SHEng
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Welding of stainless steel

Part 4

Class content material

This document is part of a training materials collection developed within the Erasmus+ project “Smart healthcare engineering”, SHEng, project No. 2023-1-RO01-KA220-HED-000159985.

The collection is intended for engineering students and professionals working in the healthcare sector. It covers technical subjects relevant to hospital infrastructure, equipment, materials and support services, helping readers understand how engineering contributes to safe patient care and the reliable operation of healthcare facilities.

These materials support classroom teaching and independent study. They should be used alongside the project handbook and the presentations, courses and other learning resources available on the project website. Each document addresses a specific subject, while the collection provides a broader understanding of the responsibilities and practical challenges of healthcare engineering.

The content is educational. Its application in practice requires consideration of the conditions of each healthcare facility, the applicable standards and the instructions provided by equipment manufacturers.

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SMART HEALTHCARE ENGINEERING

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Welding of stainless steel

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1. Welding process

Various welding process cand be used for welding of stainless-steel components. The main ones are:

TIG welding, also known as GTAW, uses a non-consumable tungsten electrode and a shielding gas to protect the weld area, while filler metal can be added separately when required by the joint design. Thin stainless steel tubes can also be welded without filler if the fit-up and material composition are suitable. The process provides good control of the weld pool, and orbital TIG improves repeatability by moving the welding head around the tube under controlled conditions. However, consistent results still depend on joint preparation, alignment and the selected welding parameters.

MIG, MAG and manual metal arc welding are suitable for a range of fabrication tasks, with the choice depending on material thickness, access to the joint, required productivity and surface condition. Depending on the process, slag and spatter may need to be removed before the component enters service. A process that

works well for a structural frame may therefore be less suitable for a small tube where the internal surface must remain smooth and easy to clean.

Laser welding concentrates energy within a small area and can produce narrow welds with limited distortion, which makes it useful in the manufacture of selected medical devices and equipment. These advantages depend on accurate fit-up, correct focus and suitable control of shielding and penetration, especially when thin components are joined without filler. Filler metal can also be used when the application requires it. Although welding may take place inside a closed laser enclosure, the enclosure provides protection from the laser beam and should not be assumed to provide sterile conditions.

Joint preparation and shielding

Joint preparation should begin with cutting and cleaning methods suitable for stainless steel, followed by checks of alignment and joint gap against the welding procedure. Tools and abrasives must not introduce iron contamination, while oil, grease and other residues should be removed using the approved cleaning method.

During welding, the external shielding gas protects the weld pool, while internal purging protects the root from oxidation. Both require attention because an acceptable external bead may hide a heavily oxidised internal surface, particularly in tubes where direct inspection is difficult.

Heat tint develops through oxidation during heating and can be associated with chromium depletion beneath the oxide layer, reducing resistance to local corrosion. Effective shielding helps prevent this damage and reduces the need for subsequent cleaning, which can be difficult inside small tubes or complex assemblies. When heat tint must be removed, the selected treatment should address both the oxide and the affected surface beneath it, according to the service requirements.

Metallurgical considerations

Austenitic stainless steel weld metal may contain some delta ferrite, which can reduce susceptibility to solidification cracking. However, the amount that is acceptable depends on the alloy and its intended service, so a single ferrite value cannot be applied to all stainless steel welds. Filler composition, dilution from the base material and impurities influence the final weld structure, while ferrite number and volume percentage describe different measures and should not be used interchangeably.

Schaeffler and DeLong diagrams estimate weld constitution from the chemical composition and can support the selection of materials and fillers. Their predictions remain limited by the compositions and conditions for which they were developed, so they cannot confirm weld quality or replace procedure qualification. Particular care is needed when interpreting results for laser welding, where rapid solidification may affect the weld structure, or when the alloy composition falls outside the range covered by the diagram.

For pulsed welding, the calculation must account for changes in power throughout the pulse cycle. Multiplying the average voltage by the average current may give an inaccurate result because both values change with time, so the calculation should use a suitable average of the instantaneous power.

Welding records should link each joint to the material identification, approved procedure, operator, consumables and relevant machine settings, with inspection results recorded under the same joint number. Keeping this information together allows the maintenance team to trace how a joint was produced and provides useful evidence if a defect or service failure needs to be investigated.

2. Inspection and maintenance

Inspection should answer whether a component is suitable for its intended service. The required checks depend on the function and consequences of failure. An accessible furniture weld and a medical gas joint do not need the same acceptance route.

Table 1. Method to defect matching

Method	What it can reveal	Main limitation
Visual inspection	Staining, geometry, cracks open to view and poor finish	Cannot establish internal soundness.
Borescope inspection	Internal root shape, oxidation and visible deposits	Access and image coverage limit the result.
Liquid penetrant testing	Surface-breaking defects on suitable clean surfaces	Cannot detect closed internal flaws; residues need control.
Radiography or ultrasound	Selected internal discontinuities	Method and geometry must suit the joint.

