THE INDIAN INSTITUTE OF METALS
DELHI CHAPTER

"MET-INFO"
INHOUSE PUBLICATION

ISSUE NO. 27 SEPTEMBER 2021

Dr. Mukesh Kumar-Chairman, Delhi Chapter

S C Suri-Editor-in-Chief (IIM-DC Newsletter)

For Private Circulation only

Contents

Photos of IIM Delhi Chapter Building

Published By

The Indian Institute of Metals Delhi Chapter

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ISSUE NO. 27 SEPTEMBER 2021

Dr. Mukesh Kumar
Chairman

MESSAGE

Dear Fellow Members,

It is my proud privilege to be the Chairman of Indian Institute of Metals, Delhi Chapter and I feel honoured to serve this Chapter having illustrious members from industries, R& D Institutions, Academia & Government. I would like to sincerely thank the EC members for reposing their faith in me & look forward to our collective leadership in organizing various technical activities with larger participation to take this Chapter to greater height.

I would also like to thank all past Chairmen and Executive Committee Members for their outstanding contribution in making this Chapter most active and vibrant.

As you are aware, we could not undertake any technical activity at our Chapter's premises in 2020-21 because of impact of Covid-19. We held various webinars and technical talks on virtual platforms in 2020-21. We will start holding technical activities at our Chapter's premises once situation becomes conducive. Till the situation improves we will be holding our activities online. Our focus will be to organise more and more technical activities related to contemporary and futuristic industry oriented issues.

I look forward to have suggestions and ideas from fellow members to increase the activities of Delhi Chapter. I have no doubt that with your support and active participation, our Chapter will continue to climb ladders of excellence and make the Chapter more industry oriented.

With Best Regards,

Dr. Mukesh Kumar

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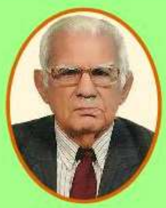

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RAW MATERIALS SCENARIO FOR STEEL INDUSTRY

Introduction

The paper briefly highlights the raw materials scenario for Iron and Steel industry with focus on India. The primary raw materials like iron ore and coal have to undergo technological processing before use for achieving quality and economic steel production. Both primary and processed raw materials are being discussed together.

The primary raw materials for Iron and Steel industry are of diverse quality, voluminous, spread over various locations worldwide, extraction involves big challenges and also have substantial environmental effects. For an Industry known as 'Industry of Industries', the supply chain of raw materials is extremely complex, of enormous proportions and itself a massive industry on its own. The Industry is facing and will continue to face the challenge of supply economics mainly on price volatility of iron ore, coking coal and steel scrap for Blast furnace route as well as for Electric furnace route.

The primary raw materials have fundamentally not changed much, apart from quality and size like lumps to fines for iron ore but based on availability, characteristics, economic and environment necessity had to adjust itself as per technological needs for economic and quality production. With the current global production of about 2 billion tonnes of crude steel, about 70 percent is through blast furnace route and the rest through Electric furnace route. With increased production worldwide, the availability of basic raw materials, iron ore and metallurgical coal needing extraction from mother earth are either depleting or not as per required form and quality necessitating further processing. For about 2 billion tonnes of production worldwide annually, about 2.4 billion tonnes of Iron ore and 1.2 billion tonnes of metallurgical coal and 600 million tonnes (Mt) of steel scrap are required globally for blast furnace and electric furnace route. Every country India no exception being now the second highest producer of steel, have their needs and priorities for developing and expanding the core industry Iron and Steel unlike the western world who reached their development level and only need to maintain it. As a comparison, China, the largest producer, has over the years have grown in gigantic proportions with capacity of 1 billion tonne of steel production, practically controls the world raw materials trade, pricing and availability. India, way behind with about 112 Mt of crude steel production have substantial iron ore and limited reserves of prime and medium coking coal have to face the price volatility of coking coal due to dependence on imports. The country has a plans of going to 300 Mt of crude steel in 2030/2031 as per Government's National Steel Policy. This will require about 450 Mt of Iron ore and 180 Mt of metallurgical coal, non-coking coal apart from limestone, DRI, Scrap, Ferro alloys, Refractory raw materials and other essential inputs like power which again is dependent on coal.

The worldwide raw materials business scenario as it stands now shows the total Iron ore trade volume to the tune of USD 124 Billion with Australian exports amounting to USD 67 billion out of which USD 83 billion is roughly the share of imports by China alone. Out of two major Iron ore exporters, Australia exported 53 percent and Brazil, 18.5 percent. China alone imports 67 percent of Iron ore traded worldwide totaling to about 1.17 billion tonnes in 2020. Share of China in global steel consumption was at 16 percent at the beginning of 21st century has reached to 55 percent with India at 5 to 6 percent.

Resources

The country has 28.52 billion tonnes of Iron ore reserves out of which 17.88 billion tonnes is Hematite and 10.644 billion tonnes Magnetite. The Magnetite deposits are mostly in eco-fragile areas of Western Ghats and unable to be exploited till adoption of special mining techniques. The total coal reserves in the country is 33.18 billion tonnes out of which 5.3 billion tonnes is prime coking coal and 28.38 billion tonnes, medium and semi coking coal. The country has huge reserves of non-coking coal, about 259.8 billion tonnes but with high ash. The Indian coal deposits are basically in the Gondwana sediments. The country also has large reserves of Limestone, Dolomite and raw materials for Ferro alloys.

Total iron ore production in the country in 2020 was 189 Mt. The major contributor was NMDC. In 2030 this production capacity needs doubling to meet the target of 300 Mt. The total coal production capacity in the country during the same period was 716 Mt and the major contributor was Coal India. There has been disruption in supply of iron ore in 2020 due to closure of some mines due to expiry of lease. This resulted in import of iron ore to overcome the shortage. Mines and Minerals Development and Regulation (MMDR) regulates the mining sector in India by governing the mining lease and ensuring the wellbeing of the population in the mining area with respect to rehabilitation. Various provisions have been announced as per MMDR Amendment Bill of 2021 with an objective towards growth. Mines' auction has been planned by Government to allot mining lease to prospective bidders to open new mines to meet the requirement of raw materials.

Certain growth options have been taken by Govt. sector to boost ore and coal production, such as opening of Bailadilla deposits 4 in Chhattisgarh and operation of Rowghat and Chiria deposit for ore and also for enhancing usage of domestic coking coal and arranging additional sources of imported coking coal. Limestone, Manganese ore, Chromite ore are available indigenously. However, for steel grade limestone, high grade low phosphorus manganese ore and high grade lumpy chromite, country has to depend on imports as these are available in limited quantity. As regards Refractory grade raw materials, high quality bauxite and magnesite are not available, have to be imported. Fireclay is generally available with coal deposits.

Quality of Available Raw Materials

Depletion of high grade ores due to extraction over decades, have given rise to the need to utilize large amount of fines and also exploit lower grade Hematite ores upto 45 percent Fe.

Growth of steel industry coupled with depleted resource of high grade ores have led to technological intervention by way of agglomeration, sintering and now pelletizing in large scale.

For sintering, iron ore fines having 60 percent Fe of acceptable grain size, limestone, dolomite, calcined dolomite, mill scale, steel making slag are used to obtain product grade sinter. For blast furnace grade pellets, 65 percent Fe fines, binder like bentonite and limestone are required. However, input consumption of fines for pelletizing is more, about 1:1 per tonne of pellets as compared to about 740 kgs per tonne of sinter. DR grade pellets require minimum 66-67 percent Fe fines with lower gangue materials.

Sintering process started in Tata Steel in fifties, but now pellets are also a main input in blast furnace burden. Pelletization transforms fine ore concentrates into pellets utilizing blue dust and ultra-fine concentrates from beneficiation plants.

Use of pellets results in improved productivity, reduced coke consumption and ease of handling over long distances which enabled pellets as main input to blast furnaces all over the world in recent times and expected to grow many fold. Many countries are shutting down sinter plants due to environmental regulations and switching over to pellets in greater proportions. Moreover pellets have the advantage of transportation over long distances without breakage. But, importance of sintering cannot be ruled out as its function of acting as a scavenger unit.

In the steel value chain particularly in India for blast furnace route, hot metal contributes 70 percent to the steel cost on account of coking coal, being mostly imported. One enabler for addressing this is, reduction in fuel rate by pulverized coal injection (PCI) by using non-coking coal.

Indian ores are high in Alumina and Silica and have adverse Alumina-Silica ratio which is detrimental to Blast furnace operation requiring beneficiation for achieving improved specification to ensure economic and productive Blast furnace iron making.

