ArcelorMittal Powders

AdamIQ™ SAM 3

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ROBUST AND HOMOGENOUS VERSATILE STEEL FOR ADDITIVE MANUFACTURING

Made from 100% recycled steel and renewable energy. Spherical, with high flowability and low level of impurities.

At ArcelorMittal we believe that Steel Additive Manufacturing can create new opportunities for all manufacturing sectors, providing complex, customised parts with superior properties, performance, and longevity. Let us take you through our vision for the future of Additive Manufacturing, a uniquely Steel perspective with our SAM products.

Low alloy steels (LAS) have captured significant interest across various industries, particularly in the automotive and industrial sectors. However, the rapid solidification inherent in Additive Manufacturing (AM) processes often results in highly segregated microstructural profiles at the microscale. This can lead to a heterogeneous microstructure in LAS post-printing, causing localized variations in mechanical properties, which is undesirable for many engineering applications.

AdamIQ™ SAM 3 stands out as a robust feedstock for any laser powder bed fusion machine (L-PBF). Specifically designed for AM processes, it enhances microstructural homogeneity and robustness against varying printing conditions or sample geometries

Key features

• **Microstructural Homogeneity.** AdamIQ™ SAM 3 is designed for additive manufacturing processes, enhancing microstructural homogeneity and robustness against different printing conditions or sample geometries.

• **High Strength.** The product features a consistent and strong martensitic microstructure, making it suitable for various markets

• **Quenchability and Fine-Tuning.** The addition of specific alloying elements with Mn enhances its quenchability, reduces segregation during solidification, and allows fine-tuning of microstructure and properties through heat treatments

Main characteristics	Markets
Printable	Automotive
High strength	Nuclear
Toughness	Aerospace
Good weldability	Defence
Good ductility	Oil and gas

Powder properties

Chemical composition in weight (%) [1]

Iron	Balance
Manganese	3.50 - 5.00
Carbon	0.10 - 0.15
Aluminum[4]	< 1.00
Molybdenum[4]	< 0.65
Silicon[4]	< 0.50
Nickel[4]	< 0.50
Vanadium[4]	< 0.30
Titanium[4]	< 0.20
Nitrogen	< 0.20
Niobium[4]	< 0.20
Oxygen	< 0.10
Phosphorus	< 0.02
Sulphur	< 0.02
Boron[4]	< 0.01

Physical test data

Nominal particle range	20-53 µm
Apparent density[2]	4.0 g /cm³
Hall Flow[3]	<20 s / 50g
Skeletal Density[5]	7.8 g /cm³

Also available in particle sizes:
• Less than 20 microns for Binder Jetting (BJT), Metal Injection Molding (MIM) or specific processes targeting very thin walls.
• 53-105 microns typically for Electron Beam Melting (EBM, E-PBF) and Laser Metal Deposition (LMD).
• Specific sizing can be considered under conditions.

1. Patent Pending
2. Apparent density according to ASTM B212
3. Hall Flow according to ASTM B213
4. Comprising optionally one or more of these elements
5. Skeletal density according to ASTM B923

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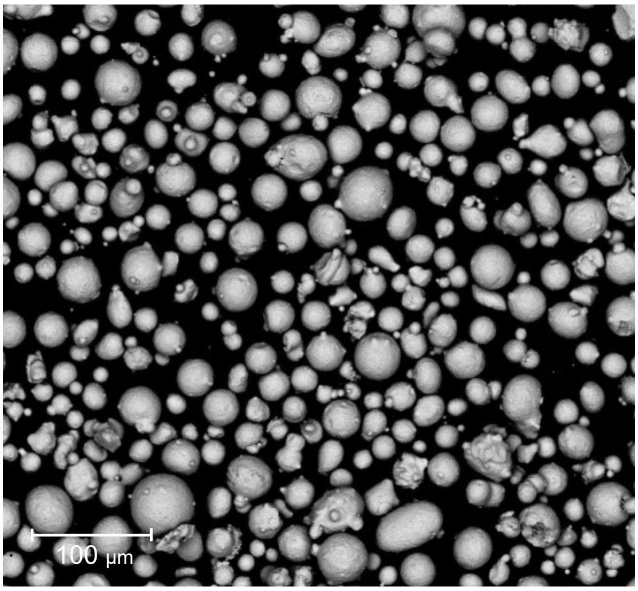
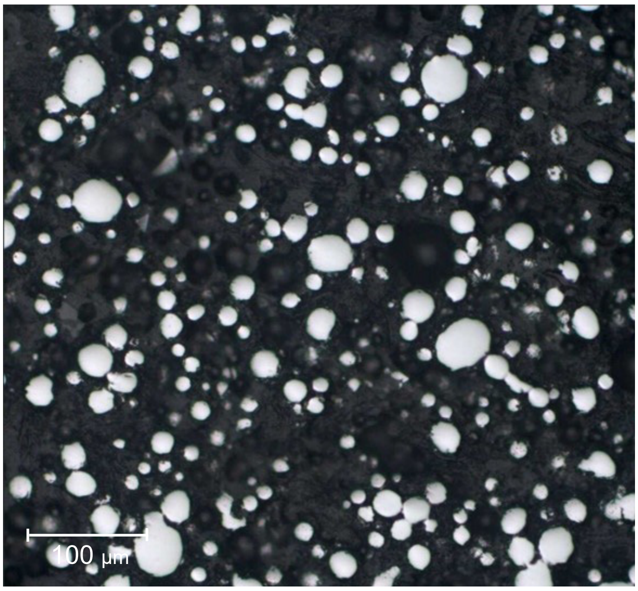
Powder morphology



