MANUFACTURE OF OUTSTANDING THICK-WALLED CONSTRUCTIONS

E. ENGINDENIZ[1], E. KAPLAN[2], E. GANIOGLU[2], F. YUKSEL[2], N. BAYEZID[2] and R. ROSERT[1]
[1]Altleiningen, Germany
[2]Istanbul, Gemlik, Turkey

Manufacture of specific elements up to a unit weight of 1000 t, used in current refinery projects, is presented. Constructions of the highest apartment and office tower in Moscow, Russia, as well as the football stadium «Shakhtar» in Donetsk, Ukraine, are described. In addition to the specific welding procedure variants, logistic issues during transport and assembly are discussed.

Keywords: *arc welding, welded structures, thick-walled sheets, multi-pass welding, flux-cored wires, efficiency of welding process, unique constructions*

CIMTAS was founded 37 years ago as subsidiary of the largest construction company ENKA in Turkey, and mainly produces pressure vessels, storage tanks, wind turbines and all kinds of steel constructions. While the Company headquarters are located in Istanbul on the European side of the Bosporus, two production facilities are situated in Gemlik on the Asian side of Turkey. The town of Gemlik is located approximately 100 km south of Istanbul at the Sea of Marmara close to Bursa.

A total of 47,000 t of steel was processed in these facilities in the year 2007. Amongst others numerous pressure vessels were produced for the GASCO project in the United Arab Emirates and the LNG project in Angola. The construction of these petrochemical facilities is still on-going. In addition, the Company supplies a number of pressure vessels to the companies PETROFAC BG, Tunisia, and MAN. Six of these vessels had a unit weight of slightly more than 500 t. One vessel which is currently being manufactured will even reach a shipping weight of 1000 t.

In this paper we will describe the latest activities of the CIMTAS Corporation, which include the manufacture of extremely thick-walled pressure vessels, as well as building special steel and elevated steel constructions. Two of these buildings are the currently highest apartment and office building in Moscow, Russia, and the football stadium «Shakhtar» in Donetsk, Ukraine. These steel construction projects also require the use of thick-walled sheets currently exceeding a thickness of 200 mm.

High-rise building «Eurasia» in Moscow. Currently the highest building in Russia is being built in the city centre of Moscow. The two-tiered tower with 5 underground and 74 above ground floors is of 310 m high. The high-rise building houses office space, as well as apartments, shops, restaurants and a health club.

The multi-storey car park on the lower floors can accommodate up to 1000 vehicles. Figure 1 shows how the building is planned to look after its completion in May 2009.

The construction is made from steel and weights 27,000 t. The total net floor area of the building is 200,000 m^2. 24,000 components have been manufactured by welding, thereof 21,000 beams, 2300 box profiles as support columns and 700 braces. Steel grades S355 J2G3 and P 460 NL1 with a sheet thickness up to 404 mm were used for the base plates of the foundations and steels with sheet thicknesses up to 220 mm were used for the closed box profiles.

Football stadium «Shakhtar» in Donetsk. In June 2006 ENKA group was commissioned to build a 5 star stadium in line with UEFA and FIFA regulations in Donetsk.

In August of the same year the Company already started to excavate the foundations and will thus be able to finish this huge building in time in August 2008.

Figure 2 shows impressively the special form of the roof construction which weighs approximately

Figure 1. High-rise building «Eurasia» in Moscow

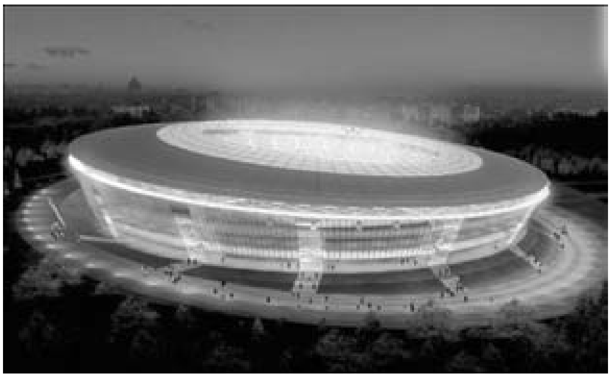


Figure 2. Football stadium «Shakhtar» in Donetsk

3800 t with the total steel weight of the construction amounting to 4300 t.

