euro inox
The European
Stainless Steel
Development Association

The Mechanical Finishing of Decorative Stainless Steel Surfaces

Materials and Applications Series, Volume 6

Euro Inox

Euro Inox is the European market development association for stainless steel.
The members of Euro Inox include:

- European stainless steel producers
- National stainless steel development associations
- Development associations of the alloying element industries.

The prime objectives of Euro Inox are to create awareness of the unique properties of stainless steels and to further their use in existing applications and in new markets. To achieve these objectives, Euro Inox organises conferences and seminars, and issues guidance in printed and electronic form, to enable designers, specifiers, fabricators and end-users to become more familiar with the material. Euro Inox also supports technical and market research.

Disclaimer

Euro Inox has made every effort to ensure that the information presented in this publication is technically correct. However, the reader is advised that the material contained herein is for general information purposes only. Euro Inox, its members, staff and consultants, specifically disclaim any liability or responsibility for loss, damage or injury, resulting from the use of the information contained in this document.

The Mechanical Finishing of Decorative
Stainless Steel Surfaces
First Edition 2005
(Materials and Application Series, Volume 6)

Publisher
Euro Inox
Registered office: 241 route d'Arlon
1150 Luxemburg, Grand Duchy of Luxemburg
Tel.: +352 261 03 050 / Fax: +352 261 03 051
Executive office: Diamant Building, Bd. A. Reyers 80
1030 Brussels, Belgium
Tel.: +32 2 706 82 67 / Fax: +32 2 706 82 69
E-mail: info@euro-inox.org
Internet: www.euro-inox.org

Author
Benoît Van Hecke, Brussels (B), with kind support by
Marc Thijs, Tildonk (B)

Acknowledgements
Translation: Roger Crookes, Sheffield (UK)
Photographs:
- AID (1, 5.2, 6.1) / Genk (B)
- CIBO (cover, 3, 4, 5.1) / Tildonk (B)
- Suhner (4, 6.1) / Brugg (CH)
- Cavale (5.4) / Diepenbeek (B)
- Wolters (6.2) / Diest (B)
- Engineering (6.3) / Drogenbos (B)

ISBN 2-87997-162-4

2-87997-163-2	Dutch version
2-87997-164-0	Finnish version
2-87997-165-9	French version
2-87997-166-7	German version
2-87997-167-5	Polish version
2-87997-168-3	Spanish version
2-87997-169-1	Swedish version
2-87997-170-5	Italian version
2-87997-171-3	Czech version
2-87997-172-1	Turkish version

Contents

1 Introduction

Stainless steels offer a number of properties that make them highly suitable for decorative and structural applications in the building and related sectors. They are:

- modern and attractive
- hygienic and easy to clean
- resistant to corrosion
- sustainable
- maintenance friendly
- easy to fabricate
- fully recyclable.

For these reasons, architects, designers and contractors enjoy specifying and using stainless steels in a wide range of industries that include building and construction, architectural metalwork (handrails and balustrades), street furniture, food production, catering and kitchen equipment, domestic appliances etc.

The plans for these projects often reach small and medium sized companies, who are increasingly faced with developments in materials, finishes and technologies like sheet metal working, laser welding that they may not understand or be fully up to date with. Finishing operations like grinding, polishing and brushing require special attention to get the optimum service performance and life from stainless steel fabrications. This part of the fabrication process could indeed be seen as the manufacturer's "quality label" and provides an excellent opportunity, if carried out properly, to demonstrate the benefits of the stainless steel.

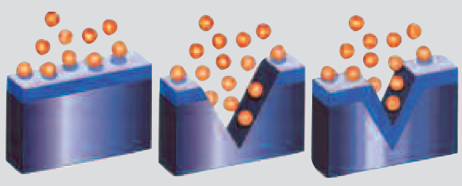
This publication outlines mechanical finishing methods that are appropriate for stainless steel fabrications, describing and illustrating current "best-practice" and emphasizing some of the differences between carbon steel and stainless steel practice.

Stainless steel designs for stylish, decorative applications are often carried out by small and medium sized construction companies. They may be faced with developments in materials, finishes and technologies like sheet metal working, laser welding etc. that are new to them. Finishing operations like grinding, polishing and brushing are examples of these technologies.

2 Specifying mechanically finished surfaces for stainless steel fabrications

Clear, precise specification of the mechanical finishing of stainless steel fabrication work is an essential step to optimize the benefits of using the material. Identifying the grit ("grain" can be used, but "grit" is more common) size of the abrasive for mechanical finishing operations is only a part of the specification process. When the aim is to precisely match an existing or intended finish, the best approach is to use comparative surface finish "swatch" samples. The fabricator or finishing contractor can only ensure that the required finish is produced if agreed samples are used as part of the specification process. Written descriptions (qualitative) or numeric (quantitative), e.g. R_a surface roughness figures, alone, are not sufficient to fully specify a mechanical finish on a stainless steel surface.

The correct choice of steel grade is also important from a surface finish point of view, especially when very smooth, highly reflective polished finishes are required. The most commonly used stainless grades for external applications are EN 1.4301/1.4307 and, in more corrosive environments, EN 1.4401/1.4404. In some countries and end-user segments, EN 1.4541 and 1.4571 are used as alternative grades for resistance against intercristalline corrosion (instead of the low carbon grades 1.4307 and 1.4404 respectively). These two grades are alloyed with titanium and are less suitable for decorative polishing purposes, because they may result in an uneven look. When carrying out repair work on existing fabrications, these alternative grades, if offered by suppliers, should not be used as it may be difficult to match the existing finish.



Stainless steel has a unique feature: It is self healing. Due to the alloying elements in the stainless steel, a thin, transparent "passive layer" is formed on the surface. Even if the stainless steel surface is scratched or otherwise damaged, this passive layer, which is only a few atoms thick, instantaneously reforms under the influence of oxygen from air or water. This explains why stainless steel does not require any coating or other corrosion protection in service.

3 Frequently used finishing methods

The terms grinding, polishing, buffing and brushing are frequently used in the specification of surface finishes for stainless steel fabrications. To ensure that the designer's intended finish is achieved, contractors, fabricators, suppliers and the final customer must have a clear understanding of these terms and how the finishes can be achieved.

Grinding and Polishing

"Grinding" and "Polishing" are a form of machining, involving the removal of a layer of metal from the surface by a cutting (abrading) action. This involves the use of hard particles (bonded together or bound on a backing). The surface finish created is dependent on a number of factors, including the grit size (coarseness) of the abrasive used.

In this publication, the term "grinding" will be used to describe the removal of deleterious surface material such as weld seams and oxide layers. "Polishing" will be used to describe decorative finishing operations where surface material is intentionally removed.

An illustration of the grit sizes used to produce a range of ground and polished finishes on stainless steel fabrications is shown below. As a starting point, using finer grit size abrasives produces smoother finishes.

Operation	Typical grain size
• removal of weld seams (requires finer finishing)	36
• grinding of hot rolled stainless "1D" material	36/60
• pre-polishing of cold-rolled stainless	80/120
• polishing as a finishing step or as preparation	120/180/240
• fine polishing (final stages)	320/400

This ranking only aims to illustrate the effect of the abrasive grit sizes on the finishes produced on stainless steel mill products (coils and plates). It is not a universal ranking system that can be applied to all stainless steel polishing methods, including hand-polishing.

The finishes obtained using one particular grit size are dependent on the type of equipment and the way in which they are used. Suppliers of abrasives and polishing equipment should be contacted for advice on the appropriate polishing equipment and abrasives to achieve specific finishes on stainless steel fabrications.

Hard particles on a backing (for finishing stainless steel, this is usually cloth) produce an abrasive effect, which can range from the removal of weld seams to aesthetically attractive decorative finishes.
Such abrasives are available for use with various power tools including belt grinders, power files, angle grinders, straight grinders etc.

Buffing

In contrast to grinding and polishing, buffing is not intended to deliberately remove any of the stainless steel surface. It is instead a smoothing process, making the surface brighter and more reflective. The process can involve the use of pastes, liquids or solid buffing compounds to enhance the finish. The finish produced by buffing is dependent in part on the pre-buffing stage finish. Buffing can be done following either single stage intermediate grit size polishing or multiple stage, smooth grit polishing. The intermediate grit buffed finish should be less costly to produce but is unlikely to have the “higher quality” of finish of a smooth polished and finally buffed finished surface.