SEM image AdamIQ™ SAM 3 20-53 µm



LOM image AdamIQ™ SAM 3 20-53 µm

Mechanical properties As-Built

	Yield Strength $R_{p0.2}$ [Mpa]	Tensile Strength R_m [Mpa]	Elongation A [%]	Impact Energy at 20 °C [J]	Impact Energy at -60 °C [J]	Impact Energy at -196 °C [J]	Vickers hardness HV10
Vertical	1,038	1209	9	33	24	5	344
Horizontal	1,030	1181	16	87	66	-	-

Microstructure

Fig. 1 Micrograph of polished and etched areas.

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Designing Steel Alloys for Additive Manufacturing

The degree of microstructural homogeneity was compared between two different LAS materials: AdamIQ™ SAM 3 and a composition comparable to Dual Phase (DP) like steel. The results showed that AdamIQ™ SAM 3 had greater hardenability, making its microstructure less susceptible to variations in cooling rate and more homogeneous.

To perform this comparison, a printed part from each material was analysed using SEM. Various types of microstructures were identified across the cross-section and marked with distinct colour labels.

The figure below compiles these identified microstructures, each displayed with its corresponding colour label. homogeneity and robustness against varying printing conditions or sample geometries.

Fresh or weakly self-tempered martensite
Coarse tempering area
Intercritic lamellar
Lamellar with 2nd phase like MA or carbides
Fine equiaxed microstructure tempering
Very fine equiaxed tempered microstructure with MA
Intercritical equiaxed tempered
Not identified

Fig. 2 Colour code of the different microstructures observed by SEM in Low Alloys Steels.

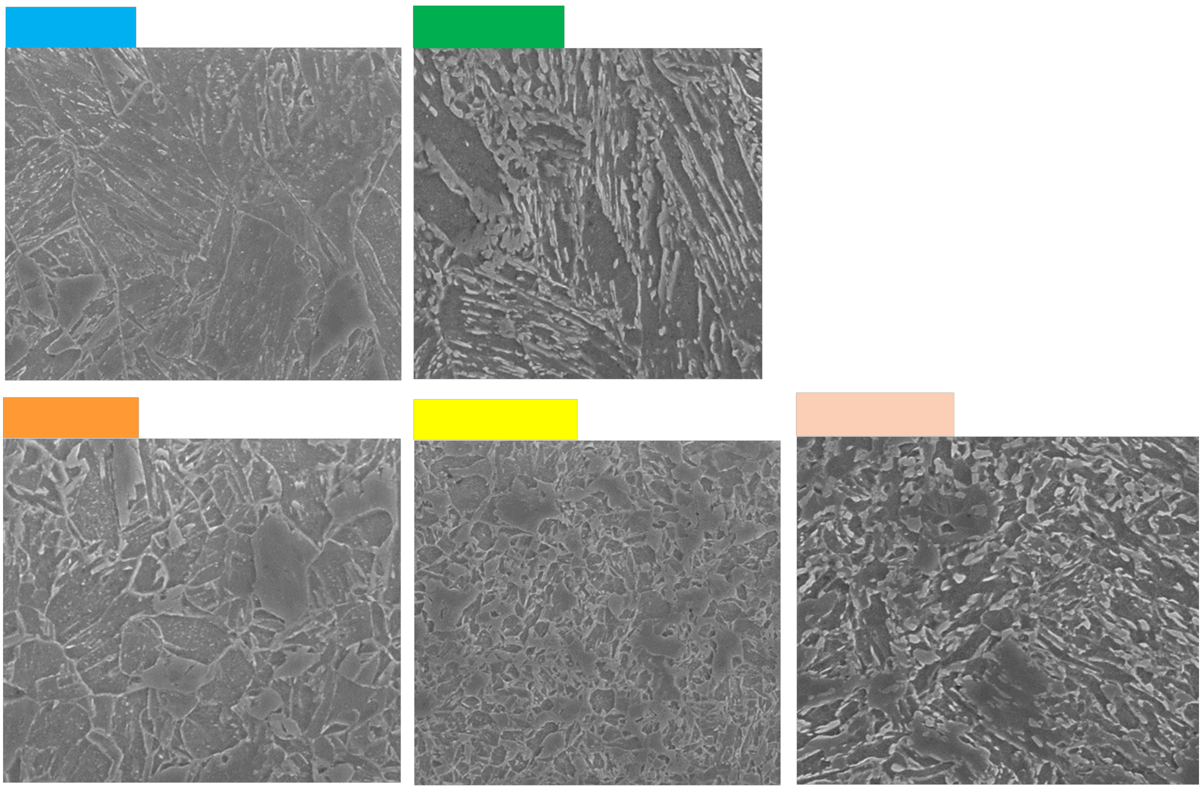

Fig. 3 Representative SEM micrographs of different microstructures observed in Low Alloy Steels and the given colour label.

