IBAAS 2025
TECHNICAL LECTURE SERIES

BILLETS ALLOYS APPLICATION AND NEW DEVELOPMENTS

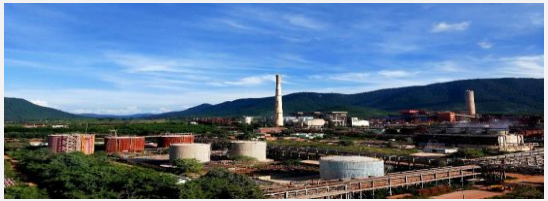
FABIO ROBERTO MARTINS

CEO Billet, Vedanta Aluminium Business

Mr. Fabio Roberto Martins
CEO Billet, Vedanta Aluminium Business

- **Fabio Martins** is a global leader with over 25 years of experience in business management and team leadership within the Mining and Metal industry. As **CEO of Billets at Vedanta**, he has driven the implementation of best practices and operational systems.
- He also represents Vedanta as a Board Director at the **International Aluminium Institute (IAI**).
- Before joining Vedanta Fabio had been associated with Alcoa since the beginning of his career and held board roles at the Brazilian Aluminium Association (ABAL) and the American Chamber of Commerce in Brazil (AMCHAM).
- He holds a degree in Business Management from Fundação Getulio Vargas and a degree in Industrial Engineering from Universidade Paulista, Brazil.

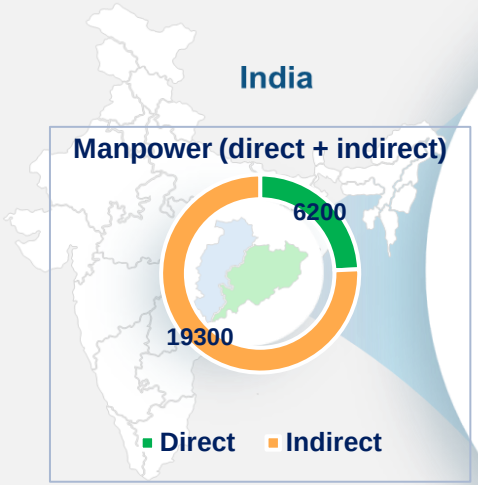
Vedanta's - Irreplicable and Unparalleled Assets

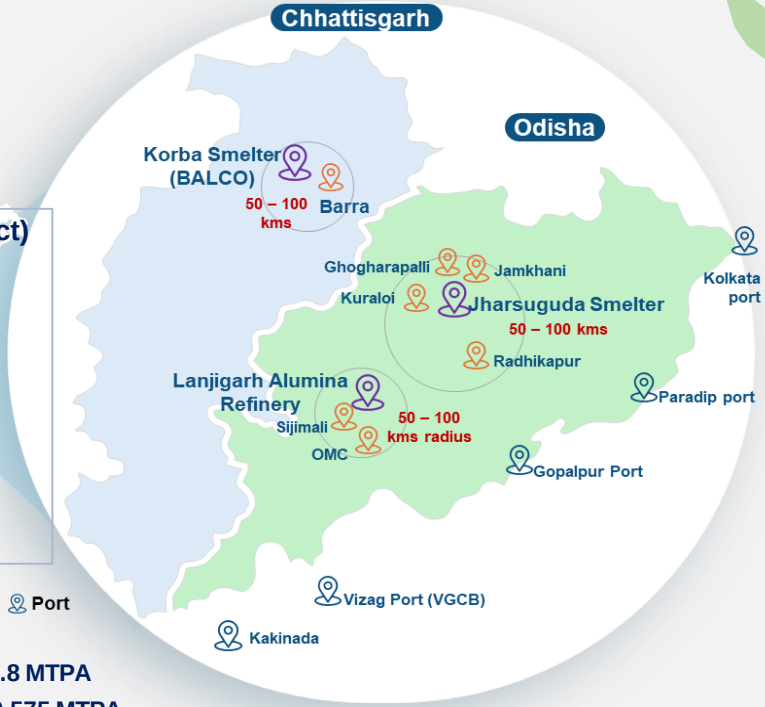


Alumina Refinery, Vedanta Ltd.
Lanjigarh, Odisha

Bharat Aluminium Company Ltd.
Korba, Chhattisgarh

Aluminium Smelter, Vedanta Ltd.
Jharsuguda, Odisha





Bauxite Plant Coal Mine Port

Jharsuguda Smelter	1.8 MTPA
BALCO Smelter	0.575 MTPA
Lanjigarh Refinery	5.0 MTPA

Reduce Absolute emissions by 25% by 2030 and Net Zero Carbon by 2050 or sooner

WE ARE INDIA'S LARGEST ALUMINIUM PRODUCER

vedanta transforming for good

From the Earth to the Sky

BAUXITE → (3:1 Bauxite to Alumina — Alumina Refinery) → ALUMINA → (2:1 Alumina to Aluminium — Aluminium Smelter) → ALUMINIUM → (Downstream) → APPLICATIONS