As buffing always produces smooth, high gloss effect finishes, it is a finishing technique commonly used on pharmaceutical equipment. Examples of products finished using the “immediate buffing” technique ie with no pre-polishing of the mill finish, are some cutlery pieces ie knives, forks, spoons etc.

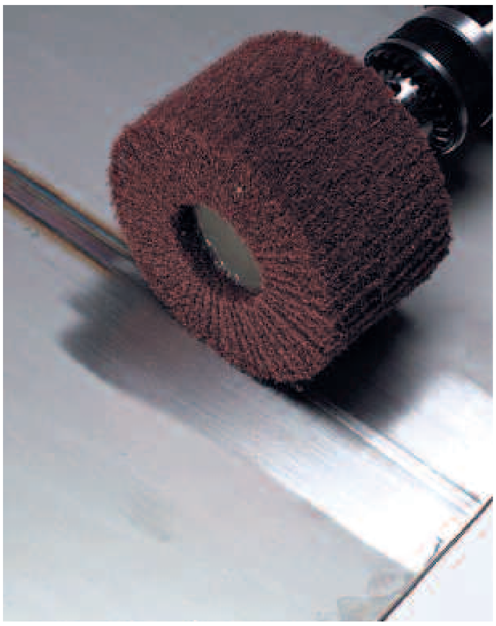
Buffing can be done using cotton or felt mops, either dry or with buffing compounds.
The surface of tubes can be buffed to mirror-like finishes on floor mounted long-spindle machines. Flap discs mounted on hand tools and using buffing pastes can also be used for buffing.

Brushing

Brushing, like grinding and polishing, is an abrasive finishing process. The terms “brushing” and “polishing” are often confused. Milder abrasives intended to "texture" the surface rather than cut away metal layers are used for brush finishing fabrications. Whenever brushing is carried out the abrasive effect on the stainless steel surface is minimal. Brushing media include a range of “Scotch-Brite ™” belts, pads or wheels.

“Scotch-Brite ™” is a trade name of the 3M Company. The term is however widely used by metal finishing specialists for a range of three dimensional nylon fabric materials with impregnated abrasive particles. These finishing media are classified, not by a specific grit size or grade, but as a range of products including coarse, medium, fine, very fine and super fine. For ease of reference the term “Scotch-Brite” will be used throughout this publication, when discussing the application of these finishing media.

It is very important to use representative surface finish samples when specifying brushed finishes.



Example of a flap wheel made of Scotch-Brite™. Here the Scotch-Brite™ wheel is brushing the weld heat tint to blend the weld seam in with the surrounding metal. This finishing operation is not intended to flatten the seam. This would require an initial grinding operation.

4 Frequently used abrasives and power tools

The final appearance and surface quality of mechanically finished stainless steel fabrications is dependent on several factors, including:

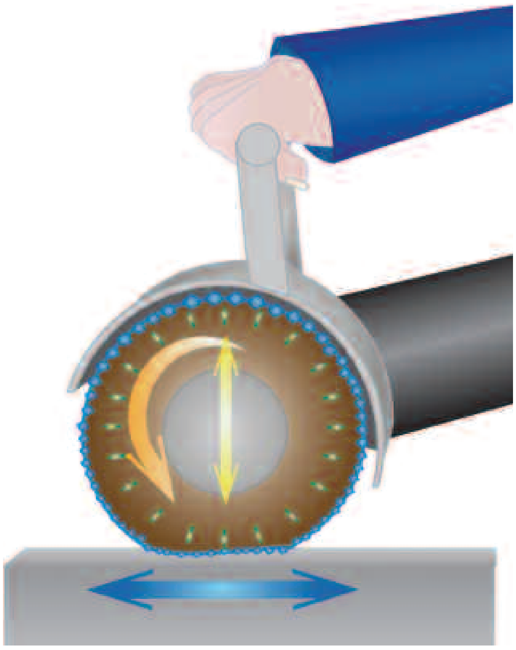
- Abrasive type: backing material, grit size, shape and hardness,
- Number of finishing steps,
- Equipment used,
- Type of power supply to the equipment,
- How the abrasive is supported (ie belt or disc support, wheel type and flexibility),
- Surface speed and applied pressure.

The optimum choice of finishing equipment, consumables and method will depend on:

- The existing surface condition of the semi-finished fabrication,
- The accessibility of the areas to be finished,
- The required final visual effect.

4.1 Process control during hand-tool finishing

When carrying out hand finishing work, the applied pressure and hence work-piece temperature must be controlled so that abrasive is not allowed to dig-in and cause an uneven surface that can be difficult to correct afterwards.

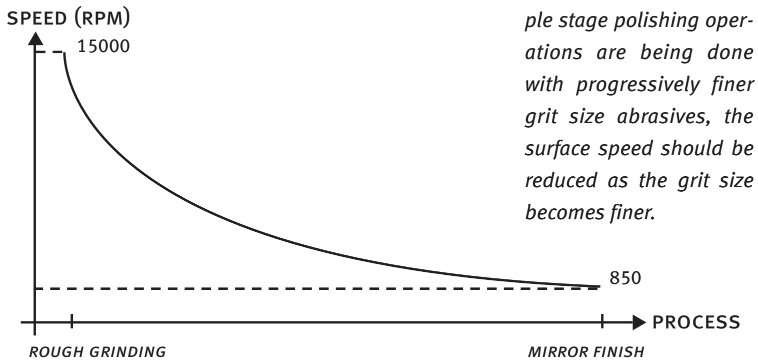


When carrying out hand finishing work, the temperature as well as the pressure must be controlled

The combined effect of the operator's movement, the pressure exerted and the peripheral speed of the abrasive contribute to the finished result.

Oil and grease lubricants can extend the service-life of abrasives as they are a cooling medium and also help remove the grinding dust. The overall visual effect from using "wet" polishing is different from "dry" polishing.

Because it is often difficult to ensure the essential, consistent supply of lubricant to the abrasive / metal surface during the polishing of fabrications, wet polishing is not widely used here.



The acceptable surface speed range of the abrasive is dependent on the grit size of the abrasive being used. When multiple stage polishing operations are being done with progressively finer grit size abrasives, the surface speed should be reduced as the grit size becomes finer.

4.2 Abrasives

The abrasives used for grinding and polishing stainless steel fabrications under workshop and on-site conditions are usually different from those used for finishing coils, sheets or plates in steel mills and service centres where aluminium oxide or silicon carbide abrasives are mainly used.
During the finishing of fabrications zirconium oxide abrasives are more commonly used in the grit size range 24 to 120. These types of abrasives have better durability under these arduous working conditions than either aluminium oxide or silicon carbide abrasives. For finer grit size finishes aluminium oxide or silicon carbide can be used. The properties of the abrasives that determine the final polishing results are:

- The grit size,
- The size (diameter) of the support discs or wheels and their peripheral speed,
- The backing material type and stiffness,
- The use of any lubricating grease or oils in conjunction with the abrasive (not normal practice in hand grinding and polishing).

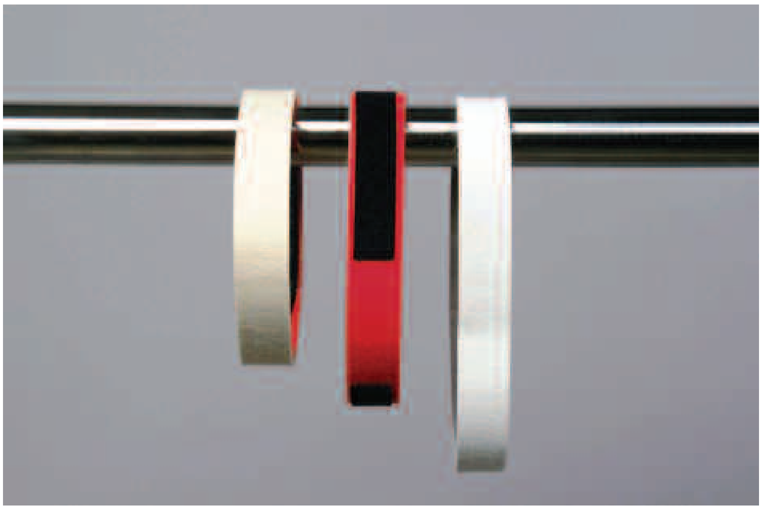
Contrary to the range of abrasives used for coil and sheet polishing, the wear of the grain - and hence the variation in visual aspect of the finished coil - is not such a disturbing feature in abrasives used for manual operations. Not only do manual jobs incorporate a lot of finishing steps using fleece (which would mask the effect of a wearing grain from pre-polishing), the wear of the abrasives used (e.g. wheels) shows a different behaviour to that of large abrasive belts used for coil and sheet polishing.