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Microstructure reconstructions were done on the top section and middle cross-section of the specimens. SEM images from various angles were overlaid to create a composite map, with each micrograph labelled by colour. Fig. 4 and Fig. 5 show the microstructure of DP-Like steel and AdamIQ™ SAM 3 using this colour system.

DP-like steel-upper part

DP-like steel-central part

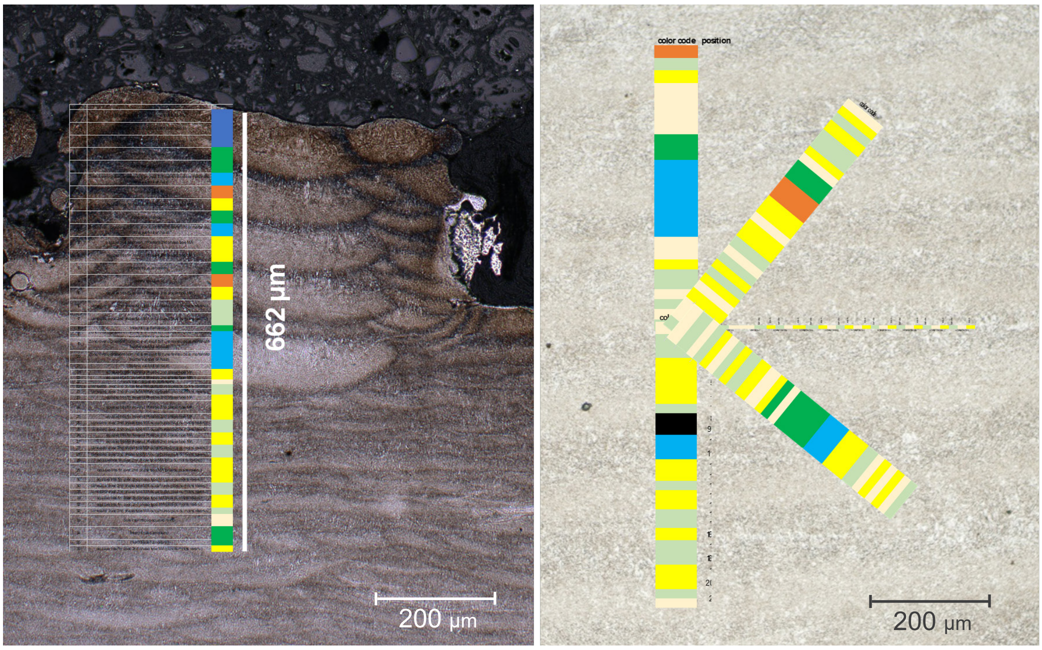

Fig. 4 Microstructural reconstruction of conventional DP like steels in the upper layers and in the cross-section of the material using the internal colour code.

