Keeping up appearances: why surface treatment of stainless steel is important

Anish Kapoor's "Cloud Gate" sculpture in Chicago was made of type 316L stainless steel plate supplied by Outokumpu. Inspired by the shape of mercury, it has been polished to a highly reflective finish.

It goes without saying that correct grade selection is indispensible in preventing material degradation. No stainless steel is completely corrosion-free, and choosing the wrong grade will have serious consequences. But correct specification is inadequate unless an appropriate surface treatment is applied, which can have a critical effect on the material's properties. These treatments range from "ex-mill" hot- and cold-rolled finishes to special ones added to create an aesthetic effect. They also comprise various types of polishing, including manual and mechanical and, for more critical applications, electropolishing.

By James Chater

Introduction

Surface finishing can have several objectives and take several forms. Among the objectives are cleaning the surface to improve corrosion resistance or hygiene, to reduce adhesion or to enhance brightness and achieve a certain aesthetic effect. Surface treatments include pickling, passivation (including electropolishing) and special surface finishes… .

Pickling and passivation

Pickling and passivation can occur in one or two steps. The need for pickling (descaling) arises from certain manufacturing operations, including hot-forming, annealing, hardening or welding, where the metal is exposed to hot gas, which causes scale to form on the surface. This scale consists of oxides of chromium, nickel and/or other alloying elements with iron. To restore corrosion resistance it needs to be removed. Various methods are used, usually involving cleaning in an alkaline substance, then immersion (pickling) in nitric and hydrofluoric acids. The result is a dull uniform finish with restored corrosion resistance. Pickling can be done by immersing the workpiece in a tank or with a spray, depending on the shape of the part.

Monument of Freedom, Narvik, Norway. Outokumpu 4404 with 2B surface, polished to mirror-like finish. Photo: Espen Gangvik.

To obtain even higher corrosion resistance (such as required in chemical process plants), chemical passivation can be carried out after pickling. Passivation restores a stainless steel's passive layer (i.e. its oxide film) by accelerating the interaction of chromium with oxygen. Corrosion resistance is enhanced by removal of exogenous iron or iron compounds by applying a mild oxidant such as citric acid. Passivation can be applied to vessels, pipes, tubing, manifolds, frames and architectural components. It causes no changes in surface roughness.

Electropolishing

Electropolishing is the most thorough means to achieve passivation and is often an essential step in severe applications in the energy and process industries. Although mechanical polishing and electropolishing can achieve the same appearance, electropolishing does a more thorough job in removing contaminants and is thus required in high-purity applications such as semiconductor or pharmaceutical. Apart from corrosion resistance, benefits include greater hygiene and a non-adhesive surface.

Outokumpu 2B surface finish. Courtesy of Outokumpu.

The electropolishing process removes from the surface any metal that impedes corrosion resistance, so that only chromium and nickel remain. The resulting surface is clean and smooth, an important requirement in sterile environments. In food and drink applications, growth of bacteria is inhibited; in pulp and paper, fibres are less likely to snag in stainless steel components.

The workpiece is immersed in a bath of electrolyte, consisting usually of phosphoric and sulphuric acids. It is then charged with a positive voltage (anode), while cathode (negatively charged) bars suspended in the tank draw current from the workpiece through the electrolyte. The unwanted metal is thus drawn out of the workpiece.

Electropolishing is used in several products, and the list is continually growing. Here are just some of them:

- Washing machine drums.
- Auto: radiator grills.
- Chemical: polymeriser vessels.
- Food and drink: hot water tanks, mixing blades.
- Surgical: instruments, stents, implants.
- Marine: boat handrails and fittings.
- Paper and pulp: screen cylinders, headboxes, slices and stock feed tubes.
- Pharmaceutical: process tanks, pipes and valves.
- Architecture: lamp posts, sculptures etc.
- Semiconductor; pipework, valves.

Ex-mill finishes

Ex-mill finishes are those normally applied as part of the normal manufacturing process of semi-finished stainless steel products. They vary according to the application and each has a different appearance. Various classification systems exist. In the BS EN 10088-2 system, codes beginning in "1" denote finishes based on hot-rolling, those beginning in "2" finishes based on cold-rolling. Here is a selection:

- 1C. Hot-rolled, heat-treated, not pickled. Suitable for heat (oxidation) resisting applications.
- 1D. Hot-rolled, heat-treated, pickled. This is the most common hot-rolled finish.
- 2B. Cold rolled, heat-treated, pickled, pinch-passed. The most common cold-rolled mill finish. Dull grey, slightly reflective finish. Often serves as a starting point for further finishing.
- 2D. Cold-rolled, heat-treated, pickled. Dull silver-grey finish applied to thin coils. Applied in auto exhaust systems, chemical and petrochemical equipment, roofing and roof drainage.
- 2Q. Cold-hardened and tempered; applied only to martensitics.
- 2R (or BA). Cold-rolled and bright-annealed. Can be used in this