The most frequently used abrasives are: abrasive belts, non-woven fabric (fleece), flap discs, fibre discs, buffing discs

The most commonly used abrasives are highlighted:

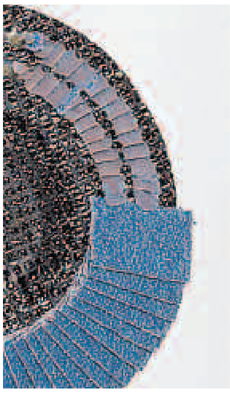
Abrasive belts

These are available in a range of widths and backing material types. For polishing stainless steel these include flexible cloth and tough polyester-cotton. The backing material type affects performance of the belt and the right amount of backing material flexibility for a particular abrasive grit size is important for achieving the desired finish. Recent developments in abrasive belt technology have produced abrasive cloths with built-in cooling additives. These reduce the heat produced during polishing and give improved belt service life.



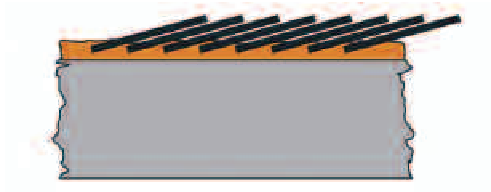
Scotch-Brite™ pads

The abrasive effect of Scotch-Brite™ is minimal compared to abrasive grit-media. The main application of Scotch-Brite™ media is in blending-in existing finishes on semi-finished stainless steel parts. These materials are available in pad (sheet), belt and wheel forms with different degrees of roughness such as coarse, medium, fine, very fine and super fine.



Flap discs

Because of their construction these durable abrasives are widely used in the initial stages of mechanical finishing of stainless steel fabrications. The basic construction of a flap disc is shown. The abrasive "flaps" are glued to a glass-fibre backing material. Where larger contact surfaces are needed the discs can have the flaps glued on to a cone. This arrangement reduces the risks of grinding defects enabling finer finishes to be created.



Fibre discs

These are a similar abrasive type to flap discs but in the form of a single piece abrasive. They are sometimes known simply as “sanding discs”.

Fibre disc abrasives are less aggressive than flap discs and although not as cost effective for metal removal, are less prone to localized "digging-in" or undercutting. They are useful for finishing weld seams on stainless steel fabrications.

Unitised wheels

These abrasive discs are made by hot pressing an impregnated, bonded nylon (Scotch-Brite™ type) material. For manual work, wheels up to 150 mm diameter in a range of densities and flexibility are available.

These abrasives give a long service-life and enable uniform finishes to be produced. They are especially useful for removing weld, heat tinted metal.

Convolute wheels

These are similar to unitised wheels, but are formed by wrapping and bonding layers of abrasive around a hard core to form a wheel. They are less flexible, but less aggressive than unitised wheels.

The surface speeds for both these wheel types should be carefully controlled in accordance with the supplier's guidelines.

Special (Engineered) Abrasives

This new generation of advanced, three-dimensional multiple layer abrasives are especially useful for polishing stainless steel fabrication work. They produce a high degree of finish consistency and, unlike conventional belt-backed abrasives, are extremely durable even under the arduous working conditions when finishing stainless steel.

The individual working abrasive particles are bonded together into regular three dimensional shapes. These shapes include flat sided pyramids or wedge shapes (like a ridge tent), systematically arranged on the backing material. As the pyramid composite wears, stripping away worn abrasive, fresh abrasive particles are exposed to maintain the efficiency of the abrasive. This in turn results in longer belt life, higher cutting rates, a more consistent finish and reduced power consumption, compared with conventional belt abrasives.

Engineered abrasives usually also have built-in coolants, which combined with the self-replacement of the working abrasive, reduce localized heat generation and the risk of surface scorching (heat tinting).

4.3 Finishing tools and equipment

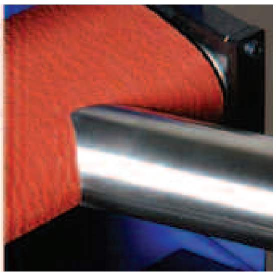
The range of tools and equipment used in the finishing of stainless steel fabrications includes fixed (workshop) equipment and portable hand tools.

Fixed equipment

For certain finishing operations, for example, where productions runs of tube end T-joint preparation or de-burring are being done, fixed finishing machines are the best choice.

Fixed belt grinders (shown in the middle) are ideally suited for de-burring operations. The machine shown at the front is designed to be used with a variety of inter-changeable grinding tools which are driven through a flexible shaft. These machines, sometimes known as “flexi-polishers” are well suited to arduous in-shop polishing work. As there is no heavy motor near the

working head, these machines can help reduce operator fatigue and provide a low electric shock risk working area.
The "long spindle" polishing/buffing mill to the right, can be used with a wide range of polishing and buffing wheels.
The tube notching machine shown on the left is used to prepare the ends of tubes for T-jointed assemblies. This method produces accurate, repeatable weld preparation profiles that minimise the amount of post weld grinding needed on the final fabrication.
The way this machine works in detail is illustrated below:



The abrasive belt runs over a metal contact wheel and produces the required profile for the tube-end being fed to it.

Portable hand tools

There is a wide range of portable tools for hand grinding, polishing and finishing suitable for use with stainless steel fabrications. Portable tools are particularly versatile and useful for finishing difficult-to-access areas. The range of tools required can be kept to a minimum by careful selection. It is important to know the specific applications that each tool was designed for as damage to flat surfaces can result if inappropriate tools are used and can be difficult and time-consuming to rectify.

Portable electrically powered drilling machines should not be used with spindle-mounted abrasive heads for stainless steel finishing work. The design of the spindle bearings in these machines is inappropriate for the demands of this kind of work. For finishing stainless steel fabrications, where this type of tool is required, custom designed straight grinders must be used.

The advice of tool suppliers should be sought when selecting portable tools for finishing stainless steel fabrications.

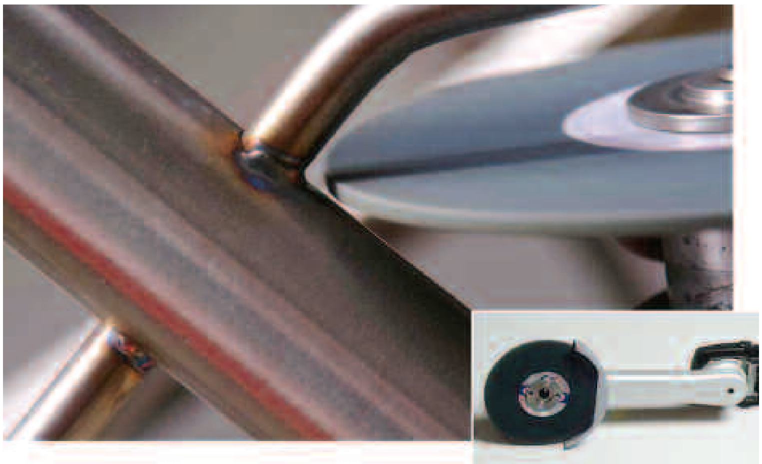
Examples of the most commonly used portable tools for finishing stainless steel fabrications include belt grinders, angle grinders, long reach angle grinders, tube polishers and power-files.