Coal → (Power generation) → Captive Power Plant

Aluminium Smelter

RE Power

Industry Value Chain

Vedanta Aluminium | Business Credentials

ESG EXCELLENCE & AIDING CUSTOMERS IN DECARBONISATION

1st rank **in the S&P Global Corporate Sustainability Assessment (CSA) 2023 for the aluminium industry**

S&P Global

1st smelter in India to be **Aluminium Stewardship Initiative (ASI)** certified, demonstrating responsible Aluminium production

asi Aluminium Stewardship Initiative

Received **Environmental Product Declaration (EPD) International** verification for diverse range of products, acknowledging them as environmentally sustainable

EPD®

Elevating industry standards through **Bureau of Indian Standards (BIS) certification**, ensuring consistent high quality in domestic production

BIS CERTIFIED

Vedanta Aluminum Business

STRONG GLOBAL PRESENCE

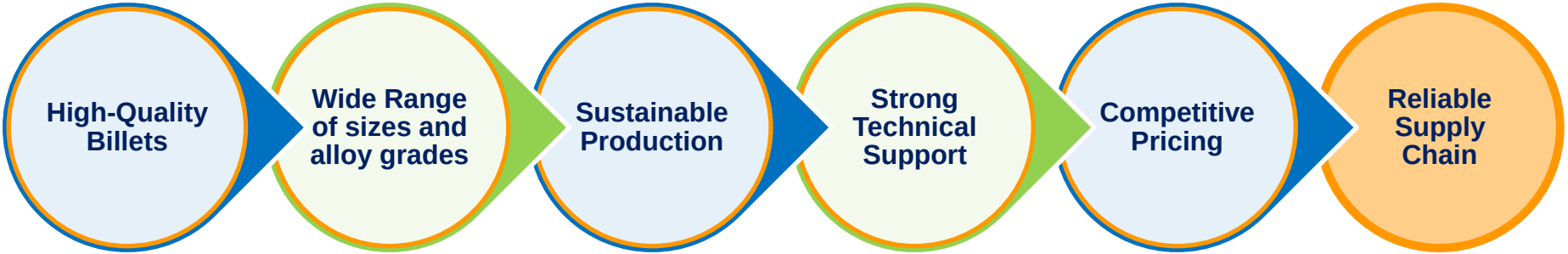
- Our Operations
- North & South America
- Asia Pacific, Middle East, Africa
- Europe

SUPPLYING TO 60+ COUNTRIES

Developed Markets | Discerning Customers | High-end applications

USP – What makes us unique ?

Holistic Billet Solutions, Extruded for You



- State-of-the-art facility
- Superior metal hygiene
- Consistent quality

- Available in 5", 6", 7", 8", 9", 10" & 12" diameters
- Alloy offering - 6XXX, 1XXX & 3XXX series
- Customizable

- Environmental Responsibility
- Ethical Sourcing
- Available in Green form (Restora / Restora Ultra)

- Expert Assistance
- New alloy / application development
- Problem-Solving

- Cost-Effective
- Value Proposition
- Channel financing

- Consistent Delivery
- Inventory Management

WE ARE THE LARGEST BILLET PRODUCER & EXPORTER IN INDIAN SUBCONTINENT & SOUTH-EAST ASIA

Vedanta Product Portfolio

Restora Low Carbon Aluminium

Any Application

Wire Rod

Electrical

P1O2O Ingot/Sows

Automotive, Electrical, Building & Construction, Re-melting

Alloy Ingot

Automotive (Alloy Wheels, Cylinder Heads)

Billets

Automotive, Building & Construction, Electrical

Billet Offered
6XXX
1XXX
3XXX

Slab

Automotive, Building & Construction, Cold & Hot Rolling

Rolled Product

Automotive, Insulations, Bus Bars, Power Projects, Electrical, Packaging

AlSi T-Ingots

Building & Construction, Automobile, Transportation, Electrical, Appliances, Re-melting

Flip Coils

Steel Manufacturing

Hot/Liquid Metal

Any Application

Billet Aluminium Application

THE METAL OF FUTURE

vedanta
transforming for good

Billet Production | Schematic process

Molten metal from Potline

Furnace - 1

Furnace - 2

Launder

TiBOR Unit

In-Line Degassing Unit

Filtration Unit

Casting station

Ultrasonic Testing

UT QC Billet sent to Homo Furnace

Temp ^{0}C

Time (hrs)