AdamIQ™ SAM 3 - upper part

AdamIQ™ SAM 3 - central part

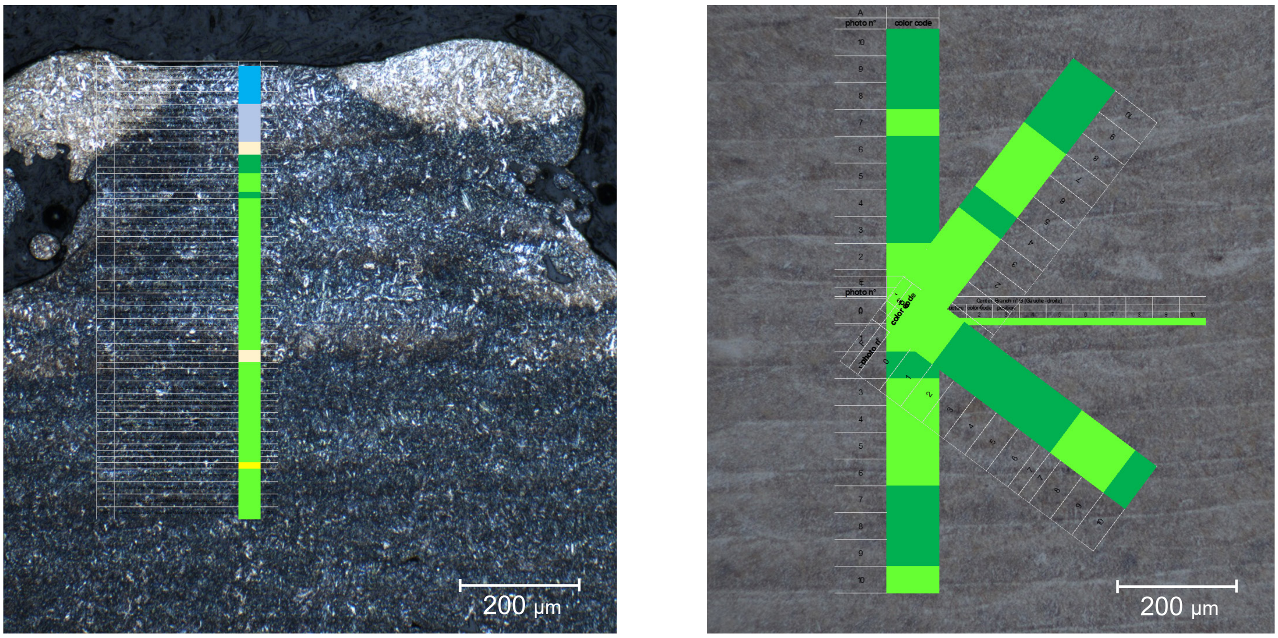

Fig. 5: Microstructural reconstruction of AdamIQ™ SAM 3 steel in the upper layers and in the cross-section of the material using the internal colour code.

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Microhardness measurements were conducted over a 1.5 x 1.5 mm^2 area of the cross-section with over 600 indentations at a 100 g load, enabling the study of local hardness variations and their correlation with microstructural differences.

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DP like steel

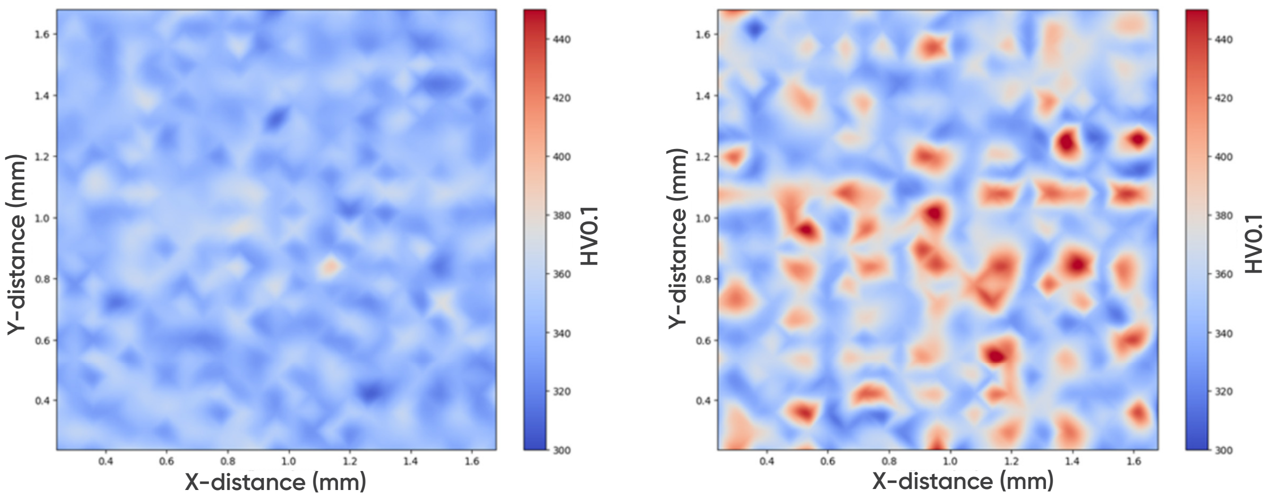

Fig. 6 Hardness mapping of an area of 1.5 x 1.5 mm2 for AdamIQ™ SAM 3 (344 ±10) Hv0.1 and Kaplan-LAS (363 ± 26) HV0.1.

The standard deviation decreases in AdamIQ™ SAM 3, with no prominent red or blue regions, unlike conventional DP-Like steels. Nanoindentations were performed over a 100 x 100 µm^2 area with a 3.5 mN load, loading at 0.2 mN/s, unloading at 0.5 mN/s, and a 10-second dwell period. Indentations were spaced 4 µm apart. In Figure 11, DP-Like (blue) shows an average nanohardness of 3.91 GPa (SD 0.37 GPa), while AdamIQ™ SAM 3 (red) has an average of 4.25 GPa (SD 0.28 GPa).

When approximating the experimental measurements to a normal distribution for qualitative comparison, it becomes clear that the standard deviation in DP-Like is higher (blue), indicating a broader distribution compared to AdamIQ™ SAM 3 (red). This observation suggests greater local variations across the sample section in DP-Like-type steel.