Portable grinder

These multi-purpose tools can be used for plate as well as tube finishing. A range of easy-to-change abrasives can be used with them. Here a Scotch-Brite™ wheel is being used.
Keeping the speed down avoids excessive heating, surface damage that can be difficult to repair and excessive wear of the abrasives.

Variable angle grinder

These tools use flexible abrasive discs for stainless steel work. A variable speed motor is best, making these tools very versatile for both grinding and polishing.

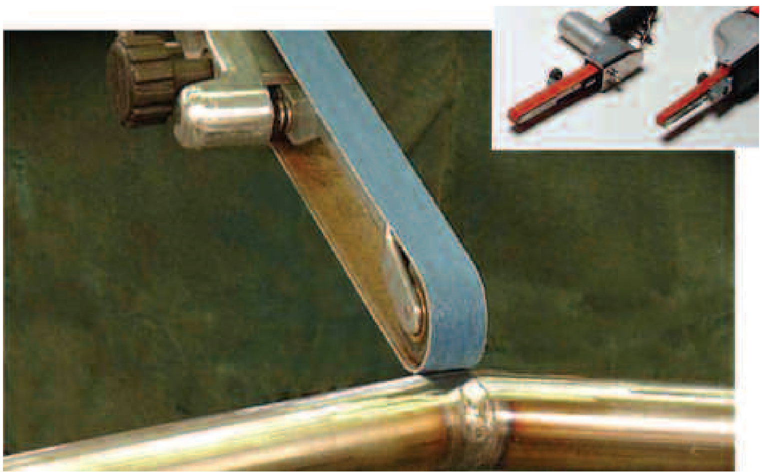


Internal angle finishing tool

The main use for these tools is for finishing welded angle joints, where tool access is limited by acute angles. Both weld bead grinding, heat tint removal and final finishing of the joint is possible using a range of abrasive discs with varying degrees of stiffness.

Tube polishers

These tools are used for finishing tubular assemblies, such as handrails. Their main feature is a flexible abrasive belt which is wrapped around the circumference of the tube, covering angles up to 270° . With this abrasive arrangement these tools can be used for finishing “closed assemblies”.



Power files

These highly portable narrow belt grinders, sometimes referred to as “dynafiles” can be used to grind-off weld seams. These tools need to be used with care to avoid damaging the surrounding metal surface and a final polishing operation is usually needed to properly blend in the finishes.

Power sources for finishing tools

For stainless steel finishing the tool power source can be either electrical or pneumatic. The choice of power source does not directly affect the finish obtained.
Compressed air can be used for powering finishing shop equipment, provided there is sufficient pressure and air-flow rate capacity in the system. There may be a larger air demand for finishing stainless steel than for other metals of the same shape and size as larger operating forces may be needed. In addition because the mechanical finishing of stainless steel usually involves a wider range of tool speeds than is needed for carbon steel work, air driven tools should be equipped with variable speed drives.
As pneumatic finishing tools can be more expensive to buy and operate than electrically powered tools of the same capacity, they may not be an economic choice. Pneumatically powered equipment is however sometimes needed when finishing is being done inside containers, tanks, vessels etc. In these circumstances, where it is not possible to provide a safe electrical earthing system for 220 V or 380 V electrical equipment and low voltage equipment is not available or powerful enough, pneumatically powered equipment can be a safe alternative.
Power supplies for the full range of electrically operated finishing equipment needed for finishing stainless steel fabrications includes both single phase, 220/240 V and three phase 380 V. Both types of supply are likely to be needed in a fully equipped finishing shop.

Flexible drive "flexi-polisher" machines usually use a heavy duty electric motor running on a 380 V power supply. This enables a wide range of powerful, but light finishing heads to be used. If very powerful, heavier units are used, this can limit the portability of the equipment.

The table summarizes the scope and limitations of the various types of power supplies:

Type of power supply	Advantages	Disadvantages
Portable Electrical	• Normally work on readily available single phase (220/240V) supplies • Equipment powered generally easy-to-use, versatile and mobile	• Possible electrical hazard if misused • Sensitive to overload
Pneumatic	• Powers tools that are normally lightweight and compact • High rotational tool speeds possible • No risk of electrical shock to operators • No risk of motor burn-out failures	• Higher energy costs • Higher investment costs for installing compressors and distribution system • Higher finishing equipment costs • Noise levels in operating pneumatic equipment can be higher
Electrically driven flexible shaft drive equipment	• Single, reliable, power source capable of driving a wide range of polishing operations • Enables repetitive work with reduced operator fatigue • A range of tool speeds from one power unit is possible • Motor is remote from working head, reducing electric shock hazard to operators	• Limited drive shaft length can reduce accessibility in large fabrications • High level of operator skill needed to get the best out of this versatile power source

5 Best practice finishing

5.1 Minimising finishing

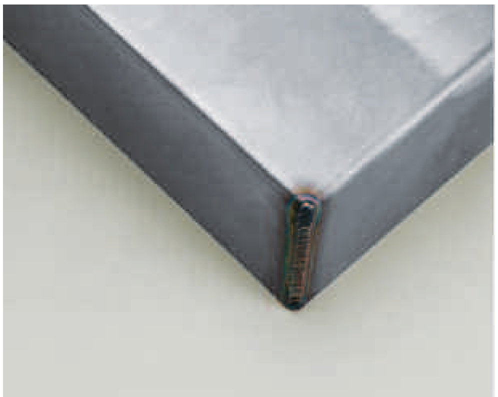
Stainless steel is widely used for decorative applications, requiring surface finishing to a very high standard.
The amount of final grinding, polishing and/or buffing can be minimized if previous operations like cutting, bending and welding are done correctly.
During fabrication of decorative stainless steel fabrications it is important to:

- purchase as many components as possible already polished
- protect these high-value “finished” parts throughout all stages of manufacture and storage

The choice of correct welding procedures and equipment are important considerations:

- GTAW (TIG) welding methods, although slower than GMAW (MIG) methods, are the best choice on balance for decorative fabrication work, where high quality finishes are involved.
- The precision required with either manual or (semi-)automatic GTAW (TIG) processes, can be maintained as electrode wear is limited and the arc has good stability.
- Avoid excessively thick weld seams. This can result in distortion and an unnecessary and costly amount of grinding and finishing.

Although most finishing equipment is versatile and a limited number of tools will cover most finishing jobs, it is important to use the right tools for the particular piece of finishing being worked on. Most fabrication and finishing shops will have fixed machines, such as belt grinders, tube notching machines and "long spindle" polishing/buffing mills. A suitable range of portable tools is also needed for finishing work on decorative stainless steel parts and fabrications.



The corners of this worktop should be carefully finished to make them consistent with the adjoining surfaces. The finished corner, although not an essential structural part of the fabrication, enhances the perception that designers and users of stainless steel should have that stainless steel is a visually appealing and hygienic material. Attention to details like these are an essential part of "best practice" finishing.

5.2 Selecting finishing methods appropriate to the design and fabrication methods

Both mechanical fixing or welded joint methods are widely used in stainless steel fabrication work. Tube joints in stainless steel fabrications such as handrails are very common and can be used to illustrate appropriate finishing techniques.

The examples illustrated, show the finishing of two different angle joints.

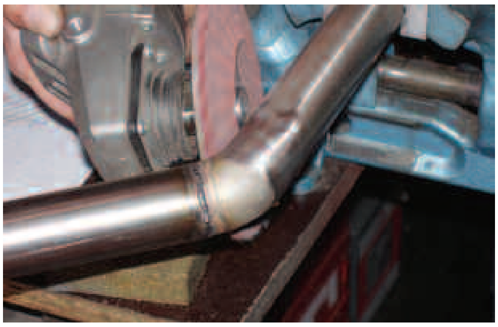
The fabrication on the left shows a “soft” tube joint, using a preformed elbow connector.

To complete the joint only two straight butt joints are needed. This has the advantage of good access for welding and finishing the joint.

The example on the right shows a mitred butt joint, forming a “sharp” angle between the straight sections. Access during welding and finishing is more restricted in this case. The inside of the joint has to be ground and polished using a narrow wheel internal angle grinder. The outside angle can however be finished with the faster flap disc abrasives.

In both cases the areas close to the welded joint can be blended-in all the way round either by hand or with a hand held power tool using a Scotch-Brite™ type abrasive.