The architect had the idea to construct a harmonic roof without supports. This was realized by using space trusses spanning 60 m supported on space truss beams which protrude as far as the trusses. As shown in Figure 3, the space truss beams and the space truss are in one plane. The roof height is 54 m. Thanks to its roof which is dipping down to the south the stadium matches the contours of Leninsky park. This reduces the height of the roof by one third resulting in a significantly increased amount of sunlight shining on the lawn. However, in terms of structural design this means that all 12 truss beams have different dimensions. Therefore, the production of the elements and the subsequent assembly logistics were extremely time-consuming and expensive. The roof segments have been designed in such a way that they can compensate certain ground shifts caused by the coal mining activities which used to take place at this site. The stadium accommodates 50,000 football fans including 5000 VIP guests. The size of the construction site amounts to 255,000 m^2. The built-up area including the rising gradient is 46,780 m^2. The stadium cost approximately 180 mln Euros.

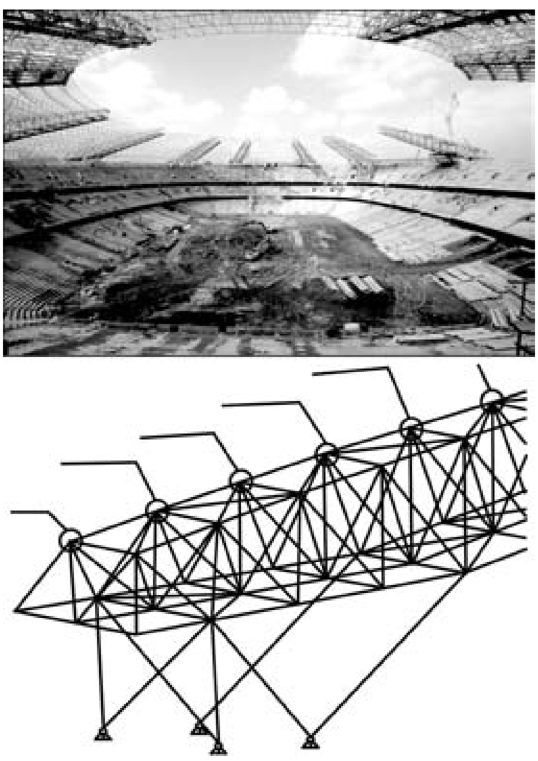
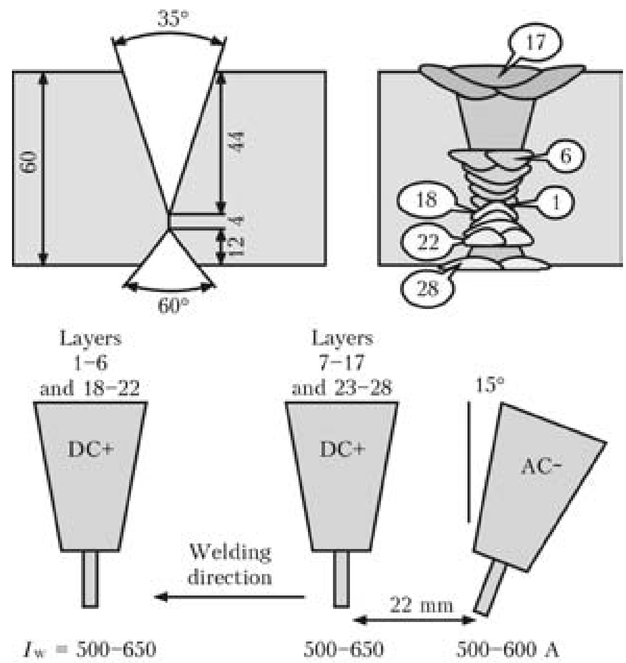


Figure 3. «Shakhtar» roof construction (May 2008)

Another special feature of this stadium is the impressing lawn which has a size of 24,000 m^2. The glass facade which runs around the entire perimeter and includes some transparent roof constructions will make the stadium look like a jewel once the floodlights are turned on. It seems that the football club «Shakhtar» will be the owner of the most modern stadium in Eastern Europe for some time to come and the stadium is planned to be the venue of a semi-final game of the European Football Championship 2012.

Welding procedure variants. On account of the operating conditions and the practical experiences submerged-arc welding (SAW) was chosen as the main pre-production process, especially since the dimensions and geometries of the elements were predestined for this method. The use of flux-cored electrodes was considered for economic and qualitative reasons and qualified for wall thicknesses up to approximately 60 mm in twin-wire tandem variants. As can be seen



Impact work at –46 °C of welded bead with notch at the middle part, J/m^2	
Layers 1–17	Layers 18–28
224	134
180	202
190	164
Average 204.5	176.5

Figure 4. Scheme of SAW of steel SA 516 Cr 70 N (heat-treated at 630°C for 12 h) with flux-cored wire TC 731B 4.0 mm diameter and flux BF 10, and results of the procedure test

in Figure 4, 4.0 mm diameter basic flux-cored wires are used for this method with the first 5–6 beads at the root area on each side being welded using the single-wire technique.

