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TRENDS IN DEVELOPMENT OF WELD OVERLAYING DURING THE 21ST CENTURY

Mitko NIKOLOV

'Angel Kanchev' University of Ruse, Bulgaria

The present article discusses the trends in the development of welding and weld overlaying on the threshold of the new millennium and during it. It presents the trends in the production of welding materials for welding and weld overlaying in industrially developed and developing countries. The structure of welding methods is also shown, giving priority to its development until 2020.

Keywords: welding, arc welding, gas shielded arc welding, submerged arc welding

Between the 20th and 21st century, welding and weld overlaying are still one of the leading technological processes in the world economy. They are used in many industrial sectors such as the energy sector, machine building, ship building, bridge construction, automobile industry, transport, agriculture, petrol industry and even in space technologies. Welding is a technology for joining practically all kind of materials such as metals, non-metallic compounds, composite and non-organic materials. For this reason, the quality and competitiveness of welding production is of key importance for the effectiveness of each country's economy.

The aim of the present article is to determine the trends in the development of welding and weld overlaying at the beginning of the new millennium.

Exposition: At the beginning of the third millennium, welding and weld overlaying are one of the main technological processes for creating the material foundation of modern civilization. Perspectives for their development are directly related to the production of construction and welding materials. Despite the fact that the use of polymers, light alloys and composite materials in welded structures is constantly increasing, steel remains the main construction material in a worldwide scale (Fig. 1) (Karaganova, 2013). The big steel manufacturing countries at the beginning of the 21st century are China, Japan, the USA, Germany and Russia. In 2004 the world production of steel exceeded 1 billion tonnes. It is expected steel production to reach 1.8 billion tonnes during next years, with 31 % of it to come from China. According to world forecasts, the consumption of steel will remain stable and it will reach 40 billion tonnes annually. This amounts to 4–6 % of the total production of steel. It is well known that up to 70 % of the world steel production is used for the manufacturing of welded products, structures and equipment. In many cases, welding is the only possible and most effective method of building unassembled joints and resource retaining structures, approximating the optimal shape. In the future, the use of high-tensile steels in welded structures will continue to increase. The use of aluminium alloys, high-alloy steels as well as alloys containing effective modifiers (scandium and zirconium), which improve the weldability and mechanic properties of welds, will continue to rise. Titanium alloys with good weldability, high strength and corrosion resistance are being developed.

At the beginning of the 21st century, the world production of welding equipment and materials amounts to 40 billion dollars. According to Bernardskii and Makovetskaya (2005), 70 % of incomes are from welding materials while other 30 % come from equipment. According to specialists from German Welding Association, DVS, the production of electrode materials and equipment in 2004 amounted to 3.6 billion euros. This is one third of the production in the EU and equals to 11 billion euros. The world production at this time was three times higher and amounted to 33 billion euros (Bernardskii and Makovetskaya, 2007).

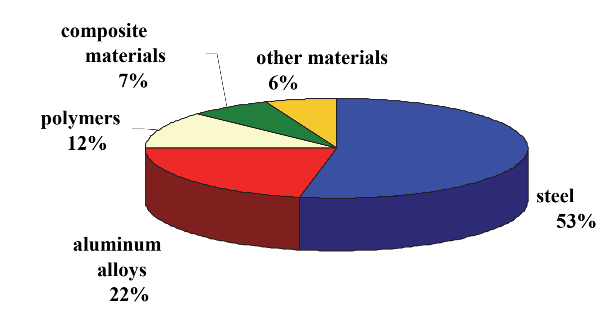

Figure 1 Materials used for welded structures

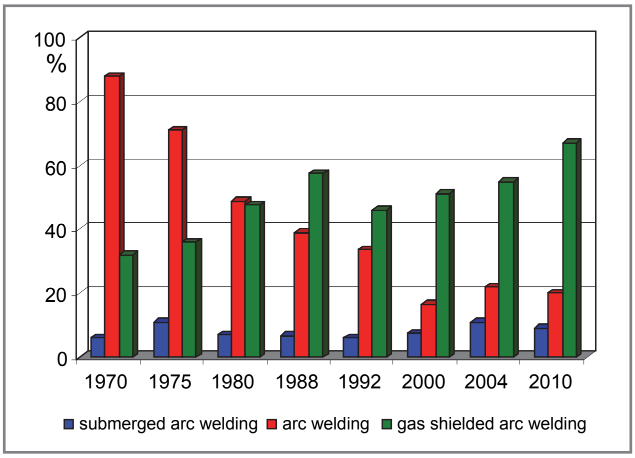

Figure 2 Production of welding materials for arc welding in industrially developed countries of the EU, the USA and Japan