About 85 percent of coking coal is imported in India to meet the present demand.

Impact of Technology

Raw materials are intrinsically related to quality and economic production of iron and steel. With passage of time over decades since organized steel making started, there has been huge growth in capacity, world has seen two world wars and rebuilding various parts of the world, fuel crisis, globalization and need to be profitable in business for sustenance. All these factors have impacted in some way or other the availability and use of basic raw materials, iron ore, coking coal and scrap. Days are gone, whatever one produces can sell. Quality aspect and economic production has come to stay and will continue to be so. Over and above the climate change factor has come in a big way for environmental protection.

As mentioned earlier, technology has come in the way to help iron making through use of agglomeration countering the depletion of lump ore during mining enabling utilization of quality fines.

India has large reserves of coal, of inferior grade having high ash content of about 40 percent and above which has fundamentally resulted from open cast mining. Govt. of India have stipulated beneficiation to 34 percent ash before use in power plants.

Coal based technologies are in advanced stage of research and implementation in the country and some have already been initiated and some under consideration. Sole aim is to reduce coking coal use and at the same time produce steel in environment friendly manner and economic way. Coal to Syn gas for DRI production has already been implemented by Jindal Steel and Power. Coal to Methanol production is also a reality which will be a valuable fuel in future with proper mix with other fuel. Hence, use of coal as raw material remains important directly or indirectly to Iron and Steel industry, particularly in India.

Environmental Impact

Iron & Steel Industry generates about 7 to 9 percent of CO_2 emissions globally due to use of fossil fuel. For every tonne of crude steel produced, ideally steel industry should generate 1.85 tonnes of CO_2 per tone of steel whereas Indian plants generate 2.5 tonnes or more due to poor quality of raw materials.

India is now one of the largest producers of DRI in the World. Out of total 28 Mt produced, 80 percent was coal based feeding mostly to secondary steel sector.

Natural gas based DRI with scrap as metallics operated electric furnace based plants generate much less CO_2, whereas coal based DRI plants produce more.

Mining of iron ore also causes pollution in the form of nitrous oxide, sulphur dioxide and CO_2 from large number of heavy duty mobile equipment used for mining.

In view of Climate change awareness in recent years, all iron and steel making countries have seriously embarked on finding alternative to fossil fuel as reductant for iron making. Hydrogen gas as reductant can replace coke and thereby reduce CO_2 generation to a great extent. This of course requires establishing technology for economic method of hydrogen production and safe distribution.

This change in concept of use of alternative reductant or migrating to electric furnace route will not however be easy for India as the basic fuel is coal based including power generation using vast amount of non-coking coal the country has. Moreover, India needs major increase in steel production for growth and its contribution to GDP. Hence, coal as basic input material for power generation will continue to remain for some more time as well as coke as reductant in iron making and not switch to zero-carbon as early as the Western World.

Logistics

As of now, large amounts of iron ore and coal need to be transported from mines to plants which are mostly in interior region of the country. Only two plants, RINL and Hazira plant of ArcelorMittal/Nippon Steel are close to coast. With further growth, more than double, enormous amount of raw materials will have to be transported necessitating massive growth in infrastructure, mainly railways and road network. Moreover, with technological plans to increase the size of blast furnaces, use of pellets will increase requiring grinding of ores/fines and beneficiation for which slurry transportation of concentrates through pipelines is a sustainable route. Slurry transportation has already started in India but have some challenging issues in cross country routing which needs to be overcome. Operating cost of slurry transportation per tonne per km is much lower compared to railway or road movement.

Raw Materials Management

The complex supply chain of iron and steel making raw materials encompasses critical activities like acquiring mines, operating, purchasing related numerous input materials, refining, developing and delivering to user units of the plant. Quality of iron ore and coal as reductant greatly affects production process and economics of plants. With fluctuation in quality, the production process needs to tune itself. With advancement in technology, this aspect can be taken care of by Automation processes like, Digitization and other new tools.

For ensuring trouble free plant operation and raw materials security, long term supply arrangements from prospective sources both domestic as well as imported is necessary. This aspect, mostly for coking coal is being looked into by both private and public sector companies.

Future Scenario

The world is generally aligned to the importance and need to address climate change issue by controlling CO_2, aiming to achieve zero carbon by 2050 as the top most priority. Some of the advanced countries intending to eliminate use of coal in metal industry is trying to replace carbonaceous reductant coke in iron making by H_2 gas. Carbon capture from blast furnaces while using coke as reductant is also under consideration. Coal based power plants are being shut down, increase in electric furnace steel making by using scrap and DRI to drastically reduce emissions.

India also cannot stay away from this endeavour and have to undertake necessary measures. Unlike the Western world, India needs steel for growth. Large reserves of iron ore and high ash non-coking coal have to be utilized after beneficiation as overnight transition to alternative fuel may not be possible, it will take time.

Slurry pipelines for transporting concentrates needs further expansion. Electric power cost which is very high making electric furnace operation using DRI or scrap uneconomical needs rationalization between States for boosting steel and other metals production.

Road Ahead

Some of the possibilities for sustenance of Indian steel industry may be considered as:

- Look beyond only coke charge in blast furnace, increase blending with non-coking coal, optimize PCI rate.
- Seriously explore alternative iron making processes based on use of fines with minimum coke
- Alternative reductant in blast furnace like hydrogen
- Plan migration of induction furnaces in secondary sector to arc furnaces.
- Create scrap pool for increasing scrap charge in electric furnaces as scrap availability is likely to improve.
- Rationalization of power charges at affordable rate across states to enable electric furnace operation
- Allotment of mines need to be expedited
- Utilize advanced mining techniques for magnetite ore mining in eco-friendly region
- Utilize water ways to deliver primary and processed raw materials

Conclusion

The country is blessed with large raw materials base, except some like coking coal, have to grow in the steel sector with maximum utilization of indigenously available resources.

India has matured experience in mining of raw materials and only need to modernize the existing mines and develop new mines based on latest technology. The country has premier institutes under Govt. of India, like CSIR- Central Mining & Fuel Research Dhanbad, Institute of Minerals & Materials Technology, Bhubaneswar who are actively engaged in research work as well as Indian School of Mines, Dhanbad, providing world class mining and mineral processing engineers. Considering all these, the country can very well take up the challenge of providing quality raw materials to the steel industry required for growth of economy.

Source: Steel Tech

CHINA STEEL OUTPUT MAY RISE 4%-7% THIS YEAR, MISSING CO_2 EMISSIONS CURB TARGET: TRANSITIONZERO

China, the world's biggest steel producer, may produce 4%-7% more steel this year than last, missing its pollution control targets, according to a recent report based on studies of satellite imagery of steel producers globally.

China's government recently stated that it would limit its crude steel production this year to 2020 levels to curb CO2 emissions. However, the report drawn up by climatics analytics provider TransitionZero, a not for profit organization, says that steel production in China may be 88.01 million mt for August, up 1% from July.
The Asian giant's crude steel output from January to August was 734.99 million mt, up 6% on year, and mainly from carbon-intensive blast furnace and basic oxygen furnace production routes, according to the data gathered via satellite imagery by TransitionZero.

"China's crude steel production could be up 4-7% this year, meaning the country's ability to meet its Government target of limiting 2021 steel outputs to 2020 levels is unlikely without reform," said Matthew Gray, TransitionZero energy analyst. "As a result, China risks emitting an additional 158 million mt of CO_2 - the equivalent of the Netherlands' total emissions."

The target of limiting output to 2020 levels may now only be reached via a crackdown, particularly in the central and western areas, Gray said.

"China's central authorities have made good progress in reducing production in Eastern provinces, but more needs to be done in Central and Western provinces to meet their production target," Gray said. "With additional action, China could reduce emissions and show climate leadership in the run up to COP26."

TransitionZero's data is based on a scaling-factor comparison between its own data -- which quantifies crude steel produced via the BF/BOF route via the heat intensity of furnace "hotspots" -- and data from worldsteel, which provides monthly total crude steel production figures. Analysts from Liberum bank said in an Aug. 31 report that "there is signal confusion caused by the Chinese government's steel output cap." Conflicting reports have emerged from different sources and regions as to the extent of its success.

Source: www.mjunction.in

TOWARDS EMISSION-FREE STEEL PRODUCTION

Direct emissions from heavy industries such as steel, cement and chemicals make up around a quarter of global greenhouse gas emissions. Steel is the highest emitting of these sectors. It generates **over 7%** of global greenhouse gas emissions. Steelmaking releases more than 3 billion metric tons of carbon dioxide each year, making it the industrial material with the biggest climate impact.

