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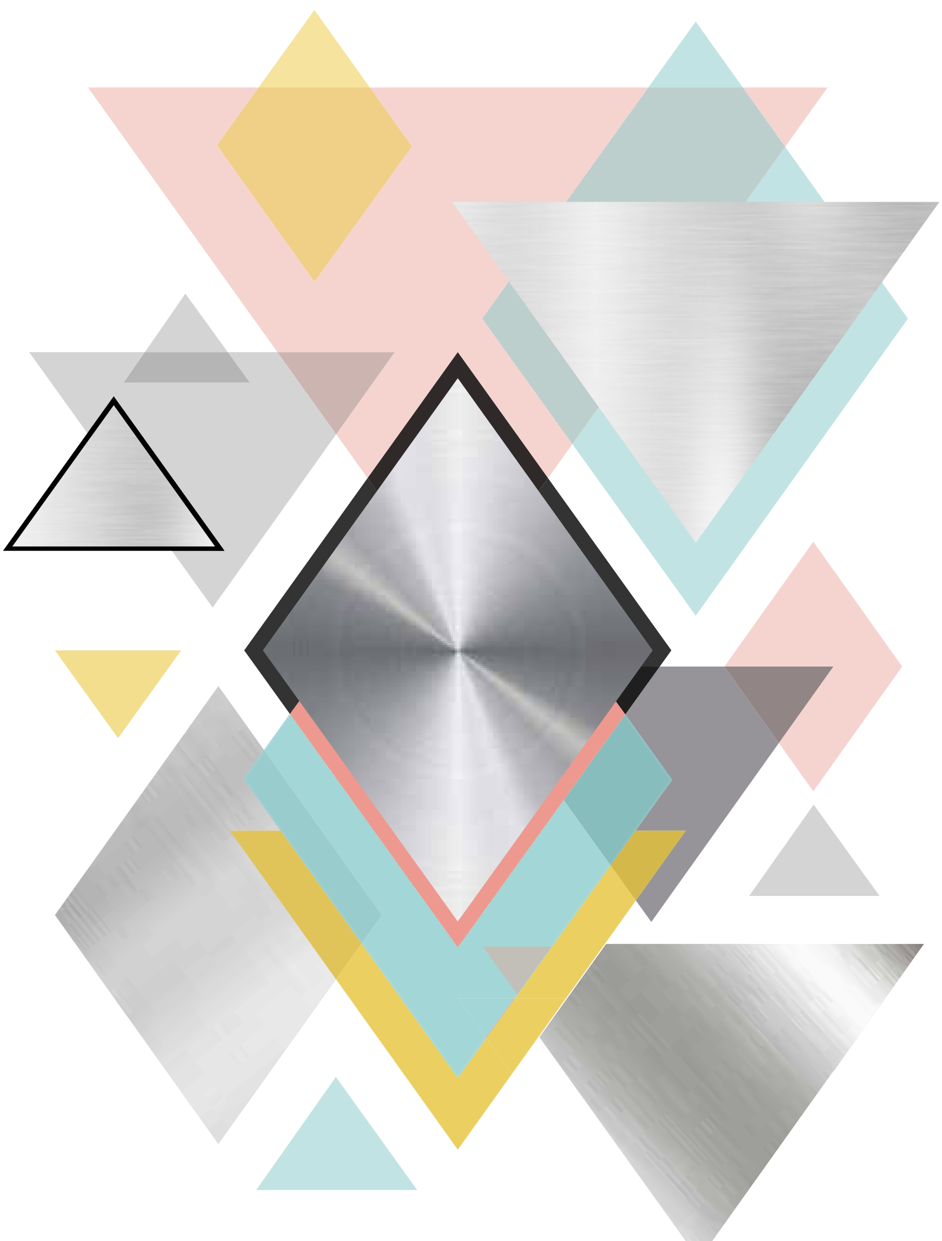
A Quarterly Journal

Aluminium in India



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Bengaluru - 560 001. India

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editorial desk

Ashok Kumar Murthy,
Editor-in-Chief

Dear Readers,

Indian economy managed recovery after the disruption of the second wave of Covid-19. The government has initiated key structural changes in the policy and regulatory regime for improving the investment climate and boosting economic growth. These initiatives are likely to play a pivotal role in the country's economic recovery.

The Indian aluminum industry has a bright future as it can become one of the largest players in the global aluminum market as in India the consumption is fairly low, and is in fact an opportunity for growth in Aluminium consumption along with the consistent GDP growth and fast growing economic conditions in India. The industry may use the surplus production to cater the international need for aluminum which is used all over the world for several applications such as aircraft manufacturing, automobile manufacturing, utensils, etc.

With the government's visionary initiatives the domestic production is being encouraged to create self-sufficiency for catering to increasing demand, country should not be dependent on imports. The National Monetisation Pipeline (NMP), announced by the Government, aims to recycle assets worth INR 6 trillion is expected to spark a virtuous investment cycle in terms of new infrastructure creation, by releasing funds for building fresh infrastructure, creating employment opportunities, thereby enabling high economic growth.

Leveraging the abundant aluminium reserves in the country, with the support of Government visionary initiatives, the Indian Aluminium Industries decided to pursue major capacity expansion programmes, by building new capacity, expanding the existing capacity, expanding VAPs portfolio to protect itself from fluctuations in LME metal prices, enhance VAPs capacity as part of downstream strategy, building greenfield smelters and expand alumina refinery capacity.

This issue of Aluminium-in-India consists of articles – Specialty Alumina and Hydrates – An Overview, Implementation Of Starbag™ Technology for Aluminium Smelter Gas Treatment Centres in India, Better Profiles Faster: Material Selection for Extrusion Tooling, Study of Thermal, Lightweight Aluminium Passenger Bus, and Electrical Properties of Aluminium Cerium Alloy with varying Cerium doping for high energy storage battery applications.

We hope this information will be useful to all those concerned. We look forward to receiving feedback from readers of our journal on layout, contents, etc., to enable us improve the journal and make it more and more useful to members.

Membership of the Association is open to all producers of aluminium and its downstream products, researchers, teaching faculty, technologists and personnel from Institutions engaged in education, research, consultancy and management services.

We value and understand the importance of cultivating relationships and expanding our horizons as to what is new in the area of technology development and added-value and benefits to the members.

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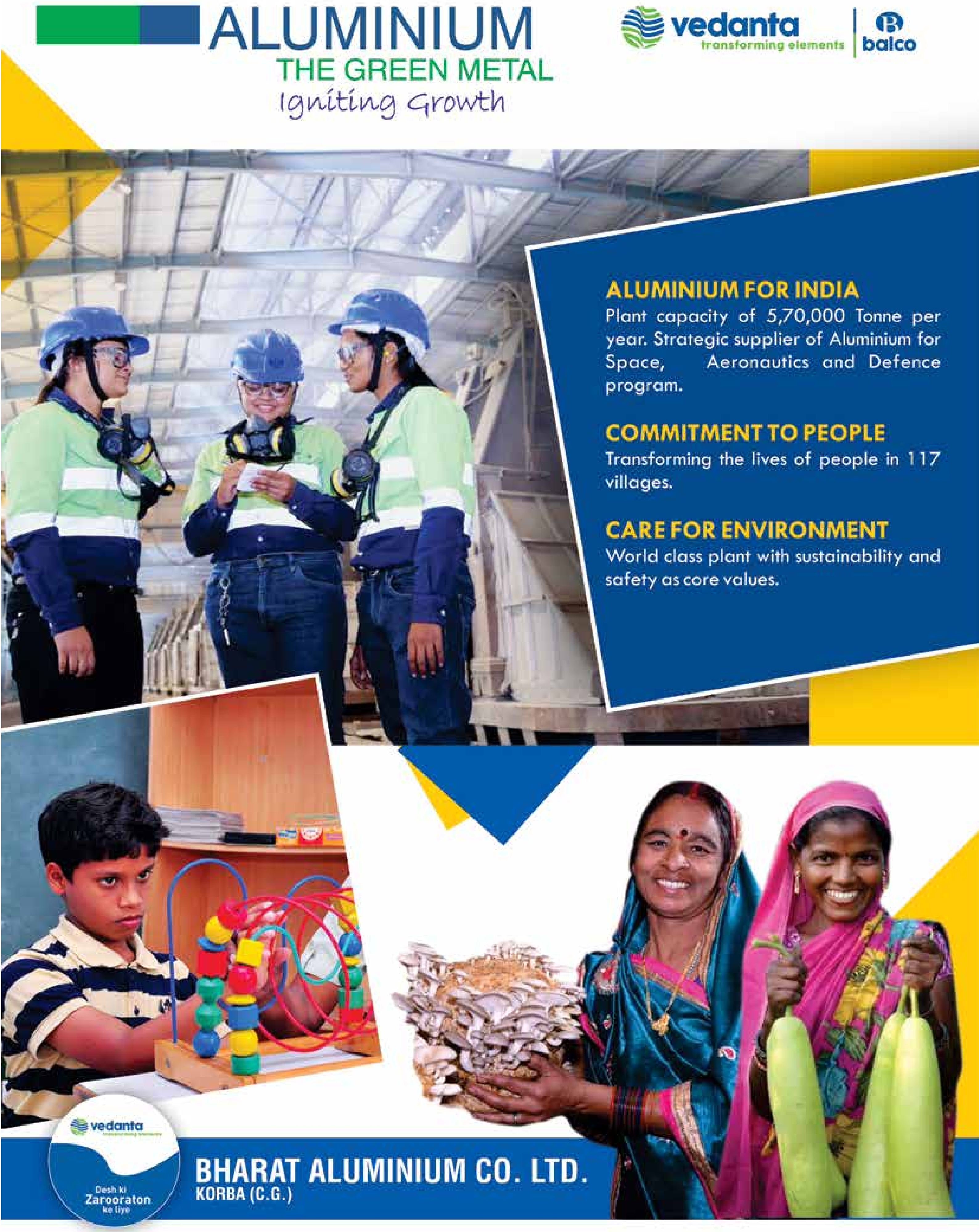
"Aluminium-in-India" (ISSN 2581-6055) which is the flagship quarterly journal of Aluminium Association of India.

The Journal is focused on technical articles and featured techno-commercial articles dealing with product development, process development focusing on tremendous change in the aluminium industry scenario both in India and world over and other articles of general interest for the benefit of Indian Aluminium Industry.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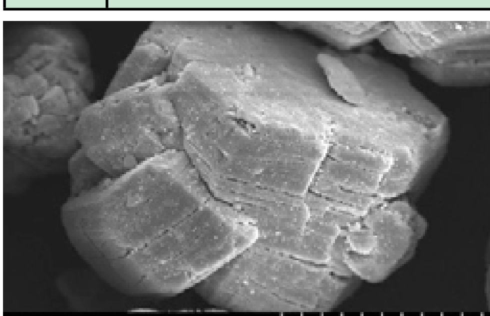
SPECIALTY ALUMINA AND HYDRATES – AN OVERVIEW

NAGESWAR KAPURI
AVP & Head: Hindalco Innovation Centre Alumina,
Hindalco Industries Limited, Belagavi – 590010

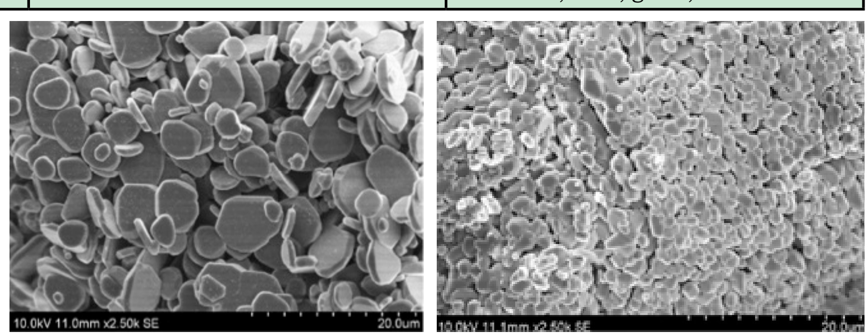
Specialty alumina is produced through the calcination of aluminium hydroxide (conventionally called alumina hydrate), generally produced through Bayer Process, using bauxite ore as an input raw material. The nature of alumina largely depends on the calcination process and the quality of the hydrate used. Low temperature calcination process is adopted for producing metallurgical grade alumina or standard grade alumina. Non-metallurgical grade alumina or Specialty grade alumina is produced through high temperature calcination. The metallurgical grade alumina is used for production of aluminium metal through Hall Heroult Technology which is the only technology commercially available for the metal production. The non-metallurgical grade alumina cannot be used for the metal production through this technology. It is being used for various other applications, such as, refractory, insulators, spark plug, glass, HT insulators, different types of industrial / technical ceramics, polishing, abrasives, etc. A quick comparison between these two types of materials could be summarise below.

