other than weight reduction plastics offered various other advantages such as good aesthetic appeal, colouring and self-colouring properties. They also offer excellent corrosion resistance, intricate and undercut design options and good toughness factor. Plastics in automobiles are the second most used material by volume next to ferrous components.

Even though a dozen type of polymers are used for automobile construction, only a hand full of them are used in majority which include, Polypropene, Polyurethane, and Poly Vinyl Chloride (PVC). They also offer excellent corrosion resistance, intricate and undercut design options and good toughness factor. Plastics in automobiles are the second most used material by volume next to ferrous components. Even though a dozen type of polymers are used for automobile construction, only a hand full of them are used in majority which include, Polypropene, Polyurethane, and Poly Vinyl Chloride (PVC). The following components in today’s automobile are in plastic: Seating, Bumpers, Dashboard, Body panels, fuel system, Bonnet components, Exterior convolute, lightings, fuel tanks and more. More over safety components such as air bags and seat belts are made of plastics. One of the greatest challenges in using plastics is recyclability of the material. Automotive industry is the best of all engineering industries in recycling with an average of almost 75%, but targets are being made still stringent with the usage of plastics. Plastics have reached the heart of an automobile in recent past, like the thermostet polymers being used in engine cage offers higher temperature resistance and noise reduction possibilities.

The better known engine applications include intake manifolds, cooling systems and fuel containers. Plastics in chassis systems help reduce vibration and serve as supports, floors, and in brake systems.

Titanium in Automotive Sector
Titanium attracts designers from automotive field for its very properties of Higher Strength, Lower Density and excellent corrosion resistance even though being a metal. The excellent performance characteristics of vehicles with the usage of titanium simply eclipses the higher cost involved in the usage of the same. The usage of titanium in automobiles have far been restricted to racing segment. For over years race car makers have adhered to the usage of titanium for their engine components such as intake valves and connecting rods since they offer higher resistance to deflection and enhances performance. Titanium has also been employed in mufflers and exhaust parts. The only thing that stands in way of titanium usage is its cost of manufacturing, but the recent past has seen an alternative way of producing titanium in form of powder metallurgy. They are mainly used in valve spring retainers and suspension coils. Titanium reduces noise, vibration and delivers better performance. Some of the potential auto components to be employed with titanium are: valves, retainers, springs, coils, power shafts, brake pad supports, exhaust components, suspension components, bumper supporters, and shock rods.

Summary
As this article is entitled, so is the current automotive scenario, Automotive light weighting is a never ending phenomenon wherein in automobile makers are facing a high time situation where they have meet the stringent environmental regulations, which his becoming the need of the day, by fuel saving and emission control. And the potential option being light weighting of automobiles. While the aviation sector is predominantly into light weighting with a light weight share of 80%, the automotive sector aim at a stunning 70% light weighting share from a mere 28% by 2030 sources say. Also carbon fibre shall slope down on its rate from about 76% difference with steel to 25% difference with steel in the not too distant future as anticipated and shall become the material of regular usage. Hence automotive light weighting happens with on par improvement in vehicular performance as a never ending process.
Advantages of Low Pressure Carburising Technology in Manufacturing of Auto components
Mr. Niranjan More
ALD Dynatech Furnaces Pvt. Ltd.

With the many advances that have taken place to improve quality of the auto components, it is only logical that heat treat services would have to evolve itself to meet the increasing demands of precision auto parts. Low pressure technology which also referred as Vacuum Carburising has already become a preferred case hardening process over the conventional gas carburising processes in Europe and North America. Driven by cost savings in manufacturing of gears, shafts and spindles, the heat treatment process has gone into the focus of the manufacturers. The potential of savings in heat treatment cost is huge because the new technology allows shortening of the total process time compared to the conventional process. Quenching after low pressure carburising can either be followed with high pressure gas or oil as quench media. Selection of the quench medial is generally decided based on the part sizes and steel grades. The advantages of vacuum technology are in particular: the absence of surface oxidation, the cold wall technology, the gas quenching technology, Oil Quenching technology, the reduced logistics, flexible reaction on the needs of production and the control of distortion. Vacuum furnaces are flexible in their reaction to the production requirements. Only with these types of heat treatment furnaces it is possible to switch them off after use and save immediately energy and costs.

