# **Wind towers:** factors leading to fabrication success

**Erwin Gering, global key account manager for wind energy, pipe mills and steel construction at voestalpine Böhler Welding, outlines key consideration for those wishing to improve the performance of onshore and offshore wind tower fabrication processes.**

For a total solution for the three related global problems of energy security, climate change and affordability, the key lies clearly in generating more power from renewables. To achieve the net-zero emission targets by 2050, wind energy will be a major contributor. But strong growth in wind power capacity will require large-scale manufacturing of wind towers and foundations, where standardisation and automated welding is key.

Most of the welding required for wind towers involves circumferential and longitudinal joining of the large diameter sections for towers and in the components for the offshore foundations, such as monopile jacket foundations and pin piles to anchor the towers to the sea bed. These welding joints are mostly welded using the submerged-arc welding process (SAW).

The welding procedures for these foundation components require high performance welding flux and wire that can deliver consistent product quality. voestalpine Böhler Welding is continuously optimising welding consumables for the different applications in wind energy to fulfil new challenges due to increased dimensions, weights and thicknesses and the growing use of steel grades with higher strength.

### Erwin Gering: voestalpine Böhler Welding

Working for voestalpine Böhler Welding for 13 years, Erwin Gering's current focus is on the submerged-arc welding (SAW) process, having previously been the global product manager for SAW wire and flux. "My job is focused on understanding the needs of customers in wind energy, especially concerning the use of SAW for the manufacture of wind towers and offshore foundations," says Gering.

## General requirements for welding wind towers

**1. Minimal welding defects**

For serial manufacture of these large components, it is essential to have a constant predictable throughput. Therefore welding defects that need to be repaired before progressing to the next production step must be kept to the absolute minimum.

Possible weld defects include: slag inclusions; gas inclusions/porosity; lack of fusion; poor bead aspect; pock marks on the weld surface; solidification cracks; and hydrogen-induced cracks.

In general, the majority of weld defects are caused by factors such as incorrect parameter settings; inconsistent manipulation, wire positioning or seam tracking; poor weld preparation with respect to either geometry, or contamination; inappropriate flux properties and quality; and unreliable or inadequate welding equipment.

Often, we tend to look for a single root cause when a problem or weld defect arises. A more holistic approach is recommended, however, due to the interaction of all the above mentioned weld defects and their causes. But let us first focus on the influence of SAW welding flux, which is very important in minimising welding defects.

Selecting a fluoride-basic flux with a high basicity index is often necessary for wind towers to achieve the required high toughness properties in the weld metal. An aluminate-basic flux with lower basicity is often preferred because it gives better welding stability, but this flux may not deliver the required toughness levels. Flux types are purpose-designed as a compromise between conflicting requirements, with their characteristics depending on the exact formulation and selection of the raw materials and the flux manufacturing process.

Relevant flux characteristics to minimise weld defects are: good arc stability; nice wetting and bead aspect; good bead appearance; easy slag release with no residuals; proper grain size distribution of small and large grains; and the required grain shape and strength.

*voestalpine BÖHLER Welding's SAW range of cored wire and flux combinations offer the welding performance and quality required for the manufacture of offshore and onshore wind towers.*

During welding operation, not all of the flux is melted to form slag and a large percentage of this flux can be re-used. It is important to avoid too much mechanical abrasion on the flux during flux feeding, though, since the flux granules are relatively soft and can easily be reduced to dust. This changes the particle size distribution of the flux, which affects performance characteristics such as wetting, bead appearance and gas shielding. To ensure a constant grain size distribution during recycling it is important to have good grain shape, strength and abrasion resistance to minimise dust formation. A consistent mixing ratio of recycled and fresh flux should also be maintained to prevent welding performance being affected. In addition, the flux must be kept dry to avoid moisture-related issues such as gas inclusions, pock marks and hydrogen cracking.

The lowest possible level of diffusible hydrogen is essential to reduce the risk of hydrogen-induced cracking. Fluxes with a higher level of diffusible hydrogen normally require higher preheat temperature, especially in the case of base metals with higher Carbon-equivalents, such as flanges and components that use higher strength grades (S420/S460). Robust moisture-proof flux packaging, aluminium composite foil, for example, is key to ensuring low hydrogen levels without the need to pre-dry the SAW flux.