Pictorial view of a Bayer Process

Sl. No.	Criteria/Parameters	Metallurgical Grade	Non-Metallurgical Grade
1	Raw Materials for its production	Aluminium hydroxide	Aluminium hydroxide
2	Calcination Technology	Circulating Fluidized Bed (CFB), Gas Suspension (GSC) or Fluid Flash (FF) Calciners preferred	Rotary Kilns, preferably
3	Calcination temp, ^{0}C	Low (1000-1150)	High (1400-1600)
4	Alpha Alumina content in product, %(extent of calcination)	Very low (typically 6-8)	High (80-100)
5	BET surface area, m^2/g	65-80	0.5- 20.0 (for different grades)
6	Soda Content	Normal /High	Ultra low – Normal
7	Other impurities	Normal as per the need of Smelter plant	Varies depending upon the applications
8	Granulometry	Coarse (-45 micron ~12%)	Ultrafine, fine & coarse, as per application
9	Crystallography	Normally blocky	Platy, roundish, etc
10	Applications	Aluminium metal production	Refractories, insulators, spark plug, industrial / technical ceramics, tiles, glass, etc

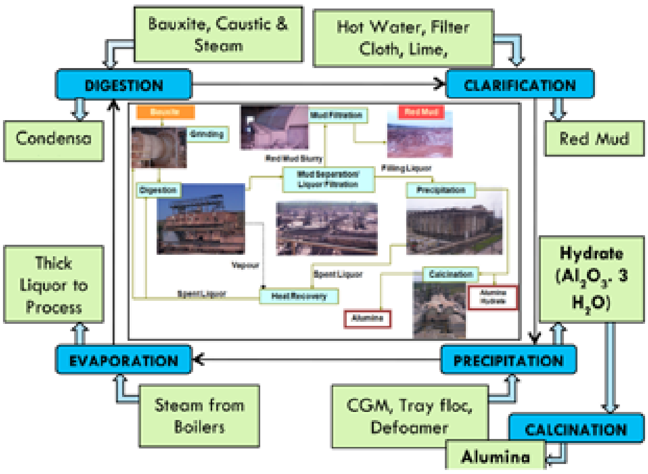


Metallurgical Grade



Non-metallurgical Grade

An overview of Bayer process for producing aluminium hydroxide could be explained in the following process flow chart.

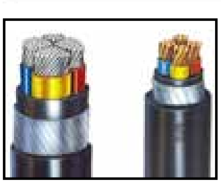


Similar way, specialty hydrates are produced from Bayer hydrate (mostly), mostly through controlled precipitation, washing / drying, some cases size reduction and modification of size distribution, in order to make it suitable for flame retardant, desiccant, sheet moulding compound (SMC), dough moulding compound (DMC), catalyst and varieties of alumina based chemicals.

Some of the important applications and their basic quality parameters could be visible in the following application data sheet.

ALUMINA HYDRATE - APPLICATION & SPECIFICATION DATA

		COARSE HYDRATE		FINE HYDRATE		
		MOIST. HYDRATE	DRY HYDRATE	WIDE DISTRIBUTION	NARROW DISTRIBUTION	SUPER GROUND
APPLICATION	PAC	●	●			
	Aluminium Fluoride	●	●			
	Other Alumina Chemicals	●	●			
	Paper					●
	SMC/DMC/FRP			●	●	●
	Rubber			●	●	
	Carpet backing			●	●	
	Glass	●	●			
	Pigment/Ceramic colour	●	●			
	Catalyst carriers	●	●			
	Cable				●	●
KEY QUALITY PARAMETERS	Moisture, %	7 (12)	0.15 (0.3)	0.2 (0.5)	0.2 (0.75)	0.6 (1.0)
	LOI, %	34.5 (34.2)	34.5 (34.2)	34.5 (34.2)	34.5 (34.2)	34.5 (34.2)
	Median Particle size, d50 (Microns)	85-110	85-110	9.0-15	4.5 - 18	2.0-3.0
	Screen Analysis (% >44 Micron)	95 (90)	90 (80)		0.2 (15)	
	Total Na2O (%)	0.25 (0.30)	0.25 (0.30)	0.25 (0.30)	0.25 (0.30)	0.4 (0.7)


Cable


Solid Surface

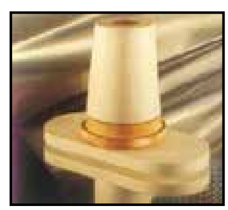

Rly Window

On the other hand, specialty aluminas are produced through controlled calcination at desired temperature and soaking period to modify the morphology of calcined products and subsequently tailor made to different particle size, distribution and surface characteristics, in order to suit to the specific application.

A broad overview of specialty alumina and its applications (with desired basic properties) could be visible in the flowing application data sheet.

CALCINED ALUMINA - APPLICATION & SPECIFICATION DATA

	Product Type	Application: Abrasives	Industrial ceramics	Technical ceramics	Refractories	Polishing	Glass	Electrical Insulators	Ceramic fibers	Ceramic tiles	Catalyst bed supports	Key Quality Parameters: Specific Surface Area (m2/g)	Medium Particle size-d50 (Microns)	Screen Analysis (% >44 Micron)	Total Na2O (%)	Ultimate Crystal Size (Microns)
Coarse	Normal Soda (High UCS)	●	●		●		●	●	●	●		<1.0 (2.5)	75 - 90	85 (70)	0.32 (0.45)	2.1 - 2.8
	Normal Soda (Low UCS)				●	●	●				●	10 (20)	75 - 90	85 (70)	0.35 (0.45)	<1.0
	Medium Soda		●	●	●							0.8 (1.0)	75 - 90	85 (70)	0.15 (0.20)	2.1 - 2.5
	Low Soda		●	●	●							0.8 (1.0)	75 - 90	85 (70)	0.10 (0.13)	2.1 - 2.5
Fine	Normal Soda		●		●	●		●	●	●		1.0 (3.0)	4.0 (5.5)	0.2 (3)	0.25 (0.35)	2.1 - 2.8
	Normal Soda					●		●			●	12 (19)	5.0	2 (5)	0.45 (0.50)	<1
	Medium Soda		●		●			●				0.8 (1.3)	4.0 (5.0)	0.2	0.15 (0.20)	2.1 - 2.5
	Low Soda		●	●	●			●				0.8 (1.3)	4.0 (5.0)	0.2	0.1 (0.13)	2.1 - 2.5
Reactive	Normal Soda		●		●			●		●		1.2 (3.0)	3.1 (3.5)	3.0	0.35 (0.45)	2.1-2.8
	Normal Soda				●	●						5(10)	0.9(2)	3.0	0.35 (0.45)	<1
	Medium Soda		●	●	●							1.2 (2.0)	3.0 (3.5)	3.0	0.15 (0.20)	2.1 - 2.5
	Low Soda		●	●	●							1.2 (2.0)	3.0 (3.5)	3.0	0.1 (0.12)	2.1 - 2.5
	Ultra Low Soda			●	●							5 (10)	0.5 (0.7)		0.08 (0.12)	0.5

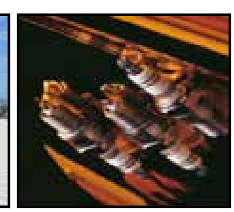

Slide Gate


Different Ceramic Products


Technical Ceramics


HT Insulators


Solar Panel

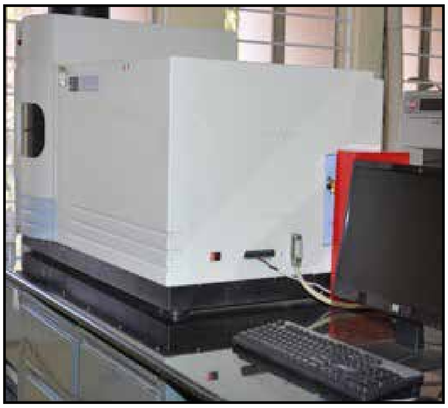

Spark Plug

Generally, most of the specialty products are tailor made needed for fulfilling the individual customer's need. Hence understanding of customer's application is very critical for the successful development and production of the products. Therefore, highly technical staff with detailed process competence is a must. Since the production process of this specialty business is capital intensive, selection of right equipment for the right type of products is very much necessitated for the high success rate of first time-right products. Therefore, a state-of-art R&D facility is a must for such type of business. This is not only


Hindalco Innovation Centre – Alumina, Belagavi

X-Ray Fluorescence

SEM



ICP – OES / MS

required for development of processes and products, but also for application studies, which helps to provide supports to customers for the usage of the products in actual applications at their end.

There are lot of demanding products / applications, like advanced electrical & electronic ceramics, high power density substrates, long lasting spark plug, LCD/ LED and other display glasses, environmental ceramics are gaining greater importance in the market place. Here innovation power, quality & reliability and some cases backward integration is key to success of the business.

It is worth to mention that many product parameters influence customer's processing and final product properties. The most important for a customer is to have a homogeneous and consistent product (from lot-to-lot and inside the same lot). Manufacturers need to fix first the quality (impurity, morphology) of feed hydrate, followed by calcination and other processing parameters

Calcination process control (frequency of SSA controls, input stability, separation of in-spec and out-of-spec materials) is a must for the system. Finally, a controlled milling process (for fine product), also needs customization in surface treatment / modification of the required products.

Invitation for Contributory Technical Papers

The quarterly in-house journal "Aluminium-In-India" published by Aluminium Association of India, which contains technical papers and articles dealing with product development, process development and other articles of general interest benefits the entire fraternity of Indian Aluminium Industry.

We would like to invite you to contribute technical articles, case studies, innovation & research papers, trends / technology perspectives and news related to your area of work. You can also send in any other communication requests, details about new product launches and press releases for inclusion in the magazine.

The article can be around 1,000 to 1,500 words along with graphs, tables and images (high-resolution) having captions + name of author/s (author's present designation and company name).

Your expertise and knowledge-share will indeed be a value-add for our wide and varied readers.

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1. All figures and tables to be captioned with title.
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IMPLEMENTATION OF STARBAG™ TECHNOLOGY FOR ALUMINIUM SMELTER GAS TREATMENT CENTRES IN INDIA

MICHAEL NEATE[1], BRAD CURRELL[2]
SOLAFT Filtration Solutions Pty Ltd; 6 Chivers Road, Somersby, New South Wales, 2250, Australia

Keywords:
Extended Surface Filters, Emission Control, Fabric Filter, Capacity Increase, Baghouse Retrofit, Filter Efficiency, Gas Filtration, Pressure Drop, Gas Treatment Centre, StarBags™

Abstract
StarBags™ increase the collection and fluoride scrubbing capacity of existing Gas Treatment Centres (GTCs) and provide aluminium smelters with an alternative to major capital equipment upgrades, lowering the production cost per tonne of aluminium where GTC capacity limitations restrict metal production.

Existing embodiments of StarBag™ designs have focused on maximising filtration area within GTC's utilising conventional filter bags typically shorter than 6 metres.

This paper summarises the success of the StarBag™ in those environments.

1. INTRODUCTION

Introduction to Aluminium Reduction Potline Gas Treatment

In the dry scrubbing process, primary alumina is injected into the fumes collected from the electrolytic cells. The alumina reacts with the fluoride gas emitted from the cells forming aluminium hydroxyfluoride (equation 1) and aluminium fluoride (equation 2) [1]. The reacted alumina dust is collected in the baghouses and fed back to the electrolytic cells where the fluoride reports back to the electrolyte.

$Al_2O3+2xHF(gas)+(15\text{-}2x)H_2O \rightarrow 2AlFx(OH)_3\text{-}x{\bullet}6H_2O$ (1)

$2AlFx(OH)_3\text{-}x{\bullet}6H_2O \rightarrow 2xAlF_3+(45\text{-}3x)H_2O+(3\text{-}x)Al_2O_3$ (2)

While the rate of this reaction is independent of the HF concentration in the gas, it is highly dependent on the alumina specific surface area, pore size distribution, the gas turbulence and contact time, the gas relative humidity, and the gas temperature [2].