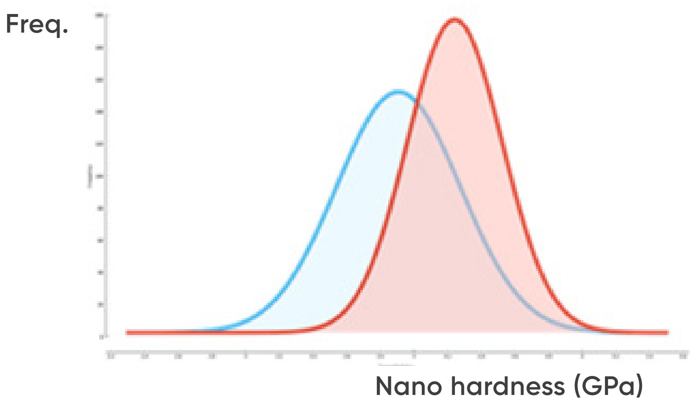

Fig. 7 Nanoindentations normal distribution comparison between DP-Like in blue and AdamIQ™ SAM 3 in red.

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Microstructural and mechanical robustness refers to a material's capacity to maintain consistent microstructure and tensile properties across various printing conditions, thermal inputs, and solidification rates. While uniform thermal input is easy to achieve in small samples, large or complex parts might experience significant variations.

To evaluate these potential variations, researchers established six different printing parameters, each with unique energy inputs relevant to steel processing. They used 18 ASTM E8/E8M rectangular subsize tensile samples (three per condition) to examine tensile behaviour under different printing conditions. This method allows for a comprehensive study of local variations in industrial-scale parts.

A 1 cm^3 cube was printed for each condition to confirm density. One condition was excluded due to high porosity.

Fig. 8 presents cross sections of samples printed with Volumetric Energy Density (VED) conditions achieving good and fair density levels for comparison.

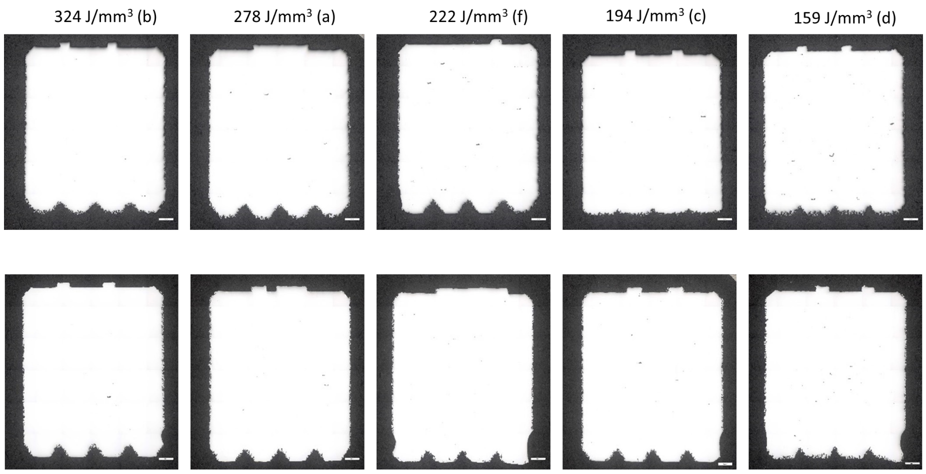

Fig. 8 Representative cross sections of the cubes printed with the different printing parameters that assures a good density level.

Fig. 9 shows representative tensile curves for each printing condition for both steels, indicating different tensile behaviours. The VED values are listed in the legends. DP-like-type steel's yield strength (YS) strongly depends on VED, increasing as VED decreases. This variation is less pronounced in AdamIQ™ SAM 3 steel.

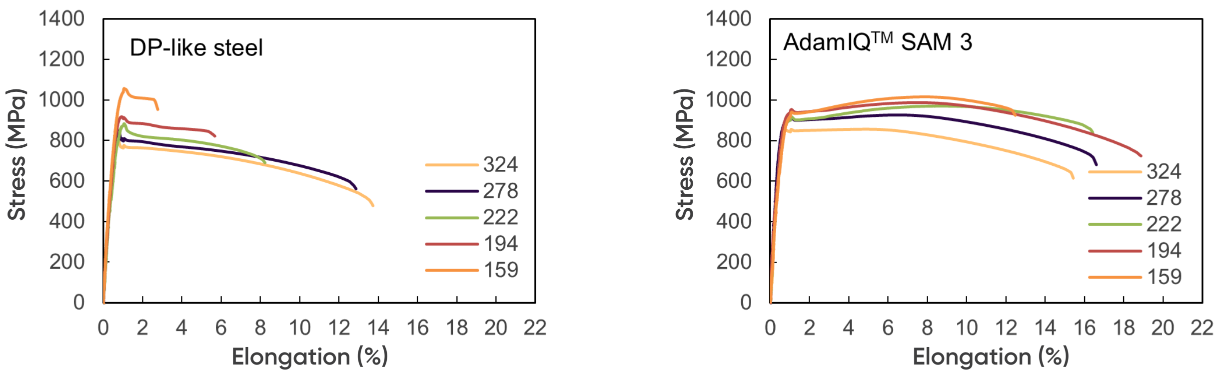

Fig. 9 Tensile curves of DP-Like (conventional DP like steels) and AdamIQ™ SAM 3 steel with different printing parameters and VED values

The average YS in both steels is similar, but DP-like steels have a higher standard deviation than AdamIQ™ SAM 3 (78 vs. 31) and a wider range between maximum and minimum values (202±27 vs. 67±32). These results highlight the superior performance of AdamIQ™ SAM 3 steels over regular LAS in Additive Manufacturing, thanks to improved microstructural homogeneity and robustness.