Although the “soft” elbow joint option can be easier to fabricate and finish, it relies on holding stocks of a range of elbow sizes (outside diameter and tolerances).

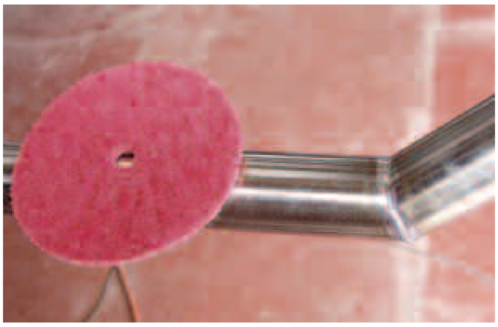


Angle formed using an elbow

Absence of a sharp inside angle

The complete perimeter of the joint can be pretreated with just flap discs abrasives.

Hand finish blending the complete rail into one finish forming a smooth connection between the two tubes.



Angle formed as a mitre with a single welded joint

Treatment of the inside angle with an internal angle finishing tool

Treatment of the outside angle with flap disc abrasives

Finishing operation with an easy-to-use powered hand-held tool. The sharp angle of the joint is still visible with the weld fully blended in.

5.3 Precautions when finishing decorative stainless steel fabrications

Keep surface dressing to a minimum

Pre-finished (polished, brushed and plastic coated) stainless steel sheet, tube and bar for the fabrication of decorative products is now widely available. With careful selection of available pre-finished materials, the total amount of finishing work needed on the assembled fabrication can normally be limited to dressing and blending-in joints.

Where localised dressing is required it is advisable not to use too coarse a grit size abrasive. This is likely to remove more surface than is necessary and may leave unwanted depressions in the surface with the underlying metal possibly being too thin.

For finishing fabrications made up from several welded sheets, disc type abrasives, rather than belt-grinding abrasive techniques should be used. This should keep to a minimum the size of the affected ground area around the weld seam on the parent material. The diameter of the abrasive disc should be as small as possible, to help keep the ground area as small as possible.

Avoid localised heating

The most commonly used stainless steel grades in the building industry are Cr-Ni alloys, technically termed “austenitic” stainless steels (mostly EN 1.4301/1.4307 and - in a more corrosive environment - EN 1.4401/1.4404). They have higher thermal expansion rates and lower thermal conduc-

tivities than the Cr-alloyed ("ferritic") stainless steel type 1.4016, which should be limited to interior applications. Ferritic stainless steels have similar physical properties to carbon steels.
The result is that during grinding and polishing austenitic stainless steel components where some heat is bound to generated, it cannot flow away into the surrounding metal as quickly as the ferritic steels. Tool speeds and applied pressure should be adjusted to compensate for this, otherwise excessive heat tinting and distortion can occur.

Work with the existing polished finish grit
During polishing, the pattern of scratches left is dependent on the grit size of the abrasive and the direction it is used in. When blending-in surfaces using hand-polishing methods, such as Scotch-Brite™, it is important to work with the original polishing direction. This should minimise the time and effort needed to get the required finish.

The main points to bear in mind when mechanically finishing decorative stainless steel fabrications can be summarized as:

- Keep the heat input as low as possible to avoid unnecessary distortion and heat-tinting.
- Carefully consider the possible effects of increasing the tool speed or pressure applied where increases in productivity might be needed.
- When changing grit sizes between finishing steps, it is advisable to clean the work piece surface and finishing equipment. This will help prevent any larger grinding particles left over from previous polishing stages damaging the new surface.
- When blending-in, always keep to the polishing direction used in the previous stage. Use as long a stroke as possible when completing the final stages of hand polishing.
- If in doubt about choosing the grit size for manual finishing, it is better to start off with one that may be too fine, rather than too coarse. Using too coarse a grit size abrasive can result in damage to the surface that can be time consuming to repair or may be irreversible. As a guide, a 120 grit is usually the coarsest used on stainless steel fabrication work of this type.
- In contrast to steel fabrications that are finally paint finished, it is difficult to remedy or hide poor workmanship during mechanical finishing of stainless steel fabrications.
- The choice of successive abrasive grit sizes used for producing finely finished (mirror) polished surfaces is important. As a guide, the grit size number of each successive abrasive should be no more than twice the previous grit size used. If there is too large a difference in the grit sizes used, traces of some of the coarser polishing abrasives may be visible on the finished surface.
- When buffing, altering the direction between consecutive steps by 90 degrees is advisable.

5.4 Good house-keeping during storage, fabrication, finishing and installation of decorative stainless steel products

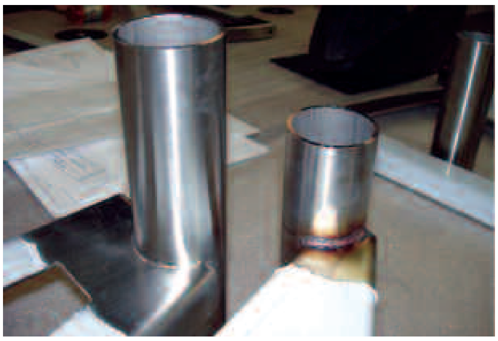
Using a range of different metals, that may include structural, carbon steels and stainless steels is common practice in many fabrication shops. Many fabrications may also require a combination of metal parts which may include both carbon and stainless steel elements. In these situations some basic rules of good house-keeping and workmanship are essential to avoid rust staining problems during the service life of the stainless steel fabrication. It is equally important that care is taken to avoid mechanical damage to semi-finished or finished stainless steel surfaces.

The following precautions should be taken to avoid the risk of iron contamination or mechanical damage to stainless steel surfaces:

- Use plastic coatings to protect the surfaces of fabrications, whenever possible. Sheets, tubes and bars are often supplied from the mills or service centres with these protective coatings. It is good practice to keep these coatings on the steel as long as possible during the fabrication stages and to renew them when the fabrication is finished and ready for despatch. As stainless steel raw materials are approximately 2.5 to 5 times more expensive than carbon steel products, plastic coating should not be considered a "luxury". They are important for maintaining the value of pre-finished stainless steel products by reducing the risk of scratching and contamination.

During fabrication of decorative assemblies like stairs, handrails and railings, all raw materials used should be purchased as polished and plastic coated items, whenever possible. These protective coatings reduce the risk of mechanical damage and iron contamination.

- Abrasives used for carbon steel must not be mixed with abrasives intended for use on stainless steel. Always keep all abrasives segregated in "mixed metal" finishing shops to avoid the risk of iron contamination.
- The use of separate storage and working areas in multi-metal fabrication shops, wherever possible. Ideally, where practical, completely separate shops should be used. This should eliminate the two most common causes of iron contamination: direct contamination from carbon steel grinding dust settlement and cross contamination from the use of shared tooling.



Individual treads for a staircase fabrication show the surfaces before (right) and after (left) finishing of the welds. As much of the plastic film as possible has been kept on the as-supplied steel to protect the original finish.

- Care must also be taken during storage and handling to avoid damage and contamination pick-up. Storage racks, fork-lift truck forks etc. should be coated with suitable materials such as plastic, rubber or wood. Alternative lifting equipment materials to those used in carbon steel fabrications shops are also advisable. Fabric or rope slings should be used rather than steel chains. Conveyor tables should be designed and operated to avoid damage and contamination. Where these are shared with carbon steel fabrication work, any remaining iron particles must be removed before the stainless steel work is started. (This also applies to tools such as shears, presses and all hand tools.)
- It is important that the fabrication shop is managed and operated in a way that workers do not walk on stainless steel sheets. Contamination such as carbon steel particles, grease and oil are easily spread in this way.
- Packaging materials and methods used must help prevent surface damage. Carbon steel strapping must not be allowed to come into contact with the stainless steel surfaces. If used, wooden bearers should be inserted between the carbon steel strapping and the stainless steel surfaces.