With global steel demand expected to rise to 2.5 billion t per year by 2050, environmental burden of steel sector will be growing. Steel industry is making efforts to cut in carbon emissions so as to meet the objectives of the Paris Agreement. Overall reduction in worldwide carbon emissions is needed to limit global warming to a maximum of 2°C above preindustrial levels—the goal of the 2015 Paris climate agreement. It is suggested that the steel industry's annual emissions must fall to about 500 million t of CO_2 by 2050. Achieving that target will require the industry to reduce its carbon intensity from average of about 1.85 t of CO_2 per metric ton of steel to just 0.2 t.

To help limit global warming, the steel industry will need to shrink its carbon footprint significantly. Accordingly, a number of low emission steel initiatives are planned or underway. Some of the world's largest steel companies, including ArcelorMittal, Baowu Group and Nippon Steel have adopted "net zero commitments". Leading figures in the industry have also come together to establish an important new voluntary standard and certification programme, ResponsibleSteel.

Steel industry relies on gigantic equipment such as blast furnaces, BOF etc. which last 20–40 years. It will be quite difficult to shift to a new technology because there's so much investment done in existing facilities.

Steel decarbonisation is a complex challenge. Some major steelmakers and start-ups have started investing in alternative technologies to make steel, mostly using green hydrogen or electrochemistry to reduce iron oxides to iron. Hydrogen offers possibility of a completely carbon dioxide-free process for making steel. In traditional blast furnaces, coal is used to strip the oxygen out of the iron ore, generating and CO_2. By using hydrogen instead of coal for that process, the by-product is water (H_2O) instead of CO_2.

Several established steel makers have taken up the daunting challenge of developing disruptive technologies that could curb steel's carbon emissions, by using new ways to reduce iron oxides into iron. Mostly approach is to utilize hydrogen from electrolyzers powered by renewable electricity. One process under development aims to use green power directly in electrochemical reactions.

Biggest obstacle to hydrogen steel production is the vast amounts of renewable energy needed to keep the process carbon-free. *Three times the currently installed solar and wind energy sources will be needed to power the green energy steel industry.*

Green Steel Initiatives

Green steel, or carbon-neutral steel, would be produced using green hydrogen generated from renewable energy sources rather than fossil fuels, either as an alternative to pulverized coal injection in BF, or as an alternative reductant to produce direct reduced iron. DRI production, based solely on hydrogen manufactured via electrolysis, may occur as early as 2030.

China released a draft of stricter iron and steel capacity replacement measures in Dec. 16 that included the development of electric arc furnaces and other lower emission steelmaking facilities targeted at helping China reach carbon neutrality by 2060.

Japanese steel manufacturer Kobe Steel recently developed a new technique for making iron in natural gas blast furnaces that use less coke. By adding hot briquetted iron to the blast furnaces at a precise ratio, it has perfected a way to use less coke as fuel. The process reduces CO_2 emissions associated with production by about 20 percent. While this is not a final solution to the steel industry's carbon emission woes, it can be considered as a transitional technology to help reduce emissions

Metallurgical Poem for Grey and Ductile Cast Iron

Higher the Manganese	→	Higher the Pearlite
Higher the Copper	→	Higher the Pearlite
Higher the Chromium	→	Higher the Carbide
Higher the Chilling	→	Higher the Carbide
Sooner the Knock-out	→	Later the Carbide
Poor the inoculation	→	Richer the Carbide
Higher the Silicon	→	Higher the Ferrite
Lower the Manganese	→	Higher the Ferrite
Higher the Phosphorus	→	Higher the Steadite
Smaller the Thickness	→	Greater the Cementite
Higher the Sulphur	→	Higher the Dross
Higher the Sulphur	→	Higher the Brittleness
Higher the Sulphur	→	Higher the Crack Propagation
Higher the Sulphur	→	Higher the Mn/Mg Consumption
Better the Inoculation	→	Better the Property
Better the Mg-Treatment	→	Better the Nodularity

Rio Tinto and BHP have signed memorandums of understanding with Japan's Nippon Steel and JFE Steel, to develop processes that cut or eliminate greenhouse gases from steelmaking. Other green steel agreements include China Baowu Steel Group Corp., which signed a five-year MOU with BHP in November 2020 to develop low carbon technologies for integrated steelmaking.

In South Korea, steelmaker Posco wants to decarbonize its steelmaking by 2050 by using green hydrogen to replace coal, estimating it will need 3.7 million mt/year. It also plans to become a major producer and supplier of hydrogen, making 5 million mt of green hydrogen by 2050. To meet its goals, it will invest Won 10 billion to harness hydrogen for steelmaking.
Netherlands-based EIT InnoEnergy, a sustainable innovations accelerator funded by the European Union, investor Vargas Holdings and Scania, a Swedish truck manufacturer, is working to developing a fully scaled commercial hydrogen steel plant to produce 5 million metric tons of green steel by 2024.

A new technology originally created at MIT, *molten oxide electrolysis*, aims to separate the oxygen from the iron ore using electricity and creating O_2 as the by-product instead of CO_2.

Boston Metal is tasked with bringing this technology to a commercial level for the steel industry. Over the next two to three years, the company hopes to take its laboratory success and bring it to market. Electrolysis process requires access to large amounts of clean power to keep the process carbon-free.

India has launched a green hydrogen energy mission that could see the domestic steel industry moving towards decarbonization. Investment decisions in existing and new steel production in this decade will determine whether the industry pathway aligns with below 1.5 degree global warming.

THE WORLD'S FIRST FOSSIL-FREE STEEL

It is reported that, SSAB the Swedish steel producer, has produced the **world's first fossil-free steel** and delivered it to a customer. It is considered a completely fossil-free value chain for iron- and steelmaking and a milestone in the HYBRIT partnership between SSAB, LKAB and Vattenfall.

In July, SSAB Oxelösund rolled the first steel produced using HYBRIT technology, i.e., reduced by 100% fossil-free hydrogen instead of coal and coke, with good results. The steel is delivered to Volvo Group. This is first reported breakthrough, a proof that it's possible to make the transition to low CO_2 steelmaking and significantly reduce the global carbon footprint of the steel industry. This may be considered a big step to speed up the green transition of steel industry. Commercialization of this technology in the future and making the transition to the production of sponge iron will enable the steel industry to make the transition.

SSAB, LKAB and Vattenfall created HYBRIT (Hydrogen Breakthrough Ironmaking Technology), in 2016, with the aim of developing a technology for fossil-free iron- and steelmaking. In June 2021, the three companies were able to showcase the world's first hydrogen-reduced sponge iron produced at HYBRIT's pilot plant in Luleå. This first sponge iron has since been used to produce the first steel made with this breakthrough technology. The goal is to deliver fossil-free steel to the market and demonstrate the technology on an industrial scale as early as 2026. Using HYBRIT technology, SSAB has the potential to reduce Sweden's total carbon dioxide emissions by approximately ten per cent and Finland's by approximately seven per cent.

Source : SSAB press releases

Shri Arvind Pande, Former Chairman SAIL and Shri Sanjay Kumar, Chief General Manager, SAIL have written a book titled "Making the Elephant Dance: Turnaround Story of SAIL".

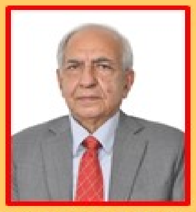
The Book has fifteen Chapters. Shri S C Suri, Past Chairman, IIM Delhi Chapter, has Chapter-wise summarised the contents of the Book.

The Summary of the Book is given in the succeeding paragraphs.

Chapter-wise Summary of Book

MAKING THE ELEPHANT DANCE: TURNAROUND STORY OF SAIL

Written by



Shri Arvind Pande
Former Chairman, SAIL
&

Shri Sanjay Kumar
Chief General Manager, SAIL

THE TURBULENT NINETIES AND INDIAN STEEL

This Chapter describes about evolution of steel industry in India and transition from controlled scenario to liberalised scenario in steel sector. It talks about steel making by smelting of wrought iron with charcoal in the 3rd century BCE followed by invention of steel making through Bessemer Converter Process in the middle of 19th century. The Bessemer process was overtaken by production of steel through open hearth furnace in 1850. This was replaced by steel making from LD Process in 1950. This process underwent change through Continuous Casting process. In 1960 there was entry of Electric Arc Furnace in steel making.