Introduction
LPC is a case hardening process which is performed in a pressure of only a few (5 to 15) mbar in a protective atmosphere and in temperature range of 870 to 1050 °C. In most of the case temperature is maintain between 920 to 980 °C. In most applications acetylene is used as carburising gas carbon source. Case hardening essentially consists of three steps. First, the parts are austenitized, then carburized, and Once the required carbon profile is reached, they are quenched. Required surface microstructure in case harden layer of case hardened parts are martensite with maximum of 15-20% retained austenite LPC is usually combined with High Pressure-
-ure Gas Quenching (HPGQ) and Oil quenching. During HPGQ the load is quenched using an inert gas-stream. Usually nitrogen or helium are used as quench gas. In LPC with oil quench process parts are quench in special oil’s designed for vacuum furnaces.00

Process
Figure 1 depicts a typical carbon profile, and Fig. 2 shows a typical hardness profile after a case hardening process. In this example, the surface hardness is 750 HV and the case-hardening depth (CHD) is 0.95 mm (0.03 in.). The common definition of case-hardening depth is the distance from the surface in which the hardness is still above the hardness limit of 550 HV(50 HRC). Process cycle for low pressure carburising is shown schematic drawing in fig 3. After loading the parts, vacuum is created in chamber.

Fig. 1: Example of C profile after case hardening

Initially parts are heated under convective operation with help of nitrogen at 1.5 bar. Convective heating offers faster ramp rate and also homogenous along load, compared to vacuum heating. After reaching to a temperature of 750°C, Parts are further heated in under vacuum condition till the carburising temperature is reached. Carburising takes place by introduction of acetylene C2H2 in to furnace chamber. Acetylene act as source of carbon in carburising process.
These steps are further repeated - Fig 4 till the required carbon profile is reached in the steel. After completion of all boost steps, final diffusion time is given for achieving required surface carbon content. The high Carbon yield from Acetylene Gas and fast mass transfer of carbon during carburising leads to the saving of almost 30% of process time compared to conventional process.

As soon as the required carbon profile has been achieved, parts are then further quench in either gas or oil media.

**Low pressure Carburising at High temperatures**

Low pressure carburising equipment’s are based on cold wall technologies, i.e. the vessel is manufactured with a double wall jacketed steel structure, Furnace walls will be continuously cooled with flow of water and the hot zone is insulated with graphite plates.

Therefore, from the technical point of view, higher process temperatures can be used in Low pressure carburising furnaces. Conventional carburising furnace eg SQF, Pit Type furnace with its insulation systems can go maximum 910-930°C. As shown in Table 1, With Low pressure carburising substantial amount of time can be saved compared conventional gas carburising due to high mass transfer of carbon from surface. This effect can be further enhance by increasing temperature for carburising. With higher carburising temperature leads to faster diffusion of Carbon in to the steel, thus carburising time is reduced significantly. This can be seen from Fig 4, carburising time reduces drastically as the temperature is increased.
**Comparison of Carburising Process Time**

Below Table 1 compares the process times of both technologies at a carburising temperature of 930°C. Charging, heating and quench times vary slightly. Time savings clearly become evident in the carburising and diffusion time. The example in Table 1 shows a 20MnCr5 with a CHD of 0.8 mm (0.35%). Carburising with the conventional technology takes 180 min, low pressure carburising only takes 140 min, 40 min less, or 30% (based on the carburising cycle).

![Microphotograph](image)

Microphotograph shown above indicates the surface of steel parts after both Low pressure carburising and Gas carburising. It clearly shows that surface after LPC process is completely free from any intergranular oxidation compared to conventional gas carburising. This further affect in reduced surface hardness, low impact and fatigue properties of parts.