If appropriate fabrication and finishing techniques and workshop housekeeping had been used, the faults shown on this fabrication could have been avoided. Specific problems are:

- *Poor quality of the weld seam: aesthetically poor and with compromised corrosion resistance,*
- *Use of bolts of an incompatible, low corrosion resistant alloy,*
- *General rust staining on the polished stainless square tubes.*

An aggressive (e.g. coastal) atmosphere will compound the corrosion problems.
To reduce the risk of these problems occurring, the following points should be considered:

- *More care during welding to avoid the uneven weld bead and spatter,*
- *Correct finishing of the weld,*
- *Use of matching grade stainless steel fasteners,*
- *Proper protection of all stainless steel components around the fabrication shop,*
- *Appropriate on-site cleaning with a non-chlorine based product.*

6 Case studies

6.1 Handrails

Although the main function of handrails and balustrades is in improving safety, they can be used to enhance the architectural design concepts in a wide range of construction and building applications.
The benefits of using stainless steel in these applications include:

- A sustainable solution, requiring very low maintenance,
- Looks that keep their original appearance throughout the service life of the building,
- A very good strength-to-weight ratio.

In external sites stainless steel fabrications should have excellent corrosion resistance, providing the following points have been considered:

- Select an appropriate grade for the service environment.
- Choose a surface finish (roughness) that does not compromise the corrosion resistance of the grade selected.
- Provide good water run-off and drainage in the design and ensure that the design enables a high standard of fabrication and finishing to be achieved.

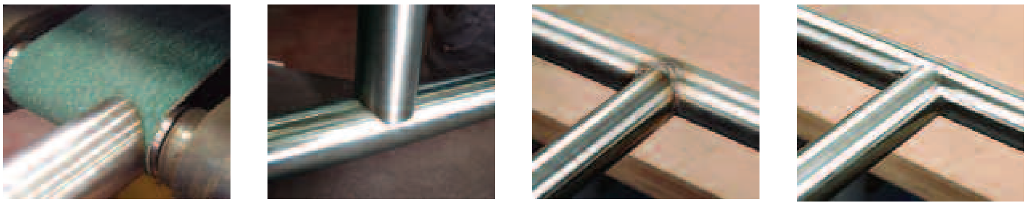
The last point, in particular, is illustrated in this case study. Although handrail and balustrade fabrications often involve joining techniques such as mechanical fixings (inc bolting or spigot-end fittings) adhesive bonding etc, the majority usually have welded joints. These require particular attention during fabrication and finishing to get the desired finish and aesthetic appearance.
A number of frequently used weld joining and finishing methods used on handrail and balustrade fabrications are illustrated here.

Choosing stainless steel to fabricate handrails represents:

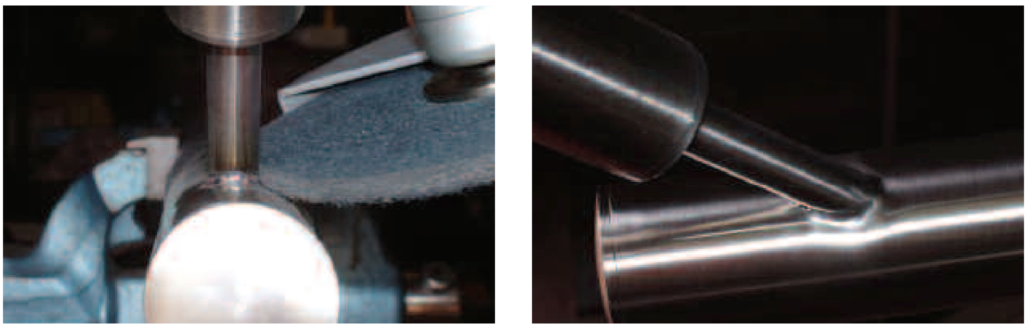
- *A sustainable solution, requiring very low maintenance,*
- *Looks that keep their original appearance throughout the service life of the building,*
- *A very good strength-to-weight ratio.*

The steel tubes, profiles and bars required for the fabrication work, can usually be purchased with the required decorative finish. Using these pre-finished products minimises the finishing work on the assembled fabrication.
During storing and handling, the stainless steel tubes and bars should be protected from damage by keeping the original wrapping on. Storage racking surfaces should also be protected with soft materials such as plastic or rubber to avoid damaging the steel finish.

Mitred angle tube joints require accurate cuts and dressing to give neat fit-up before welding and reduce the risk of cut wounds. Removing sawing burr on the external edges, using a fixed belt grinder, enables sound welds to be made more easily and minimises the amount of post weld dressing needed.



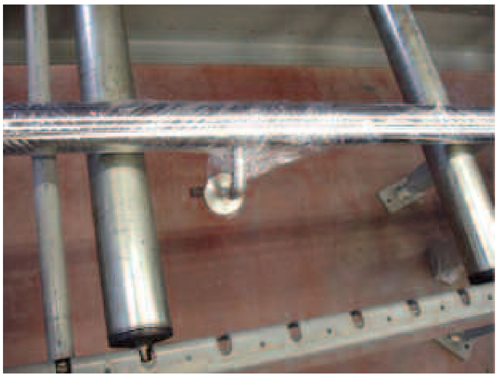
T-joint tube end preparation can be done using a fixed tube notching belt grinder. This should enable sound welds to be made more easily and reduces the post weld finishing efforts in these types of joints.



Tube joint links using small diameter bar infils are often used in handrail and balustrade designs. This type of joint reduces the amount of welding required and can also provide better access for finishing than a corresponding full tube diameter joint.

As handrail and balustrade sections are assembled, accessibilty for the final finishing operations can become restricted. In some cases this may make producing the required finish impossible. Final finishing of sub-assemblies should be built into the fabrication scheme.
In these cases the pre-finished assembly surfaces should be protected with plastic film to reduce the risk of damage during final assembly.

Using pre-finished steel sections reduces the total finishing effort, time and cost for the fabricator.
To correctly blend the welded joint finish with the pre-finished steel section then only needs minimum amount of work.
It is important to use an appropriate combination of tool and abrasive. Scotch-Brite™ type abrasive belts are often used for these finishing jobs.



When all finishing operations have been completed, suitable protection during the final stages of handling, storage and shipping is important to avoid damage and the risk of contamination pick-up. Here a simple, but effective, plastic film wrap has been used.

6.2 Street furniture

The use of stainless steel for today's urban architecture provides sustainable, safe and elegant products, such as:

- benches,
- waste bins,
- bicycle racks,
- bollards.

This case study illustrates the manufacture of street bollards, with particular attention to the finishing.
Stainless steel has several advantages when used for these products that result in long service life and provide a unique aesthetic appeal. These include:

- Good tensile and impact strength. This enables the use of lightweight posts, without compromising the safety of pedestrians or buildings that the bollards are designed to protect.
- A range of smooth finishes that optimise the corrosion resistance, minimise the adherence of dirt and promote in-situ cleaning by rainwater.

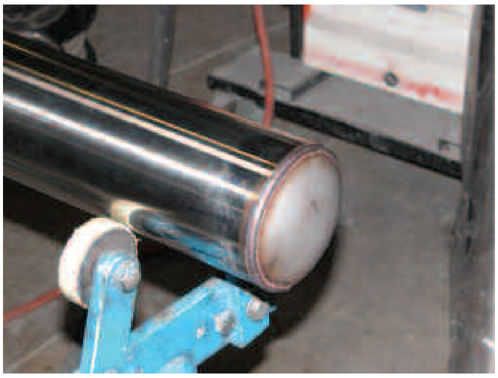
The use of stainless steel for street furniture offers a number of advantages:
- *High strength, making lightweight fabrications possible, without compromising street user safety.*
- *Smooth stainless steel surfaces ensure excellent corrosion resistance and reduce dirt adherence.*

Stainless steel tubes can be supplied in either standard lengths or pre-cut to length by the distributors. Alternatively the tubes can be sawn to length in the fabrication shop.
A choice of either mill supplied 2B cold rolled or a variety of polished finishes are available.
Using pre-polished tubes can save a considerable amount of work at the end of the manufacturing process.

Designs featuring a convex shaped stop-end have several advantages: :
- *The smooth shape reduces the risk of injuries to passing pedestrians.*
- *The convex design will tend to make foreign objects or litter placed on the top of the bollard fall off.*
- *The inside of the tube will not collect litter or dirt.*

The lid is tack welded into position before the circumferential seam weld bead is done.