As production rates in the smelter increase, there is a greater load placed on the gas treatment system, and a greater need to modify the gas treatment system to retain emissions below licensed limits. Increased production rates result in a compounding detrimental effect on the gas treatment system in both its duties as a dust collector and as a dry scrubbing reactor.

Higher smelter production rates cause increases in the quantity of hydrogen fluoride in the gas, higher gas volume, temperature and thermal buoyancy in the pot. Where the pot draft from the GTC is insufficient to overcome the increased pot gas buoyancy, significant increases in potroom roof emissions become evident. Figure 1 is an adaptation of the theory of pot emissions with increased pot gas buoyancy [3], illustrating adequate pot draft, as well as higher pot emissions with increased gas buoyancy from higher potline amperage.

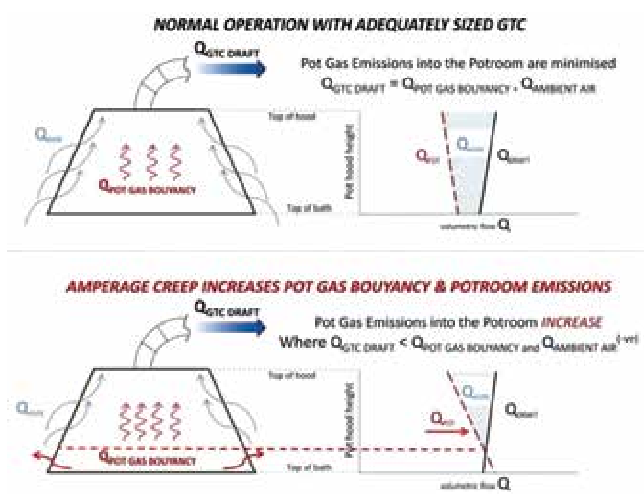

Figure 1: Increased pot emissions with amperage creep

The increase in hydrogen fluoride evolution and increase in pot gas temperature with amperage creep also increase the loading of fluoride on the alumina. This reduces the driving force and subsequently, an increase in the amount of alumina particulate (higher GTC recycle rate) that is required to react with the increased hydrogen fluoride in an attempt to compensate for the lower reaction rate. The GTC is therefore subject to increases in both gas volume and particulate dust load, resulting in a higher GTC filter baghouse operational pressure drop and more frequent pulse cleaning of the filter bags. Increased pulse cleaning yields higher particulate emissions with each pulse spike, and greater hydrogen fluoride emissions with the more frequent disruption to the reactive filter cake.

The overall effect of an increased smelter production from amperage creep on emissions from both the potroom roof and the GTC is illustrated in Figure 2.

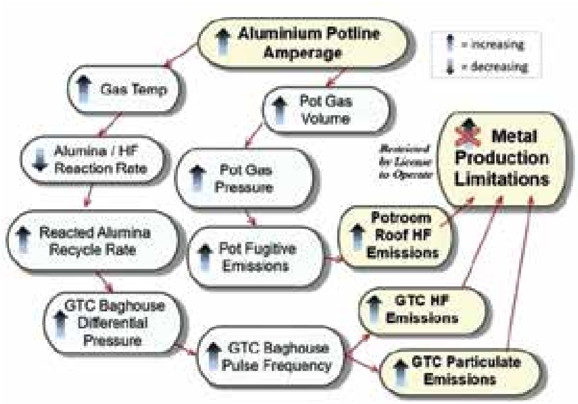

Figure 2: Increased smelter production leads to increased emissions

Introduction to ESB Technology

StarBag™ technology was originally developed [4] to provide an alternative to capital equipment upgrade in filtration systems whose design was insufficient to meet increasing capacity requirements. StarBag™ filters (figure 3) are designed to offer approximately 80% [5] increase in available filtration area compared to a traditional cylindrical filter bag.

Figure 3: Example StarBag™ ESB filters

The StarBag™ bag and cage combination offers a much lower air-to-cloth ratio, a broader distribution of dust cake over a greater filtration area providing a dramatically reduced gas and dust velocity at the face of the filter, yielding lower particulate emissions from a significant reduction in pulse frequency [5].

Theory of StarBag™ In Potline Gas Treatment

The reduction of the GTC baghouse air-to-cloth ratio with conversion to ESB, reduces gas flow resistance at the same gas flows or increases the draft to the GTC from the pots if a similar pressure head is maintained. When the pot draft is increased it will pull more ambient potroom air through to the GTC providing some gas cooling benefits to the GTC inlet gas. Figure 4 is a further adaptation of the theory of pot emissions with increased pot gas buoyancy [3], illustrating increased pot draft with StarBag™ conversion.

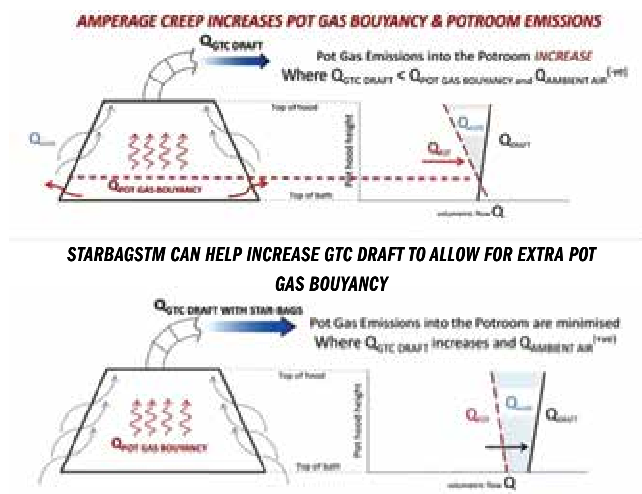

Figure 4: Reduced pot emissions with StarBag™

Fluoride emissions from aluminium pots and fume scrubbers exist in both gaseous form as hydrogen fluoride and solid form as compounds of aluminium and sodium fluoride. The effective scrubbing of the gas stream with solid alumina controls gaseous fluoride emissions, and solid fluoride compound particulate emissions are controlled by effective operation of the fabric filters.

The Light Metals Research Centre [6, p96] illustrated that gaseous HF emissions increase with increasing pulse cleaning frequency. In the same publication [6, p86] they illustrate that particulate fluoride emissions increase with increasing dust load, while gaseous HF emissions increase with decreasing dust load. In the GTC these parameters meet at an optimal operation point [5] as increasing gas and dust load in the dust collector leads to more frequent pulse cleaning and higher fluoride emissions, both particulate and gaseous.

The expected benefits of ESB technology in aluminium potline fume scrubbing include: lower gaseous fluoride emissions, lower particulate fluoride emissions, reduced pulse cleaning frequency, longer filter bag life (see Figure 5), and therefore a lower production cost per tonne of aluminium. The Light Metals Research Centre [6, p80] state that Extended Surface Bags are a cost effective way of lowering fluoride emissions and baghouse differential pressure by increasing the available filter media surface area. StarBag™ technology allows the establishment of a new, lower emission, GTC optimum operation point [5].

Figure 5: Impact of StarBag™ application

Application of StarBag™

The results published [7, 8] for the Australian and Canadian Smelters full conversion to StarBag™ have now been replicated with further successful applications of StarBag™ in other aluminum smelter GTCs around the world.

In such installations where the conversion to StarBag™ was conducted with either no additional gas flow to the GTC or with a small percentage of increase in gas flow, the efficiency and productivity gains when compared to the results from the standard cylindrical filter bags are typically expressed as:

- 30-35% reduction in filter differential pressure
- 50%-70% reduction in pulse frequency
- 40-45% reduction in particulate and gaseous HF emissions from the GTCs
- Reduced electrical load on the ID fans
- Reduced AlF3 addition requirement to the pots

Application of ESB SOLAFT StarBag™ in Indian Aluminium Smelter

SOLAFT were approached in 2020 to provide a single Cell test installation at a major Indian Aluminium Smelter. Each Filter Cell of the GTC consists of 408 x conventional filter bags and is very similar to other previous installations of StarBag™ technology around the globe.

The cloth area of each Cell fitted with conventional design is 814m². Installation of SOLAFT StarBags™ in the same length as the conventional bags resulted in a total cloth are for the trial cell of 1,428m²; an increase in cloth of 75%.

The single Cell trial was installed and commissioned in February 2021 with the following results:

Single chamber trial	Conventional Bags	Star Bag™
DP	1.9kPa	1.41kPa
Pulse interval	50 secs	200 secs
Gas velocity	14.6 m/s	14.4 m/s *(70% O/L damper opened)

Figure 6: Trial Result

Conclusion

Similar to results seen in numerous other installations, SOLAFT StarBag™ again delivered significant reductions in Differential Pressure (26%) and Cleaning frequency (75%), both of which would result in power savings and extended life; and were able to maintain the same flow rate with the outlet throttled by 30%.

Further Work

SOLAFT continues to lead the way in application of Extended Surface Filter Technology but also in the development of improved versions of the original design.

With significant in-house design and testing facilities, SOLAFT is now focused on delivering the next evolution of StarBag™ technology which allows implementation in systems with long filter bags. These designs will not only provide the same level of improvement to systems previously unable to be upgraded without significant capital projects, but also to further upgrade existing StarBag™ (and other ESB designs) installations.

References

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BETTER PROFILES FASTER: MATERIAL SELECTION FOR EXTRUSION TOOLING

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Abstract
This paper will discuss the most important aspects of material selection for extrusion tooling in detail. Correct material selection and proper heat treatment for tooling are vital factors of profitability. A good decision theory must consider different aspects and variables, including cost, longevity, cycle time, recovery, energy, health and safety, and environmental impact. All tooling fails at some point; the questions to ask are how long it lasts and why it fails. The process is mostly to blame for premature failures such as improper temperature, cycle time, alignment, pressure, and lubrication. Next come design-related issues such as strength, thermal management, lubrication, and wall thickness. Making a design change at little to no cost is often the solution for these problems. As a last resort, alternative materials may exist to offer better protection and extend useful life with better strength, conductivity, wear resistance, and other factors. Finally, it is necessary to avoid overspending on tooling materials by optimizing a combination of variables: cost, longevity, ram speed, and recovery. Simulation is a powerful tool for material selection, evaluation, and optimization before ever committing.

Introduction

Extrusion tooling parts can be classified into two categories: tools in direct contact with the deforming workpiece such as the container liner, dummy block, and die; and tools that are not in direct contact with the deforming workpiece and act as support or auxiliary parts, such as the container body, stem and die bolster [1].

The first group are the tools that either directly or indirectly participate in producing the shape of the profile. Within this group, some parts are moving against each other with a tiny gap between them. Sometimes they may even touch and slide on each other during the process. The container liner, dummy block and clean-out block are good examples of this. These tools need to have excellent wear resistance in high temperatures to maintain the critical gap between themselves over their operational life. They must also be able to resist wear and damage in case of contact.

On the other hand, there are periods when these tools are not in contact with the hot workpiece, i.e. dead cycle and idle time, and they experience relatively large thermal fluctuations at the surface: especially once they touch the hot billet. When this happens, they need to have good toughness and thermal shock resistance. A drop in hardness always follows a gain in toughness: this is a good rule of thumb for engineering materials. The challenge here is to balance the hardness and toughness to get the best life out of the tool.

Material selection for extrusion tooling is a key factor in profitability [1]. Hot work tool steels with a tempering temperature of around 600°C (such as H13) are the primary materials used for extrusion tooling that directly contact the workpiece. These materials are appropriate because they provide a good combination of mechanical properties (wear resistance and strength) at elevated temperatures. Hot work tool steels are suitable up to about 50°C below the tempering point, which allows them to perform properly for extrusion of a wide range of materials such as Aluminum, Magnesium, and Zinc alloys. For extrusion of materials with higher melting points such as copper, the surface temperature of tooling in direct contact with the workpiece can reach 700°C and above, which is well above softening temperature of hot work tool steel. Depending on the process and expected tooling life, alternative materials can be used, such as superalloys and hot work tool steels with higher Mo and W.

The tooling that is not in direct contact with the workpiece, such as the container subliner, usually performs at lower temperature ranges. They do not have to be hot work tool steel, except the super hot billet temperature or process parameters mandate using hot working materials. For example, using hot work tool steel for the container body is overspending considering that some low alloy steels (such as 4340) are suitable based on strength and temper resistance. 4340 is even better than hot work tool steel in terms of toughness and conductivity, and it makes it a better choice for the container body.