Homogenizing process

Heating

Soaking

Cooling

Packaging

Final Product

Crafted with Precision: Your Billets, Our Priority

Billet Production | Overview

Furnace
- High Capacity of **60 MT**
- Efficient **electrical heating** minimizes melt loss
- **Automated raking**
- **PLC controlled** metal supply

Inline Degassing
- **SNIF** for effective inline degassing
- Optional furnace degassing for **ultra-low hydrogen**
- Removes **inclusions, alkali metals**
- Proper **melt mixing**

Wagstaff Air Slip Casting
- Excellent surface finish and **minimal shell zone**
- Consistent product quality
- Higher production rate and **reduced rejections**
- **Improved recovery** i
  further processing

Grain Refining
- **TiBor** addition via rod feeder
- Precise **feed rate control**
- Enhanced grain refinement
- Improved grain structure

Metal Filtration
- **Ceramic foam filters** f
  filtration
- **40 PPI filters** for optimal filtration
- Regular filter set changes for each batch

Homogenization
- **Uniform** chemistry distribution
- **Stress relief**
- Beta-to-alpha **phase transformation**
- Fine **Mg_2Si** distribution

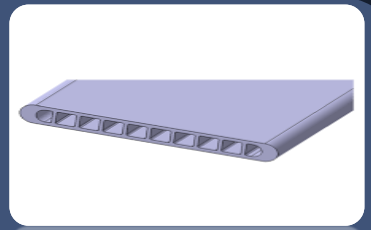
Crafted with Precision: Your Billets, Our Priority

Billet Aluminum Alloy: 1xxx, 3xxx & 6xxx Series Application

1XXX: >99% pure Aluminum (Al)
- High Corrosion resistance
- Excellent finish ability
- Low strength
- Poor machinability
- Easily joined by all methods.
- Low strength &Excellent workability.
- High electrical and thermal conductivity

3XXX: Manganese
- Low to medium strength
- Good corrosion resistance.
- Poor machinability.
- Good workability






6XXX: Magnesium & Silicon
- Most popular extrusion alloy class
- Good strength & Good extrudability
- Good corrosion resistance.
- Good machinability
- Good weldability
- Good formability



Billet Aluminum Alloy :2xxx, 5xxx & & 7xxx Series Application

2xxx Series: Copper
- ❑ High strength
- ❑ Relatively low corrosion resistance.
- ❑ Excellent machinability
- ❑ Heat treatable

5xxx Series:Magnesium
- ❑ Low to moderate strength
- ❑ Excellent marine corrosion resistance
- ❑ Very good weldability.

7xxx Series:Zinc
- ❑ Very high strength
- ❑ Poor corrosion resistance
- ❑ Good machinability
- ❑ Heat treatable






Our New Product Offering

High Speed Billet

- ❑ Delivers > 20% higher extrusion speed
- ❑ Exhibits better physical / mechanical properties
- ❑ Improves die life
- ❑ Enhances recovery

High Strength Billet 6063

- ❑ Designed to sustain high wind load, fatigue, for architectural
- ❑ Dent resistance and 5% higher corrosion resistance
- ❑ 7% increased strength over standard billets
- ❑ Sleek design and better profile aesthetics

High Machinable Alloy, Billet

- ❑ 8% higher strength
- ❑ Demonstrates better mechanical properties with excellent machinability without compromising on environmental aspects (lead-free product)

Ultra Strength Alloy 5xxx Sc, Billet

- ❑ AA5XXX series alloys exhibit good corrosion resistance and good weldability
- ❑ Application for Aerospace, Marine, Defence and Automotive

Basics of 6XXX Billet Metallurgy

Si ↑ + Mg ↓

Strength ↑
Finish ↓
Productivity ↑

Expectation from a good 6xxx series Billet
With reduction in Mg Content Tensile strength goes down, improves _extrudability. Strength can be compensated by increasing Si content, but beyond 0.50%, it affects the surface quality

Si ↑ + Mg ↓ + Fe ↓

Strength ↑
Finish –
Productivity ↑

Fe could increase the formation of beta Al-Fe-Si, adversely affecting the extrudability, hence Fe in the alloy was optimised without compromising on the response to anodizing treatment

Si ↑ + Mg ↓ + Fe ↓ + Mn ↑

Strength ↑
Finish ↑
Productivity ↑

Mn accelerates the transformation and break up of as cast beta Fe particles into finely broken up alpha

+ Cr

Corrosion Resistant ↑

Addition of Cr may positively impact the corrosion resistivity

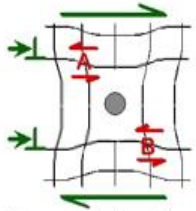
+ Cu

Bright Finish ↑
Strength ↑

Cu to improve response to bright anodised finish as well as extruded surface finish. Cu also is known to contribute strength.