Thanks to the cleaning effect of the basic slag formers contained in the welding flux the sealing run does not have to be ground or bored out. The wetting of the side walls is always error-free and the overlap is always guaranteed at the chosen process parameters and with a root face of 4 mm. This is the main reason for the superior cost effectiveness of this method compared to solid-wire welding. The repair quota is almost zero and the inconvenient non-productive times spent preparing the joints of the sealing run are no longer required. One of the reasons why the Company is extremely popular with customers and buyers is their brilliant impact toughness values which also contribute to its excellent reputation.

For the extreme wall thicknesses required in vessel production and for manufacturing the box profiles for the steel constructions mentioned above it was decided to use the twin-wire technology with two thick flux-cored wires 2.4 mm in diameter. After the pre-testing had been successfully completed this variant was approved in the scope of another procedure test and at the same time even upgraded to twin wire tandem. Figure 5 shows the documentation for a 197 mm thick sheet SA 516 Gr 70 N. While commercial mobile welding tractors are available for twin-wire tandem applications, the twin-arc tandem machines had to be built in-house.

Figure 6 shows a mobile station with two automatic machines. Two welds are simultaneously welded onto the box girder to meet the manufacturing tolerances.

As can be seen, the commercial twin-wire tractor was coupled with a trailer bearing additional twin-wire reels. Thus the profile is welded using 8 reels simultaneously.

Figure 7 shows the welding time using the example of a 197 mm thick joint in comparison of all SAW procedure variants. This examination should be regarded as supplement to increase the cost effectiveness if flux-cored wire SAW is used. Although the reduction of the welding time achieved by using the flux-cored welding technology in comparison to the other procedure variants lies between 18.8 and 20.0 %, the Company reports cost savings in production of up to 30 % since, as already mentioned earlier, the downtimes and repair times are minimized. Absolutely the same process parameters have been used for calculating the welding times represented in Figure 7.

These performance parameters are also used in production. The weld weight of the joint selected for this example was 76.6 kg/m. The weld reinforcement was

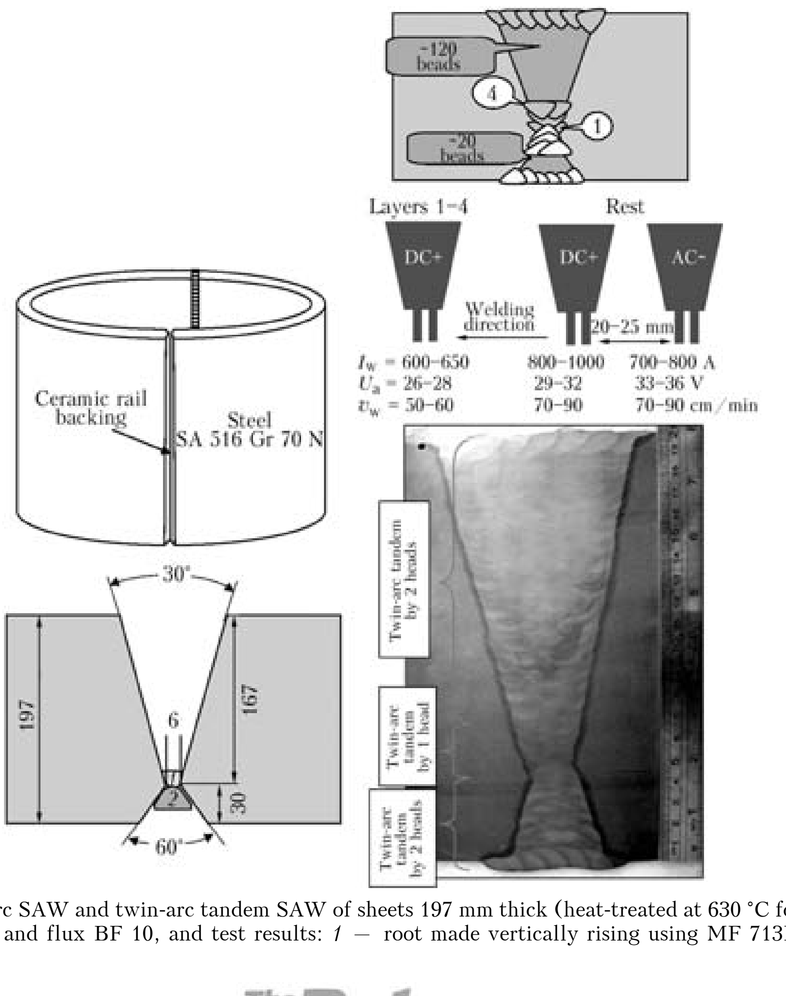


Figure 5. Scheme of twin-arc SAW and twin-arc tandem SAW of sheets 197 mm thick (heat-treated at 630 °C for 12 h) with two 2.4 mm flux-cored wires TC 731 B and flux BF 10, and test results: *1* — root made vertically rising using MF 713R and M21; *2* — formed ceramic rail backing