TISCO, Mysore Iron and Steel Works and Indian Iron and Steel Company were in steel production at the time of independence.

2nd Five Year Plan gave highest priority to steel sector. Development of iron and steel was the responsibility of government in 2nd Five year Plan. Rourkela Steel Plant, Bhilai Steel Plant and Durgapur Steel Plant were set up in latter part of fifties. Steel was a controlled commodity upto 1990. In 1991 steel sector was deregulated and there was entry of private sector post liberalisation.

Being Prescient Makes One proactive

Description of many ups and downs in SAIL finds mention in this Chapter.

There was a time when SAIL was an undisrupted leader in steel sector. SAIL also witnessed times when its existence was in peril. Its losses were increasing. Need of the hour was embarking upon its turnaround strategy.

Disinvestment of part equity of SAIL was done by Government of India from 1992 onwards. SAIL raised equity through issue of GDRs in March 1996.

It is the beginning or the end

SAIL faced liquidity crunch from 1995-96. Production was more but sales were declining. Managing funds were difficult. Cost of borrowing was very high. SAIL was convinced of the need to initiate turnaround plan. Multipronged interventions were initiated in the area of production, cost reduction, marketing and HR. Turnaround and transformation plan for SAIL was prepared in 1998.

With a turnaround plan in hand SAIL approached Ministry of Steel to initiate a Cabinet Note on Financial and Business Restructuring of SAIL for writing off of SDF loan.

Impecuniously leads to creativity

Chapter IV describes that post liberalisation there was a need to produce steel with low cost with high quality. Cost reduction drives were undertaken. This included innovative ideas and identification of areas where savings could be effected. Thrust was given on improvement of techno-economic parameters. Focus was marketing measures and sale of idle assets to generate cash.

The Balance Sheet Matters

Government share holding in SAIL was pruned to 86% by March 1996.

The Disinvestment Commission analysed the business of SAIL and major area of concern was its 1.8 lakh manpower. The problems analysed were requirement for technological upgradation, loss making units of SAIL which were being subsidised by SAIL and high manpower. The Commission recommended that financial restructuring of SAIL should be addressed through Steel Development Fund (SDF), which was started in 1978. SAIL and Tisco were contributing to SDF. SAIL also commissioned IDBI as a Consultant to examine the financial restructuring of SAIL. IDBI recommended about writing of SDF loan.

SAIL approached Ministry of Steel in September 1998 for financial restructuring plan.

Courts Pave the Way

McKinsey & Co. was appointed by SAIL as a consultant. They also endorsed the restructuring proposal of SAIL.

SAIL's financial restructuring proposal was examined by Ministry of Finance but initially Ministry of Finance did not favour write-off of SDF loan. The Law Ministry was of the view that Ministry of Steel in consultation with Ministry of Finance may decide the waiver of SDF loan taken by SAIL.

One of the companies approached Kolkata High Court in mid-1999 claiming their right over SDF which according to them was public money. The Kolkata High Court judgement in February 2000 justified the right of SAIL on SDF. Immediately after this judgement, a cabinet note was prepared by Ministry of Steel for Financial & Business Restructuring which included a waiver of loan of SDF loan of Rs 5,073 crore. This matter was challenged in Supreme Court. But Supreme Court also decided the matter in favour of SAIL.

In February 2000, Government of India accorded its approval to Financial & Business Restructuring of SAIL waiver of SDF loan of Rs 5,073 crore to SAIL and this helped SAIL to improve its balance sheet.

Dynamics of Power Asset Transfer

The restructuring proposal of SAIL approved by Govt. envisaged waiver of SDF loan of Rs 5073 crore and divestment of non-core assets. These included Captive Power Plants of SAIL, SSP, ASP, VISL Rourkela Fertiliser Plant conversion of IISCO into a joint venture with SAIL and Oxygen Plant of BSP.

Challenges in Divesting Loss Making

This chapter talks about challenges in divesting loss-making units of SAIL like ASP, VISL, SSP, and Rourkela Fertiliser Plant and divestment of IISCO. However, the efforts of SAIL in divestment of these loss-making units cold not fructify on account of various reasons. However, the Fertiliser Plant of RSP and Kulti works operation of IISCO were closed.

The Human Dimension

Restructuring the SAIL's business called for manpower right sizing. The manpower cost of SAIL was very high SAIL initiated actions to downsize its manpower. The interventions introduced by SAIL included the introduction of VR Scheme introduction of sabbatical leave, reduction in contract labour, reduction of CISF and thrust on Training & Development and Multiskilling, Focus on Succession planning and introduction of Reward & Punishment Scheme and Slowing down of recruitment.

In the Interest of Employees

This Chapter states about the curtailment of some employees benefit and perks like deferment of LTC/ LLTC, stoppage of leave encashment, closure of unviable schools in township and higher rates for the subsidized services. This was done after taking the employees union and officers association into confidence.

Wage revision of workers and salary revision of officers was done after consultation with unions & officers association. Employees were not paid the arrears from a back date for which workers union and SEFI were taken into confidence.

Monetization of SAIL's houses was done. An employee-friendly scheme "own your house scheme" was launched.

Perspective from the Unit

This Chapter deals with the Turnaround of the Rourkela Steel Plant. RSP was incurring losses after losses since the nineties. Morale for the workforce at RSP was very low. The existence of RSP was threatened.

SAIL decided to change the leadership of RSP in 2001.

Dr. Sanak Mishra was made MD of RSP. He brought about a member of interventions which helped RSP to come out of the red. He identified the priority areas to improve the working of RSP. He started visiting shop floors to understand the problems and interacted frequently with workers. He told workers that the future of RSP is in their hands. There were a number of other positive interventions introduced by Dr Sanak Mishra for improvement of Rourkela Steel Plant. With all the interventions RSP started making profit from January 2004.

Battles within Battles

Chapter XII deals with the problems of BSP, BSL, and Durgapur Steel Plant. Bhilai & Bokaro Steel Plants were profit-making plant from 1997-98 to 2003-04 but their profits were declining. Each plant had its unique problems. The interventions of cost reduction drive, minimizing rejections, utilization of coal dust injection, increased production of rails and plates helped BSP to increase its profitability.

The modernisation of BSL, creation of Continuous Casting facilities, improvement in techno-eco parameters reduction in the cost of production of HR Coils and automation in the Hot Strip Mill helped BSL in its profitability.

DSP was a perennial loss-making plant. But things started improving after its modernization. Reduction in manpower at DSP helped to bring about improvement at DSP. Marked improvement in work culture at DSP was brought Major HR initiatives to improve age mix and skill mix contributed to improvement in the working of DSP. All this was done after persuasive talking to Unions.

How the market was won

Steel markets were in turmoil during 1997-98 to 2003-04. There was stagnation in demand and sharp fall in steel prices in domestic and international market. Reorganisation of CMO was done into two segments – long products and flat products. There was increased delegation of power to Branch Managers. Thrust was on export performance.

Increased production of plates for exporting to USA, Europe, Canada and Japan and ability of SAIL to handle trade disputes with regard to plates helped in marketing and new destinations of export were identified. Ability of BSP to supply rails to Railways with stringent specifications helped it in improving the market.

Communication Holds the Key

This Chapter deals with communication drive launched by SAIL. Communication drive with employees, trade unions, officers and politicians helped SAIL to bring about improvements. In the communication exercise they were told that it is in the interest of employees to bring about changes which even affected employees like suspension of LTC/LLTC, house building loans, vehicle and other advances, reduction in the workforce, changes in the incentive schemes, closing of uneconomic units of SAIL. Need of the hour was change in the mind-set of people. There was significant improvement in the steel plants on account of sound communication policy implemented across SAIL.

The sense of a New Dawn

SAIL posted a net profit of Rs. 242 crores in the 4th quarter of 2002-03 after a gap of five years.

Post restructuring SAIL acquired a very solid foundation and it became the leading profit earning company among all steel plants in India.

The restructuring initiative saw continuous improvement in all business parameters of SAIL.

The then PM, Atal Behari Vajpayee, while responding to allegations that his government's intent is to finish the public sector, announced in Parliament in August 2003 that SAIL is back on its feet.

Conclusion

This is an excellent narrative about turnaround of SAIL. Needless to say that vision of Shri Arvind Pande in transforming the fate of SAIL is laudable. There was a time when SAIL was on the brink of being referred to BIFR. Sincere efforts of the then Chief Executive of SAIL in the latter half of Nineties have played a vital role in making SAIL a vibrant company. Shri

Arvind Pande's persuasive and reasoning skills to elicit the support of higher echelons of bureaucracy in Ministry of Steel, Ministry of Finance and other Ministries to write off SDF loan for SAIL are praiseworthy. Today SAIL collective feels proud about the strengths of this robust Company.