Solid Solution strengthening

Smaller substitutional impurity



Impurity generates local shear at A and B that opposes dislocation motion to the right.

Precipitation Hardening

- Forms because of supersaturation
  - Solubility changes with temperature
- What does the processing do to the microstructure?
  1. Point of Solutionizing - create solution
  2. Point of Quenching – supersaturate the solution
  3. Point of P-H Heat Treatment – allow the elements to diffuse and form precipitates
- Too long heat treatment leads to overaging
  - Precipitates become too large/too far apart to block dislocation motion effectively causing lower strength

New Alloy offerings | High Speed Billet

Voice of Customer

A 6063 Billet that demonstrates the same (if not better) Physical properties but extrudes faster, with less surface pick up and improving overall productivity.

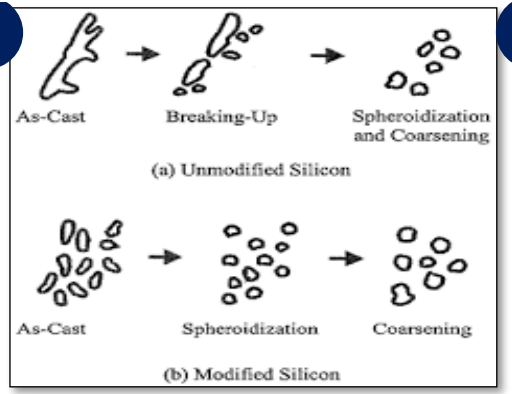
Product Design

Homogenising: Homogenization cycle will be modified aiming for higher alpha to beta transformation percentage.
Alpha Stabilizer: Addition of alpha stabilizers will be optimized to obtain spherical alpha precipitates.

- Eutectic Silicon in the as cast alloy gets modified by the added alpha Phase stabilizers.
- Precipitates have a **spherical morphology** compared to angular morphology
- Extrusion improves as a result of increased percentage of **uniformly dispersed desirable alpha phase with a spherical morphology**

Chemistry

1



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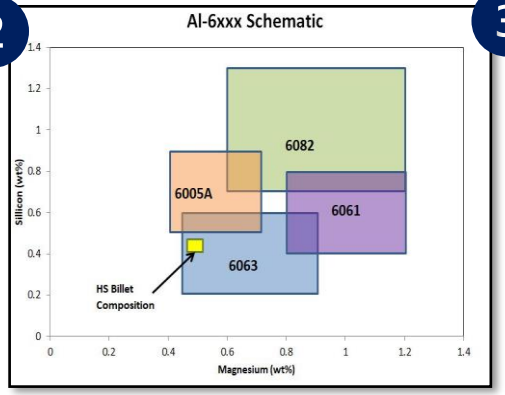
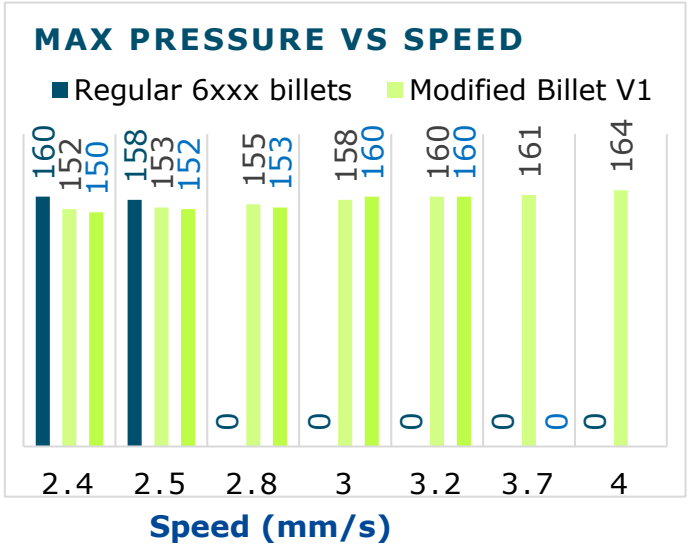


3

ALLOYING ELEMENTS	PERCENTAGE (%)
Iron	<0.20
Silicon	0.40-0.50
Magnesium	0.46-0.56
Manganese	< 0.04
Copper	< 0.02
Chromium	< 0.02
Titanium	< 0.05
Zinc	< 0.02

New Alloy offerings | High Speed Billet



- V1 and V2 billets shows significant lower extrusion breakout pressure in comparison to regular billets.
- Surface finish of the modified billets was similar to the regular billets.