The continuous weld seam provides the necessary strength and seal.
This type of joint can be made using either manual GTAW (TIG)-welding or a semi-automatic (orbital) process. Although manual welding is slower, smooth, sound joints can be made provided there is a good initial fit-up. Semi-automatic welding can be used where faster weld speed or only poorer joint fit-up is possible. The disadvantage of using this faster process is that more post-weld grinding may be needed.
The more care devoted to the welding operations, the less finishing will be required.



The complete circumference of the tube, next to where the end-stop has been welded into place is given a pre-polish.
The tube polishing tool used enables a large radial section of the tube to be dressed from any position. The result is a more even polished finish.
Supporting the tube on a pair of rollers at one end and holding it in position in a self-centering three-jaw chuck at the other enables good control over the polishing tool to be achieved.

The weld seam is ground off using a hand held flap discs tool.
The flap disc abrasive gives a larger area of contact than belt grinding abrasives. This reduces the risk of grinding marks and undercuts on the dressed area, which would be difficult to blend-in later.

Getting a high standard of finish requires using skilled operators. Using the best, most ergonomic, position for each job is also important.

After the initial grinding stages, mechanical polishing using successively finer grit size abrasives is done before the final buffing stage.
A fixed long spindle buffing machine is used for the final buffing.
Attempts to buff finish a surface that has not been correctly pre-polished will not produce the intended highly reflective finish.

The outside diameter of the bollard is finally treated with a Scotch-Brite™ band abrasive. These abrasives produce even surface finishes with little trace of abrasive marks.
Combining a good work piece clamping and support system with the polishing tool and Scotch-Brite™ abrasive belt again makes it possible to produce a consistent and even finish over the whole surface of of the bollard.

Using only a limited range of flexible hand tools, appropriate handling equipment and methods of working, it is possible to produce an attractive finish with no evidence of the welded joint.
It is important to make sure that at all stages of storage, fabrication and shipping, stainless steel surfaces do not get mechanically damaged or become subject to iron pick-up or contamination.
To get the best possible corrosion resistance welded joints must have traces of weld heat tint removed and be finished as smoothly as possible, consistent with the overall intended visual appearance.

The display of such craftsmanship makes an impressive statement about the durability, safety and elegance of stainless steel in street furniture applications
Mechanically finished surfaces also enable the appearance to be further enhanced with bespoke designs, logos or lettering.

6.3 Catering equipment

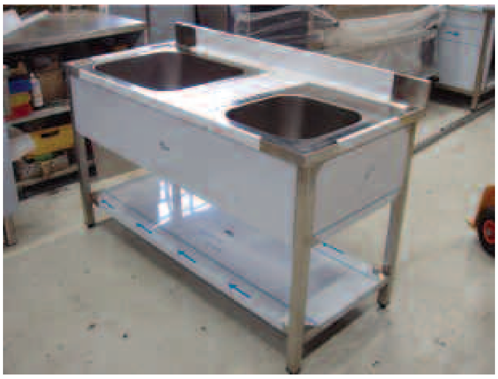
Modern professional kitchens in restaurants, hospitals, schools etc require that the materials used for all their equipment and working surfaces not only look good but also meet high standards of hygiene. Stainless steel fulfills these requirements by being:

- Visually attractive in modern designs,
- Suitable for stringent public health hygienic demands,
- Easy to clean,
- Corrosion resistant,
- Mechanically resistant,
- Easy to fabricate.

For these reasons, stainless steel is the natural material of choice in the catering sector. Good design involves careful consideration of the fabrication and finishing stages that will be needed in the manufacture of the equipment. The factors that must be borne in mind include:

- Limiting the number of polishing steps to the ones strictly necessary,
- Skillful execution of techniques like bending, cutting and welding,
- Appropriate protection of the finished surfaces at all stages of fabrication.

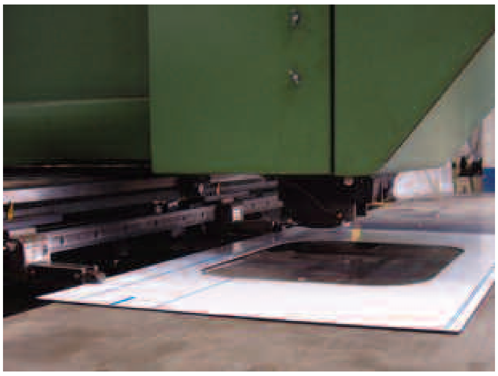
The manufacture of a free standing, stainless steel catering kitchen sink unit is illustrated in this case study, highlighting good finishing practice.

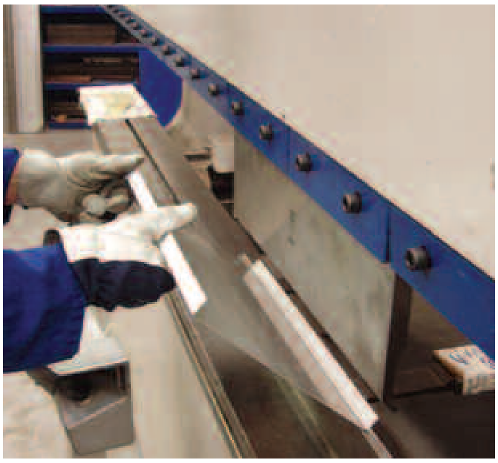


This kind of sink unit is typical of those used by professional caterers. Stainless steel provides the answers to the challenges of hygiene, corrosion resistance and visual appeal posed by professional kitchen design, whist also being easy to fabricate.
These features make it the material of choice for designers and users in professional catering.

The sink unit can be fabricated starting from plastic coated polished stainless steel sheet. Precoated sheets and tubes can commonly be sourced through the metals distribution. Deepdrawn parts like the sink bowl are best sourced from specialist pressworkers.
The bowls have been out-sourced to a specialist deep-drawing company

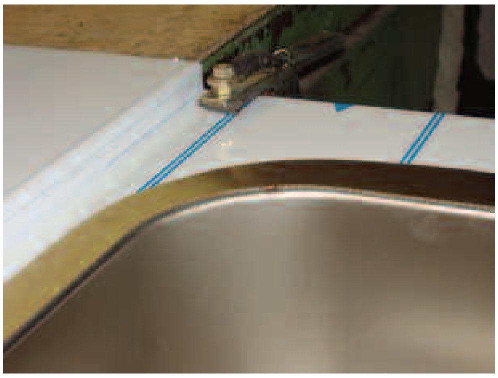
The recess in the sink top for the bowl has to be carefully cut out, with a minimum of edge burr, so that a neat joint fit-up with the bowl is possible. These cutting operations are best done on automatic machines. This will enable neat welds to be made that can be easily finished to high standards of hygiene required.





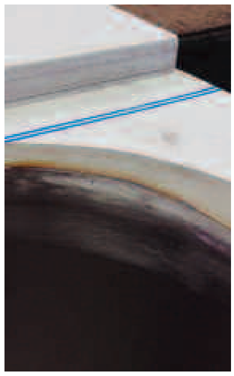
Protective plastic coatings or wrappings should be used wherever possible to avoid surface damage or iron contamination pick-up from tooling and handling equipment. The cost of this essential protection should be built into raw material costings and not treated as an "extra". In multi-metal shops separate cutting and forming equipment for carbon steel and stainless steel is advisable. If this is not possible, then a thorough clean down of all contact equipment between production runs of the different steels must be done.

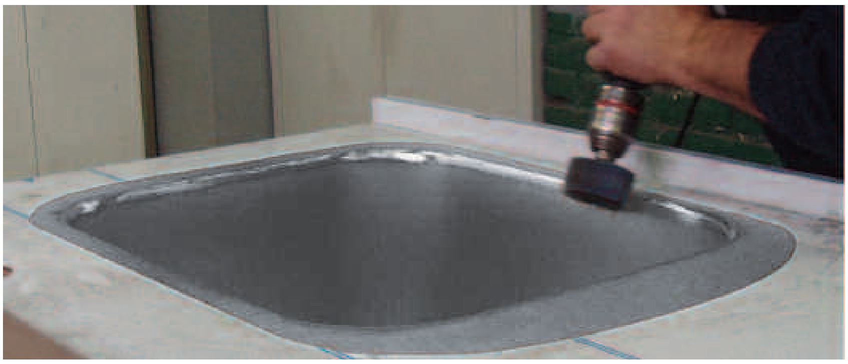
Where there is no specific reason to remove any of the plastic coating or wrapping, damage or soiling of the surfaces can be prevented by leaving it on the steel surfaces. Specially designed racking, trolleys and other storage equipment, like the stainless steel trolley shown here for storing tubes, should be used to prevent surface damage and contamination.