There is a sound relationship between the volume of production (consumption) of steel and the use of welding materials employed for arc welding. What is more, for every tonne of rolled steel, there are 4–6 kg welding materials used. According to data from ESAB (Ruhlin, 2004), in 2000 weld overlaid metal in the countries of Western Europe was 422 thousand tonnes and 344 thousand tonnes in the USA, 236 thousand tonnes in Japan, 180 thousand tonnes in China (Bernardskii and Makovetskaya, 2005) and 152 thousand tonnes in India (Gehani, 2006). Arc welding continues to be one of the most widely spread technological options, occupying a share of up to 50 %. In fact, the total volume of produced welding materials is for welding with consumable electrodes (Ruhlin, 2004). In industrially developed countries during the last 30 years, weld overlaid manually arc welded metal has reduced three times and is 20–30 % of the total amount of weld overlaid metal (Gumenyuk and Ivaskov, 2006). Modern welding and weld overlaying are characterized by high level of mechanization, automation, use of robots and information technologies, computerized management, diagnostics and control. These trends have brought during the last 25–30 years a change in the structure of welding materials used for arc welding and weld overlaying in economically developed countries of the EU, the USA and Japan (Fig. 2).

During the period of 1986–2005, the amount of produced welding materials ranged from 320 million tonnes to 370 million tonnes. In 1991 it reached a record level of 422 million tonnes. After that, in 1994 production sharply decreased to reach 303 million tonnes in 2000. The structure of the world market of arc welding materials for the last five years is as follows: electrodes for manual arc welding – 20 %; solid electrode wire – 63 %; tubular-wire electrodes – 9 %; submerged arc welding materials – 8 % (Ilyushenko et al., 2009).

The production of electrode wire is highest in Japan. It increased 3.5 times (from 45 million tonnes to 160 million tonnes) for the period of 1990–2008. For the same period, the production of electrodes for manual arc welding went down 8 times, from 400 million tonnes to 48 million tonnes. There is a steady trend of reducing the production of electrodes for manual arc welding, while the production of small-diameter welding wire electrodes has increased in Japan. During the last years, the import of cheap welding wire in Japan from Korea, Taiwan, Thailand, etc. has risen (Bernardskii and Makovetskaya, 2007; Nikolov and Todorov, 2007; Karaganova, 2013; Ruhlin, 2004; Shalimov and Panov, 2008).

In Germany, which is the leading economy in the EU, the production of electrode wire increased approximately 2.5 times, i.e. from 30 million tonnes in 1978 to 76 million tonnes in 2010, while the production of electrodes for manual arc welding went down more than 5 times (from 88 million tonnes to 15 million tonnes respectively). It should be noted that there was a sharp rise of 41.7 % in the production of electrode materials in 1998 compared to that in 1997. The structure of produced welding materials in Germany corresponds to that in the EU where there is a drop in the production of electrodes and an increase in the production of electrode wire. During this period, there is also an annual growth of 2–3 % in the production of tubular-wire electrodes compared to the production of solid electrode wire (Bernardskii and Makovetskaya, 2007; Nikolov and Todorov, 2007; Karaganova, 2013; Ruhlin, 2004; Shalimov and Panov, 2008).

The production of electrode wire in the USA is analogical. From 1980 to 2010, it increased 3 times (from 35 million tonnes to 105 million tonnes), while the production of electrodes for manual arc welding decreased 2.5 times (from 33 million tonnes to 13 million tonnes). In the USA, there is a continuous trend of increasing the production of electrode wire, although until 1988, this growth was marked by certain drops (Bernardskii and Makovetskaya, 2007; Nikolov and Todorov, 2007; Karaganova, 2013; Shalimov and Panov, 2008).

For the period of 1970–2010, submerged welding and weld overlaying retained almost constant values for the three developed countries, being approximately 28 thousand tonnes for Japan, 10 thousand tonnes for Germany and 40 thousand tonnes for the USA.