*BÖHLER Welding SAW fluxes are designed to deliver good arc stability; nice wetting and bead aspect ratios; good bead appearance; easy slag release; proper grain size distribution; and the required grain shape and strength.*

## Stable, high level mechanical properties

Mechanical properties of the weld metal depend on: the welding wire and its chemical composition; the chemical activity of the flux; the base metal composition and the dilution rate with the base metal; the welding parameters – current type, interpass temperatures and wall thickness; and the weld bead thickness and grain refining under single- or multi-pass conditions.

Clearly, the SAW wire-flux combination has a major influence on the mechanical properties of the weld metal. Table 1 highlights how wire-flux combinations have been optimised for different SAW welding requirements.

For onshore wind towers, mostly mild steel grades are used with a minimum specified yield strength of 355 MPa. Some parts of the wind tower might be constructed with a higher strength steels such as S420. Charpy V-notch toughness requirements vary from 27 to 50 J at test temperatures of between 0 and -50 °C.

In general, there is a preference for using a single flux and wire combination for fabricating all the wind tower sections for onshore projects with different requirements. This is not only for logistical reasons but also to eradicate errors that could result in inadequate weld metal properties. The combination of the Union S 2 Si wire with UV 408 TT flux has been developed specifically for onshore wind towers to cover this wide application range.

For offshore wind towers and foundations, the manufacturing requirements are on a higher level. Base metals vary from S355-S460 and Charpy toughness requirements vary from 27 - 50 J at test temperatures of between -40 and -60 °C. However, the industry normally demands wire-flux combinations that provide Charpy-V toughness levels greater that 100 J at -60° C. For this toughness level, a fluoride-basic flux with a relatively high basicity index is frequently used, mostly with neutral chemical additions with respect to Mn and Si. To ensure the higher strength level, the matching SAW wire has a higher S 3 Si alloy composition.

Union S 3 Si wire with UV 418 TT flux is the optimised combination for these offshore requirements. For large components with high wall thickness that use these high strength steels with higher CE-equivalents, a very low level of diffusible hydrogen is very important to avoid cold cracking issues. Fluxes with a higher level of diffusible hydrogen will normally require a higher preheat temperature.

The latest improvements of UV 418 TT flux have resulted in a very low level of diffusible hydrogen for DCEP and for AC polarity for both sinus and square wave shapes.

## Minimising welding time

Tact time – the time between starting units – is a critical number because it decides the total output of a production line. Depending on the situation, the SAW welding station could be the bottle-neck that governs this tact time. Every subdivided action/element inside the SAW station should be

| SAW wire | Flux | Flux type BI | Min yield (MPa) | Min tensile (MPa) | CVN toughness M-Run (J) | Application Steel grade | Classification EN ISO AWS |
|---|---|---|---|---|---|---|---|
| Union S 2 Si | UV 408 TT | AB 1,7 | 420 | 500 | 70 @ -50°C | 2 run/multi-run Onshore, S355-S420 | S 42 5 AB S2Si H5 F7A8-EM12K-H4 |
| Union S 3 Si | UV 418 TT | FB 2,7 | 460 | 530 | > 100 @ -60°C | Esp. multi-run Offshore, S355-S460 | S 46 6 AB S3Si H5 F7A8-EH12K-H4 |
| Diamondspark S 55 HP | UV 418 TT | FB 2,7 | 460 | 530 | > 100 @ -60°C | Esp. multi-run High dep rate | S 46 6 FB T3 H5 F7A8-EC1 |
| Diamondspark S 56 HP | UV 400 | AB 1,9 | 460 | 530 | > 80 @ -60°C | 2 run/multi-run, High dep rate | S 46 6 FB TZ3 H5 F7A8-ECG |

*Table 1: voestalpine Böhler Welding wire and flux combinations optimised for different SAW welding requirements.*

evaluated to create reliable time-savings. Welding time (arc time) is one of them. Additionally, the increasing dimensions (diameter, length and wall thickness) of the components will have a significant effect on the number of cans/circumferential welds; the number of longitudinal welds, which may have two or three longitudinal welds per can; the weld lengths, particularly for the circumferential seams; the total weld volume and the total arc time.

A very efficient solution is to simultaneously complete several SAW weld seams in parallel. Another possibility is to reduce the weld volume. Attention must be paid to avoiding weld preparations that are too narrow, which increases weld defects rates. A good example of an efficient 'narrow gap' weld preparation for SAW process is a 7 - 8° bevel angle with a radius of 7 - 8 mm. Such a weld preparation can be made by dedicated machining equipment.