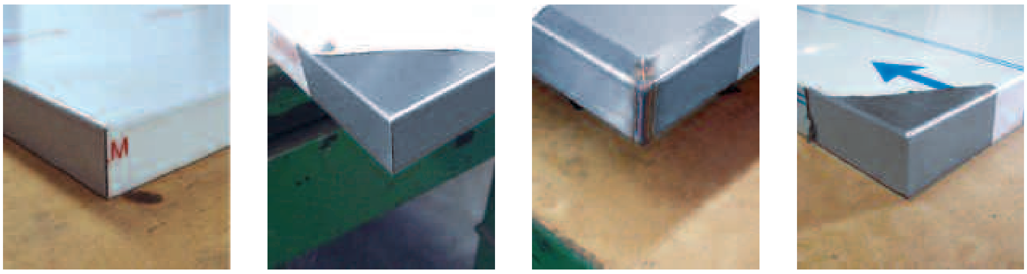

The accurately formed bowl and work-top cut out are carefully fitted together to minimise the amount of welding that will be needed. Tack welds are used to secure the fit-up before the welded seam is made.
A copper bar is used to remove heat from the welded area as quickly as possible, minimising the risk of distortion and the unnecessary build up of heat tint around the weld (see also 5.3.).

After welding the weld bead requires grinding to remove any heat tinted layer and to make it follow the contour of the joint. This will enable the joint to be finished to the high standards of corrosion resistance and hygiene required in service.
A flexible fibre disc abrasive is used so that the grinding action can follow the contour of the curved joint.




After the initial grinding stage a series of flap wheel abrasives mounted on a spindle driven hand tool are used to polish the joint. Final blending of the joint into the bowl and work top to produce a uniform finish is a skilled manual job. Scotch-Brite™ pad abrasives are carefully used for this operation.



After careful folding the corner joint is sealed by welding. This is done to provide a joint that can be finished to a high hygienic standard and that has a low risk of contact injuries, rather than for strength or leak tightness, which are not required in this joint. The neater the welding, the less finishing effort and hence cost, is expended.

Although the cost of the stainless steel raw materials used in fabricating the finished unit are a considerable part of the total cost, a significant amount of value has been added by the skilled fabrication and finishing. The value of the final product should be protected by careful final packaging for shipment.

All handling operations when the fabrication is finished must also be done so that there is no damage to the goods.
Possible sources and causes of damage include:

- *Unprotected contact faces on fork-lift trucks and other lifting gear,*
- *Using storage racks or handling equipment not fitted with suitable protection intended for contact with for stainless steel.*

7 Health, safety and environmental issues

The Euro Inox publication "Stainless Steel – The Safe Choice (Environment and Human Health Series – Volume 1)" describes in some detail the human health and environmental issues associated with stainless steel. This publication concludes that the health effects from the release of either nickel or chromium in most situations is negligible. However, as fine dust can be generated during finishing operations on stainless steel products, special care is needed. If not properly controlled and limited, fine dust may be of concern to health.
Incorrect use of mechanical finishing equipment and inappropriate disposal of waste materials may also have an adverse impact on health and the environment.

7.1 Health effects concerned with finishing stainless steels

As previously stated, finishing of stainless steel produces dust. In order to protect workers' health, concentrations of dust in the workplace must not be excessive, especially over long periods, and must be kept within the occupational exposure limits set by European and national health & safety regulations. To ensure these limits are not exceeded, general and local ventilation or dust extraction should be provided.
There are no occupational exposure limits for stainless steel. Although, as an alloy, stainless steel should not be considered as the sum of its constituents, it is important to be aware that occupational exposure limits apply to some of its constituent elements (e.g. Ni, Cr, Mn, Mo) and certain of their compounds.
Close and prolonged contact with nickel can lead to skin sensitisation and nickel allergic contact dermatitis. As nickel is present in significant amounts in some stainless steels, a potential risk of skin sensitisation with finishing of stainless steels has been suggested. However, approved tests involving close and prolonged skin contact show that the common stainless steel grades 1.4301 (304), 1.4541 (321), 1.4401 (316) will not result in a person becoming sensitised to nickel. However, close and prolonged contact with re-sulphurised (free-machining) grades like 1.4305 (303) may result in allergic (elicitation) reactions in people who are already "nickel sensitised".
It is important to note that nickel sensitisation is not the only reason for outbreaks of dermatitis in susceptible people. Contact with cooling/cutting fluids (e.g. used in saws and other machinery), dirty rags or clothing can all be contributory causes of dermatitis in people susceptible to these types of skin complaint.
The stainless steel supplier is obliged to provide, upon request, a Materials Safety Data Sheet (MSDS), which outlines all known risks associated with their products and recommends safe working practices.
Further information on the health effects of stainless steel is provided in a publication entitled "Manufacture, processing and use of stainless steel: A review of health effects" prepared for Eurofer by H.J. Cross, J. Beach, S. Sadhra, T. Sorahan, C. McRoy, Institute of Occupational Health, University of Birmingham, 1999.

7.2 Safe working methods for mechanical finishing tools and abrasives

The ranges of finishing tools and abrasives used for the mechanical finishing of stainless steels fabrications are no more hazardous than those used for similar finishing operations on other types of steel and metals.
Risk assessment procedures should therefore consider the effects of:

- Contact with moving or rotating abrasives,
- Rupture or fragmentation of abrasives,
- Release of grinding fragments and dust,
- Vibration,
- Noise,
- Heat.

The European Federation of Abrasives' Producers (FEPA) provides detailed information about the safe handling of polishing equipment.

7.3 Environmental issues for working with stainless steel and disposing of waste products

Stainless steel is 100% recyclable. Although it can be safely disposed of as landfill, steel scrap is a valuable commodity and, therefore, fabrication companies prefer to recycle it.

Both larger off-cuts and smaller pieces of steel (e.g. turnings and sawing swarf) are recycled for re-melting by the steelmakers, through scrap merchants. Grinding dust, which contains significant proportions of abrasive dust, is usually disposed of in landfill. This disposal route is subject to EU waste regulations that should be checked.
The so-called EU end-of-life legislation for packaging and packaging waste, vehicles and waste electronic and electrical equipment place restrictions on the content of lead, cadmium, mercury and hexavalent chromium in materials. Although these restrictions are unlikely to be relevant to the use of stainless steels in fabrications, as the levels of these elements in commercially produced stainless steels are unlikely to be deemed as a hazard, it would be wise to check.

References

[1] Surface Finishing of Stainless Steel products, Brugg: Suhner

[2] BURKART, Walter, Handbuch für das Schleifen und Polieren, Bad Saulgau: Eugen G. Leuze Verlag, [6]1991

[3] BOVENSIEPEN, Egon, Geländer und Treppen aus Edelstahl Rostfrei (Dokumentation 871), Düsseldorf: Informationsstelle Edelstahl Rostfrei, [1]1998

[4] CIBO Time Saving Abrasives, Tildonk: CIBO, [4]2003

[5] STEINHART, Hans-Joachim, „Damit Edelstahl rostfrei bleibt“, Mitteilungen 1/2004, Düsseldorf: Informationsstelle Edelstahl Rostfrei

[6] Code de sécurité pour les abrasifs agglomérés et les superabrasifs de précision, Paris: Fédération Européenne des Fabricants de Produits Abrasifs (FEPA), 2001

euro inox
The European Stainless Steel Development Association

ISBN 2-87997-162-4

Diamant Building • Bd. A. Reyers 80 • 1030 Brussels • Belgium • Phone +32 2 706 82-67 • Fax -69 • e-mail info@euro-inox.org • www.euro-inox.org