Billet description	Speed (mm/sec)	Production rate (kg/hr)	% Improvement
Regular	2.2	755	NA
Regular	2.5	789	NA
V1 Billet	3.5	852	12
V1 Billet	3.8	956	26.6
V1 Billet	**4.1**	**980**	**29.8**
V2 Billet	3.2	875	15.9

Demonstrated performance at press

1. Delivers > 20% higher extrusion speed
2. Exhibit same if not better physical / Mechanical properties
3. Improves die life
4. Enhances recovery

New Alloys offerings | High Strength Billet

Voice of customer

Sufficient strength in billet to support extrusion for Building & Construction segment, Solar Frame

- to sustain **high wind load, fatigue, dent resistance and corrosion resistance**
- to demonstrate same strength with slick design and better **aesthetics** of the profile

Product Design

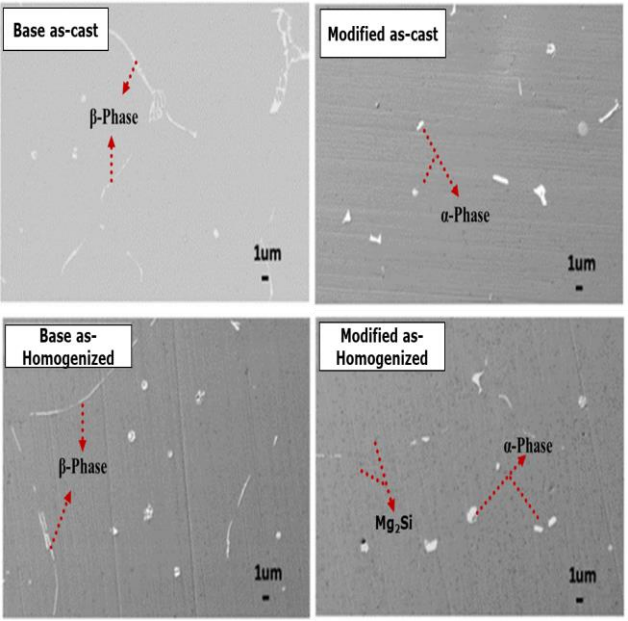
Sr, Na, and Sb are the most effective β-Al-Fe-Si intermetallic modifiers in trace levels of additions in Aluminium alloys.
Addition of Cr to improve on the corrosion resistant.

Chemistry

Alloy	Fe	Si	Mg	Mn	Cu	Cr	Zn	Ti	Sr	Al
Regular 6063	0.35 max	0.20-0.60	0.45-0.90	0.10max	0.10max	0.10 max	0.10max	0.10max	_	Remainder
Modified 6063	0.10-0.25	0.40-0.55	0.45-0.60	0.02-0.10	0.10max	0.10 max	0.02max	0.05max	0.10 max	Remainder

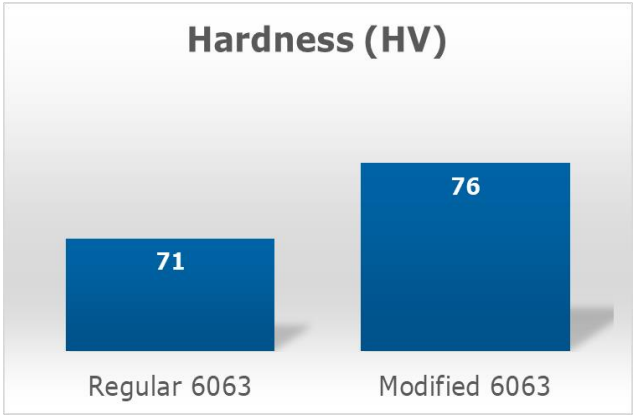
New Alloys Offerings | High Strength Billet

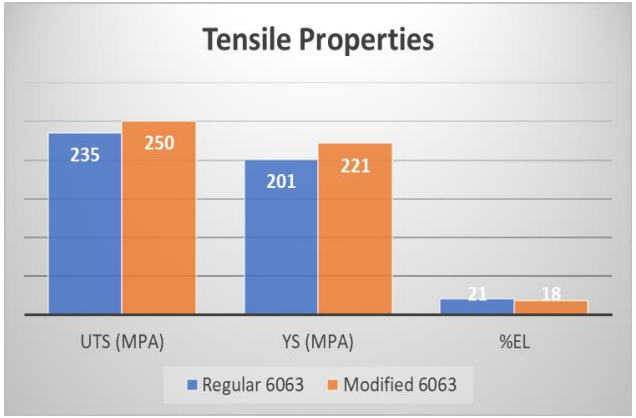
1 Microstructure analysis of as-cast and as-homogenized samples



