Perfecting Materials for Challenging Industrial Environments

Using brazing to create wear-resistant surfaces and manufacture components with complex cooling structures

Brazing is a versatile process that is applicable to several industrial fields, from the automotive to the energy industries. Although primarily known as a joining process, brazing has interesting applications as a coating process as well. The two case studies presented in this article are good examples of how brazing can be used to create wear-resistant surfaces on specific locations of highly stressed components and to manufacture components with complex cooling structures.

Joining and Coating of Metallic Sieve Screens

Motivation

Metallic sieve screens are subjected to high mechanical loads — Fig. 1. Wear, impact, and vibrations are caused by waste, mainly metallic, that should be sorted out in groups according to the waste's dimensions.

Materials and the Current Manufacturing Process

A combination of different materials in the same sieve can improve the operating life of such components. The types of steel, 1.4301 and 1.4404 (Ref. 1), were selected based on their characteristics and availability in the required forms of plate and tubes. The pipe sections were first fixed via gas tungsten arc welding and finally brazed with Ni 620. The typical damages observed were throughgoing cracks in the brazed joints and a generally heavy worn condition of the pipe sections — Fig. 2.

To increase the life of the metallic sieve screens with limited development effort, the brazing alloy was changed and the pipe sections were protected by a wear-resistant brazing coating. This strategy had the advantage of keeping roughly the same manufacturing processes and raw material of the ongoing serial production. However, a longer lifetime was expected. Some simplified trials have been performed to estimate the advantage of these changes.

Fig. 1 — Overview of a metallic sieve screen plant and typical waste after sieving. (Photos courtesy of ZAV Recycling AG.)
Development Trials

A mock-up was designed to select a more-suitable brazing alloy and verify the coatability of the tubes — Fig. 3. The real advantage of this change could only be verified by implementation in a real part (a prototype).

The main challenge for the joint was its clearance width, which in some locations was approximately 0.25 mm due to manufacturing tolerances. Therefore, the Alloy Ni 620 (Ref. 3) was not the best candidate since high fractions of brittle phases typically form clearances wider than 0.1 mm. Finally, according to manufacturing experience collected in recent years, the brazing alloy needed to be applied to both sides of the sieve screen to avoid unacceptable brazing defects. The brazing mixtures described in Table 1 were checked in the brazing trial.

The following criteria have been used to determine the best brazing alloy for this application:

- Ability to fill wide gaps,
- Hardness of the brazed metal (the harder the phase, the higher the possibility to form brittle phases),
- Application of a brazing paste on one or two sides of the screen sieves, and
- Availability and cost of the brazing paste.

As shown in Figs. 4–6, the iron brazing alloy achieved outstanding brazed joints despite the high volume to be filled, and at the same time, the brazed metal was generally slightly softer compared to the baseline Ni 620 (Ref. 3). A wear-resistant coating (Brazecoat®, M, made by Innobraze GmbH) was brazed on the surface of the pipe sections to reduce wear during service. This coating consists mainly of a nickel-based matrix, which melts during brazing and is enriched by metal carbides (Ref. 2). Since the melting range of the coating is the same as the Fe-based brazing alloy, both alloys were applied in the same process (joining and coating). The metallographic investigation could prove that a good bond was achieved between the base and brazed metals.

Prototype

The process (joining by using a Fe-based brazing alloy and coating) used on the mock-up was finally implemented on a real part and on 50% of the component surface — Fig. 7. In this way, it was possible to verify the effective impact of the modified process on the result. In fact, the different screen sieves were installed in different locations and were not all subjected to the same types of loads. The half-coated screen sieve was implemented in the machine, which is subject to the highest mechanical loads according to the user’s experience.