I would like to compliment Shri Arvind Pande and Shri Sanjay Kumar who have meticulously collated the various pertinent facts to write this Book.

I had the privilege of working under Shri Arvind Pande when he was at the helm of SAIL.

Shri Sanjay Kumar was my colleague when I was working in Corporate Planning Department in SAIL.

This Book will throw up a number of learning points for posterity of SAIL.

Summarised by S C Suri, Former Executive Director, SAIL

Name of the Publisher:
SAGE Publications India Pvt. Ltd
B 1/1-1, Mohan Cooperative Industrial Area
Mathura Road, New Delhi-110 044

Cost of the Book:
Rs. 850.00

ARCELORMITTAL NIPPON STEEL INDIA COMMISSIONS SECOND PLANT AT ODISHA'S PARADIP

ArcelorMittal Nippon Steel India (AMNS India), a joint venture between ArcelorMittal and Nippon Steel, announced recently about commissioning of its second six million tonne per annum (MTPA) pellet plant at Paradip.

The plant doubles production capacity to 12 million tonne, making it the largest single-location pelletisation complex in the country. With this, AMNS India's national pelletisation capacity rose to 20 MTPA. AMNS India CEO Dilip Oommen said despite operational challenges in the last 18 months due to Covid-19 pandemic, the commissioning of the second pellet plant at Paradip is an important milestone. "We aim to achieve domestic steel production capacity of 300 MT in the coming decade.

AMNS India will continue investing in Odisha, a promising hub for steel production. We are now sincerely planning for a greenfield steel plant in the State," he added. Chief Operating Officer Wim Van Gerven said, "Paradip's pellet plant II will produce superior quality directly reduced iron grade pellets for domestic steel production." AMNS India's national pellet production operations comprise 12 MTPA at Paradip and 8 MTPA at Vishakhapatnam.

Source: www.mjunction.in

THE GRIM FUTURE OF THE EXPORT OF LOWER GRADE IRON ORE FINES FROM INDIA

The years 2020 and 2021 have seen unprecedented volatility in commodity prices. The price of iron ore touched 230 US dollars per ton at its peak in May 2021. So far there is no sign of significant decrease in the price under 200 US dollars. The larger players in the mining industry have generated a tremendous amount of profit in the first half of 2021. The profit margin has also increased for medium scale and smaller scale iron ore miners in countries like Brazil, South Africa, etc. However the largely defragmented sector of smaller and medium scale iron ore mining industry in India, most of whom have so far relied on the export of lower grade fines to China, have missed this opportunity to succeed in terms of revenue generation. There have not been transactions of lower grade fines from India to China in the months of April to May. Several piles of Indian lower grade fines are waiting at major ports like Qingdao, Rizhao etc. for buyers but with almost no takers. What could be the short and long-term aftermath of this situation – the question hovers above the mining industry in India.

The Problem with Indian Low Grade Iron Ore Fines

The scale of the problem of the production, export and usage of lower grade iron ore fines is a complex entanglement of technological as well as financial aspects. Indian low grade iron ores have been classified by Indian government to contain iron content less than 58% to be allowed for exporting. All iron ore fines and lumps containing more than 58% of iron are either prohibited for export or it could be exported with an exorbitant amount of export taxes which makes it financially unviable in the international market.

Throughout the last two decades China has been the sole importer of low grade fines even including materials containing only 52 to 53% Iron. This material was available in plenty (and still is) and this was one of the low cost sinter feeds for the Chinese sinter plants. However as the Chinese blast furnaces started becoming more and more modern in terms of operational practices, the demand for higher grade iron carriers increased.

Another large disadvantage of Indian iron ore is the high amount of alumina, sometimes up to even 7% in the lower grade fines. Alumina is known to increase the viscosity of the bosch slag inside the blast furnace. If the slag becomes more viscous, the gas flow inside the furnace becomes interrupted and non-uniform thereby generating several furnace irregularities and most importantly, ends up into high coke consumption per ton of hot metal. In accordance with the present global trends, China has also taken certain steps for Decarbonisation and imposed higher carbon taxes on emission. The plants using lower grade ores lose money in both ways: 1) Increased coke consumption per ton of hot metal and 2) more and more carbon taxes. These reasons have generated a gradual disinterest towards Indian iron ore fines in the past few years. The manifestation of this disinterest first was shown in strong bargaining from Chinese buyers in order to secure a steep discount on the adjusted index price which subsequently resulted in no exports.

Mining Practice in India

Indian iron ore mining sector is somewhat defragmented. There are large-scale government and public companies who have mines vertically integrated to downstream steel production. On the other hand, there are standalone merchant mines mostly producing fines for domestic pelletization plants and exports. As per export restrictions imposed by government authorities, the miners cannot export fines above 58% of iron. Therefore in several cases the beneficiation process of hematite beneficiation is deliberately stopped midway so that the iron content doesn't exceed 58%. This practice is extremely detrimental from the point of view of economies, environmental sustainability and general business awareness about the global market. The ore which had the opportunity to be beneficiated up to 62 or 63% iron is being deliberately down-valued so that it could be exported and as a result giving rise to huge volumes of iron ore tailings inside India which is a huge wastage and inefficient usage of valuable natural resources and a potential risk of accidents due to dam failure. It is also strange to observe that even India based blast furnace steel producers operating sinter plants are not willing to buy the low-grade fines and ironically the miners are trying to desperately sell this material thousands of kilometers away where there is even lesser interest and a lower price. The operational practices and the supply chain of Indian smaller scale iron ore business from miners, agents, traders and shippers are not topics of discussion for this article, however it could be mentioned that the whole operation becomes more and more inefficient from all perspectives.

Future Outlook

Our company has observed the market in H1 2021 and found out the dismal price and export scenario of low grade iron ore. Even after offering 30 to 35% discount on adjusted index prices, the Chinese buyers are refusing to buy any Indian iron ore fines. From the customer's point of view it is quite logical that the performance of blast furnaces is significantly hampered by lower grade fines. The Indian small scale and medium scale miners are losing revenue on all aspects of the supply chain. With development of several new mining projects in Australia and North America as well as upscaling of existing domestic mines in China and new exploration projects, there is even less chance in the future that Indian low-grade ore will ever be sold in the international markets. The whole idea of incomplete beneficiation process does not make any sense at all and all stakeholders in the business face a lose-lose situation. Possibly the Indian mining industry should concentrate on exporting only pellets under present circumstances and in near future there is an undeniable requirement of allowing the export of all grades of lumps and fine ores so that the miners can sell it according to global price indices and that will also allow more revenue for the sellers as well as the government. In a globalized world banning and trade restrictions of products and natural resources will only lead to a deformed economic structure which will be extremely detrimental for any country.

Source: Steel Tech

REVIEWS ON ALUMINUM ALLOY SERIES AND ITS APPLICATIONS

The demands for lightweight automotive parts are soaring tremendously in the quest for energy efficiency. Most of these parts are produced using aluminum alloy in order to gain parts that has lightweight, high strength and good rigidity. However, the forming process for this aluminum alloy has to be carried out under elevated temperatures with processes such as warm forming and heated forming in-die quench (HFQ). This work will provide reviews and intensive lookout on the available aluminum alloy which can be used as aluminum parts for automotive application in particular. Finally, there was concluding remarks on the underline challenges of forming heat-treatable aluminum alloy and subsequently highlighting the potential work that can be applied in order to ensure a more efficient and sustainable manufacturing agenda for heat treatable aluminum alloy.

Introduction

Presently, the demands for vehicles have increased tremendously and this has led to high fuel emissions. Therefore, reducing the vehicle weight is very important in order to minimize the carbon dioxide emission. One of the most effective solutions was to make chassis components out of Ultra High Strength Steel (UHSS).

UHSS significantly helps in reducing the weight of the vehicle while improving its safety and crashworthiness qualities. The importance of lightweight vehicle was realized since year 1997, where a total of 8 million UHSS parts were produced for consumerism which continually increased until it reached 107 million parts in 2007. However, in order to form these lightweight parts made out of UHSS, elevated temperature environment is essential.