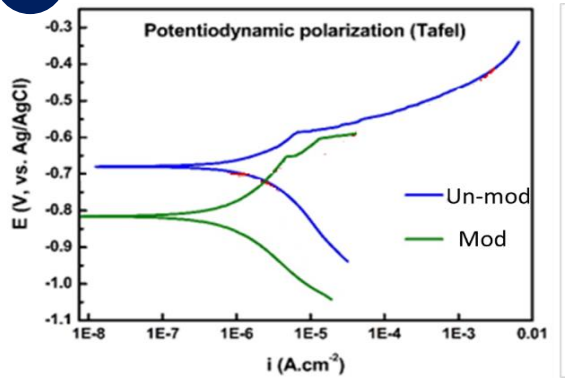
Higher β-phase (Al_5FeSi) to α-phase (Al_8Fe_2Si) transformations observed in modified alloy

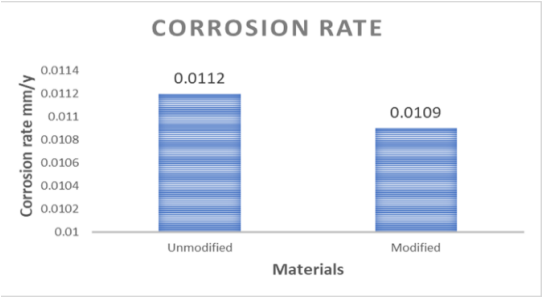
2 Mechanical property enhancement





3 Equivalent corrosion properties





Potentiodynamic corrosion study was carried out at laboratory under 3.5% concentrated NaCl solution

New Alloy Offering | High Strength Billet

Conclusion

	Regular 6063	Modified	Remarks
1. Intermetallic particle	Bigger	Smaller	
2. Aspect Ratio	>1	~1	Ease of plastic deformation
3. Hardness	71 Hv	76 Hv	7% higher
4. UTS	235 MPa	250 MPa	6% higher
5. Yield Strength (YS)	201 MPa	221 MPa	10% higher
6. Corrosion Resistance	0.0112 mm/y	0.0109 mm/y	~3% better

Under commercial trial

New Alloy Offerings | High Machinable Alloy

Voice of Customer

Available Machinable alloy 6262 and 6020 contains Pb and Sn. Pb and Sn being phased out due to non-environment friendly lead to an increasing demand for an improved substitute alloy that is more sustainable, while demonstrating better/equivalent machining performance.

Product design

Addition of Bi in 6XXX alloy leads to formation of low melting phases (Bi and Bi-Mg3-Bi2) which get melt during machining and forms short and discontinuous chips

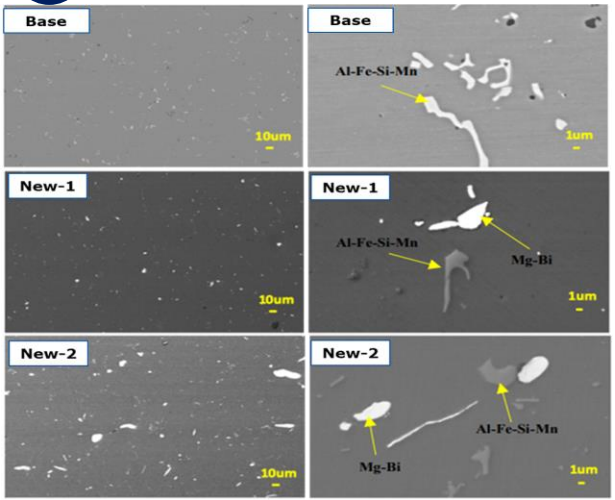
Applications

Chemistry

Alloy	Fe	Si	Mg	Mn	Cu	Cr	Zn	Ti	Bi	Al
Modified 6XXX	>0.2	0.70-1.0	0.55-0.70	0.6-0.90	0.05-0.10	<0.03	<0.03	<0.03	0.05-2.00	Bal.