One may see a conflict of interest when some steel manufacturers promote overspending in materials. In contrast, Castool Tooling Systems does not manufacture steel but uses over 5,000,000 lbs per year for various tooling products. The goal is to deliver the best tooling possible to extruders.

Decision Theory

There are several aspects to consider when deciding on a suitable material, including:

- Cost
- Longevity
- Cycle time
- Recovery
- Energy
- Health and safety
- Environmental impact

Extruders want tooling with maximum longevity and minimum cost. Therefore, it is essential to have a reasonable estimation of a reliable life span of the tooling to avoid unscheduled downtime. Besides, cost and life are not the only important parameters. Good tooling is supposed to improve productivity [2] by helping the extruder make "Better Profiles Faster."

The most important parameters for extrusion tooling materials are listed in Table 1 (below). By defining weighting factors for material parameters, one can easily select the best material that fits the specific application.

Longevity is a function of several parameters, including strength, toughness, and temper resistance.

Extrusion cycle time consists of contact time and dead time. Contact time is in direct relation with the ram speed. Therefore, a more conductive material can dissipate more deformation heat to extrude faster and shorten the cycle time.

Dead cycle time is usually as short as possible, depending on press capabilities. However, in copper extrusion with super hot billets, dead cycle time is deliberately prolonged so that the tooling has enough time to dissipate the heat absorbed during the contact time. In this case, a material with higher thermal conductivity can help to reduce the dead cycle time.

The effect of tooling material on recovery is not as obvious. However, any scrap due to tooling material limits and tooling failure will decrease the recovery.

Energy can be saved by shortening the contact time.

Alloy		Strength	Toughness	Tempered/ Aged [°C]	Thermal conductivity [W/mK]	Cost factor	Application
Low Alloyz Steel	4340	●●	●●●●●●	540 (38 HRC) 600 (34 HRC) 630 (32 HRC)	42	75	Container body Subliner (34-38 HRC)
Hot Work Tool Steel	L6 (1.2714)	●●○	●●●	530 (42 HRC) 570 (38 HRC)	35	75	Container body (38-42 HRC)
	H11 (1.2343)	●●●	●●○	630 (42 HRC) 650 (38 HRC)	26	100	Container subliner (38-42 HRC)
	H13 (1.2344)	●●●●	●●○	620 (48 HRC) 630 (46 HRC) 650 (42 HRC) 660 (38 HRC)	24	100	Container liner (46-48 HRC) Container subliner (38-42 HRC) Dummy block
	E40K	●●●●	●●●○	600 (48 HRC) 620 (46 HRC)	30	200	Container liner (46-48 HRC)
	Tuff Temper	●●●●●	●●	640 (48 HRC) 650 (46 HRC)	30	200	Dummy block (48-50 HRC)
	Q10	●●●●	●●●	610 (48 HRC) 620 (46 HRC)	30	200	Container liner (46-48 HRC)
	DAC3	●●●●	●●●	600 (48 HRC) 620 (46 HRC)	30	200	Container liner (46-48 HRC)
Super Alloys	IN718	●●●	●●●●	720 (44 HRC)	13	1500	Copper extrusion liner (40-44 HRC)
	A286	●●	●●●●●	720 (34 HRC)	15	750	Copper extrusion liner

Table 1: Key properties for materials used for extrusion tooling

Failure Analysis

All tooling fails at some point. When this happens, the questions to consider are:

- How long the tooling performs before failing
- The cause of the tooling failure

Processes that cause overheating or overloading are often to blame for premature failures. Next comes the design, which can be modified with minimal or no additional cost. Finally, there may be materials that can extend the useful life of the tooling, but they are often associated with a significant cost increase.

Wear and fatigue fracture (crack propagation) are the usual failure modes of extrusion tooling. Wear can be tolerated by sacrificing some recovery, but fracture will cause unscheduled downtime by stopping the process. Unfortunately, unscheduled downtime often costs more than the tooling price, causing possible damage and safety concerns.

Process

Each material has its own thermal/mechanical limits. A premature failure is possible if these limits are met or passed due to overloading, overheating, or improper process control. Factors to consider include the following:

1. Temperature: tooling temperature must be kept 50°C below the tempering temperature of the material to avoid softening. In extrusion, the set temperatures for the billet, container, and die preheat are well below the softening temperature of the tooling materials. However, during the process, some locations may be uncontrolled for temperature, such as die bearing. These locations are usually the hottest points where the temperature can reach and even surpass the softening temperature.
2. Cycle time: if the contact time is too long, the tooling (specifically the dummy block) is under enormous loads for a long time which can cause permanent deformation by creep phenomenon, even though stresses are kept below the material's yield point.
3. Alignment: misalignment can cause unwanted wear of the container liner by the dummy block. It can also generate huge stresses from bending forces applied on the stem.
4. Pressure: for extrusion of hard alloys, a face pressure of over 90ksi is usually needed, which reduces the tooling life significantly.
5. Billet length: billets with a larger length-to-diameter ratio need higher pressures, and at the same time, they generate more heat inside the container. Extruding a double-length billet can produce a quadruple amount of heat inside the container.
6. Lubrication: lubrication can prolong tooling life by decreasing pressure and wear.
7. Alloy: billet material is the key parameter that dictates extrusion process conditions. Structural alloys with high Mg and Si can cause more wear while requiring higher pressure and longer cycle times. In Table 2 (below), aluminum alloys are divided into four categories based on their hardness/strength. The range of extrusion parameters is listed for each category, and recommended materials for extrusion tooling (container and dummy block) are noted.

Table 2: Recommended container and dummy block material, considering process parameters categorized based on the extruded alloy.

Process parameters	Aluminum alloys			
	Soft	Medium	Hard	Extra Hard
Aluminum Alloy	1100 / 1060 / 1350 / 3003 / …	6063 / 6005A / 6061 / …	6082 / HS6S / 7003 / …	7075 / 7BO4 / 7178 /2011 / 2014 / 2024 / 5083 / 5086 / …
Container Design Material (Body/ Subliner/Liner)	3 pc 4340/4340/H13	2 pc / 3 pc 4340/4340/H13	3 pc 4340/4340/H13	3 pc 4340/H13/H13
Dummy Block	H13 Marathon	H13 RRB	H13 Marathon	TuffTemper Marathon
Extrusion Exit Speed	high (>100 ft/min)	medium to high (30 - 250 ft/min)	medium (15 - 70 ft/ min)	slow (3 - 7 ft/min)
Ram Speed	8 - 20 in/min	15 - 40 in/min	8 - 20 in/min	2 - 8 in/min
Exit Temperature Window	Large	Medium (6061: small)	small (7003:medium)	small
Load	Low	Medium	High	Extra High
Extrusion Ratio	High	Medium	Medium	Low
Profile Complexity	Thin-walled (micro-tube, ...)	medium to high	medium	Low
Container Taper (°F/cm)	0.5	1	0.5	No taper
Container Air Cooling	Free air with fins	Forced air through fins	Free air with fins	No cooling

Design

A design change is an effective and inexpensive method to improve the tooling life and extrusion productivity. For example, moving the heating elements from the container body to the subliner makes the body stronger and improves thermal management at almost no extra manufacturing and material cost.

Material

The material cost usually accounts for more than half of the total price of tooling. There might be materials that can extend tooling life, but they are often more expensive, making the new material economically unreasonable. For example, E40K is 100% more expensive than H13 (Table 1), but using it in the container liner should extend the liner life by at least 50%. E40K has better toughness than H13 but with the same strength level. So considering that wear is the leading cause of failure, using E40K may not truly increase the useful life of the tooling.

Optimization and Simulation

Optimization of the process can only be achieved with consideration of the mechanical and physical limits of the tooling material. For example, press manufacturers are constantly increasing the face pressure of the extrusion presses. This will allow the extruders to extrude colder and longer billets faster, but on the other hand, it can also shorten the tooling life and cause unscheduled downtime. Simulation tools can be used to effectively prevent such inconsistency between the machine capabilities and material limits. Simulation is an ideal tool to visualize the outcome before committing [3]. Furthermore, material selection, design and even recipe development can be optimized and balanced using simulation software.

Conclusions

- Material selection for extrusion must be consistent with the process conditions and failure mode of the tooling.
- The key parameter in the extrusion process is the alloy being extruded. The rest of the process parameters can be estimated based on the billet material.
- The process is often the primary source of the failure; next comes the design, which can often be improved with minimal cost.
- There may be materials that provide better tooling life, but overspending must be avoided.

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FORTHCOMING EVENTS

ALUMINIUM SAFETY SUMMIT TOOLS FOR SAFETY EXCELLENCE

9-10, November 2021
Loews Hotel Chicago, Rosemont, Illinois USA.
https://www.aec.org/page/al-safety-summit

9TH BMR INTERNATIONAL RECYCLING CONFERENCE

14-15 November 2021
Grand Hyatt, Dubai UAE.
http://bmr.ae/forth-coming-events.html

AZ CHINA VIRTUAL CONFERENCE

16 - 18 November 2021
https://conference.az-china.com/

9TH CONFERENCE AND EXHIBITION HYBRID ICSOBA 2021

22 -25 November 2021
Manama, Bahrain and online
https://icsoba.org/upcoming-icsoba-event-2021/

FUTURE ALUMINIUM FORUM DIGITAL EVENT

1st - 2nd December 2021
https://futurealuminiumforum.com/

LIGHTWEIGHT ALUMINIUM PASSENGER BUS

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As we all know that Aluminium is now well established globally as one of most versatile material in transport applications Light weighting using Aluminium offers multiple benefits and advantage to various stakeholders like bodybuilders and operators in the supply chain.

Hindalco is India's leading manufacturer of Aluminium products for various industries including Transport segment. ARAI is having expertise in computer aided Engineering for various automotive applications while MG Group is leading player in manufacturing of various type of Buses in steel and Aluminium.

One of such project of National importance undertaken by Hindalco is focussed on public transport .Hindalco collaborated with ARAI, Pune and MG Automotive Group to develop lightweight Bus made using Aluminium for structure and outer skin. Concept and material was developed by Hindalco. ARAI was involved in design, Engineering, validations and compliance activities while MG Automotives carried out manufacturing of the bus at their Belgaum facility. The Bus structure profile design and unique mechanical joinery is based on modular concept and this engineering feature makes it suitable for deployment for Intercity and Intracity application across various class of buses.

Aluminium Bus offers value for money as its lightweight, fuel efficient, safe, environmental friendly and rust free

Energy Efficient	Lower TCO	Safer	Superior NVH	Lower GHG	Weatherproof

To elaborate more about its benefits and advantages, details are given below for study and reference.