Leak or pressure testing	Specified aspects of integrity	Does not prove gas identity, cleanliness or every weld feature.
Material identification	Selected alloying elements	Method capability and traceability still matter.

Respond to a defect in a controlled way

When a defect is found, record the component, its location, the date and the operating conditions, then describe what is visible before suggesting a cause. Brown staining, for example, is an observation, while chloride pitting is a diagnosis that requires supporting evidence. The assessment should include the material certificate, fabrication history and any recent changes in cleaning products or operating conditions that may help explain the damage.

If the defect could affect safe use or cleanability, follow the facility's procedure for restricting use and obtaining a technical assessment. Grinding, coating or chemical treatment of a medical device should only be carried out through an authorised repair procedure, since improving its appearance may hide underlying damage or change dimensions that are important for its function.

For facility components, agree on the repair method and acceptance criteria before work begins, then check both the surface condition and the function of the repaired part. The investigation must also address the cause, because removing a visible mark will provide only a temporary improvement if stagnant liquid or an unsuitable cleaning product remains part of normal operation.

Inspection records

An inspection record should bring together the asset identification, material, service conditions and photographs, along with any immediate action and the person responsible for follow-up. As the investigation progresses, add the findings, repair decision, verification results and next review date, while keeping the original description even if the diagnosis changes. This preserves the history of the problem and helps others understand how the final decision was reached.

Cost over the service life

The purchase price represents only part of a component's total cost, which also includes installation, routine cleaning, inspection, repairs and eventual replacement, together with any

downtime caused by these activities. A more expensive stainless steel grade may justify its additional cost in a demanding wet environment if it reduces corrosion and maintenance, while the same material may offer little practical benefit in a mild, dry location.

Compare the alternatives over the same period and include the same cost categories for each option, making the assumed service life clear. Since the result depends partly on how long each component is expected to last, check whether a shorter or longer service life would change the preferred choice.

3. Durability and hygiene

The stainless steel use in healthcare should addresses both the metal and the condition of its surface. Three questions are closely connected: how the surface survives repeated processing, how it interacts with microorganisms, and whether laboratory improvements remain useful during service. For a hospital engineer, the useful question is whether a proposed finish has been tested after repeated exposure. A new surface may look satisfactory but change with use. Acceptance should consider the condition after representative processing, including joint regions and areas that are difficult to drain.

Cleaning chemistry and corrosion

The bleach-wipe study [1] found less corrosion when the tested wipes were used with a specific additive. Its practical contribution is evidence that formulation can change material damage. The result is product- and test-specific. It should not be interpreted as a recommendation to add unapproved substances to hospital disinfectants.

Copper and clinical evidence

Albarqouni et al. [2] reviewed seven studies involving 12,362 patients. The pooled estimate for several types of copper-treated surfaces suggested lower healthcare-associated infection risk, but the evidence was judged low quality. The hard-surface subgroup alone did not show a statistically significant reduction. This distinction matters when evaluating a claim about copper handrails or bed surfaces.

Laboratory antimicrobial activity, lower surface contamination and fewer patient infections are different outcomes. A laboratory test can support a mechanism. A hospital study must also account for cleaning, staff behaviour, exposure and clinical conditions. Results from these levels should not be treated as interchangeable.

What is established and what still needs evidence

Established practice is to select an appropriate grade, avoid contamination, produce sound joints and use a compatible cleaning route. The recent evidence strengthens the case for testing the complete surface through repeated service conditions. Antimicrobial modifications add another function, but their durability and clinical value need separate verification. Corrosion resistance, cleanability and antimicrobial activity should be measured independently rather than combined into one general claim of hygiene.

4. State of the art in surface engineering

Silver deposits on stainless steel

Malvi et al. [3] deposited silver nano-islands on 316L and studied antimicrobial and antiviral behaviour. The approach uses discrete deposits rather than requiring full surface coverage. The reported activity is associated with controlled silver release. For hospital use, questions remain about release during cleaning, surface wear, exposure and retained performance over the intended lifetime. The study is evidence for a surface concept, not proof of reduced hospital infection rates.

Coatings with several functions, Laser texturing

Outón et al. examined laser-induced periodic surface structures on ferritic stainless steel [4]. Periodicity, depth and changes in wettability affected E. coli adhesion. Some smaller structures reduced adhesion, while deeper structures could increase it. This is a useful warning against assuming that any laser texture improves hygiene. Geometry and surface ageing must be evaluated for the selected organism and exposure conditions.

Table 2. Read a surface claim critically

Question	Evidence needed
What was measured?	Separate attached cells, viable counts, biofilm and clinical infection.
What was the control?	Compare with the same base material and a defined finish.
Was the surface aged?	Test after realistic wear, cleaning and sterilization where relevant.