Table 1 — Brazing Alloys Used on the Mock-Up

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<tr>
<th>Brazing Alloy Checked</th>
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<tr>
<td>Option 1 Ni 610 (B-Ni74CrFe-SiB-980/1070 [Ref. 3])</td>
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<tr>
<td>Option 2 ML7813/S (Fe-based brazing alloy)</td>
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<tr>
<td>Option 3 A mixture of Ni 620 (B-Ni82CrSiBFe-970/1000 [Ref. 3]) with a CrNi-based powder</td>
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After service, the component was inspected at the customer site and the following conclusion was reached: The joining material had provided a mechanical performance similar to the Fe-based brazing alloy. So, in this case, the main advantage is the reduced application time compared to the Ni-based brazing alloys. The coating performed well, but the lifetime of the component could not be prolonged due to other design limitations of the screen sieve itself, such as wall thickness reductions in the uncoated areas.
after service. Eventually, the combination of coating and joining should lead to a massive increase in the life of the component after the construction of the screen sieve is improved.

**Manufacturing of Cooled Components**

**Motivation**

Advanced manufacturing technologies (for example, selective laser melting) are convenient and relevant from an economic point of view when the business model behind the selected components justifies the use of these innovative and partly R&D-intensive technologies. In some cases, the use of brazing could be sufficient to provide moderately complex cooled geometries that cannot be directly included in the raw material manufacturing step (e.g., casting) (Ref. 4). This case study shows an example of cooled steel components whereby brazing provided excellent joining quality, low development effort, and low joining material costs.

**Materials**

The components discussed here arrived in raw material form as two steel slabs (metal 1.4542, according to Ref. 1) with cooling features on the surface to be joined — Fig. 8. After joining, a closed cooling system will form. The brazed joint needs to be tight, and no leakage is allowed even in the event of high pressure (maximum pressure required for the function inspection is 5 bar). A Ni-based brazing foil was positioned between the two slabs and brazed in a vacuum furnace. The brazed components were two types of products with different dimensions (approximately 200 × 170 × 40 mm and 270 × 270 × 40 mm). The brazing process, furnace parameters included, were first developed for the small models and then implemented in the big ones. This final step showed the significative impact of the volume to be heat treated on the quality of the final brazing.

**Results**

During the development, brazing quality was evaluated based on a visual inspection (molten brazing alloy to be recognized) and an immersion ultrasonic inspection — Fig. 9. As for the big components, in different cases, the nondestructive testing inspection provided good results. However, the function check (applying a defined internal pressure on the channels with water) did not always confirm those results. Metallographic investigations were performed to verify whether the brazed joint really formed in the components that did not pass the pressure test. The cut-ups showed that a diffusion zone could be detected, which means the brazing alloy had melted and brazed the base metal. Additionally, it was observed that all investigated loose locations did not fail in the brittle phases, which frequently form in the case of nickel-based brazing alloys, but rather in the interface base metal/braze metal. The described situation was explained as follows: The bond between the brazed metal and the base metal formed during the heat treatment. However, the strength of

![Fig. 5 — Hardness values in the brazed metal and on the heat-treated base metal.](image1)

![Fig. 6 — Exemplary cross sections of the coated sieve screens.](image2)

![Fig. 7 — Detail of a brazed screen sieve.](image3)
the joint was not sufficient to bear high pressure in the test — Figs. 10 and 11.

A close analysis of the furnace chart revealed a possible reason for the weak joints: The temperature difference in the heating phase between the thermal cuttings in the furnace was higher in the big slabs than in the small ones. This most likely resulted in a brazing time in some areas of the voluminous parts that was too short (lower diffusion), causing a weak brazed joint. A customized furnace program (one for small slabs and one for big slabs with low heating rates and the use of gas in place of vacuum at temperatures lower than 700°C) could result in a robust process with a good brazing quality.

**Conclusion**

The challenge of the first case was to coat and simultaneously join the different elements of a metallic sieve screen used to separate metallic waste. Brazing was chosen to join the pipe sections on the sieve screen surface and achieve wear-resistant surfaces. The second application shows how brazing can be used to manufacture components with complex cooling structures. An interesting challenge of this development was transferring the furnace parameters to different types of cooled components. The process had to be adapted with consideration of the specific component dimensions and masses of the required process productivity.

**Acknowledgments**

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