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Vacuum Furnace 930°C min</th>
<th>Gas Furnace 930°C min</th>
<th>Vacuum Furnace 960°C min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<td>Decrease temp. to core hard temperature</td>
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<td>Process Time Reduction%</td>
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<td>112 - 31%</td>
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**Advantages of Low Pressure Carburising**

Following are the various advantages /benefits of vacuum carburising over conventional gas carburising techniques

- Uniform case depth
- Surface free from intergranular oxidation and surface oxidations
- Environmentally friendly process
- No fire /flame hazards.
- Shorter process cycle time thus lower production costs.

- Better control on distortion
- Enhancing Energy efficiency.

**Applications**

Various Automobile components can be case hardened through Low pressure carburising technologies for case depth ranging from 0.3 to 2.5 mm. Available Furnace technology for this process are Vacuum Chamber Furnace with High Pressure Gas Quenching and Double chamber Vacuum Oil Quench Furnaces for low alloy steel parts

**References**

1. Low Pressure Carburising Services For Precision Parts By Dr Volker Heuer and Klaus Löser
History of Quenching

D. Scott MacKenzie, PhD
Houghton International, Inc.
Valley Forge, PA 19426
smackenzie@houghtonintl.com

“GOLD is for the mistress - Silver for the maid - Copper for the craftsman cunning at his trade.”

“Good!” said the Baron, sitting in his hall, “But Iron - Cold Iron - is master of them all.”

Rudyard Kipling - Cold Iron

Iron scented a simple metal, but in its nature are many mysteries, and men who bend to them their minds shall, in arriving days, gather therefrom great profit, not to themselves alone but to all mankind.

attributed to Joseph Glanvill (1636-80)

Introduction

The basic concept of heat-treating, and specifically quenching, is intertwined with the history of civilization. It is the efforts of these pre-industrialized people that laid the foundation for modern metallurgy, and our understanding of materials behavior. In this paper, the early history of quenching will be described from the dawn of civilization to the early industrial age. The focus will be primarily on the contributions of Europeans, Indian, Chinese and Japanese peoples.

Much of the history of quenching is shrouded in mystery - especially from roughly 400 BC to approximately 1500 AD. This is thought to be a result of the general education of the people, and the desire to protect intellectual property by the many blacksmiths and guilds. It was only until much later, that many of the quenchants, and the methods of quenching were described. This was accomplished through empirical research, and much experimentation. It was only until much later, after approximately 1850 AD, that the science of quantifying the effects of quenchants and alloying elements was developed. Steel hardenability, martensite formation and the mechanism of quenching would have to wait until the necessary analytical tools were developed.

Figure 1 - Process in creating a Japanese Sword, from top to bottom: The Steel is Heated Prior to the Forging Process in a Charcoal Fire; After hammering the steel out, it is cut in half and folded; The folded steel is then hammer welded together, as the forging process continues; The smith then continues to shape the blade, first with a power hammer and then with a hand held hammer; After forging, the blade is shaped by hand, and then coated with clay, prior to the hardening process; After the claying of the blade, it is heated to critical (about 1450 degrees) and then quenched in water, creating the martensite edge and pearlite body of the sword; The blade is then final shaped and polished. This sharpens the blade and reveals the hamon that is created by the hardening process. Figures courtesy Bugai Trading Company.
History of Quenching

Much of the history of quenching is interlaced with the early production of iron. Probably one of the earliest references to smelting and blacksmithing is from the Old Testament in Genesis 4:22:

“Zillah also had a son, Tubal-Cain, who was an artificer of bronze and iron.”

Interestingly, the name “Cain” is a cognate with the Arabic qayin “smith”. The name Cainities is also the description of the Midianite tribe, which some have inferred to be the Hittites.