New Alloys Offerings | High Machinable Alloy

1 Microstructure Analysis

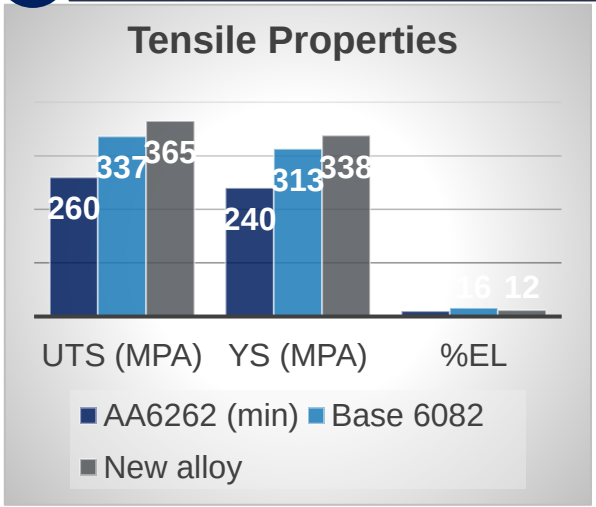


Microstructure shows presence of Bi

- Which forms low melting phases (Bi and Bi-Mg_3-Bi_2)

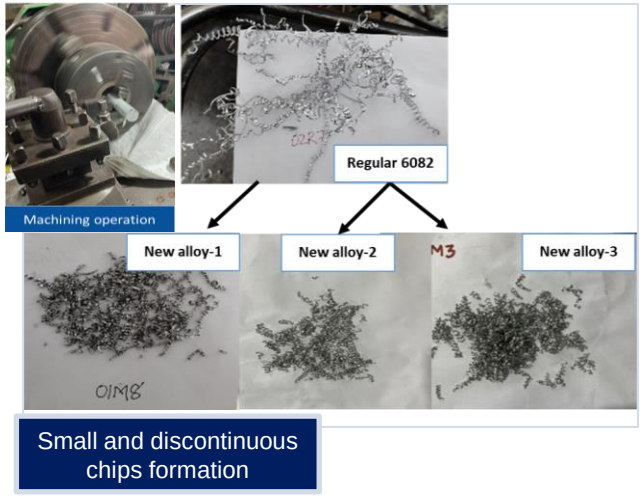
Phase	Melting point
Bi	271°C
Bi-Mg_3-Bi_2	260°C

2 Mechanical property achievement



- AA6262 is Lead + Bismuth based free-machining alloy
- AA6082 is currently available alloy grade for machining
- Newly developed lead free highly machinable alloy by Vedanta Ltd.

3 Machinability performance



Small and discontinuous chips formation

- Machining study done on base and modified alloys extrusions
- Newly developed alloys showing better machining performance in terms of smaller and discontinuous chip formation (due to presence of low-melting phases)

New Alloys Offerings | High Machinable Billet

Conclusion

	Regular 6082	Modified	Remarks
1. Metallography Properties		Bi-Mg_3-Bi_2 and Bi	Low melting phases enables short chip formation
2. UTS	337 MPa	365 MPa	8% higher
3. Yield Strength	313 MPa	338 MPa	8% Higher
4. Hardness	110 Hv	140 Hv	27% Higher
5. Chips Formation	Long and continuous	Short and discontinuous	Ensures good machining
6. Surface Roughness	>0.7 (Ra in μm)	<0.5 (Ra in μm)	~30% better

Under commercial trial

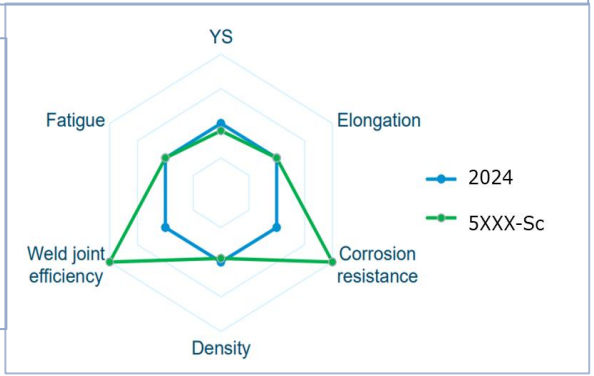
Ultra-High Strength 5XXX-Sc Alloy Billet

Voice of Customer

- Aluminum-based light alloys, for Aerospace, Marine, Defence and Automotive application must have high mechanical strength, corrosion resistance, weldability and fatigue strength. AA2XXX:~400 Mpa strength, good fatigue ,poor corrosion & weldability but these alloys suffer from poor corrosion resistance and very poor weldability.
- AA5XXX series alloys exhibit good corrosion resistance and good weldability but show slightly lower strength (~ 275-350 Mpa).

Product Design

Solution: The addition of rare earth alloying elements and optimized thermo-mechanical process can lead to ~90% higher Yield Strength in 5XXX-series alloy (similar to AA2XXX) along with superior corrosion resistance and weldability.