The elevated temperature forming process also known as hot forming process (HPF) helps to eliminate the spring back effect that occurs in cold forming. Some of available UHSS parts include chassis components like A pillar, B-pillar, bumper, roof rail, rocker rail and tunnel. In order to ensure effective heat removal within HPF, its forming die is equipped with cooling system consisting of cooling channels which drilled within the structure of the forming die. Apart from that, effective rapid cooling during HPF was achieved by making the forming die out of high thermal conductivity value material. A suitable material known as High Thermal Conductivity Steel (HTCS) was produced in 2013 by Rovalma ® possessing very high thermal conductivity values (up to 66 W/mK) and highly wears resistances. It is specifically designed for forming dies in hot stamping and specially reinforced with abrasive fiber materials and closed die forging. HTCS obtains its optimized mechanical and physical properties through a corresponding heat treatment of the material prior to final machining. Effective press quenching from the die ensures production of good properties and high tensile strength parts.

Aluminium Alloys

Aluminium plays an important role for future car generation due to its advantages and it also open up new way for multiple applications in the automotive industry. Lightweight material such as aluminium alloy was applied for automotive applications especially in wrought and cast forms while aluminium sheets has the potential to be used as vehicle components. There are a wide range of opportunities for using aluminium in automotive powertrains, chassis and body structures. A study showed that car bodies contributes to 20% of total weight of the car, so a promising way to reduce car weight is to use aluminium alloys.

In contrast to steel, aluminium has low formability, particularly, at room temperature making it more difficult to stamp. High number of recent research explores the methods to improve the formability of aluminium alloys. There are two ways in manufacturing aluminium body structure: 1) By stamping it into structure and 2) Through a combination of many processes such as castings, extrusions and stamping and welding as in a space frame.

Table 1: Designation system of wrought aluminium alloys.

Alloy series	Principal alloying elements
1xxx	99.00% minimum aluminium
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and Silicon
7xxx	Zinc
8xxx	Other elements

A study showed that the weight of vehicle can be significantly reduced by improving the body panels of the automotive which consist of an outer and inner panel as a double structure. Inner panels of an automotive must have a high deep drawing capability to deform into more complex shapes while the outer panels should have sufficient denting resistance which was both achieved by manufacturing it out of high strength materials.

There are different requirements for automobile manufacturing and different strategies in the development of aluminium body panels carried out in different regions especially in Europe, North America and Japan. In Japan, higher formability alloys are required from automobile manufacturers. Therefore, special AA5xxx alloys, such as AA5022 and AA5023, were developed. On the other hand, high strength alloys are required in Europe and North America. Consequently, AA2xxx alloys, such as AA2036 and AA6xxx alloys, such as AA6061, AA6111 and AA6022, were developed.

Type of Aluminium Alloys

An aluminum alloy is a chemical composition where other elements are added to pure aluminum in order to enhance its properties and increase its strength. These other elements include copper, magnesium, iron, silicon, tin, zinc and manganese at levels that combined to make up a 15% of the alloy total weight. Alloying requires thorough mixing of pure aluminum with these other elements at its molten liquid form. The primary alloying element added to the aluminium alloys allow it to be categorized into several numbers of groups. These groups represent the material's characteristics such as its ability to respond to mechanical and thermal treatment. Aluminium alloys are mainly assigned with four-digit number, in which the first digit identifies the series of the alloy by characterizing its main alloying elements. Table 1 shows the designation of wrought aluminium alloy based on the first digit on the assigned name and its series.

According to Table 1, each of the digit of series have an identity for each series. The first digit (Xxxx) is used to describe the aluminium alloy series and will also indicate the principal alloying element added to the aluminium alloy. The second single digit (xXxx) indicates the number of modification made to the specific alloy, and the third and fourth digits (xxXX) are arbitrary numbers used to identify the specific alloy within the series. Example: In alloy 6105, the number 6 indicates that the principal alloying elements are magnesium and silicon alloy series, while 1 indicate that it is the 1st modification to the original alloy 6005 and the 05 identifies it in the 6xxx series.

Commercially pure aluminum

1xxx Series

The 1xxx series alloy is comprised of 99% or higher aluminum in its composition. This series have excellent workability, excellent corrosion resistance and high thermal and electrical conductivity. The 1xxx series is commonly used for power grid or power transmission line. The national grid of the United States of America is made out of the 1xxx series alloys. In this series, the most common alloys consumed were the AA1350 and AA1100 used for electrical applications and food trays, respectively. Apart from that, 1xxx series alloys has also been proposed as base material for shear panels, which can be applied as dampers for the passive seismic protection of both steel and reinforced concrete buildings. Figure 1 shows the application of

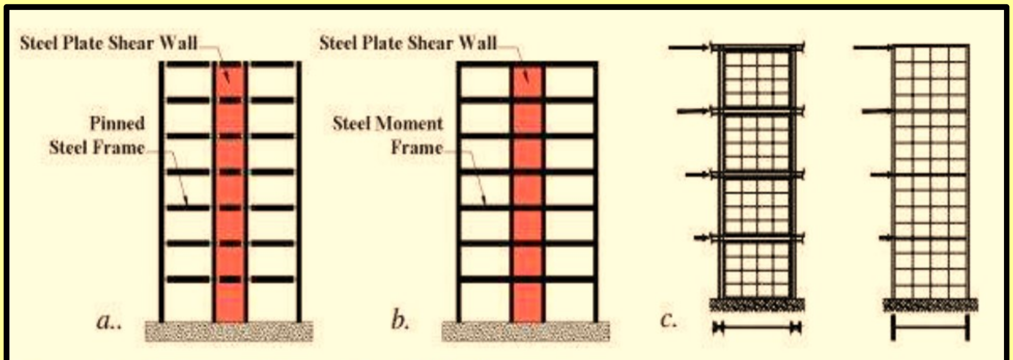


Figure 1: Pure aluminium steel frame acting as building dampers.

the 1xxx series as building dampers.

The low value of conventional yield strength and high ductility of the 1xxx series proved to be applicable as dampers for the building. Within the application, 1xxx shear panels are installed within the frames of the primary structure. The shear panels will behave as sacrificial elements that dissipate the input energy received during earthquake. Recently, pure aluminium has also been proposed to be fabricated as special torsional link which then were arranged within the vortex nodes of timber frames in buildings.

Currently, the authors are developing other innovative dissipative devices out of pure aluminium which will provide solution in seismic protection of new and existing buildings.

Heat-treatable alloys

Some alloys are strengthened by solution heat-treating process followed by quenching or rapid cooling. Heat treating process involves taking the solid, alloyed metal and heating it to a specific point. Through heating the metal, the alloy elements will be distributed homogeneously with the aluminum transformed into a solid solution. The metal will then be rapidly cooled or subsequently quenched, which freezes the solute atoms in place. The metal will then be left at room temperature to undergo natural aging or left in a low temperature furnace operation to undergo artificial aging. After aging, the solute atoms of the metal will finally combine into a finely distributed precipitate.

2xxx Series

Copper is used as the principle alloying element in the 2xxx series aluminium alloy and this series can be strengthened significantly through solution heat-treating. These alloys do not have the levels of atmospheric corrosion resistance as many other aluminum alloys but possess a good combination of high strength and toughness. These alloys are generally clad with a high purity alloy or a 6xxx series alloy to greatly resist corrosion. Alloy 2024, perhaps the most widely known is applied as the aircraft alloy. Due to its good combination of strength and fatigue resistance, aluminium alloy 2024 (AA2024) is widely used as structural parts for the aerospace industry. The microstructure and mechanical behaviour of AA2024 can be altered through age hardening. After appropriate heat treatment process, a high strength to weight ratio metal was achieved and finely dispersed precipitates were obtained.
However, AA2024 have poor ductility making it hard to form complex-shaped parts with traditional cold forming processes. Hence, in order to reduce spring back in the forming process, some thin-walled and complex-shaped parts are machined from solid blocks of metal. The machining process contributes to 90% material wastage for some applications, with corresponding energy and cost.

In recent years, many efforts have been made in order to improve the strength and ductility of AA2024. Efforts involving the altering of properties through severe plastic deformation such as ECAP, cryo-rolling and suitable ageing were proven to results in highly dispersed nanometres sized precipitates within the metal. An elongation of 18% can be achieved at room temperature with the low density of dislocations present after ageing and the strong pinning effect and aggregation of precipitates to dislocations.

However, the use of these extreme strain levels methods were not a suitable alternative for bulk materials processing. On the other hand, pre-homogenisation treatment (Kim et al., 2003; Ma, 2006) might be an effective way of improving the ductility of AA2024. However, the material strength were sacrificed which were then solved by adding SiCp into AA2024, but the ductility of the resulting composite was found to have decreased.