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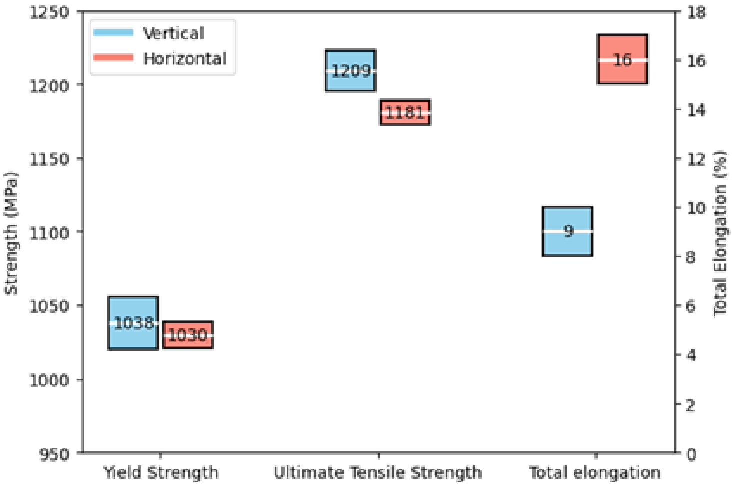
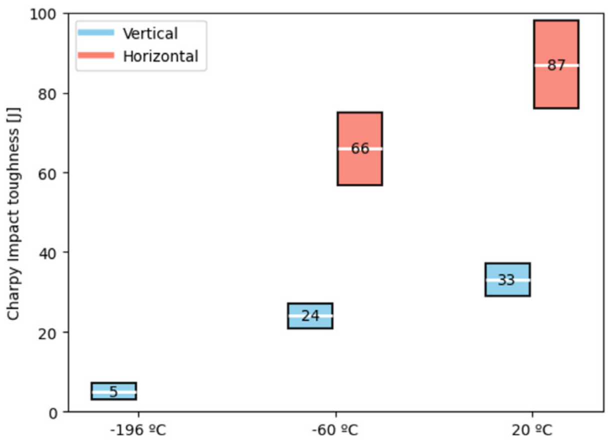
Mechanical properties As-Built

	Yield Strength Rp0.2 [Mpa]	Tensile Strength Rm [Mpa]	Elongation A [%]	Vickers hardness HV10
Vertical	1,038	1,209	9	344
Horizontal	1030	1,181	16	-



	Impact Energy at 20 °C [J]	Impact Energy at -60 °C [J]	Impact Energy at -196 °C [J]
Vertical	33	24	5
Horizontal	87	66	



Impact toughness can exceed 200 J, varying with parameters. Select parameters carefully to match the final application, as optimizing for impact toughness may affect tensile properties, as noted in the microstructure section.

Heat treatments

Heat treatments have not yet been studied in AdamIQ™ SAM 3 steel, although this is an area of interest for these steels due to their potential for tuneable mechanical properties through heat treatments and move along the steel banana-plot.