Applications: Aerospace, Marine, Defence, Railways and Automotive




Primary vs. Secondary Billets: An Extruder's Guide

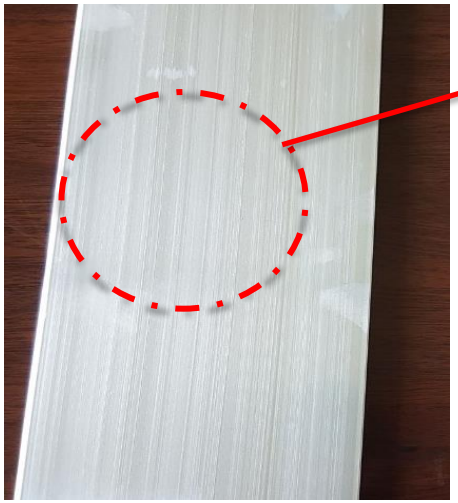
- **Enhanced Extrusion Efficiency:** Reduced extrusion pressure, increased productivity by **20%.**
- **Superior Product Quality:** Improved mechanical strength, better surface finish, and cleaner metal matrix.
- **Extended Equipment Lifespan: 50%** longer die life, increased extrusion longevity.
- **Higher Yield:** Increase in extrusion recovery by **10%**.
- **Eliminates Casting Stress:** Ensures uniform grain structure and provides consistent chemical composition
- **Reduces Iron Content:** Facilitates smoother extrusion and die durability.
- **Minimizes Solid Melting:** Prevents oxide formation, resulting in a cleaner metal matrix.

Primary vs. Secondary Billets: An Extruder's Guide

- **Faster Project Delivery:** Primary homogenized profiles offer significantly faster extrusion times and reduced maintenance, leading to accelerated project completion.
- **Superior Fe Control:** Primary billets provide better control over iron content, enabling precise management of anodizing characteristics and surface finish.
- **Enhanced Structural Integrity:** Primary billets offer higher structural strength and wind load resistance due to their lower gaseous and solid impurities
- **Cost Savings:** Primary billets allow for a 10% reduction in profile thickness for similar applications, resulting in significant cost savings while maintaining equivalent strength.
- **Longer Lifespan:** Products made from primary billets exhibit a longer lifespan, ensuring durability and longevity.

Primary Vs Secondary Billets

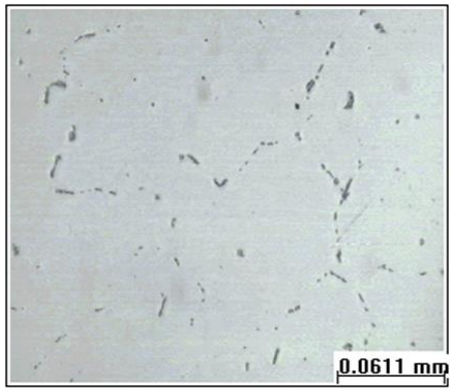
1. Profile from Primary Homogenized Billets

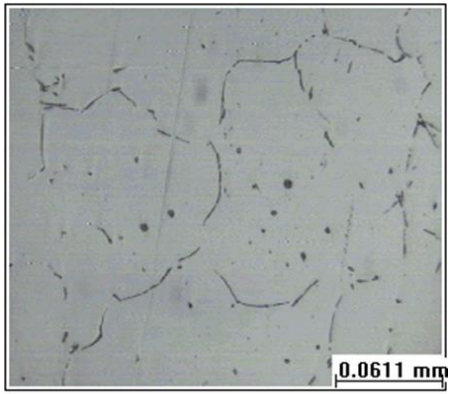


Poor Finish
Flow lines
Rough surface

Profile from Secondary Billet produced from scrap

2. With homogenization





Without homogenization

GREEN ALUMINIUM - JOURNEY TO NET ZERO CARBON BY 2050 OR SOONER

RESTORA, INDIA'S 1st GREEN ALUMINIUM

- India's first manufacturer to produce Low Carbon Aluminium
- Two product lines – Restora (low carbon aluminium) and Restora Ultra (ultra-low carbon aluminium)

Réstora

- Low carbon aluminium, made using renewable energy
- GHG emission intensity well below 4 tCO2e/tonne
- Reflects our commitment to achieve Net Zero Carbon by 2050

RéstoraULTRA

- Ultra-low carbon aluminium, in collaboration with Runaya Refining
- Near-zero carbon footprint - one of the lowest in the world!
- Ttestament to our focus on 'zero-waste' through operational efficiencies and recovery from dross

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