As for most metallic alloys, the ductility of AA2024 was directly proportional to the deformation temperature (Cheng et al., 2007). Hot stamping process was most applicable in order to improve AA2024 ductility but this process is seldom used for forming complex-shaped parts. This was due to tendency in destruction of the desired microstructure (which has been fixed in the sheet prior to forming) at high temperatures leading to reduction in mechanical performance. Furthermore, due to thermal distortion, the parts tend to lose their shape if heat treatment were to be carried out after stamping. Recently, a new technique, Hot Forming and cold-die Quenching (HFQ) was developed.

The basic idea of this novel process involves heating the sheet metal to its solution heat treatment (SHT) temperature, at which its ductility is expected to be maximally followed by simultaneously formed and quenched sheet with cold dies. After the forming process, the workpiece material is held within the dies for 5 to 6 s to reduce its temperature rapidly to approximately 100°C and freeze the microstructure as a supersaturated solid solution (SSSS). Heat-treatable aluminium alloy can obtain its full strength after aging. The feasibility of this novel process was demonstrated for AA6XXX in the study. This technique has gained more demand over traditional forming methods because it produces parts with high formability, rapid processing, efficacious mechanical properties and negligible spring back.

Copper is the most effective strengthening constituent in AA2024. By increasing copper content to 6% wt the age hardening effect can be increased. The age hardening effect at room temperature was accelerated with the addition of magnesium. The equilibrium precipitate phases for this system are mainly $CuAl_2$ (θ phase) and $CuMgAl_2$ (Sand phase), although $CuAl_2$ is less often observed in the alloy as compared to $CuMgAl_2$. Both of these phases are largely soluble during SHT. In addition, manganese addition influenced material properties through the formation of intermetallics that provide Zener drag and limit grain size.

6xxx Series

The 6xxx series are heat treatable, versatile, weldable, highly formable, highly corrosion resistance and have moderately high strength. Alloying elements in this series are silicon and magnesium that will form magnesium silicate within the alloy. 6xxx series extrusion products are the first choice for architectural and structural applications.

Aluminium alloy 6061 (AA6061) is the most widely used alloy in this series and is often used for truck and marine ship frames. Additionally, the Apple's iPhone product uses 6xxx series alloy as their frame and components. Recently, the demands for 6xxx series alloys have significantly increased especially in the automotive and construction industry. Therefore, several research works have been undertaken whereby small copper additions were added to the metal. The addition of copper substance to the metal indicates improvement especially in the material properties.

The addition of copper and pre-deformation treatment of the alloys help to increase the peak hardness and yield strength of the metal during ageing and improve the peak hardness of the quenched alloys. Addition of copper also helps to concentrate the precipitates and increase the volume of the precipitates formed.

7xxx Series

Zinc is the primary alloying agent for this series and the small addition of magnesium to the series makes it heat treatable and a very high strength alloy. Other elements such as chromium and copper may also be added in small quantities. The most commonly used alloys in this series are 7050 and 7075, which are widely used in the aircraft industry. Apple's aluminum 2015 was made Watch from custom that 7xxx series released alloy. In comparison in year to 6xxx series alloy, the strength to weight ratio of 7xxx is optimum for security crash components and the most efficient in cost per kg saved. The main disadvantage of 7xxx series is its reduced formability in room temperature. Henceforth, the metal had to be formed at elevated temperature in order to improve formability. However, the final properties of this material degrade when it is formed at elevated temperature.

A recent study shows that pertinent pre-treatment condition and deformation temperature can ensure sufficient formability for 7xxx series alloy. Apart from that, AA7075 tubes were warm hydro formed at a temperature of 300°C and significant improvement of formability was achieved.

A paper presented where material characterization of AA7075-T6 material was performed. It was discovered that the total elongation at fracture increased at temperature between 140 and 220°C. This was due to the increase in strain rate sensitivity, which prevents plastic strain from concentrating in a localized neck and reduced diffuse necking.

Non heat-treatable alloys

Non-heat treated alloys are strengthened through cold working process. Rolling and forging methods are examples of cold working and these methods strengthen the metal in the action of working. For example, when rolling aluminum is down to thinner gauges, it gets stronger.

This is because cold working builds up vacancies and dislocations in the structure, which then inhibits the movement of atoms relative to each other. This leads to the increase of the metal strength. Alloying elements like magnesium will intensify this effect, hence, resulting in even higher strength improvement.

3xxx Series

The major alloying element in this series is manganese, which is often added with smaller amounts of magnesium. However, percentage addition of manganese to aluminium is very limited. AA3003 is a popular alloy in the 3xxx series for general purposes application due to its moderate strength and good workability which is very efficient in applications such as heat exchangers and cooking utensils. Alloy 3004 and its modifications are often used in the bodies of aluminum beverage cans.

4xxx Series

4xxx series alloys are combined with silicon, which is added in sufficient quantities in order to reduce the melting point of aluminum without producing any brittleness. Hence, the 4xxx series are applied widely in the making of welding wire and brazing alloys where lower melting point is a necessity. Alloy 4043 is one of the most commonly used filler alloys for welding 6xxx series alloys for structural and automotive applications.

5xxx Series

Magnesium is the primary alloying agent in the 5xxx series and is one of the most effective and widely used aluminum alloys. Alloys in this series possess good weldability, high resistance to corrosion and moderate to high strength characteristics. Aluminum-magnesium alloys are widely used in building and construction, marine applications, storage tanks and pressure vessels. Examples of common alloy applications include: anodized AA5005 sheet for architectural applications, AA5052 in electronics, AA5083 in marine applications and AA5182 for aluminum beverage can lid. AA5083 and the 7xxx series aluminum were also applied as the main material in constructing U.S. military's Bradley Fighting Vehicle.

Developments of new Aluminium Alloys

The wrought alloy designation system was established by the Aluminium Association more than 60 years ago through its Technical Committee on Product Standards (TCPS), which was then adopted in the US in year 1954. Three years later, American National Standard H35.1 approves the system. In 1970, this designation system became an international designation system and was officially adopted by the International Signatories of the Declaration of Accord. Later in year 1970, Standards Committee H35 on Aluminum Alloys was authorized by the American National Standards Institute (ANSI), with the Association serving as the Secretariat. The Association has served as the major standard setter for the global aluminum industry ever since. Currently, the alloy registration system is managed by the Association. Registering to TCPS assigning process of a new designation alloy takes between 60 to 90 days. Originally in year 1954, the list had 75 unique chemical compositions. The list had more than 530 registered active compositions presently and that number continues to grow. That underscores and concludes how versatile and ubiquitous aluminum has become in our modern world.

Applications of Aluminium and its Alloys

New developments in aluminum alloys have opened a wide range of applications of wrought aluminum in place of aluminum castings. Wrought aluminum alloys are produced from cast ingots, which are prepared for subsequent mechanical processing. The microstructures and mechanical properties of wrought aluminum alloys are significantly dependent on various working operations and thermal treatments. The improvement of aluminium alloy mechanical properties by adding various alloying elements has opened a wider field of applications for these alloys, particularly in the aerospace and automotive industries.

Aluminium alloys for automotive applications

Throughout the decade, an increasing demand for vehicles was observed around the world. The number of produced cars had increased by 39% which shows a total of 65 million of vehicles in 2004 to a total of 90 million of vehicles in 2014. This number subsequently leads to the high fuel emissions. Therefore, the reduction of vehicle weight is essential to minimizing the fuel and CO_2 emission to the environment. Henceforth, a significant increase was seen in efforts to reduce the vehicles weight. One of the efforts was to apply the use of the newly designed aluminium alloy.

The advantageous material properties of these aluminium alloys led to its significant role in the future of automotive industries. The weldability, formability, high corrosion resistance and high strength of aluminium alloy opened several new ways for new applications in the automotive industry. The application of aluminum alloy within the automotive industry had increased more than 80% in the past 5 years. In 1996, a total of 110 kg of aluminum alloys were used in a vehicle. This amount is predicted to increase to a range of between 250 or 340 kg regardless of the structural applications. Figure 2 shows the aluminium usage within passenger's car. Furthermore, it was expected that the trend of using aluminium parts will keep evolving in the coming years.

Vast availability of semi-finished form for aluminium is the main advantage of this material when mass production and innovative solutions were considered. The high demands in high performance and cost efficient manufacturing process leads to the increment in the needs of highly integrated and compact part. However, in recent production several materials gave a fierce competition over aluminium in which those material or novel steels developed are claimed to have higher strength to weight ratio. The materials developed include magnesium, titanium and carbon fibre reinforced plastics.