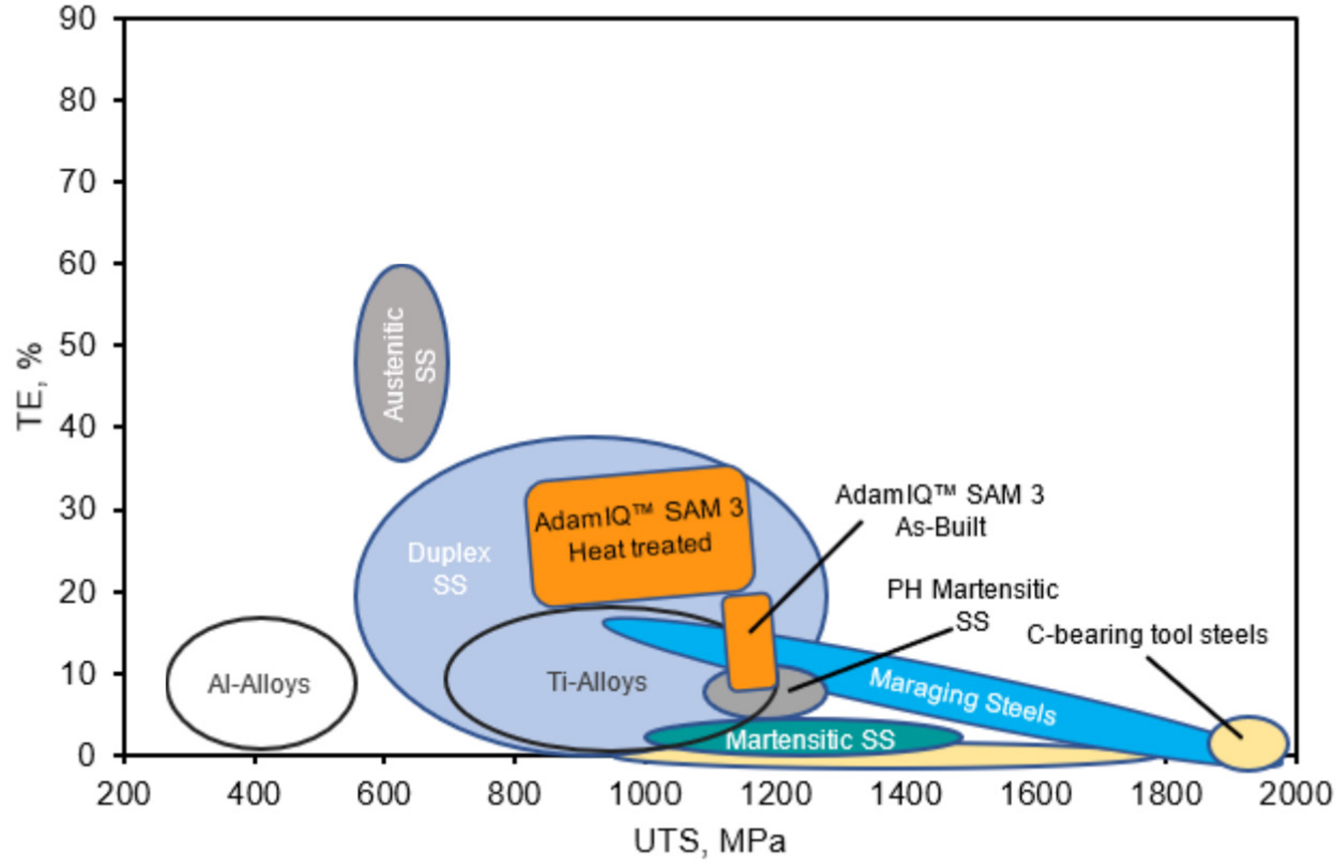


Fig. 10. Graph comparing ultimate tensile strength (UTS) and total elongation (TE) of AdamIQ™ SAM 3 in as-built and heat-treated conditions alongside various steels and alloys

However, research has begun with conventional DP like steels as it is expected to behave similarly. This study examined both single-step and multi-step heat treatment approaches for this steel. Initially, Cycle A was applied to fully austenitize the material by holding it for 180 seconds, followed by water quenching to form the base microstructure. Subsequently, a second heat treatment was carried out at various intercritical temperatures, also for 180 seconds, to adjust the martensite fraction and create a customized dual-phase microstructure. A schematic of the heat treatment process is provided.

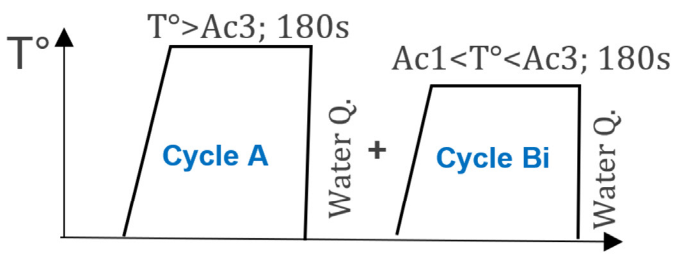


Fig. 11 Sketch of the heat treatments studied.

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Fig. 12 shows representative tensile curves for different heat treatments. The as-built material is in blue, the austenitized material is in black, and the materials with additional intercritical annealing at two temperatures are in green and red. This study demonstrates that LAS's mechanical properties can be adjusted through heat treatments, affecting tensile strength and elongation.

