11. Surfacing and Shape Welding
DIN 1910 ("Welding") classifies the welding process according to its applications: welding of joints and surfacing. According to DIN 1910 surfacing is the coating of a workpiece by means of welding.

Dependent on the applied filler material a further classification may be made: deposition repair welding and surfacing for the production of a composite material with certain functions. Surfacing carried out with wear-resistant materials in preference to the base metal material is called hardfacing; but when mainly chemically stable filler materials are used, the method is called cladding. In the case of buffering, surfacing layers are produced which allow the appropriate-to-the-type-of-duty joining of dissimilar materials and/or of materials with differing properties, Figure 11.1.

A buffering, for instance, is an intermediate layer made from a relatively tough material between two layers with strongly differing thermal expansion coefficients.

Figure 11.2 shows different kinds of stresses which demand the surfacing of components. Furthermore surfacing may be used for primary forming as well as for joining by primary forming.
In case of surfacing - as for all fabrication processes - certain limiting conditions have to be observed. For example, hard and wear-resistant weld filler metals cannot be drawn into solid wires. Here, another form has to be selected (filler wire, continuously cast rods, powder). Process materials, as for example SA welding flux demand a certain welding position which in terms limits the method of welding.

The coating material must be selected with view to the type of duty and, moreover, must be compatible with the base metal, Figure 11.3.

For all surfacing tasks a large product line of welding filler metals is available. In dependence on the welding method as well as on the selected materials, filler metals in the form of wires, filler wires, strips, cored strips, rods or powder are applied, Figure 11.4. The filler/base metal dilution is rather important, as the desired high-quality properties of the surfacing layer deteriorate with the increasing degree of dilution.
A weld parameter optimisation has the objective to optimise the degree of dilution in order to guarantee a **sufficient adherence** of the layer with the minimum metal dissimilation. A planimetric determination of the surfacing and penetration areas will roughly assess the proportion of filler to base metal. When the analysis of base and filler metal is known, a more precise calculation is possible by the determination of the content of a certain element in the surfacing layer as well as in the base metal, Figure 11.5.

Figure 11.6 shows record charts of an electron beam microprobe analysis for the elements nickel and chromium. It is evident that - after passing a narrow transition zone between base metal and layer — the analysis inside the layer is quasi constant.

As depicted in Figure 11.7 almost all arc welding methods are not only suitable for joining but also for surfacing.
In the case of the **strip-electrode submerged-arc surfacing process** normally strips (widths: 20 - 120mm) are used. These strips allow high cladding rates. Solid wire electrodes as well as flux-cored strip electrodes are used. The flux-cored strip electrodes contain certain alloying elements. The strip is continuously fed into the process via feed rollers. Current contact is normally carried out via copper contact jaws which in some cases are protected against wear by hard metal inserts. The slag-forming flux is supplied onto the workpiece in front of the strip electrode by means of a flux support. The non-molten flux can be extracted and returned to the flux circuit.

Should the slag developed on top of the welding bead not detach itself, it will have to be removed mechanically in order to avoid slag inclusions during overwelding. The arc wanders along the lower edge of the strip. Thus the strip is melted consistently, Figure 11.8.

**Figure 11.7**

**Figure 11.8**
Figure 11.9 shows the cladding of a roll barrel. The coating is deposited helically while the workpiece is rotating. The weld head is moved axially over the workpiece.

The macro-section and possible weld defects of a strip-electrode submerged-arc surfacing process are depicted in Figure 11.10.

**Electroslag surfacing using a strip electrode** is similar to strip-electrode SA surfacing, Figure 11.11. The difference is that the weld filler metal is not melted in the arc but in liquefied welding flux — the liquid slag — as a result of Joule resistance heating. The slag is held by a slight inclination of the plate and the flux mound to prevent it from running off.
TIG weld surfacing is a suitable surfacing method for small and complicated contours and/or low quantities (e.g. repair work) with normally relatively low deposition rates. The process principle has already been shown when the TIG joint welding process was explained, Figure 11.12. The arc is burning between a gas-backed non-consumable tungsten electrode and the workpiece. The arc melts the base metal and the wire or rod-shaped weld filler metal which is fed either continuously or intermittently. Thus a fusion welded joint develops between base metal and surfacing bead.

In the case of MIG/MAG surfacing processes the arc burns between a consumable wire electrode and the workpiece. This method allows higher deposition rates. Filler as well as solid wires are used. The wire electrode has a positive, while the workpiece to be surfaced has a negative polarity, Figure 11.13.
A further development of the TIG welding process is **plasma welding**. While the TIG arc develops freely, the plasma welding arc is mechanically and thermally constricted by a water-cooled copper nozzle. Thus the arc obtains a higher energy density.

In the case of **plasma arc powder surfacing** this constricting nozzle has a positive, the tungsten electrode has a negative polarity, Figure 11.14. Through a pilot arc power supply a **non-transferred arc** (pilot arc) develops inside the torch. A second, separate power source feeds the **transferred arc** between electrode and workpiece. The non-transferred arc ionises the centrally fed plasma gas (inert gases, as, e.g., Ar or He) thus causing a plasma jet of high energy to emerge from the nozzle. This plasma jet serves to produce and to stabilise the arc striking ability of the transferred arc gap. The surfacing filler metal powder added by a feeding gas flow is melted in the plasma jet. The partly liquefied weld filler metal meets the by transferred arc molten base metal and forms the surfacing bead. A third gas flow, the shielding gas, protects the surfacing bead and the adjacent high-temperature zone from the surrounding influence. The applied gases are mainly inert gases, as, for example, Ar and He and/or Ar/He mixtures.
The method is applied for surfacing small and medium-sized parts (car exhaust valves, extruder spirals). Figure 11.15 shows a cross-section of armour plating of a car exhaust valve seat. The fusion line, i.e., the region between surfacing and base metal, is shown enlarged on the right side of Figure 11.15 (blow-up). It shows hardfacing with cobalt which is high-temperature and hot gas corrosion resistant.