TECHNICAL INFORMATION

GENERAL

Bus category	High deck Intracity
Bus type	CAT 2
Chassis Model	LYNX SMART BS6 4900
Seating capacity	34 + 1
Air conditioning	Roof Top mounted
Passenger Windows	Fixed ceramic glass 5 mm thk
Accessories	Aluminium Hat rack, Aluminium passenger door with pneumatic operating system , Telematics-Fuel monitoring system , GPS
Compliance /Standard	AIS052, AIS031,AIS153,IS15802-2008,AIS023-2005,IS14682-2004
Stiffness (static Load)	Deflection -3.5 mm against 5 mm permissible limit
Vibration	Torsional Model- 7.76 Hz (3 Hz min required) Lateral bending mode- 5.37 Hz (5 Hz min required)
Roll over test	Min clearance (Driver side -34 mm , Co-Driver side-60 mm) Stability Angle – 38 degree (28 degree Min)
Seat Anchorage	Max strain predicted -8% (against Max of 15%)

DIMENSIONS *In mm*

OA Dimensions Length x Width X height	9870 x 2350 x 3130
Sidewall -LHS/RHS	8900
Roof (L X W)	8880 x 1911
Floor (L X W)	9352 x 2230
Window Aperture (W)	920
Passenger Door Opening(W)	720
Emergency Exit (W X H)	701 x2014
Carline Angle	2 Degree
Roof Angle	6 Degree

WEIGHT *In kgs*

Gross Vehicle Weight	9300
Unladen Bus Weight	6113
Aluminium Side wall (LHS + RHS) Structure+ Roof structure	622
Aluminium Exterior Marine grade skin (Roof + side walls)	212
Aluminium Floor structure	200

CONSTRUCTION

Side walls & Roof Assembly C A G E	Semi -Open extruded profiles made of high strength alloy are used for constructing side wall frame comprising of pre-machined vertical pillars and horizontal support members . Roof structure involve pre-machined transverse roof sticks with longitudinal support profiles . Sides of roof has multi hollow cant rail profile, in single piece , running from front to end of roof on left hand and right hand side .Mechanical Joining of all members is via special type of machined alloy forged gussets with help of Loctite fasteners at specified torque. Side walls and roof are joined by same mechanical joinery. All child parts used for construction are in cut to length sizes for precise assembly and zero scrap generation. Exterior side panels are fixed to structure by automotive adhesive bonding
Front & Rear Façade	Are made using FRP with under frame of steel tubes . Façade is connected to Aluminium cage via mechanical joinery
Floor Assembly	Constructed from alloy aluminium structural sections . Joining is mechanical using high tensile passivated steel /stainless steel fasteners. Assembly with side walls is done using laser cut corner gussets via mechanical bolting

ADVANTAGES & BENEFITS of HINDALCO ALUMINIUM BUS

Lightweight

9.8 mtr long Bus Body Weight in Kgs	Aluminium	Steel	Light weighting kg (%)
sidewalls assembly, Roof Assembly + Floor structure	1034	1537	503 kg (33%)

33% lower mass make it possible to derive following benefits and advantage during life cycle of Bus

1. **Superior Driving Performance-Lower CG increases stability of vehicle** and better Driver control. **Improved NVH** provides stress-free driving experience
2. **Energy Efficient**-Fuel saving up to 2000* Litre /year (* depends on driving cycle , weight reduction and Kms of running)
3. **Enhanced Safety -Aluminium structure** provides upto 3x more energy absorption during impact resulting in minimum injury /fatalities during accidents . Lower CG and higher stability also reduces chances of roll over / toppling of Bus at sharp turn at high speed .
4. **Superior Durability** - Higher strength to weight ratio and engineered construction provides a sturdy and durable structure free from rattling and loosening of joints. This results in lower repair and maintenance making Aluminium Bus structure last for more than 15 years
5. **Environmentally Friendly** -Lower GHG emissions - up to 4 tons* per year (* depends on factor like driving in kms, driving cycle and size of Bus)
6. **Modular construction** – Bus structure is fabricated using less than 10 type of High precision ready to use lightweight profiles. Mechanical joining and absence of welding helps to produce dimensionally perfect structure. Above results in optimized production process and faster production. Workers are not exposed to fumes and light generated when using welding to construct steel structure helping to reduce fatigue and improve productivity during fabrication

Other advantages of Hindalco Aluminium Bus

7. **Recyclable material** - 100% recyclable and for infinite number of times
8. **Higher Salvage Value** – Aluminium fetches Upto 2x more salvage value compared to steel
9. **RUST FREE -Bus structure** and exterior panel are rust free making Aluminium Buses suitable for ALL WEATHER OPERATIONS
10. **Universal Design Concept** - Patented joinery and profile design is suitable for all variants based on Type I to IV , Both 9 and 12 mtr lengths , ICE as well as Electric and Intercity/ Intracity application

The bus is ready for commercial deployment now and we are keen and interested to extend our support to various State transport units in modernization /upgradation of passenger bus fleet.

CONSTELLIUM TO SUPPLY ALUMINUM COMPONENTS FOR ALL-ELECTRIC FORD F-150 LIGHTNING

They aren't yet available, but you can already order them, and just last week Constellium SE announced it will supply aluminum structural components for the all-electric Ford F-150 Lightning that will go on sale in the spring of 2022.

The Lightning will be the first all-electric Ford F-150 truck and like the rest will rely on high-strength alumninum alloys.

A France-based company, Constellium has been supplying aluminum parts to Ford's aluminum-heavy trucks and SUVs since 2015.

Along with the F-150 Lightning and Super Duty Trucks, Constellium also now supplies recyclable aluminum components and auto body sheet for Ford's Broncos, Escapes, Expeditions and Rangers, as well as Lincoln's Corsairs and Navigators.

A global company focused on rolled and extruded aluminum solutions for the automotive market, Constellium has thus far delivered over 50 million components to Ford, including 40 million since 2017.

The F-150 Lightning aluminum parts Constellium will supply include the windshield header, rockers, radiator support and more.

Radiators are needed in all-electric vehicles to cool the extremely heavy and hard-working batteries.

Recyclable aluminum is quite ecologically friendly.

"Constellium is proud to supply the electric Ford F-150 Lightning with recyclable aluminum and to contribute to Ford's commitments to sustainability," said Phillippe Hoffman, President of Constellium's Automotive Structures and Industry business unit in a released statement. "Aluminum is the metal of choice for electric vehicles, and our light, strong, crash- and intrusion-resistant solutions help make electric vehicles safe and more sustainable."

The malleability of aluminum allows engineers to design vehicle shapes optimized for maximum performance. Aluminum also gives vehicles better acceleration, braking and handling.

Aluminum also helps provide better protection in some impacts due to its intrusion resistance.

A key benefit, of course, is the lightness of aluminum. That's why its used so much in electric vehicles which carry super-heavy batteries. Aluminum has about a third of the weight of steel.

"The military-grade aluminum alloy body and upgraded frame support the advanced battery, while the first F-Series independent rear suspension and low center of gravity help improve isolation from the road, provide a more stable ride and reduce steering roll – while maintaining the durability and reliability expected from F-150," Ford wrote in a news release.

Constellium auto body components and crash management systems are produced in their plants in Van Buren, Mich., and Bowling Green, Ky.

The F-150 Lightning has a starting MSRP of around $40,000 and is shooting for an EPA-estimated driving range of 300 miles. There already are more than 150,000 reservations for F-150 Lightnings.

"We knew the F-150 Lightning was special, but the interest from the public has surpassed our highest expectations and changed the conversation around electric vehicles," said Bill Ford, executive chair of Ford Motor Company, in a release.

"F-150 Lightning is intended to be more than a no-compromise zero tailpipe-emissions truck. It's packed with ingenious features and technology that will improve over time, it's exhilarating to drive and it can power your home and worksite."

The F-series has been America's best-selling truck since 1977.

STUDY OF THERMAL AND ELECTRICAL PROPERTIES OF ALUMINIUM CERIUM ALLOY WITH VARYING CERIUM DOPING FOR HIGH ENERGY STORAGE BATTERY APPLICATIONS

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Abstract
The Aluminium- Cerium (AlCe) alloys with Cerium content from 1-8 % in Al were cast in the sand-casting mould by adding Ce% into EC grade Al (99.97% purity). The thermal conductivity, electrical conductivity and metallography analysis were measured for each alloy. The microstructural and elemental analysis was done by JEOL Scanning Electron Microscope (SEM) with Brooker EDS. The electrical and thermal conductivities were found to be in the increasing order with decreasing Ce%, from 8 % to 1% gradually. The microstructure shows the fine grains formation of average size of 77 µm for AlCe1% alloy. A correlation was observed between the electrical, thermal and mechanical properties for all prepared compositions of AlCe alloy. The results indicate that AlCe alloys with lower Ce content (1-2%) makes a more superior structure of Al grains and have higher electrical and thermal conductivity properties especially with lower Cerium content.

Keywords — AlCe alloy, Electrical Conductivity, Grain Size, Microstructure Characterisation, Thermal Conductivity

1. INTRODUCTION

Thermal conductivity of materials is measured for its ability to pass a known amount of heat through it. The effectivity of transfer of heat through surroundings depends on the thermal conductivity of the materials. The materials with poor thermal conductivity resist heat flow and also obtain heat slowly from their surroundings. The thermal conductivity of a material is measured in Cal/gm/°C/sec [1]. R L Clarke and et al has done a work on Introducing Cerium Based High Energy Redox Batteries, in which for redox battery, Cerium ion was introduced for a high energy positive electrolyte. With the use of good industrial and efficient manufacturing performs, the next goal is to develop this into practical high capacity storage batteries [2]. Some of the researchers have studied the special effects of the addition of rare earth metals (largely lanthanum and cerium) in the eutectic Al-Si alloys. It was found that addition of La or Ce increases the AlSi alloy melting and eutectic temperature, with a recalescence of 2-3°C due to precipitation of rare earth intermetallic, which bases the modification in the crystal structure and the corresponding entropy changes. The partial modification of eutectic Si particles is caused by the addition of La or Ce to Al-(7–13) %. [3]. The work done by David Weiss describes the progress and the castability of near eutectic Aluminum Cerium (Al-Ce) alloy structures. These alloys have worthy mechanical properties and are very castable at high temperatures. In alloy systems, when Si, Mg and /or Cu are added in combination with Cerium, the casting characteristics are better than the Aluminum-Copper system. The mechanical strength at room temperature can be increased by addition of Magnesium [4]. A microstructural refinement can be brought about by addition of Ce below 2 wt%. A decrease of **α**-Al grain size, refining eutectics and morphological variations in unfavourable shape of intermetallic compounds can be brought about by addition of Ce. For most of the cast commercial grades alloys such as Al–Si, Al–Li and Al–Mg the positive effects are observed. The optimum Ce addition is required to get the desired effects. For AlCu alloy system, the slight deviation in the Cerium addition can cause detrimental effects, where Ce delays precipitation of strengthening phases. The thermal stability of Al alloys at high temperature can be improved by addition of Cerium. During early days the research was done on the Al–Si–Ce, Al–Ni–Ce, Al–Cu–Ce alloys and powder metallurgy Al–Fe Ce alloy with Ce content up to 16 wt%. But in the recent decade, there is a re-established interest in using Ce as the major alloying element and research focus on Al–Ce–Si–Mg with Ce exceeding 10 wt% and Al–Cu–Ce alloys with 3–7 wt% Ce [5]. The refinement of the primary silicon and of the eutectic silicon morphology was achieved with additions of cerium (up to 1 % Ce) to hypereutectic Al-Si alloys. With the addition of 1 % Ce, the best results for the microstructural and strength properties were obtained. With an increase in the cerium additions, the precipitation temperature of the primary silicon phase decreased. The addition of 1 % Ce produced the highest reduction in the liquidus temperature, from 686.6 °C to 591.9 °C [6].

Based on the above literature survey, this project focus on the observation in the electrical and thermal conductivity of Aluminium cerium alloy with varying Ce% and its correlation with the microstructure.

2 Experimental:

2.1: Alloy Preparation:

AlCe10% alloy was made by melting route in a 20kW resistance furnace of 10 kg capacity by adding Ce MM metal (A typical composition includes approximately 55% Ce, 25% La, and 15-18% neodymium with other rare earth metals are seen as a series of 17 elements: scandium, yttrium, and the lanthanide series (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium) following[19]) with argon purging and degassing by Nitrogen. To this AlCe10% alloy, EC grade (99.97% purity) was added subsequently to cast AlCe8%, AlCe4%, AlCe2% and AlCe1% alloy by above mentioned production process. The alloys were cast in to sand casting mould with no shrinkage and blow holes casting defects.

The chemical composition of the alloys is as shown in Table 1:

Table 1: Chemical composition of AlCe alloys

AlCe Alloy	Ce%	La%	Nd%	Fe%	Others%	Al %
Alloy 1	8.63	3.673	0.0265	0.165	0.3138	Balance
Alloy 2	4.91	2.046	0.0166	0.137	0.3245	Balance
Alloy 3	2.80	1.181	0.0083	0.110	0.2987	Balance
Alloy 4	1.92	0.548	0.0045	0.095	0.3167	Balance

The alloy samples were machined with required dimensions for further study.

2.2: Metallography Characterisation and Electrical conductivity measurement:

For metallography analysis the samples were cut, hot mount and mirror polishing (0.5 µm) by LECO machines. For conductivity in % IACS the samples were machined with diameter 40 mm and thickness

8-10 mm and conductivity was calculated by Technofour conductivity meter, Type 979, which works on the principle of eddy currents.