Based on the mentioned data, it is supposed that the share of manual arc welding will be stabilized by 2020 at levels of 10–15 %, while figures for the share of gas shielded arc welding will reach 45–55 % of the total number of methods for weld overlaying worn parts. In the developed countries, argon-based gas mixtures with 8–25 % of CO_2 are widely used for gas shielding. Gas mixture containing argon, carbon dioxide and oxygen is less widely used.

The structure of welding and overlaying in the countries of the Commonwealth of Independent States (CIS) (an organization of independent countries which includes Russia, Ukraine and Belarus) as well as in India and China at the beginning of the 21st century is shown in Table 1.

On the dividing line between the 20th and 21st centuries, the structure of welding and weld overlaying methods in the CIS countries is characterized by the following figures: arc welding has a share of 68.2 %, while the share of gas shielded

Table 1 Production of welding materials in the countries of CIS, India and China at the beginning of the 21st century

No	**Country**	**Share of produced welding materials in %**		
		Manual	**Gas shielded arc welding**	**Submerged arc welding**
1	Russia	45	40	9
2	Ukraine	55	38	9
3	Belarus	50	39	10
4	India	75	13	7
5	China	80	15	5

and submerged arc welding is 22 % and 9.8 % respectively. The considerable share of manual welding indicates that the quality of mechanized welding has deteriorated. This also reveals a decrease in the economic effectiveness of welding production (Ilyushenko et al., 2009; Tarohin, 2013).

Coated electrodes for manual welding and overlaying are produced in more than 90 big manufacturing companies which work with 30–40 % of their full capacity. Small technological production lines for the production of limited series of electrodes exist in many companies. For this reason, the share of produced electrodes remains considerable and amounts to 50 %. The annual volume of electrode production in Russia is 400 thousand tonnes (Tarohin, 2013). The situation in Ukraine is similar to that in Russia and the share of produced electrodes is a little bit higher than 50 %.

In Russia and Ukraine, gas shielded welding has almost similar shares of 38–40 % (see Table 1). For gas shielding, CO_2 is mainly used. In addition, tubular electrodes with different composition are used to improve the properties of weld overlaid materials. The cost of this technology is comparable to the cost of welding using solid wire electrodes in argon-based gas mixture (Tarohin, 2013).

The present structure of arc welding methods in Belarus is as follows: manual arc welding – 50 %; welding in CO_2 – 30 %; welding in gas mixtures (Ar + CO_2) – 5.5 %; argon arc welding – 4 %; submerged arc welding – 10 % and laser beam welding – 1.5 %. In construction, manual welding methods reach 80 %, while in machine building, they amount to more than 30 % (Ilyushenko et al., 2009).

In China, a high increase of 10–12 % in the production of welding materials was forecasted. This was done to meet a high demand of the fast-developing Chinese economy. With reference to this, the expected changes in the structure of welding materials production for the period to 2010 were as follows. The production of electrodes for manual arc welding was expected to go down from 80 % to about 60–65 % compared to the total number of produced welding materials. At the same time, the share of electrode wire for gas shielded welding would increase to 30–35 %. Of this percentage, approximately 25 % would be contributed by the production of solid electrode wire, while the remaining 10–15 % would come from the production of tubular wire. Welding materials for submerged arc welding would amount to 10 % of the total volume of production. In China, it was anticipated that the production of materials for manual arc welding would decrease by 55–60 % in 2007. At the same time, it was planned that the development and production of new inverter sources for CO_2 and MIG/MAG welding would increase by 25–30 % (Bernardskii and Makovetskaya, 2005).

In India, the production of welding materials is done mainly in small enterprises since one third of the total volume of production comes from 100 small enterprises. The distribution of welding materials for arc welding for the period of 2003–2004 is as follows: manual arc welding – 75 %; submerged arc welding – 7 %; and gas shielded arc welding – 13 %. Bearing in mind the fast development of Indian economy, the share of manual arc welding will continue to decrease, while the share of gas shielded arc welding will go on rising. A similar trend is observed in all developed and developing countries. It is assumed that in India for the last 10 years, starting from 2003, the share of coated electrodes will go down to 65 %, while the share of materials used for gas shielded arc welding will increase to 17–27 % (Gehani, 2006). In India as well as in the other developed countries, the share of submerged arc welding will not change dramatically and will stay at its present level of 7 %.

