**International Institute of Welding**
**Hungarian**

**Institut International de la Soudure**
**Délégation Hongroise**

# Economy of a high power welding technology

**K. Jármai*, J. Farkas*, P. Markó****

*** University of Miskolc, Hungary**
**** MCE VOEST-H Ltd. Nyíregyháza, Hungary**

**IIW-Doc. XV- WG9-10-01, XV-1095-01**

**Ljubljana, 2001**

## Abstract

Economy has a great effect at the manufacturing of special, low series welded steel structures. The main cost is the welding one, so if the welding technology is more economic, that results in a cheaper production. In this paper three different welding technologies have been compared: the traditional mixed gas with 18% $CO_2$ and 82% Argon, the RAPID ARC technology with 92% Argon, 8% $CO_2$ and 0.03% NO and the TIME I. technology with 25% He, 72% Argon and 3% $O_2$. It is shown that increasing the free length of the electrode one can increase the power up to 20-30% comparing to the traditional one. It is shown, how to calculate the cost of RAPID ARC, and what are the differences in costs in the case of a welded box beam.

**Keywords:** welding costs, advanced welding technology, minimum cost design

In all welding processes air pollutants consist of fumes and gases, which are mainly made up of metal oxides. Gases are created due to the high temperature and ultraviolet radiation around the arc. Some gases are transformed in the welding process, i.e. ozone, nitrogen dioxide, nitric oxide, carbon dioxide. The ozone formation is the highest during MIG and TIG welding of aluminium. During welding of mild steel and stainless steel the level of ozone emission can be also very high.

Shielding gases have an effect on the emission of fumes and gases during gas shielded arc welding. Adding nitric oxide to the shielding gas, the emission of ozone can be reduced. Nitric oxide reacts readily with ozone during the formation of oxygen and nitrogen dioxide and this chemical reaction takes place in the vinicity of the electric arc, where the concentration of ozone is the highest [1].

RAPID ARC technique is intended to raise the welding speed, in many cases more than double, depending on the application. One great advantage of the RAPID ARC technique is that it can performed with existing welding equipment. The higher wire-feed speed and the preheated wire offer high deposition rates. The wire-feed speed in conventional MIG/MAG welding is between 5 and 15 meter per minute. In RAPID ARC welding one can use speeds up to 25 meters per minute. The reason of this high speed is the longer electrode stick out – 20 to 35 mm as compared to 10 to 15 in conventional MIG/MAG welding. Further raise of the resistant heating is the thinner wire diameter, 0.8-1.2 mm is recommended. The shielding gas named MISON 8 is an argon-based mixture with 285 ppm of nitrogenoxide (NO) to reduce the amount of ozone generated during the welding process [2].

Both RAPID ARC and TIME provide very even transitions from weld to base metal, which means greater fatigue resistance (Fig. 1.). The penetration profile is also better with these technologies than that of in conventional MIG/MAG process, thus they reduce the risk of fusion defects.

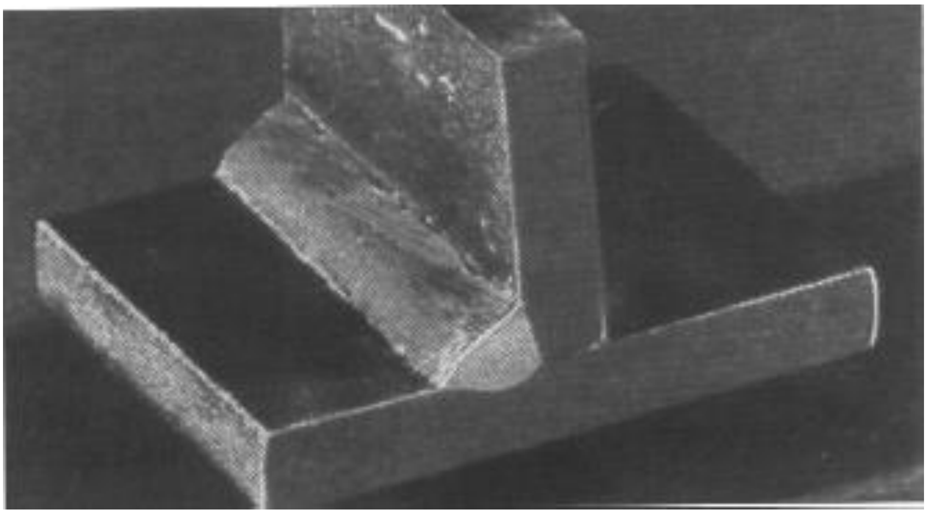

Fig. 1. Fillet weld welded with RAPID ARC

In the new technologies the heat input is somewhat lower than that in conventional MIG/MAG welding. This means that the heat-affected zone is narrower and distortion is lower. Lower heat input also means quicker cooling, creating a risk of forming brittle martensite in the heat-effected zone. However investigations show that, with the new technologies, welding provides fully satisfactory welds with good impact strength in the heat-affected zone.