2.3: Thermal Conductivity:

The Searle's apparatus to measure the thermal conductivity of a solid is shown in Figure 1. The alloy is taken in the form of a cylindrical rod AB (Diameter 1.8 cm and length 18 cm). One end A of the rod is kept at a temperature of 2-4°C by passing water from a tube with constant flow rate. Another tube is fitted at the other end B of the rod. The flow of water is adjusted using pinch cork such that water comes drop by drop from the exit side. Water enters the tube at end A away from the chilled water source and it leaves at the end B. Thermometers T3 and T4 are provided to measure the temperatures of the outgoing and incoming water. The whole apparatus is covered properly with layers of an insulating material like wood and glass wool, so as to prevent any loss of heat from the sides. The end A of the alloy rod is kept at temperature of 100°C and 5 calibrated thermocouples were inserted at various places in the rod at equidistance to measure the heat loss from end A to end B. The temperatures of all the thermocouples raise initially and ultimately become constant when the steady state is reached. The readings **θ**1, **θ**2, **θ**3 and **θ**4 are noted in steady state.

The whole procedure is repeated for all the other AlCe alloys with different Ce% to observe the effect of various Ce% on the thermal conductivity.

Figure 1: the experimental set up for Thermal Conductivity by Searle's method

Formula Used:

The coefficient of Thermal Conductivity K for a material is given by

$$K=\frac{md\,(\theta_3-\theta_4)}{A\,(\theta_1-\theta_2)}\ \text{cal/gm./°C/sec} \qquad (1)$$

Where A = Area of cross section of the rod (**π**r2 where r is the radius of the copper rod (D/2)

θ1 & **θ**2 = Steady temperatures at the two fixed point of the rod in steady state.

d = Distance between two thermometer T1 and T2

m = Mass of water collected per second

θ3 & **θ**4 = Steady temperatures of water at exit and at entrance respectively.

3. Results and Discussions:

3.1: Metallography analysis:

The initial study of the AlCe system is done by phase diagram by Thermo-Calc, Figure 2 [7]. It has a eutectic composition at about 10 wt% Ce with a eutectic temperature of 640°C. Hypo- and hyper-eutectic alloys contain the intermetallic compound Al11Ce3. The evaluation of the castability, microstructure, mechanical and physical properties of Al-12Ce, Al-12Ce-0.4 Mg, and Al-12Ce-4Si-0.4 Mg alloys were done by Sims et al [8].

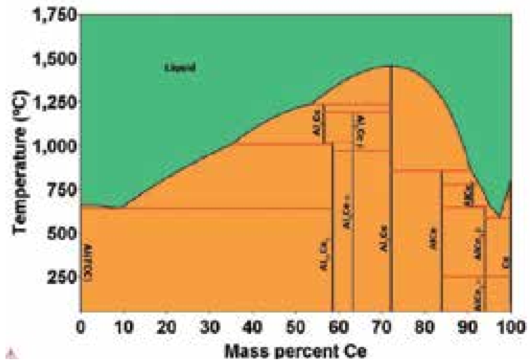


Figure 2: Thermo-Calc calculated Al-Ce phase diagram.

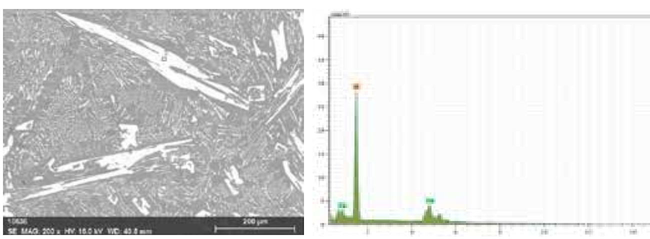


Figure 3: SEM EDS analysis of AlCe8% alloy displaying the presence of large crystals of intermetallic compound Al_{11} Ce_3. (Normal mass % of Al: 52.44 and Ce: 47.56)

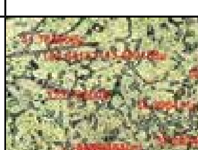
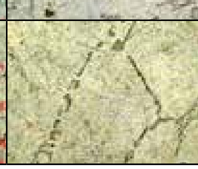
AlCe alloy (Ce%)	10X magnification	20X magnification	Avg. Grain Size (µm)
8.63			Phase size= 9-183 µm
4.91			Cluster of smaller grains of size 71-95 µm forming bigger grains of size 290 µm
2.80			115 µm
1.92			77 µm

Figure 4: SEM micrographs of AlCe alloys of 8%, 4%, 2% and 1% at 10 and 20X magnification

Among the various AlCe alloys containing 8%, 4%, 2% and 1% Ce, the first belong to the hypoeutectic group and remaining three alloys to the hypereutectic group. AlCe8% displays the presence of large crystals of intermetallic compound $Al_{11}Ce_3$ [5]. The presence of $Al_{11}Ce_3$ is confirmed by EDS analysis as per Figure 3.

The SEM micrographs of AlCe alloys of different Ce% are shown in the following Figure 4 at 10X and 20X magnifications. By contrast, a very fine interconnected eutectic microstructure is apparent for the hypoeutectic Al-4%, AlCe 2% and AlCe 1% alloy.

From the above Figure 4 it shows that with lowering the Ce% from 8% to 1% there is decrease in the grain size of alloy. AlCe8% alloy shows the presence of large intermetallic and no grain formation. AlCe4% alloy has the grain size of 290 µm whereas for AlCe2% and AlCe1% it is of 115 µm and 77 µm respectively. The efficiency of Ce has been established for the Al– 20Si alloy, where 0.3, 0.5, 0.8 and 1.0 wt% Ce led to a substantial refinement of primary Si crystals through morphology alteration from coarse polygonal and star like forms to fine blocky forms with smooth edges and corners [6, 9].

3.2: Electrical conductivity:

The benefits of Ce additions to improve tensile strength and elongation of aluminum at room temperature were carried out by earlier researcher by adding up to 0.1 wt% Cerium [10]. The negligible cerium additions used in widely held of experiments are below 1 wt%; only in nearly cases they reach 2 wt%.

According to the various researchers, Ce additions advance electrical conductivity of Al alloys due to a decrease of Fe and Si in the α-Al solution. The solvent content reduction is accredited to the development of binary, ternary or quaternary complexes of Ce, Si, Fe and Al [11, 12, 13]. It is believed that Ce increases the lattice static distortion of Al alloy solution and enlarges the average electrical free path. As a result, Ce-influenced alteration of electron energy band structure may exaggerate the operational number of electrons that participate in conduction [14]. Consequently, electrical conductors are produced from Al-based alloys with additions of 0.55 to 1.2 wt% Fe and 0.2 to 1.5 wt% Ce [15].

In this experiment the electrical conductivity was measured in terms of % IACS for all the four alloys of AlCe as mentioned above. The variation in the %IACS was observed and noted in Figure 5.

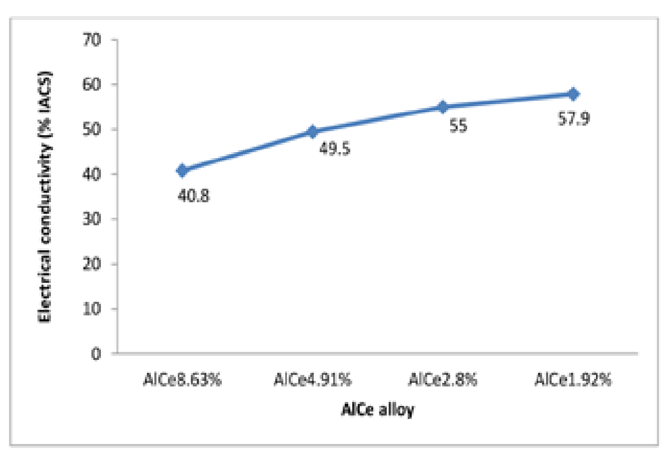


Figure 5: % IACS for AlCe alloys for various Ce%

From the above table it was observed that with decreasing the Ce% from 8% to 1% the electrical conductivity has increased. For AlCe8% alloy it is 40.8 %IACS and for AlCe1% it is 57.9 %IACS. This increase in the conductivity with decreasing Ce% is in correlation with the microstructural changes as observed in the Figure 4 and alteration of electron energy band structure.

The alloying elements having comparable electronic structure to that of aluminum can be least detrimental to conductivity. The rare earth elements, such as Ce have comparable electronic arrangement, in the solution in an aluminum matrix; yield a very low distinction change in the resistivity of aluminum this gives the greatest bonding with the largest free energy [16, 17].

3.3: Thermal Conductivity:

The thermal conductivity was determined by Searle's method as mentioned in the experimental section in terms of Cal/gm/°C/sec. Earlier studies on binary Al-Ce alloys demonstrate enhanced thermal strength at high temperatures for various claims. Therefore, the main objective of the current work is to comprehend the effect of alloying elements and correlate the microstructure-electrical conductivity-thermal stability of Al-Ce. In this experiment the thermal conductivity was determined from 4°C to 100°C.

Earlier work done by Dheeraj Kumar Saini and et al [18] studied the effect of thermal stability of AlCe12% alloy in various Al-Si-Mg alloy with and without Strontium addition at 200 – 400°C. The Al11Ce3 intermetallic phase, provides the strength and thermal stability to the alloy, has a microstructure that comprises at least one of the lath structures and rod morphological structures [6]. Elements in the solution are least harmful to conductivity if they have comparable electronic structure to that of aluminum. The rare earth elements, such as Ce have comparable electronic arrangement, in the solution in an Al matrix, produce a very little differential alteration in the resistivity of Al this gives the best bonding with the major free energy [17]. Work has been done by many researchers on effect of Ce addition in AlSiCu alloy, but here the work is presented on the effect of various % addition of Ce in EC grade Al (99.7% purity). According to M Song [4, 3], Ce improved the thermal stability of the Al-Cu-Mg-Ag alloy by reducing the diffusion velocity of Cu atoms and growing the energy barrier of the coagulating ledge nucleation thus improving the strength of the alloy at both room and raised temperatures. In this work, initially the thermal conductivity was calculated for pure Al to prove the correctness of the assembly done and it came out to be 0.516736 Cal/gm/°C/sec which was matching with the theoretical one. After this the same experiment was carried out for AlCe alloys with various Ce%. The value of thermal conductivity is as shown in Table 2.

Table 2: Thermal conductivity in cal /cm sec. K for AlCe alloy with difference Ce%

Al alloy	Δm (ml)	Δt(s)	ΔT water	ΔT Bar	Coefficient of thermal conductivity (Cal/gm/°C/sec)
Pure Al	59	193	17	61.3	0.516736
AlCe 8.63%	60	191	13	57	0.44514
AlCe 4.91%	60	193	14	58	0.466235
AlCe 2.80%	59	215	16	57.8	0.483921
AlCe 1.92%	61	206	15	52	0.480331

The thermal conductivity was found to be in the increasing order with decreasing Ce%. But for AlCe2% and AlCe1% there is a very little difference in the thermal conductivity as there is only 1% difference in the Ce% which is not sufficient to quantify the thermal conductivity variance. The thermal and electrical conductivities (Figure 5) has a good correlation with respect to the Ce% which is also has the association with grain refinement of AlCe alloy with decreasing Ce%. The more fines are the grains which is making it more thermally and electrically stable system.

The thermal stability of AlCe binary alloy is connected with Al-$Al_{11}Ce_3$ eutectic phase with melting point of 1251°C. However, the Al11Ce3 eutectic phase with lamellar morphology offers limited strengthening to the alloy [19, 20, 21]. The further improvement in the thermal conductivity of AlCe alloy can be brought about by another alloying element such as Nickel, having the diffusion coefficient in aluminum lower by about four orders of magnitude than that for Ni [21]. According to recent statements [19, 22], alloying with Ce aided holding the mechanical properties of Al alloys at higher temperatures than that seen in Ce–free Al alloy grades. After introductions to temperatures as high as 500°C for 1000 hours, Al–Ce displays widespread hardness recovery at room temperature.

Conclusion:

Cerium was added with increasing % into EC grade Al alloy to observe the effect on metallography, electrical and thermal conductivity. The refinement in the microstructure was observed with decreasing Ce%. The more fine grains of 77 μm were observed with AlCe1% alloy. This alloy with Ce1% was observed to have highest electrical (57.9%IACS) and AlCe2% alloy with maximum thermal conductivity (0.48 cal /cm sec. K) among other AlCe alloys. The difference in the thermal conductivity with AlCe2% alloy and AlCe1% alloy was very slight due to its comparative microstructural and corresponding electrical conductivity parameters. AlCe1% alloy and AlCe2% alloy are the future promising alloys for battery applications due to its enhanced thermal and electrical parameters for AlSi, AlSiCu, AlSiMg alloys.


STILL GUESSING
WHERE METAL PRICES
WILL GO IN 2021?