It is not known when steel was first created, or who first created steel. It is suggested from tradition (Herodotus, Xenophon and Strabo) and archaeological evidence that iron working developed in the Middle East, in Turkey, near the plateau of Anatolia in 1400-1200 BC by the Hittites. Iron smelting was well known by the second millennium, and described by Homeric poems (880 BC), the History of Herodotus (446 BC) and Aristotle (350BC). Because of ore variation, and the skill of the individual craftsman, the production of steel was often poor quality, and limited in production.

One of the first mentions of quenching is from Homer (circa 800BC):

“As when a man who works as a blacksmith plunges a screaming great axe blade or adze into cold water, treating it for temper, since this is the way steel is made strong, even so Cyclops' eye sizzled about the beam of the olive....” Odyssey 9.389-9394, translation by R Lattimore

This dramatic image of indicates familiarity with the concept of quenching of steel. Much of the history of quenching has been shrouded in mystery and magic.

In the first millennium, few technological advances were made in Europe. Some Icelandic sagas spoke of searching thru many kingdoms to find the proper water to harden the sword Ekkisax and weapons that are hardened in blood. Predominately, the advances in metallurgical technology were located in the Arab World, India, China and Japan. While European armor blacksmiths were improving, and gradually perfecting their craft, the Crusaders of the 12th century had no steel that was the equal of Islamic metallurgy. The Japanese sword was even better than the Islamic sword by an even greater margin.
Middle East

Not much is known of the methods of quenching in the Islamic world. It was known that the swords of the Islamic world were high quality. A writer from the Crusades, regarding the quality of Damascus blades fashioned from Wootz steel described the quality of the blade as “One blow of a Damascus sword would cleave a European helmet without turning the edge, or cut through a silk handkerchief drawn across it.”

al-Biruni, writing in the Kitab al-jamahir fi ma'rifat al-jawahir, in the 11th century AD, specifies what dawa is in Indian practice. He writes “…in the process of quenching the sword they coat the flat of the blade (mahm) with hot clay, cow dung and salt, like an ointment, and clean the two edges with two fingers…” This is similar to the process of making Japanese blades, and the application of yakatabutsuki clay.

The account of Second Captain Massalski, as published in Annuaire du Journal des Mines de Russie, 1841, says Persians quenched their Wootz Steel in pre-heated hemp oil. The Captain says some smiths added a little grease and bone marrow to the quenchant.

*If it is a dagger it is held flat; if it is a sabre, it is quenched little by little, beginning by the end of the cutting edge, holding the latter toward the bath. This manœuvre is repeated until the oil stops smoking, which proves that the blade has cooled. After quenching the blade is always soiled with burnt oil. This dirt is removed by boiling it enough to set light to a piece of wood, and by rubbing with a rag from a bedsheets.” English Translation by Graham Cross.

India

The primary contribution of India was the production of high quality steel called Wootz steel. The quality of the steel was excellent, and exported to Europe, China, and the Middle East. The 12th century Arab Idrisi wrote “The Hindus excel in the manufacture of iron. It is impossible to find anything to surpass the edge from Indian steel.”

The first real production of steel on a large scale was produced in India around 500 B.C. This steel, known as Wootz steel, was of high quality which even in relatively modern times, was known for its high quality:

‘…there is a cake which is supposed to be steel from India and the kind to be rated most highly in Egypt. I could find no artisan in Paris who succeeded in forging a tool out of it.’ Rene Antoine Ferchault de Reaumur, (1722)

Sherby, describing the production of Wootz steel, indicates that wrought iron is broken into pieces in a sealed crucible, with a pre-measured amount of charcoal. The crucible is heated to approximately 1200°C. The wrought iron absorbs the carbon, and the melting point is lowered. The process is completed when the crucible is shaken, and the sound of molten iron is heard. The crucible is slow cooled over several days. Large grains of Cementite are formed, and a homogeneous alloy of 1.5-2% carbon is formed.
These buttons are then heated to a relatively narrow range of 600°-850°C. In this temperature range the Cementite does not completely dissolve. Upon forging or hammering, the Cementite grains are broken up, resulting in a mixed, banded microstructure, with the trademark swirl of Damascus Steels. This forging technique explains the strength, toughness and ductility, and the mythology of Damascus steels, which have been produced since 330 BC. This steel was exported to China, Persia, Arabia and eventually Europe.