RAPID ARC technology needs only a small investment to change the conventional technology. Since significant higher productivity is achieved, the pay-back on this investment is usually rapid.

T.I.M.E. is a GMAW process, with solid wires. Its deposition rate is higher due to the higher wire-feed-speed. Both penetration and bead appearance are good. It has a low tendency to undercut with good side-wall-fusion. he hydrogen content is weld metal is low.

Manual arc welding is a relatively hard work, even if there were developments in the working conditions. From this point of view Hungary has a competitiveness and there was a bloom on the field of steel structure production last years.

On the other hand the labour and training costs of highly educated welding specialists increased. Also the additional costs like health insurance and taxes are increased.

Fig. 2. Welded box beam

Fig. 3. Transportation of the welded box-beam

One economic solution is to increase the power of the welding technology, keeping the health- and environmental protection on the same level.

At special box beams never one can use robots, due to their sizes and shapes (Fig. 2.). In the Hungarian steel production market mainly Euro-profiles with low labour costs are used on the computer controlled production lines. The competitiveness of these productions is very limited, comparing to the concurrent companies. The reason can be found in the transportation cost, since the cheap, but small labour cost has not too great effect. The transportation cost can be very high, if the sizes of the structure, or substructure are over the transportation limits of the roads (Fig. 3.).

We would like to show the process of development at MCE VOEST-H Ltd. in this field from 1995. MCE VOEST-H Ltd. was founded in 1989 for the production of lightweight welded steel structures. Mainly steel grades of S235 and S355, sometimes a special stainless steel have been used. The company sent qualified welders to Austria and Germany for on site welding. Even if the main technology for this kind of work was the Shielded Metal Arc Welding, we introduced the Gas Metal Arc Welding with Mixed Gas instead. Now we are producing butt weld of bridge flange plates, where the plate thickness can be around 100 mm welded with the GMAW-Mix technology. From the very beginning mixed gas with 18% $CO_2$ and 82% argon [1] has been used.

The gas price has a great effect on the cost of welding. Table 1. shows the shielding gases for different technologies. Table 2. shows the welding times, cost of shielding gases and the total cost percent in the case of a fillet weld $a_w$=6 [mm] with 1 [m] length.

Table 1. Shielding gases for different technologies

| Shielding gas | Traditional GMAW-MIX | RAPID ARC MISON 8 | TIME I. LINFAST 25 |
|---|---|---|---|
| Content | 18% $CO_2$ + 82% Ar | 92% Ar + 8% $CO_2$ + 0.03% NO | 25% HE + 72% Ar + 3% $O_2$ |

Table 2. Welding times, cost of shielding gases and the total cost

| Technology | Traditional GMAW-MIX | RAPID ARC MISON 8 | TIME I. LINFAST 25 |
|---|---|---|---|
| Welding time [min] | 100% | 84% | 81% |
| Cost of shielding gas [$/m] | 100% | 155.6% | 438.5% |
| Total cost of welded joint [$/m] | 100% | 96.9% | 134.4% |

The great difference between the cost of the technologies comes from the shielding gas costs. For the RAPID ARC technology the gas is cheaper, the use can mix himself.

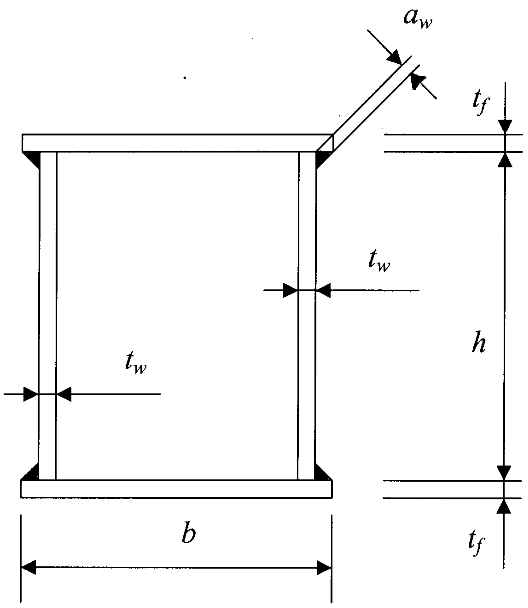

Fig. 4. Welded box beam

In order to illustrate the cost savings achievable by using the RAPID ARC technology, we compare the welding costs of a box beam shown in Figure 4. The beam is simply supported with a span length of 20 m. The beam is subjected to a uniformly distributed normal load of factored intensity $p$ = 73.5 N/mm. In the optimization the objective function is the cross-sectional area

$$A = 2ht_w + 2bt_f \tag{1}$$

The stress constraint  can be formulated as follows:

$$\sigma_{\max} = \frac{M_{\max}}{W_x} \leq f_y \tag{2}$$

where the section modulus is expressed as

$$W_x = \frac{h^2 t_w}{3} + bht_f \tag{3}$$

The local buckling constraint for the compression flange is

$$\frac{b}{t_f} \leq \frac{1}{\delta} = 42\varepsilon; \qquad \varepsilon = \sqrt{\frac{235}{f_y}} \tag{4}$$