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Future Scope of work:
Study the electrical and thermal conductivity of Al-Ce alloys with Silicon, Magnesium and Copper addition at elevated temperature (200-500°C) with and without annealing and correlate it with its mechanical and microstructural properties.

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PELEE'S ALUMINUM WINE BOTTLES BLOSSOM

Pelee Island Winery expands its packaging options with a 250-mL aluminum bottle for its Lola series that mimics the grace and beauty of its glass bottle counterpart.

The 250-mL aluminum bottle is a stock package from Trivium that is direct printed in up to six colors and is topped with a silver screw cap.

With its graceful, tapered-shoulder silhouette and stunning floral artwork, a new 250-mL bottle from Pelee Island Winery for its Lola line of four wine varieties artfully brings the aesthetics of a traditional wine package to an aluminum bottle format. Introduced initially in Ontario, Canada, the bottle and brand extension generated considerable buzz among the winery's retail and on-premise partners as well as excitement from Pelee's loyal followers when it was launched in spring 2021.

Each variety of Lola in the new aluminum bottle is variety decorated with a floral pattern that matches the label used for its 750-mL glass bottle counterpart.

VEDANTA ALUMINIUM BECOMES INDIA'S LARGEST GREEN POWER BUYER AT IEX

Vedanta said that its aluminium business unit became the largest green power procurer in the Indian Energy Exchange (IEX) platform in the first quarter of FY22, sourcing 354 million units of renewable energy (RE)–based electricity for its aluminium production facility at Jharsuguda, in Odisha.

The power was bought through the green term-ahead-market (G-TAM) market in the IEX. Corporate India is increasingly trying to reduce their carbon footprint and many corporate consumers already receive RE power through the 'open access' mechanism.

Vedanta Aluminium's purchase of green power units is more than 35% of the green power traded on IEX in Q1 FY22. "Our long-term strategy focuses on migrating to low carbon energy mix, with gradual shift from fossil fuels to renewable energy, to produce green aluminium," Rahul Sharma, CEO of Vedanta Aluminium Business said.

The GTAM mechanism was introduced last year by IEX which allowed more flexibility to buyers for purchasing RE electricity. The mechanism also opened up options for power distribution companies to resell renewable power that they procure from developers. Vedanta Aluminium Business in Odisha and Chhattisgarh, a division of Vedanta Limited, is the country's largest manufacturer of aluminium. It produced 1.96 million tonnes of aluminium in FY21.

INDIAN RAILWAYS TO GET FIRST ALUMINIUM COACHES BY EARLY 2022; WHY IT'S SIGNIFICANT

Indian Railways is likely to get its first batch of aluminium bodied coaches by February 2022. In a technological shift for railways, the Modern Coach Factory (MCF) in Raebareli is looking to manufacture aluminium coaches. The first set of 3 coaches for Kolkata Metro are expected to be ready by early next year, a railway official told TOI. Eventually, Indian Railways hopes to get aluminium coaches for Rajdhani and Shatabdi Express style premium trains.

MCF has signed a Rs 128 crore contract with South Korean firm Dawonsys for this ambitious project. The execution of the project has been delayed by the COVID-19 pandemic hitting both India and South Korea. The design for the metro coaches will likely be finalised by the end of this month. "The South Korean firm will "The South Korean firm will share the designs and once MCF approves they will be made in South Korea and brought in India in knocked down condition," the railway official told TOI.

"To begin with they (Dawonsys) will manufacture these coaches in South Korea and slowly the transfer of technology will take place to MCF," official added. The three standard gauge metro coaches will include two driver motor cars and one trailer coach with a speed potential of 100 kmph. The contract also has provision for manufacturing 8 broad gauge locomotive-hauled coaches. These include; These include; three AC-3 tier Sleeper coaches, two AC-2 tier sleepers, one AC-1 sleeper, one AC hot buffet car and one AC DSLR with Driver/Guard cabin. These Rajdhani style sleeper coaches will have speed potential of 160 kmph. Of these 8 coaches, 4 will come fully assembled and the rest will be received in knocked-down condition and assembled here. The South Korean firm's staff will provide hands-on training to MCF officials as part of the deal.

Additionally, designs for self-propelled aluminium coaches with speeds of up to 225 kmph will be provided. This will help MCF manufacture Shatabdi style aluminium coaches. The self-propelled coaches will enable Indian Railways to run superior train sets in line with its aim to connect major cities with chair car train services.

Why aluminium bodied coaches?

- Lighter compared to stainless steel coaches resulting in lower haulage cost and better fuel efficiency
- Corrosion resistant with an extended coach life of 40 years - that's 5 more years of revenue
- Modular interiors with easily removable components during maintenance and retrofitment
- Less weight allows for increased speed potential on the existing Indian Railways tracks
- Low life cycle cost with reduced wear and tear of components
- Hollow extrusion design allows for commendable crashworthiness in case of an accident
- Less time to manufacture hence increasing capacity for production

Railway Board has given its nod for making 500 aluminium coaches once MCF has the required infrastructure. The new aluminium coaches will be superior to Shatabdi and Rajdhani Express coaches in terms of comfort, safety, exterior and interior. The technology and prowess to manufacture aluminium bodied coaches will be a feather in the cap for railways which currently makes stainless steel coaches.

INTRODUCING THE BULGARI ALUMINIUM GMT

Alongside the Octo line, the Bulgari Aluminium has been gaining momentum within the brand's massive portfolio.

An intro may not be necessary here, but the collection is one of the (unconventional) true classics that first came out in the 1990s with, you guessed it, an aluminum case combined with a rubber bezel. The series was revived last

year with some updates to the details while keeping its unique stylings intact. And now, the Aluminium collection gained a GMT equipped variant.

NALCO'S PANCHPATMALI BAUXITE MINE AWARDED POLLUTION CONTROL EXCELLENCE AWARD 2021

NALCO's Panchpatmali Bauxite Mine has been awarded the prestigious Pollution Control Excellence Award 2021 by the State Pollution Control Board, Odisha, for effective pollution control measures and sound environment management practices.

In a function held at State Pollution Control Board, Odisha in Bhubaneswar, Shri Bikram Keshari Arukha, Hon'ble Minister of Forest & Environment and Parliamentary Affairs, Govt. of Odisha handed over the prestigious Award to the Mines team of National Aluminium Company Ltd (NALCO), a Navratna CPSE under Ministry of Mines, Govt. of India.

Shri Sridhar Patra, CMD, NALCO congratulated the Mines Team & reaffirmed the Company's commitment towards effective environment management. Shri Patra said, ''NALCO has always striven for achieving the highest standards in effective environment management. This Award is a testimony to the dedication of NALCO employees who have been passionately working towards following the best Sustainable Mining practices.''

Starting from implementing zero discharge system for effluent, NALCO's Bauxite Mine has adopted concurrent reclamation & rehabilitation of mined out areas. The Panchpatmali Bauxite Mine has planted more than 37 lakh trees so far. Steps have also been taken to improve biodiversity in the mined out areas. NALCO has been closely monitoring the best practices being followed across the globe for sustainable mining and is continuously adopting innovative technological advances in the field of environmental management system.

AMETEK LAND LAUNCHES NEW TEMPERATURE MEASUREMENT FOR SPOT AL ALUMINIUM PYROMETER

AMETEK Land has announced the launch of two new temperature measurement enhancements for its aluminium production and processing application pyrometer, SPOT AL.

The latest developments add low-temperature and liquid aluminium temperature measurements to the SPOT AL pyrometer series, increasing the capabilities of the machinery for operators in the aluminium sector. To monitor the cooling rate through the quenching process, it is necessary to precisely measure the aluminium temperature at each end of the process.

This ensures the aluminium product has the required physical properties and precise dimension tolerances by the time it leaves the process. The new SPOT AL low temperature (LT) enabled low-temperature quenching in aluminium extrusion, and delivers readings from 130 °C (266 °F), depending on surface emissivity.

A new liquid (L) temperature measurement mode for the SPOT AL has also been added. Designed specifically for temperature measurement control of liquid aluminium during melting and pouring – an important element in ensuring high-quality casting operations – this pyrometer mode delivers highly accurate results of liquid aluminium, ensuring process efficiency and high-quality castings.

In addition to the new enhancements, the SPOT AL offers pre-set algorithms to provide accurate digital temperature readings of low and variable emissivity aluminium in extrusion, quench, strip, forming/forging, including applications with high magnesium alloys. These algorithms are not limited to these specific applications, and provide an effective temperature measurement solution for a range of alloys and surfaces.

Data is made immediately available via the integrated rear display, web server and multiple interfacing options, and the SPOTViewer/SPOTPro advanced pyrometer software for monitoring, analysing, capturing and controlling temperatures in the process. The SPOT AL also combines Modbus TCP digital and analogue inputs and outputs ina single device.

SELF-CLEANING ALUMINIUM SURFACE

Researchers have developed a flake-like nano-structure on aluminium surface, making it durable and ideal for medical devices Aluminium is a light metal that has many industrial applications as it can be easily cast, machined and shaped.

However, atmospheric degradation due to contaminants and humidity significantly limits its performance and sustainability. Besides, the leaching of aluminium causes environmental and health issues.

Now, researchers have developed a nano-structured self-cleaning aluminium surface, which could have multiple applications ranging from biomedical to aerospace and automobiles to household appliances. The process is easily scalable to industrial-level production.

Harpreet Singh Grewal, Harpreet Singh Arora and Gopinath Perumal, researchers from the Department of Mechanical Engineering; and Sajal Kumar Ghosh and Priya Mandal from Department of Physics, Shiv Nadar University, Delhi-NCR, have jointly developed the surface, which shows immense mechanical, chemical, and thermal durability, and restricted corrosion and leaching.

They developed a flake-like nano-structure on aluminium surface by heating the sample in water at 80 degrees C for an hour. The surface obtained by this facile and environment-friendly approach showed a complete wetting nature (ability of liquid to spread over a solid surface). A coating of low surface energy hydrocarbon material ensures water droplets immediately roll off the surface. This makes it self-cleaning, reducing bacterial adhesion and growth, and hence suited for medical devices, including dental implants and heart-assistive devices.

ALUMINIUM STATISTICS

Source: Japan Aluminium Association

PRODUCTION OF ALUMINIUM AND ITS FABRICATED PRODUCTS

(Thousand Metric Tons)

	Total 2020	%Chg 20/19	2020 QI	2020 QII	2021 QIII	2021 QIV	2021 March	2021 %Chg (21/20)	2021 3 Months	2020 3 Months	%Chg
Primary Aluminium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Secondary Aluminium	690.2	-13.2	161.4	204.2	202.0	203.4	72.3	74.0	405.4	324.6	24.9
Semi-fabricated products											
F.R.P.*	1,054.5	-8.4	253.1	274.7	276.5	312.6	104.3	24.0	589.1	526.8	11.8
Extrusion	664.1	-12.1	156.8	184.6	172.2	177.5	63.8	27.1	349.7	322.7	8.4
Die-Castings	822.9	-17.8	208.2	248.1	239.4	230.3	83.8	89.4	469.6	366.6	28.1
Castings	343.7	-21.4	86.2	102.6	98.2	94.7	34.5	98.8	192.9	154.9	24.5
Electrical Conductor	35.7	5.4	8.7	9.4	10.6	7.3	2.6	-11.0	17.8	17.5	1.7
Foil	105.6	-2.3	25.4	28.2	29.3	32.2	11.3	23.7	61.5	52.0	18.3
Aluminium Windows	137.3	-12.7	34.1	37.1	31.0	31.4	11.3	0.7	62.4	66.1	-5.5
Aluminium Cans	356.6	-2.1	96.0	79.5	82.8	98.3	32.2	1.2	181.1	181.2	-0.0

**including foil stock*

IMPORTS AND EXPORTS

(Thousand Metric Tons)