**China**

The earliest known Chinese word for quench-hardening is *cui* and is still used in the modern term for quenching *cuilue*. Water was predominately the preferred quenchant:

> When a skilled metallurgical worker 'casts' [zhui] the material of a San Jiang [sword], quench-hardening [cui] its tip with pure water and grinding its edge with a whetstone from Yue, then in the water it can slice water-dragons, and on land it can cut rhinoceros hide as quickly as sweeping and sprinkling or drawing in mud.

*Sheng zhu daxian cien song presented to the Emperor Xuan-di (73 BC to 49 BC) by Wang Bao*

There is some thought that the idea of quenching was a Han Dynasty innovation. Early Tang texts indicated that the Yunnan quench-hardened steel in “the blood of a white horse”. Various texts indicate that different waters were good for quenching, while others were inadequate. The Qingzhand and the Longguan Rivers were noted for being good for quenching.

> "The Han River is sluggish and weak and is not suitable for quench-hardening. The Shu River is bold and vigorous....."

This empirical line of thinking appears to be universal. The Elder Pliny, in the 1st century, also indicated that certain waters were good for quenching.

Quenching in vinegar was considered to be poor practice “making it brittle and easy to break”. It is not known why this practice would be considered to be poor practice, as it should give similar performance to a brine-type quench.

It seems that quenching in urine was a common practice, with quenching in the urine of five Sacrificial Animals or the fat of five Sacrificial Animals. It was given that “such a sword could penetrate thirty layers of armor.”

There was also an understanding of the effects of different quenchants, and the effect on performance. In 6 AD, the blacksmith Qiu Huaiwen used animal urine and animal grease to effect different quench rates. The characters used differentiated this: *cui* was denoting quenching in animal grease, while *yu* was designated for quenching in urine. Song Yingxing discusses quenching in oil, which provides a softer quench, “since the strength of steel lies in quenching”. Further it was noted that barbarians quench in *di son*, the “urine of the earth”, a kind of oil not produced in China. This perhaps is the first possible mention of quenching in petroleum-based oils.

For further information on the metallurgical technology available to the Chinese from the earliest times, the reader is recommended to read the book by Donald Wagner, “Science and Technology in China: Ferrous Metallurgy” Cambridge University Press, who was gracious enough to provide me with a draft.
Japan

The metallurgical state-of-the-art was very advanced in Japan. The science and craftsmanship of the Japanese sword is still revered today for being beautiful and effective, capable of maintaining a sharp edge and the unique curve of the blade.

Swords made by the traditional method are manufactured from steel produced by the tataara method. This steel, or tamahagane, is produced from iron sands that have very low Phosphorus and Sulfur.

The basic process is similar to that practiced by the Europeans in the 5-6th century AD. The sharp edge consists of high carbon steel to retain an edge, and the interior of the blade consisting of lower carbon steel for toughness and ductility. However, the Europeans immersed the entire sword in the water, with the entire surface of the sword is quenched rapidly. In the Japanese method, controlled quenching is achieved at specific rates at different locations on the blade.

Prior to heating, the Japanese sword maker applies a closely guarded secret clay mixture (called yakibatsuuchi), that consists of stone powder, clay and charcoal. The stone powder helps prevent the clay from cracking during heating of the blade; the charcoal is burned out during heating, producing a site for initiation of nucleate boiling, depressing the formation of the vapor phase. The thickness of the clay determines the quench rate. The clay is thinnest at the edge of the blade, and thickest at the ridge of the blade - opposite the edge. The blade is immersed in water in the water box or mizubune). The edge is quenched with the highest heat transfer rate and produces martensite, while the ridge experiences a much milder quench and transforms to a mixture of pearlite and ferrite. The interface between the pearlite and martensite is called the hamon.