What enters the environment?	Assess ion or particle release and the intended contact route.
Does the treatment remain intact?	Check adhesion, damage, corrosion and local defects.
Can it be made consistently?	Verify coverage, geometry, inspection and batch variation.

A coating can reduce bacterial adhesion and still introduce a new failure mode if it cracks or releases unsuitable products. A texture can work in a short clean experiment yet retain soil during use. Performance should be tested on representative components, including edges and joints, rather than only on flat polished coupons.

A practical research route

For a training or development project, start with untreated and conventionally finished controls. Define the grade, surface preparation and cleaning exposure. Measure roughness and surface damage before and after ageing. Add corrosion testing and a suitable microbiological assessment with qualified laboratory support. Report variability and the limitations of each method.

The present research direction is toward surfaces that retain several useful properties together. The engineering challenge is to show that the benefit survives fabrication and repeated use. For procurement, a clear durability test and a defined maintenance route are often more useful than a high antimicrobial percentage without its test conditions.

5. Practical cases for discussion

Case 1 Pitting near a scrub sink outlet

A stainless steel sink develops small pits around the outlet six months after installation. Cleaning records show frequent use of a chlorine-based product. Liquid remains beneath the outlet fitting. The supplier describes the material only as stainless steel.

Task. Identify the missing information and propose the first investigation steps. Decide whether changing the grade alone would be enough.

Suggested approach. Record the defect and confirm whether there is material loss. Obtain the grade and product documentation and check the cleaning concentration, wet exposure, required rinsing

and actual drying. Inspect the outlet geometry for a crevice. A change from 304 to 316L may improve resistance in some conditions, but retained liquid and incompatible cleaning still need correction. Define repair or replacement through the responsible technical and hygiene teams.

Case 2 A dark root in a welded tube

A 316L utility tube has a smooth external TIG bead. A borescope shows a dark, rough internal root. The contractor provides a leak-test result but no purge record.

Task. Explain why the external appearance and leak test do not settle acceptance.

Suggested approach. The observations raise concern about root protection and internal oxidation. Compare the root with the specified acceptance criteria and review the procedure and welding records. Establish whether cleaning or repair is possible without creating new defects. If not, replacement may be required. Repeat the relevant inspections after corrective work. Low carbon content does not prevent oxidation caused by inadequate shielding.

Case 3 An antimicrobial handrail proposal. A supplier offers a coated stainless handrail with a claimed 99% reduction in bacteria. The brochure does not identify the test organism, contact time, cleaning exposure or condition of the surface after wear.

Task. List the evidence needed before comparing it with an ordinary stainless handrail.

Suggested approach. Request the full test method, control surface, repeat measurements and ageing results. Ask about coating adhesion, corrosion, cleaning compatibility and release. Establish whether the claim concerns viable cells, adhesion or another endpoint. Include maintenance and replacement costs. Do not convert a laboratory percentage into an expected reduction in infections.

Case 4 Industrial air offered as medical air

During planning of a hospital extension, a contractor proposes connecting an existing industrial compressed air system because it meets an ISO 8573 purity class.

Task. Explain what is missing from this justification.

Suggested approach. An industrial purity class does not demonstrate complete medical air or pipeline compliance. The design must address the applicable medical gas requirements, gas quality, continuity, identification, alarms, connections and commissioning. Refer the proposal to the authorised medical gas design and verification team before any connection is made.

6. Review questions and suggested answers

Questions for independent study

1. Why can stainless steel corrode even though it forms a passive film?

2. What does molybdenum add to the selection argument for 316 compared with 304?

3. What is the main welding-related benefit of 316L, and what does it not prevent?

4. Why is a low Ra value insufficient to prove that a component is easy to clean?

5. Why is industrial compressed air classification insufficient for medical air?

6. What can a borescope inspection reveal that an external visual check cannot?

7. Why should a Schaeffler diagram not be used as a weld acceptance certificate?

8. What is the difference between lower bacterial adhesion and fewer infections?

9. What information should be retained after investigating a corrosion defect?

Answers

1. The film can break down locally when chemistry, temperature, deposits or surface damage create unfavourable conditions. Repassivation does not remove a pit.

2. Molybdenum improves resistance to local corrosion in many chloride environments. It does not make 316 immune to chloride attack.

3. Low carbon reduces susceptibility to sensitisation. It does not prevent poor penetration, contamination, cracking or heat tint.

4. Ra is an average profile measure. Geometry, pits, scratches, joints and access also influence cleaning.

5. Medical air requires a broader system and quality assessment. ISO 8573 classification alone does not establish that compliance.

6. It can show internal root oxidation, penetration profile and visible deposits, within its access and coverage limits.

7. The diagram estimates constitution from composition. It does not demonstrate free of defects or suitability for the service.

8. Adhesion is a surface test endpoint. Clinical infection depends on many additional factors and requires clinical evidence.

9. Keep asset identity, material and service data, observations, photographs, investigation findings, corrective action and verification.

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