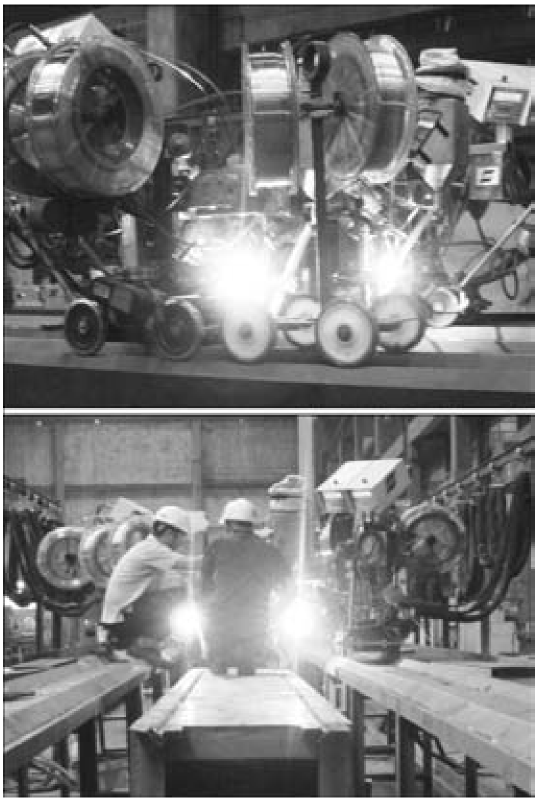
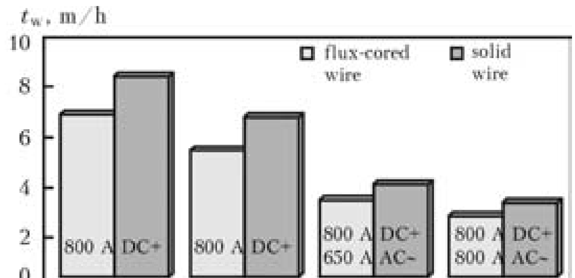


Figure 6. Mobile welding station with 2.4 mm flux-cored wires for twin-arc tandem SAW

Figure 8. Pre-production of the gusset plates for «Eurasia» (*a*) and «Shakhtar» (*b*) using flux-cored GMAW in Gemlik

taken into account with an average height of 2.5 mm. As expected, twin-arc tandem SAW using 4 flux-cored wires provides the best results.

In addition to the SAW technology, GMA welding was used exclusively with flux-cored wires. In Figure 5 it can be seen that the welding of the root using a rutile flux-cored wire on ceramics is performed in a vertical position rising upwards. This bead is used primarily to fasten the vessel halves but later it also forms the backing for the subsequent SAW.



Parameter	One-arc welding with 4.0 mm wire	Twin-arc welding: 2.4 mm two wires	4.0 mm two wires in tandem	2.4 mm four wires in twin-tandem
Flux-cored wire	6.54	5.10	3.10	2.43
Solid wire	8.06	6.38	3.73	3.0
Time saving, %	18.86	20.0	16.87	19.0

Figure 7. Comparison of the welding time for 197 mm thick joint (according to Figure 5)

CIMTAS is the company with the longest experience in flux-cored wire welding in Turkey. Its employees have been welding using flux-cored wires and shielding gas for more than 25 years. When completing the building «Eurasia» and stadium «Shakhtar», for example, all fillet and butt welds for lower sheet thicknesses were performed using the GMAW procedure and seamless flux-cored wires. Two type wires containing rutile slag (E 71 T1 and E 81 T1-Ni1) and wire with metal powder filling (E 70 C-6 M9) were used.

Figure 8 shows how intensively the shielding gas flux-cored wire technique is used. It is even used during the assembly on the construction site. Other welding procedures, which were used for the manufacture of the elements shown above, include TIG, stud and laser welding, as well as electroslag strip cladding and firecracker welding using stick electrodes.

The latter is only used to a small extent and only on construction sites. The thin-walled tubes for the roof elements of the stadium «Shakhtar» were manufactured using laser welding.