This unique and ingenious method of quenching also produces the characteristic curvature of the blade. As the blade is quenched, the edge contracts, and reverse bending occurs, called gyaku-sori. At the martensite transformation, the sori, or normal bending occurs, due to the volumetric transformation of martensite. Gyaku-sori appears again at the pearlite transformation at the ridge of the blade. Finally, the final curvature or sori appears as the pearlite contracts due to thermal contraction, contributing to strong compressive residual stress at the blade edge. Final tempering of the blade, or aidori, is done in a charcoal fire. This understanding of the quenching process, practiced since the 5-6 century, shows the advanced nature of the Japanese metal-smiths.
This was a critical observation. He indicates a critical range for quenching, based on the colors of the heated steel. Only when the steel is rose or yellow will the steel be hardened properly. Further, the observation of tempering colors was indicated. As Cyril Stanley Smith pointed out, it led Della Porta to realize the advantages of the two-stage quench over a direct quench, and reject some of the more exotic quenching baths that was cited in earlier metallurgical literature.

He emphasized the necessity of using clear quenching liquids so that the tempering colors could be observed, and recommended rubbing a blade with soap before heating it, "that it may have a better color from the fire."

Porta was one of the first people to recognize that there were various tempers of steel, and described methods to achieve those tempers. In describing the "Temper of Files" in his Thirteenth Book of Natural Magic:

"...take the chest out of the coals with iron pinchers, and plunge the files into very cold water, and so they will become extremely hard. This is the usual temper for files, for we fear not if the files should be wrested by cold waters.

Porta also showed an excellent understanding of the reason why many quenchants were effective, and some of the underlying principles:

"If you quench red hot iron in distilled vinegar, it will grow hard. The same will happen, if you do it into distilled urine, by reason of the salt it contains in it. If you temper it with dew, that in the month of May is found on vetches leaves, it will grow most hard. For what is collected above them, is salt, as I taught elsewhere out of Theophrastus. Vinegar, in which Salt Ammoniac is dissolved, will make a most strong temper. But if you temper iron with Salt of Urine and Salt peter dissolved in water, it will be very hard. Or if you powder Salt peter and Salt Ammoniac, and shut them up in a glass vessel with a long neck, in dung, or moist places, till they resolve into water, and quench the red hot iron in the water, you shall do better. Also Iron dipped into a Liquor of Quicklime, and Salt of Soda purified with a Sponge, will become extreme hard. All these are excellent things, and will do the work."

There was also an understanding of the cause of quench cracking, and the results of quenching in other than water for "The Temper for Instruments to let blood":

"..."
"It is quenched in oil, and grows hard, because it is tender and subtle. For should it be quenched in water, it would be wrested and broken."

Various authors, including, describe other quenchants: pigeon droppings, flour, honey, olive oil and milk.\textsuperscript{26,27,28} Other quenchants, including urine, water and solubilized animal fats and whale oil are described by Smith\textsuperscript{29}, Biringuccio\textsuperscript{30}, Agricola\textsuperscript{31} and others:

"Take clarified honey, fresh urine of a ho-goat, alum, borax, olive oil, and salt; mix everything well together and quench therein."

"Take varnish, dragon's blood, horn scrapings, half as much salt, juice made from earthworms, radish juice, tallow, and vervain and quench therein. It is also very advantageous in hardening if a piece that is to be hardened is first thoroughly cleaned and well polished."

Excerpts from Von Stahel und Eysen (1532).\textsuperscript{32}

Haedke\textsuperscript{28} indicated that the swords and knives made in Toledo, Spain, were known to be of high quality as early as the ninth century. Heat-treating occurred on a night with a warm south wind, and clouds obscured the stars. A cherry red heat was taken on the blade, and it was quenched immediately in the Tajo River.

Only late in medieval times, did sufficient technical advances in steel-making occur in Europe. It was only in the late 18\textsuperscript{th} century that difference between iron and steel was identified as being associated with different quantities of carbon present\textsuperscript{33,34}.