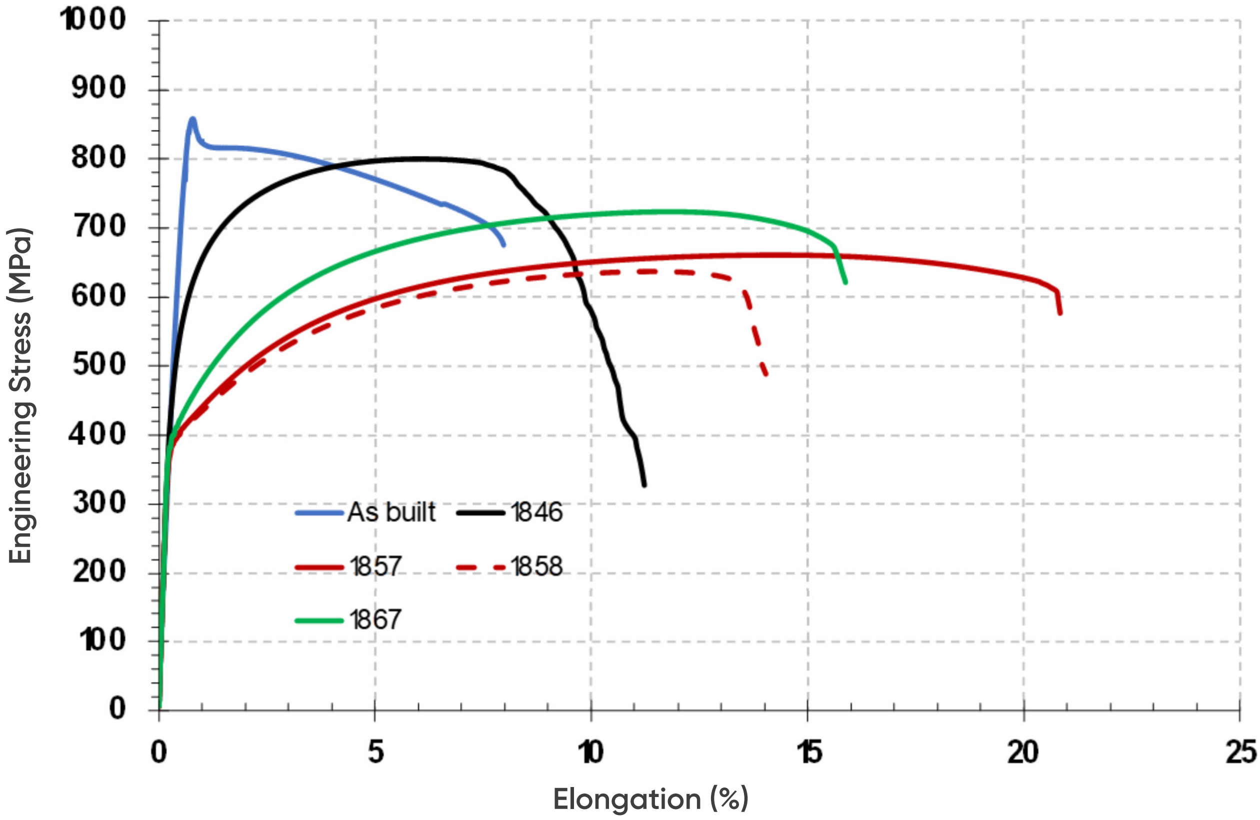

Fig. 12. Tensile properties of DP-Like measured As-Built and after different heat treatments.

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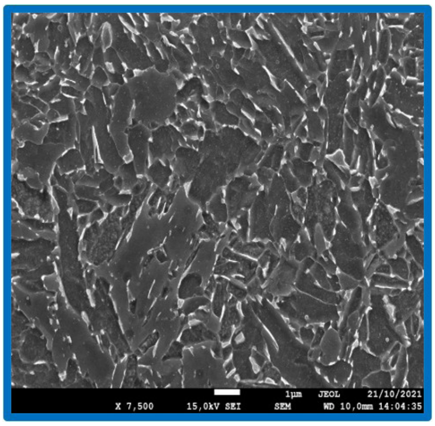
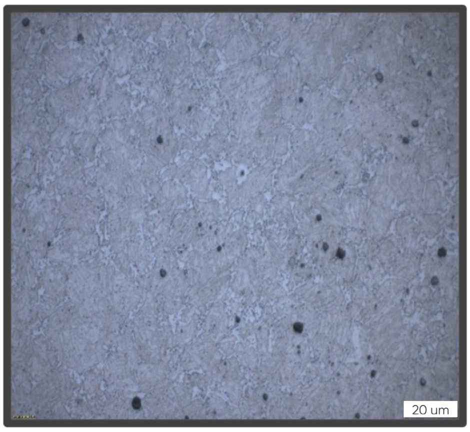
The tensile properties observed in the DP-Like after various heat treatments are related to changes in the original printed microstructure, illustrated in blue in Fig. 12. The initial microstructure consists of fine ferrite with carbides and martensite-austenite (MA) islands. Following the first austenitization treatment, the microstructure primarily becomes martensitic with some ferrite present. After a second thermal treatment, the ferrite fraction further increases.

Very fine ferrite (gray)+mainly carbides+ some MA islands (white)



As-Built

Mainly Martensite (brown) + ferrite (white)



Ref1846: after cycle A (890°C/180s +WQ)

Ferrite (white)+Martensite (dark)

Ref1857 and 1858 (µ): after cycle A +cycle B1 (720°C/180s +WQ)

Ferrite (white)+Martensite (dark)

Ref1867: after cycle A +cycle B4 (780°C/180s +WQ)

Fig. 13 Microstructures of DP-Like as built in blue and after different heat treatments in black (1 cycle), red and green (two cycles).

A similar study would be done for the AdamIQ™ SAM 3 steel, and we would expect to get similar tendencies.

Contact us to know how we can assist your production.

Visit **powders.arcelormittal.com** or
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to talk to our experts.

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