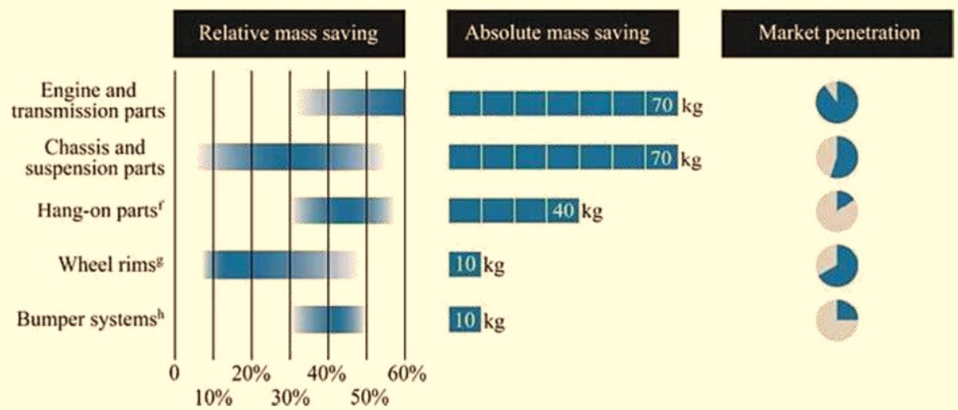


Figure 2: Aluminium usage in passengers car (Hirsch, 2014).

However, the formability of these materials is restricted and cannot achieve highly complicated form. These matter leads to an increase of application and demand for the semi-finished parts aluminium. Application of semi finished aluminium parts includes engine blocks and power train parts, sheet structures (Jaguar, Honda NSX, Rover), space frames (BMW Z8, Audi A2, A8, Lotus Elise), or as closures and hang-on parts (DC-E-class, Renault, Peugeot) and other structural components (Mohamed et al., 2012). Table 2 shows aluminium parts distribution was analyzed systematically. Based on an analysis of the average compound annual growth rate (CAGR), there were high potential for the increment in the use of aluminium part within car body.

Aluminium part is seen to contribute most on the weight of the vehicle as it gave a share of between 25 and 30% of the complete installed, integrated safety features, and engine size. The most used aluminum alloy series is the non-heat treatable Al-Mg (AA5xxx series) and the heat treatable Al-Mg-Si (AA6xxx series) alloys. Due to the variations in chemical composition and processing, AA5xxx are optimized for strength and corrosion resistance in vehicle chassis and AA6xxx are optimized for age hardening response and high formability so that efficient auto body sheets panels can be developed. The current 6xxx alloys used for auto body sheets are AA6016 and AA6111 and more recently, AA6181 and AA6082 were added for recycling aspects. AA6082 and AA6111 are usually used for the outer body panels which require high strength and good formability as shown in Figure 3.

Aerospace applications

In aerospace applications, a material that is lightweight and durable is essential. Henceforth, Aluminum-Lithium (Al-Li) alloys are the most commonly used and applied in aerospace applications. This metal is efficient in critical application of aerospace due to its lightweight, good strength and toughness, excellent corrosion resistance and compatibility with standard manufacturing techniques. Figure 4 shows it is applied in several aircrafts parts such as engine, seat track, leading and trailing edges, wing skin, and many other parts.

Currently, aircraft and aerospace industry improves their structure by double folding the raw material which will ensure a stronger sheet metal. However, this will thicken the structure and increase the cost of the materials required. Henceforth, aircraft manufacturers had come up with cost reduction program for their existing aircraft version which led to applying new material solution. This new and advanced material will help in facing the new challenges in the future involving the mass air transportation. With the cost reduction programs, the once large assemblies and build up structures consisting of riveted and joined

Table 2: Distribution of aluminium parts used

Automotive parts	Number of components analyzed	Mass (kg)
Power train (Engine, fuel system, liquid lines)	25 components analyzed in engine block, cylinder head, transmission housings and radiators.	69
Chasis and suspension (Cradle and axle)	17 components analyzed in wheels, suspension arms and steering systems.	37
Car body (Body-in-white (BIW), hoods, doors, wings, bumpers and interiors)	20 components analyzed in bonnets and doors, front structure and bumper beams	26

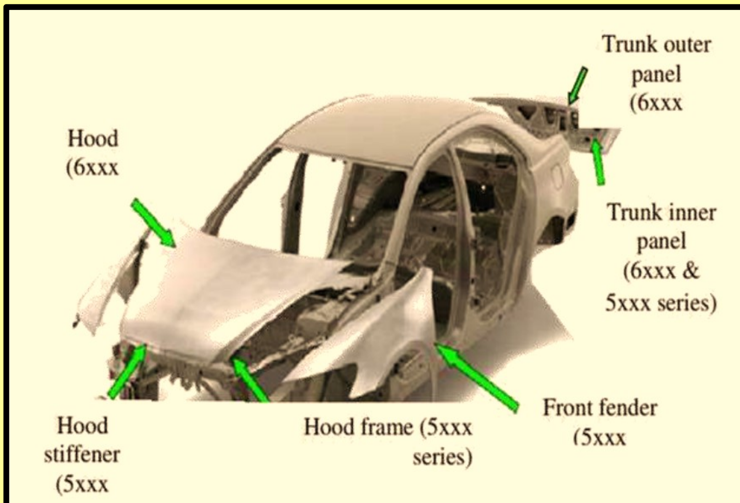


Figure 3: Application of aluminium alloy for automotive.

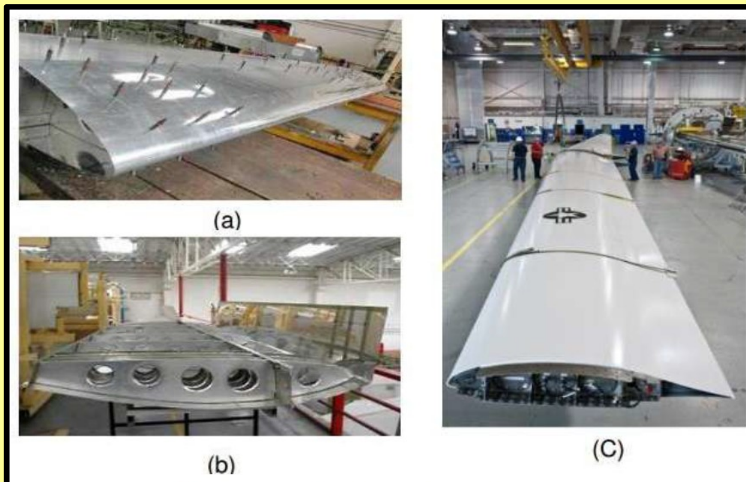


Figure 4: (a) Wing skin (b) Wing ribs made from aluminum alloys and (c) Final wing, upper skin and ribs are made of aluminum alloys.

parts were substituted with a single integrated structure which reduced the needs of rivet and joints. This is proven to be advantageous in the cost savings, weight reduction, simplifying storage system and improved production logistics.

Manufacturing process of this integrated structure itself is cost efficient due to the application of high speed milling machines, with rotational speeds of up to 25000 rpm and high feed rates, which are available for machining the high strength aluminium alloys. The major drawback for the raw material suppliers is to ensure that the property combination of the raw material will not limit the performance of the integral structure when compared to the previous assembly. Integral technology uses large machined structures to reduce the number of components and joints. Some of the parts proposed are more than 800 in. (20 m) long, with raw material thickness of up to 11 in. (280 mm). The aspect ratio after machining process can reach values of up to 35 which means up to 95% of the raw material is machined away in some of the applications producing a lot of waste. Hence, solutions such as rolled aluminium plate were proposed. The parts can be manufactured with the required dimensions but the product formed is limited to the part that is not complex and best suited for this type of application.

Conclusion

In this paper, the several available types of aluminium alloys were presented and explained. Each series of the aluminium alloy is based on its alloying element. There were 3 main classes of all the series in aluminium alloy which includes pure aluminium, heat treatable aluminium alloy and non-heat treatable aluminium alloy. Due to the great and versatile properties of aluminium alloy, the demand of usage for the aluminium alloy had improved vastly in so many applications. The two main industries that benefit most from aluminium alloys were the automotive and aerospace industries. The use of aluminium alloys ensure brighter future since its usage is almost limitless and ensures a more sustainable and greener environment.

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