Conclusions and Summary

From the earliest times, at the beginning of the Iron Age, quenching has played an important role in the growth of civilization throughout the World. Much of the development of quenching was developed out of mysticism, and empirical experimentation. It was not until much later, at the beginning of the Industrial Age (1850AD or so), that mankind started on a quest to understand and quantify the mechanism of quenching and heat treatment. While much of the empirical technology developed was used to increase the effectiveness of swords, knives and armor, there has been a technology transfer to other devices important to the arriving Industrial Age. Today, there is a firm grasp on heat treatment, and the mechanism of quenching, enabling special quenchants to be tailored to specific application. It is these original Philosophers, Alchemists and Blacksmiths that were the foundation of the Science and Art of Metallurgy today.

![Figure 7. Museum quality armor created using modern quenchants. Photograph courtesy of Robert MacPherson, Armory (http://www.lightlink.com/armory/armory.html).](image)

Acknowledgements

I wish to thank the people on the Bladesmith’ Forum (forums.dfoggknives.com) and the International Sword Forum, (swordforum.com) for their help and encouragement in writing this short article. Their patience is greatly appreciated.

I would also like to thank Robert MacPherson, for showing me his intricate and beautiful work, and his patient help in explaining many of the techniques used.
References:


Outreach Activities

• ASM International Chennai Chapter along with Madras Metallurgical Society organized Metallurgy Student Fest 2015, An initiative towards inculcating Metallurgy and Materials Science to School Students, on 9th February 2015 at Ashok Leyland School in Hosur. Shri B. Muthuraman, Ex. Vice Chairman, Tata Steel Ltd, was the Chief Guest at the event. The workshop featured events like “Fun with Materials” by Prof. Sivakumar M. Srinivasan, Dean of Students, IIT Madras and “CHEMAGIC” by Mr. C. Shanmugam, Research Scholar of Anna University and Mr. Senthil Kumar of Caterpillar, Hosur. The event was presided by Mr. V. Vedhakkan Dhanraj, District Education Officer of Hosur.

• The Materials Advantage Chapter of IIT Madras organized a Materials Quiz on 16th August 2014 along with the Indian Institute of Metals Chennai Chapter


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• ASM International Chennai Chapter won the *Best Chapter Award* under “Communications” category for 2013-2014.

• Dr. U. Kamachi Mudali, Associate Director, Corrosion Science and Technology Group; Head, Reprocessing Research and Development Division & IGCAR-Technology Transfer Cell, Indira Gandhi Centre for Atomic Research, Kalpakkam was awarded the G.D. Birla Gold Medal of Indian Institute of Metals. He received the award from Dr. R.N. Patra, President, IIM during NMD-ATM 2014 held at College of Engineering, Pune during Nov. 2014

• Dr. U. Kamachi Mudali, was awarded the 2014 *VASVIK Award* in *Materials Sciences and Technology* category for "solving the corrosion issues in nuclear industry, which include materials selection, design improvement, quality fabrication and sustained performance of components for the fast breeder reactor and associated fuel cycle facilities of DAE". He received the award from Shri Piyush Goyal, Hon’ble Minister of State with Independent Charge for Power, Coal and New & Renewable Energy.

• The biography of Dr. Srinivasa Rao Bakshi, Assistant Professor, Dept. of Metallurgical and Materials Engineering of IIT Madras has been selected to be printed in the 33rd Edition of *Marquis Who’s Who in the World*. The book is a global reference source relied upon by universities, libraries, corporations, and governments around the world.

Message from Secretary

ASM Chennai Chapter is striving hard and making sincere attempts to sustain the activities as per the guidelines earmarked by the headquarters. Special focus is envisaged to plan and implement through the executive committee, the core activities related to technical programming, students outreach, young professional engagement and membership drive. Communication has been the vital tool to keep the visibility of the chapter and various methods are adapted to suit the membership base from students to life members.

The minimum performance guidelines as finalised by the executive committee will ensure the sustenance of the chapter in the long run and will attract new members from industries, academia and research to a larger extent through networking.