Delivery of the elements. The continuously increasing weight of the units which had to be transported was a big challenge for the region at the Sea of Marmara. The capacity of the harbour facilities of the BORUSAN logistics company had to be gradually enlarged and qualified for the loading of the pressure vessels over the past 15 months. The distance on land which had to be covered between the production facility and the harbour is approximately 3 km. The

Figure 9. Loading of a 500 t slug catcher surge vessel onto a freighter at Gemlik harbour

roads along this path also had to be stabilised and reinforced in a lot of places. Figure 9 shows the loading of surge vessel onto a freighter.

The heavy lorry has 31 axles. Currently all measures are taken to prepare the harbour for the transport of the 1000 t CO_2 absorber.

The maximum unit loads for «Eurasia» and «Shakhtar» amount to 70 t.

Therefore, they can be handled as is shown in Figure 10. The logistical problems mainly regard the timing. Due to the risk of freezing waters the elements can only be transported from April to October. To minimize storage costs procurement and production planning are precisely coordinated. Currently this causes relatively large problems since the worldwide steel market is suffering from shortages.

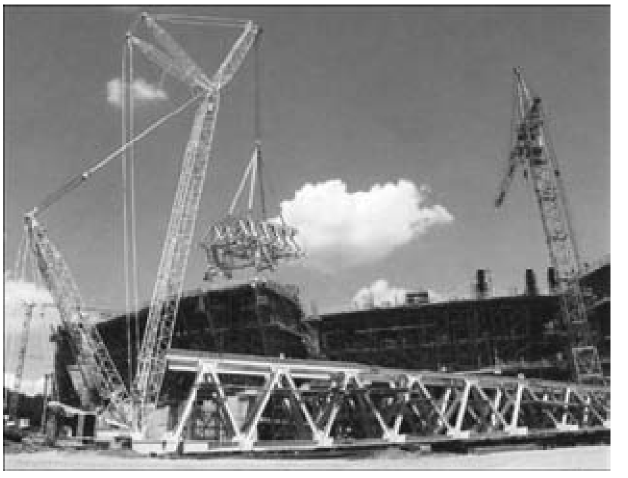


Figure 10. Handling of the roof girders in Donetsk

So, the concerned steel constructions are «Eurasia», the highest apartment and office building in Moscow, and the stadium «Shakhtar» in Donetsk. All projects include wall thicknesses of approximately 200 mm. The production facilities are located in Turkey. For the welding processes both the SAW and the GMAW procedures using flux-cored wires are applied. In addition to the qualitative advantages of the flux-cored wire technology, the economic aspect is also highlighted.

EFFICIENCY OF MELTING OF ELECTRODE WIRE IN SUBMERGED-ARC SURFACING WITH INFLUENCE OF TRANSVERSE MAGNETIC FIELD

A.D. RAZMYSHLYAEV, M.V. MIRONOVA, K.G. KUZMENKO and **P.A. VYDMYSH**
Priazovsky State Technical University, Mariupol, Ukraine

A device has been developed, which generates a transverse magnetic field (TMF), for the process of submerged-arc surfacing using wire. It is shown that in reverse polarity surfacing the impact of a constant and alternating TMF of 50 Hz frequency increases equally the coefficient of melting of electrode wire α_{melt} both of ferromagnetic and nonmagnetic materials. Maximum increase of wire α_{melt} is 20–30 % at the magnitude of transverse component of TMF induction of 30–45 mT.

Keywords: *submerged-arc surfacing, electrode wires, transverse magnetic field, induction, melting coefficient*

Technological peculiarities of arc welding and surfacing process using transverse magnetic field (TMF) are considered in the works [1–8]. It is followed from them that in consumable electrode argon arc welding [2, 3] using electrode wire of 1–1.2 mm diameter and TMF influence, the decrease of penetration depth and increase of weld width are observed. During welding and surfacing using wire of 3 and 4 mm diameter under the flux AN-348A at the impact of TMF of 50 Hz frequency, the penetration depth decreased in 1.5 times and width of a weld (bead) negligibly increased (efficiency of melting wires was not studied) [4]. For surfacing of beads using wire Sv-08GA of 2 mm diameter under the flux AN-348A, the change of frequency TMF in the limits of f = 0–20 Hz and induction of magnetic field B_x = 0–0.015 T (at reverse polarity) the data are given which are not quantitative but qualitative, i.e. only tendency of influence of frequency of induction of TMF on penetration depth of metal and width of a bead was established [5]. In the work [6] it was shown that in surfacing using wire Sv-08A of 4 and 5 mm diameter under the flux AN-348A on the plates of steel St3 under the impact of TMF of 50 Hz frequency, the depth of metal penetration decreased whereas width of a bead increased. It