In plasma arc hot wire surfacing the base metal is melted by an oscillating plasma torch, Figure 11.16.

The weld filler metal in the form of two parallel wires is added to the base metal quite independently. The arc between the tips of the two parallel wires is generated through the application of a separate power source. The plasma arc with a length of approx. 20 mm is oscillating (oscillation width between 20 to 50 mm). The two wires are fed in a V-formation at an angle of approx. 30° and melt in the high-temperature region in the trailing zone of the plasma torch.
For surfacing purposes, besides the arc-welding methods, the beam welding methods laser beam and electron beam welding may also be applied. Figure 11.17 shows the process principle of laser surfacing. The powder filler metal is added to the laser beam via a powder nozzle and the powder gas flow is, in addition, constricted by shielding gas flow.

**Friction surfacing** is, in principle, similar to friction welding for the production of joints which due to the different materials are difficult to produce with fusion welding, Figure 11.18. The filler metal is “advanced” over the workpiece with high pressure and rotation. By the pressure and the relative movement frictional heat develops and puts the weld filler end into a pasty condition. The advance motion causes an adherent, “spreaded” layer on the base metal. This method is not applied frequently and is mainly used for materials which show strong differences in their melting and oxidation behaviours.

A comparison of the different surfacing methods shows that the application fields are limited - dependent on the welding method. A specific method, for example, is the low filler/base metal dilution. These methods are applied where high-quality filler metals are
welded. Another criterion for the selection of a surfacing method is the deposition rate. In the case of cladding large surfaces a method with a high deposition rate is chosen, this with regard to profitability.

In **thermal spraying** the filler metal is melted inside the torch and then, with a high kinetic energy, discharged onto the unfused but preheated workpiece surface.

There is no fusion of base and filler metal but rather adhesive binding and mechanical interlocking of the spray deposit with the base material. These mechanisms are effective only when the workpiece surface is coarse (pre-treatment by sandblasting) and free of oxides. The filler and base materials are metallic and non-metallic. Plastics may be sprayed as well. The utilisation of filler metals in thermal spraying is relatively low. The most important methods of thermal spraying are: plasma arc spraying, flame spraying and arc spraying.

In **powder flame spraying** an oxyacetylene flame provides the heating source where the centrally fed filler metal is melted, Figure 11.19. The kinetic energy for the acceleration and atomisation of the filler metal is produced by compressed gas (air).
In contrast to powder flame spraying, is for flame spraying a wire filler metal fed mechanically into the centre cone, melted, atomised and accelerated in direction of the substrate, Figure 11.20.

In plasma arc spraying an internal, high-energy arc is ignited between the tungsten cathode and the anode, Figure 11.21. This arc ionises the plasma gas (argon, 50 - 100 l/min). The plasma emerges from the torch with a high kinetic and thermal energy and carries the side-fed powder along with it which then meets the workpiece surface in a semi-fluid state with the necessary kinetic energy. In the case of shape welding, steel shapes with larger dimensions and higher weights are produced from molten weld metal only. In comparison to cast parts this method brings about essentially more favourable mechano-technological material properties, especially a better toughness characteristic. The reason for this lies mainly in the high purity and the homogeneity of the steel which is helped by the repeated melting process and the resulting slag reactions. These properties are also put down to the favourable fine-grained structure formation which is achieved by the repeated subsequent thermal treatment with the multi-pass technique. Also in contrast with the shapes produced by forging, the workpieces produced by shape welding show quality advantages,
especially in the isotropy and the regularity of their toughness and strength properties as far as larger workpiece thicknesses are concerned. In Europe, due to the lack of expensive forging equipment, very high individual weights may not be produced as forged parts. Therefore, shape welding is, for certain applications, a sensible technological and economical alternative to the methods of primary forming, forming or joining, Figure 11.22.

Figure 11.23 shows an early application which is related to the field of arts.

The higher tooling costs in forging make the shape welding method less expensive; this applies to parts with certain increasing complexity. This comparison is, however, related to relatively low numbers of pieces, where the tooling costs per part are accordingly higher, Figure 11.24.
Figure 11.25 shows the principal procedure for the production of typical shape-welded parts. Cylindrical containers are produced with the “Baumkuchenmethode” method: the filler metal is welded by submerged-arc with helical movement in multiple passes into a tube which has the function of a traction mechanism (for the most part mechanically removed later). This brings about the possibility to produce seamless containers with bottom and flange in one working cycle.

Elbows are mainly manufactured with the Töpfer method. On the traction mechanism a rotationally symmetrical part with a semicircle cross-section is produced which is later separated and welded to an elbow, Figures 11.26 and 11.27. The Klammeraffe method serves the purpose to weld external connection pieces onto pipes. A portable unit which is connected with the pipe welds the connection pipe in a similar manner to the Töpfer method.
In the case of **electron beam surfacing** the filler metal is added to the process in the form of a film, Figure 11.28.