The local buckling of webs is

$$\frac{h}{t_w} \leq \frac{1}{\beta} = 124\varepsilon \tag{5}$$

Assuming that the local buckling constraints are active, (1) can be written as

$$A = 2\beta h^2 + 2\delta b^2 \tag{6}$$

and, using (3), (2) takes the form of

$$W_x = \frac{\beta h^3}{3} + \delta b^2 h \geq W_0 = \frac{M_{\max}}{f_y} \tag{7}$$

Substituting $b^2$ from (6) into (7) one obtains

$$A = \frac{2W_0}{h} + \frac{4\beta h^3}{3} \tag{8}$$

The condition of d$A$/d$h$ = 0 gives

$$h_{opt} = \left( \frac{3W_0}{4\beta} \right)^{1/3} \tag{9}$$

In our numerical example the maximum bending moment is

$$M_{\max} = \frac{pL^2}{8} = 3675x10^6 \text{ Nmm} \tag{10}$$

the yield stress is $f_y$ = 235 MPa, the rounded values of the optimum dimensions are

$h_{opt}$ = 1130, $t_w$ = 9, $b = h\sqrt{\beta / \delta} = 660$, $t_f$ = 16 mm.

For the welding of the plates of box beam we use 4 fillet welds of size $a_w$ = 4 mm.

It should be mentioned that it is necessary to use transverse diaphragms welded into the box beam to avoid distortions of the rectangular box shape, but we do not calculate with the welds connecting the diaphragms to the box section.

The three parts of welding cost are as follows:

$$K_W = k_W(T_1+T_2+T_3) \tag{11}$$

where $T_1$ is the time of preparation and assembly, $T_2$ is the time of welding, $T_3$ is the time for additional works such as deslagging etc. $k_W$ = 0.5-2.0 \$/min is the fabrication cost factor [4,5]. It is assumed that $T_1$ is the same for both technologies.

In the case of the traditional GMAW-Mix (gas metal arc welding with mixed gas), according to [4], for 4 fillet welds of size $a_W = 4$ mm it is

$$T_2 = C_w a_W^n L_W = 0.3258x4^2x4x20 = 417 \text{ min}$$

and

$$T_3 = 0.3T_2 = 125 \text{ min.}$$

Taking $k_W = 0.8$ \$/min, without $T_1$, the welding cost is

$$K_W = 0.8(417+125) = 434 \text{ \$.}$$

In the case of RAPID ARC technology, according to the calculations of the first author [1], 3.1% time savings can be achieved in $T_2$ and it can be assumed that the time for additional works decreases to

$T_3 = 0.15T_2$, thus

$$T_2 = 0.969x417 = 404 \text{ min}$$

$$T_3 = 0.15x404 = 61 \text{ min}$$

$$K_W = 0.8(404+61) = 372 \text{ \$,}$$

i.e. 17% cost savings can be achieved with RAPID ARC technology.

Using the TIME technology, the welding cost increases due to high price of He gas by 34%, but the additional time $T_3$ can also be decreased to 15%. Thus, the welding costs are

$$T_2 = 1.34x417 = 559 \text{ \$}$$

$$T_3 = 0.15x559 = 84 \text{ \$}$$

$$K_W = 0.8(559+84) = 514 \text{ \$.}$$

Thus, the welding cost is 16% higher than that of the traditional GMAW-M.

## Acknowledgements

The research work was supported by the Hungarian Scientific Research Found grants OTKA 29326 and Fund for the Development of Higher Education FKFP 8/2000 project.

## References

1. Markó,P. *Application of high power shielded welding technology in fabrication of steel structures* (in Hungarian). Proc. 5th Conference of Steel Structures Fabrication, Dunaferr, Hungary, 2001. pp. 20-23.
2. Farkas,A.,Hajdú,J.,Markó,P.,Virág,J. *Opening up new vistas in the application of shielding gases*. Hegesztéstechnika, Vol. VII. 1996, No. 3. pp. 18-22.
3. RAPID Processing, A program for higher productivity and reduced welding costs. Reference applications, AGA, 1996. 8. p.
4. Jármai,K., Farkas,J. *Cost calculation and optimisation of welded steel structures*. J. Constructional Steel Research Vol. 50, 1999, pp. 115-135.
5. Farkas,J.,Jármai,K.: *Analysis and optimum design of metal structures*, Balkema Publishers, Rotterdam, Brookfield, 1997, 347 p. ISBN 90 5410 669 7