



# ArcelorMittal

## Steels for Porcelain Enameling

Porcelain enameled sheet steels are used extensively in appliances, plumbing fixtures, architecture and agriculture. Some of the more common applications include oven interiors and cook tops, washing machine baskets and tops, water heater tanks, bathtubs and barbecue grills. The porcelain enameled surface offers excellent resistance to heat, corrosion, abrasion and chemical attack while providing an appealing aesthetic.

The process of enameling starts after steel is formed into the final geometry of the part. Once the steel is cleaned, either a wet slurry or dry powder enamel frit is applied to the steel by dipping, spraying or flow coating. The part is then fired in a furnace at high temperature to melt the enamel and fuse it to the steel. Once the part has cooled, the resulting bond is permanent. Multiple coats and fires may be required to obtain enamel performance characteristics and color.



*Enameled bathtub.*



*Enameled cook top.*

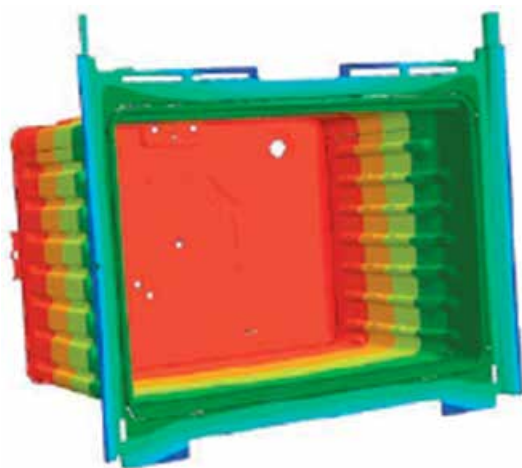
Steel selection is specific to the end use and enameling process. These are some important characteristics to consider when specifying the steel:

- **Formability** – the steel must have enough ductility to form the part geometry during stamping. Some applications may require extra drawability or very high elongation. A special grade has been developed to address these concerns. ArcelorMittal has expertise in FEA formability analysis to help ensure the right steel is specified and co-engineering support to help optimize designs.
- **Enamelability** – the steel must be able to endure the high temperature firing without affecting enamel quality and adhesion. The main concerns are black specking and blisters resulting from oxidation of carbon at the surface during firing and fish scaling resulting from evolution of trapped hydrogen. Steel chemistry can play a role in eliminating these defects by tying up carbon atoms with other alloying elements and providing trapping sites for hydrogen.
- **Sag Resistance** – steel for enameling must withstand the stress generated during firing and the subsequent cooling process without deformation. Sag resistance is a measure of the strength of the steel at high temperature.
- **After fire strength** – during the high temperature soak required for the enameling process, the grain structure of the steel can be altered, resulting in softer steel after slow cooling. The chemical composition of the steel and the amount of localized strain in the part produced during stamping, can influence the temperature at which grain growth happens. Inadequate after-fire strength can be bolstered by increasing the thickness of the material or by adding stiffening geometries or braces to the part design.

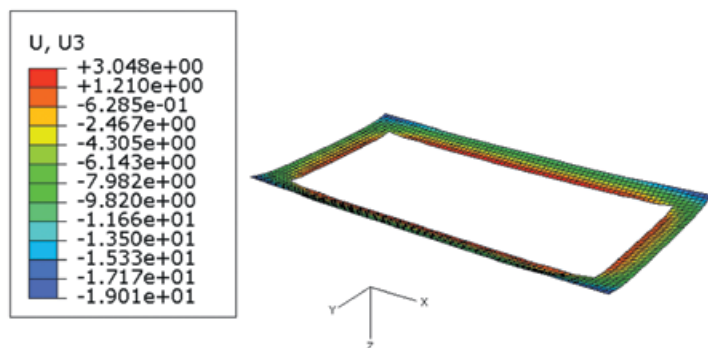
ArcelorMittal has technical expertise to assist in selecting the best steel for an enameling end use. In addition, our R&D department offers co-engineering support and is equipped with the capability to perform structural, formability and firing simulations.



*Porcelain enameled architectural panels.*



Numerical simulation of the thermal expansion of an oven cavity.



Numerical simulation of flat frame distortion after enameling.



Numerical simulation of formed frame distortion after enameling.

ArcelorMittal USA offers three grades conforming to ASTM A424

ASTM A424	Type II	Type III	Type III Extra Formability
Formability grade	CS and DS	EDDS	EDDS+
Enameling system compatibility	Ground coat 2 coat - 2 fire	2 coat - 2 fire 2 coat - 1 fire	2 coat - 2 fire 2 coat - 1 fire
Sag Resistance	OK	Better	Better
After fire strength	Better	Good	Good
Typical Application	Oven cavity	Cook top	Bathtub

In addition to these ASTM grades, ArcelorMittal USA supplies both cold rolled and hot rolled steels for specific enameling applications.

Application	Format	Requirement	Enamel
Hot water tank end	Hot rolled	Ductility, weldability	Ground coat one side enameled, non-exposed
Hot water tank body	Cold rolled	High AFS, weldability	One side enameled, non-exposed
Silo	Hot rolled	High AFS, structural component	2 side enameled, 2 or more fire
Architectural panel, White Board	Cold rolled	Superior flatness, surface critical	Ground coat 2-side, 1 side cover coat, multiple fire

ArcelorMittal offers world class enameling steel and knowledgeable support to enable an optimized design to control cost and result in a high-quality final product. Contact us to learn more.



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June 2019