	H S	Total 2020	%Chg 20/19	2020 QI	2020 QII	2021 QIII	2021 QIV	2021 December	2021 %Chg (21/20)	2021 3 Months	2020 3 Months	%Chg
IMPORTS												
Aluminium waste & scrap	7602	52.8	18.4	11.0	18.9	17.4	13.3	5.2	47.7	30.7	22.9	34.1
Unwrought aluminium												
Aluminium not alloyed	7601-10	1,169.5	-17.6	246.4	269.6	342.2	389.6	153.9	52.6	731.8	653.6	12.0
Aluminium alloyed	7601-20	882.6	-24.5	148.3	259.7	281.5	277.9	88.0	44.9	559.4	474.7	17.9
Wrought aluminium												
Plates, sheets & strip	7606	130.8	-8.2	26.9	32.7	32.5	36.8	12.6	26.2	69.3	71.3	-2.8
Bars, rods & profiles	7604	24.8	-20.5	4.9	3.8	4.9	4.4	1.5	-36.7	9.3	16.1	-42.2
Tubes & pipes	7608	3.6	-17.9	0.7	1.0	1.0	1.0	0.3	7.4	2.0	1.9	6.3
Wire	7605	11.8	-7.8	2.4	2.9	2.6	3.7	1.2	-9.9	6.3	6.5	-3.0
Foil	7607	56.0	-7.1	13.8	14.7	15.4	17.8	6.6	25.9	33.2	27.5	20.8
Rolled prod. sub total		**227.0**	**-9.6**	**48.7**	**55.1**	**56.4**	**63.8**	**22.2**	**15.5**	**120.1**	**123.2**	**-2.5**
EXPORTS												
Unwrought aluminium	7601											
Not alloyed, alloyed	-10,-20	20.7	14.4	4.1	4.8	8.5	5.6	2.3	2.0	14.1	11.7	20.3
Plates, sheets & strip	7606	145.7	-19.0	33.6	49.4	45.3	48.9	16.1	58.0	94.2	62.6	50.4
Bars, rods & profiles	7604	15.0	-8.5	2.9	4.4	4.6	4.9	1.8	74.8	9.5	7.7	24.3
Tubes & pipes	7608	4.0	-17.0	0.9	1.2	1.6	1.4	0.5	118.3	3.1	1.8	66.8
Wire	7605	6.7	8.9	1.5	2.4	2.4	1.9	0.8	126.1	4.3	2.8	52.5
Foil	7607	66.3	0.3	13.5	21.8	21.3	24.5	8.0	80.7	45.8	31.0	48.1

1. Detail may not add to the each quarter and year totals due to rounding
2. The figures of 'Total 2020' are final ones of 2020. It might be different from the total figure of each quarter of 2020, because the data of each quarter is based on temporary statistics for preliminary release

HIGHLIGHTS

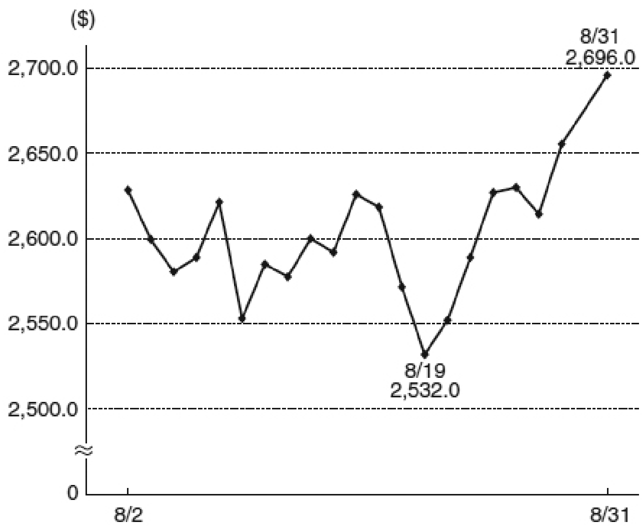
JAPANESE ALUMINIUM MARKET

Source: Nalk Report, Vol.370 September 2021

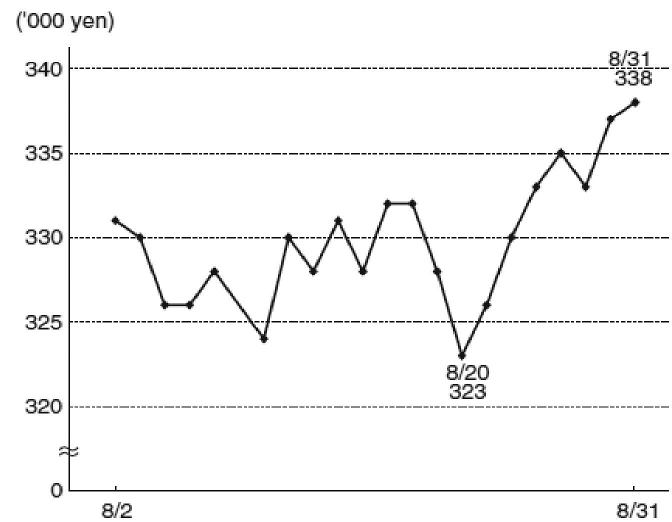
Aluminum Price Trends in August 2021

LME 3M aluminum price for August 2021 remained at the $2,500-$2,600 level reaching close to $2,700 at the end of the month. Japan's spot aluminum price reflected the movement of the LME price, hovering at a high level around ¥333,000. In September, the LME 3M price maintained a high level around $2,700. As of September 13, the LME 3 month price further increased to $2,950 and the spot price in Japan reached ¥363,000/ton. Meanwhile, talks to settle the premiums for shipments to Japan in the 4th quarter of 2021 (October-December) have kicked off.

Producers have reportedly offered premiums in the range of $230-250, which are roughly 24-35% higher than the previous quarter, but the consumers are putting up a strong resistance. Due to export tariff increase in Russia and global container shortage, premiums in the US and Europe are already rising steeply. With supply cuts from China as well, a rise in aluminum metal prices and premiums appears to be unavoidable.



LME Three-Month Prices



Domestic Spot Market Prices
Source : The Daily Light Metals News

According to data from The Daily Light Metals News, end-August 2021 stocks of primary aluminium at the three major Japanese ports totaled 316,000 tons, up 24,100 tons from the previous month, once again surpassing the 300,000-ton mark. Selling prices of secondary aluminum alloys shipped in August 2021 to small users have been settled at \3-4/kg higher than the previous month. Prices of ADC12 sold in small lots in the Tokyo area climbed \3/kg and ranged between \381 and \386/kg on September 6.

PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM AND SECONDARY ALUMINUM ALLOYS IN APRIL 2021

Production of secondary aluminum and secondary aluminum alloys in July 2021 came to 72,330 tons, up 37.3% from a year earlier, the Japan Aluminium Alloy Refiners Association announced. Shipments also recorded a 32.5% increase to 71,811 tons. Both production and shipments surpassed the previous year's level for 9 months in a row.

Data by sector shows that shipments to the main die casting sector grew 31.9% to 40,153 tons, marking an increase for 11 consecutive months. Shipments to the casting sector logged a 30.7% increase to 18,489 tons and recorded an increase for 9 straight months. All other sectors exceeded the preceding year.

Shipments of Secondary Aluminum and Secondary Aluminum Alloys by Market in July 2021 **(tons)**

	Castings	Die Castings	Rolled Products	Extruded Products	Steel	Alloys	Exports	Others	Total
	18,489	40,153	5,065	1,570	3,999	2,341	72	122	71,811
Y-on-Y% Chg	130.7	131.9	113.2	119.8	185.1	149.3	7200.0	103.4	132.5

The following papers/articles were published in Aluminium-in-India in the last four issues

- DEVELOPMENTS AND INNOVATIVE APPLICATIONS OF SPECIAL ALLOYS AND COMPOSITES OF ALUMINIUM - Prof. Saroj Kumar Nayak and Dr B K Satpathy- IIT, Bhubaneswar
- LOW LOSS CONDUCTOR FOR RENEWABLE SEGMENT - Chintan Pandya, Rakesh Tripati, Ananthakumar R, Vishal Sharma, Saikrishna Bendapudi - Sterlite Power Transmission Ltd.
- CONTAINER LESS COLD FORWARD EXTRUSION OF Alm-TiB2p COMPOSITE RODS (SOLID BODIES) - RohanMishra, Antony Alexander, K.Srinivasan - NITK, Surathkal
- HOT OIL SYSTEM DESIGN AND MAINTENANCE GUIDE - Maheswar Behera, Consultant – Aluminium Industries.
- CONTRIBUTION OF ICSOBA IN SETTING DEVELOPMENT TRENDS IN GLOBAL BAUXITE, ALUMINA AND ALUMINIUM INDUSTRY - C. Vanvoren, F. Feret, A. Panov, M. Reverdy, Houshang Alamdari - ICSOBA
- DEVELOPMENT OF SUPER THERMAL RESISTANT ALUMINIUM ALLOY FOR OVERHEAD CONDUCTOR APPLICATION -Chintan Pandya, Prasad S, Rakesh Tripati, Ananthakumar R, Vishal Sharma, Saikrishna Bendapudi, Sterlite Power Transmission Ltd.
- LIMITING ASPECT (SLENDERNESS) RATIO IN CONTAINER LESS EXTRUSION OF Al-5Zn-1Mg ALLOY - Prof. K. Srinivasan
- INSTRUMENTATION AND PROCESS CONTROL IN ALUMINIUM PROCESSES - Vishwas Kale, Vijayesh Instruments Pvt. Ltd.
- EFFECT OF BORIDES FROM ALB MASTER ALLOY IN THE REDUCTION OF TRAMP ELEMENTS TO MAKE CONDUCTOR GRADE ALUMINUM ALLOY - Pallavi Deshmukh, Prakash Tiwari, Archana Gupta, Suman Sao, S. B. Misra, Minex Metallurgical Co Ltd.
- ALUMINIUM METAL MATRIX COMPOSITE PROCESSING BY LIQUID METAL INFILTRATION TECHNIQUES - T.P.D. Rajan, M.G. Akhil, A.G. Arsha - CSIR-NIIST & AcSIR, K.M. Sree Manu, CSIR-NIIST & BCAST, Visakh Manoj - CSIR-NIIST, H. Sundara Murthy - Fenfe Metallurgicals, B.C. Pai - CSIR-NIIST
- CELL LINING REDESIGN FOR SPL MINIMIZATION AT HIRAKUD SMELTER Mahesh Sahoo - Hindalco Industries Ltd, Hirakud, Amit Gupta - Aditya Birla Science & Technology Company Pvt. Ltd., S. K. Badajena - Veer Surendra Sai University of Technology, University of Burla
- DESIGN & DEVELOPMENT OF HPC CONDUCTOR: A PERMANENT SOLUTION FOR LONG SPAN RIVER-CROSSING– 400KV D/C QUAD - Prasad S, Rakesh Tripati, Ananthakumar R, Vishal Sharma, Saikrishna Bendapudi - Sterlite Power Transmission Ltd.
- CRU EXPLAINS HOW TO UNDERSTAND INDIA'S COMPLEX CARBON EMISSIONS PROBLEM -Shankhadeep Mukherjee, Team Leader, CRU India
- BUILDING A SUSTAINABLE FUTURE WITH 'GREEN METAL' ALUMINIUM Mr. Ajay Kapur, CEO – Aluminium & Power Business, Vedanta Ltd.
- OPTIMIZATION OF BATH SHOP CRUSHING CIRCUIT FOR SUITABLE PARTICLE SIZE Mr. Maheswar Behera, Consultant – Aluminium Industry
- ALUMINIUM INDUSTRIES DURING COVID-19 AND ACTION PLAN POST COVID Dr. B.K Satpathy, Visiting Scientist, Indian Institute of Technology, Bhubaneswar

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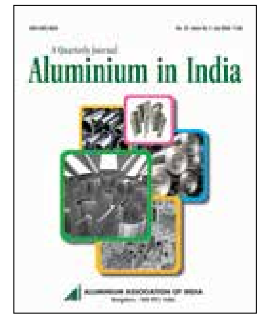

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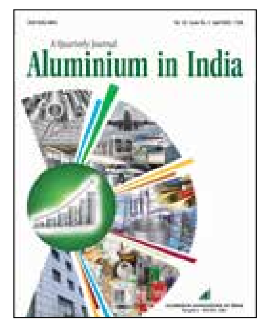

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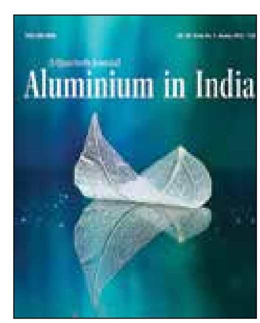

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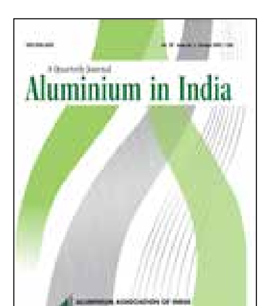

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