An alternative to reduce arc time is to increase the deposition rate. Welding procedures with very large bead cross-sections are more sensitive to inconsistent penetration profiles with less penetration introducing a lack of fusion risk. To avoid large weld beads, it may be necessary to increase the welding speed, but this must not result in poor weld bead appearance/aspect ratios. Increasing the welding speed is dependent on actual process variants, deposition rates and welding speeds; weld preparation geometry and consistency; operational characteristics of the wire and flux combination; the capabilities of the equipment (roller bed/seam tracking) and operator acceptance.

In multi-run applications, the underlying runs are partly refined by the subsequent run(s). With large weld bead cross sections, the share of reheated area decreases and this might have a negative effect on the mechanical properties, which also depend on the exact chemistry of the weld metal and the cooling rate (t8/5)

UV 418 TT flux has been optimised to reduce 'scattering' of Charpy-V toughness properties in welds with large bead cross-sections. Also, the composition of the seamless SAW wire diamondspark S 56 HP has been optimised to ensure very high toughness in large weld beads, including single-pass welds and two-run procedures.

There are a number of ways to increase the weld metal deposition rate, firstly by increasing the welding current. Using a larger diameter SAW wire will only give higher deposition rates when the welding current is also significantly increased. Similarly, using a smaller diameter wire with the same current will also result in a higher deposition rate.

*As well as being a reliable supplier of high quality and performance welding consumables, voestalpine BÖHLER Welding offers technical support and know-how from specialists in wind tower fabrication.*

Increasing the number of SAW wires in the weld pool using Tandem, Triple or 4-wires each with their own power source will also increase deposition. Here, the lead wire will often be DCEP, with the other wires using AC current to reduce magnetic interference. The advantage of AC is that it produces a 15% higher deposition rate compared to DCEP.

With twin-arc processes, a single power source is connected to a wire feeder mechanism feeding two relatively thin SAW wires via a single contact tip. Two wires with a diameter of 2.4 mm will result in a similar deposition rate curve to a single 3.2 mm wire at the same current. However, due to the double arc in the twin-arc process, it is possible to increase the current further and, in so doing, increase the deposition rate while still achieving stable welding performance. With a single 3.2 mm wire, the weld bead appearance/aspect ratio would become unacceptable at the same (high) current level.

Other high deposition process variants include adding additional cold wire; adding metal powder; Increasing the stick-out length; and using an AC welding current waveform. An AC square wave current waveform with increased negative polarity effect will also raise deposition rates.

These high speed welding solutions create a higher ratio of deposited weld metal per kW of power. The disadvantage is that they require investment in special equipment and increased complexity.

An alternative that does not require significant investment in equipment is to use the seamless SAW cored wire diamondspark S 56 HP. At same current, this wire provides an increased deposition rate of between 20% and 35% compared with a solid SAW wire with same diameter. Additionally, better operational characteristics and better bead aspect ratios enable the welding current and deposition rate to be increased. Depending on the applied welding procedure it is often possible to save 40% in welding arc time.

### Minimising product handling and preheating downtime

Optimal operative characteristics with good wetting and easy slag release will certainly help to enable welding to proceed without unscheduled process interruptions. Packaging formats such bulk packaging of up to 1 000 kg for SAW welding wire results in minimal downtime for exchanging wire spools.

For flux, we can apply our DRY SYSTEM, which means that the flux is protected against moisture pick up during transportation and storage. This is done using sealed aluminium composite foil or aluminium liners. DRY SYSTEM enables the flux to be used for most applications without prior re-baking (350° C × 2-4 hrs). Besides the standard 25 kg bags, we also provide 500 or 1 000 kg DRY SYSTEM big bags.

Properly controlled welding flux is also required to minimise the hydrogen level in the weld metal. An increased level of diffusible hydrogen might require a higher preheat and minimum interpass temperature, especially in the case of base metals with higher C-equivalents, such as flanges in S420 and S460 higher strength grades.

A higher preheat temperature results in higher energy cost and takes more time to bring the large components to temperature.

Reliable supply with high quality and performance levels of welding consumables is key, as well as technical support and know-how from our specialists in wind tower fabrication.

***www.voestalpine.com/welding***