During the last 10 years in Russia, Ukraine, China and some other countries, there is a trend of reducing the amount of coated electrodes used, which indicates that there is a shift from manual to mechanized arc welding, including gas shielded arc welding with solid and tubular wire electrodes. At the same time, the volume of automated submerged arc welding has been preserved. In the industrially developed countries, the share of metal, which has been manually weld overlaid through arc welding, has gone down almost three times and is 20–25 % although this reduction has not been so intensive in the other developing countries.

Weld overlaying is an inseparable part of the welding production. Approximately 8–10 % of electrode and electrode wires and 30 % of tubular wires of the total amount of welding materials are used for weld overlaying (Gumenyuk and Ivaskov, 2006). It is taken into account that there are not enough different materials that can be used to repair or restore worn-out components at present. For the reason related to production and the environment – protection costs, it is not necessary always to turn into scrap damaged, worn-out, or faulty materials. Even in cases when it is more profitable to replace a faulty component the practice contradicts the strategies for preserving available resources (Mideldorf, 2009). Due to the use of appropriate technologies, it is possible to recover components and use them again. For these reasons, weld overlaying will not lose its great importance in the 21st century.

Although there are considerable achievements, worldwide scientists continue to work on the development of new welding and weld overlaying methods. The structure of welding methods which will be a priority and will be further developed during the period of 2010–2020 is shown in Fig. 3 (Karaganova, 2013).

For the period till 2020, gas shielded arc welding (MIG/MAG, TIG) and cold/contact welding (done by friction/diffusion) remain the dominant methods. The share of mechanized and automated gas shielded arc welding is increasing. The development of contact welding for this

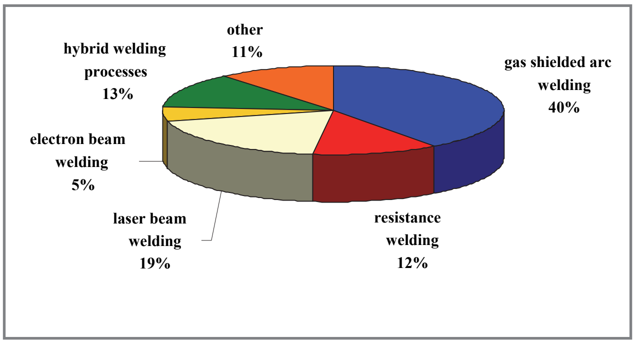

Figure 3 Structure of the welding methods that will be developed with priority in the period of 2010–2020

period is related to improving the systems for automated control and constructing powerful electricity supplying equipment. This will solve many technological problems when weld components with high thickness are made from different materials. At the same time, the consumed energy and time needed to complete the welding jobs will be reduced 2–3 times.

Taking into account the world trends, it has to be noted that the scope of applying recourse-saving and preserving technologies will be expanded. It can be assumed that the share of laser beam welding technologies will increase considerably and reach 6–8 % of all welding. The development of this method is connected with the use of accurate delivery devices. This will allow for better controlling the welding process and will make laser beams more suitable for welding easily – cracked materials or work pieces with spaces between them. The value of welding lasers produced in the EU in 2006 was 3 billion euros and increased to 5 billion euros in 2010.

New welding methods called hybrid welding processes (MAG + laser) have been developed in recent years. These methods combine laser beams with plasma or arc welding in one common welding work surface. The combined effect of the two heat sources on metal improves the effectiveness of each of them. This leads to an increase in the depth of penetration and quality of the seam. These hybrid methods are widely used in the automotive industry, ship building, machine engineering and transport. Welding methods such as electron beam welding, diffusion and high-quality welding are of key importance and will continue to develop and improve to meet the requirements of various industries.

Conclusions

1. By 2020, the share of arc welding in the industrially developed countries will be stabilized at levels of 10–15 % of the total number of methods used for weld overlaying of worn-out components. These figures will be 45–55 % and 7–9 % for gas shielded and submerged arc welding respectively.
2. In Russia, Ukraine, India and mainly China, the amount of used coated electrodes has fallen for the last 10 years but still remains rather high, at levels of about 50 %. There is also an increase in the share of gas shielded arc welding which has gone up to 30–40 %.
3. The welding methods that will be prioritized for the period until 2020 will be gas shielded arc welding, contact, laser beam and hybrid welding.
4. Weld overlaying will retain its high importance in the 21st century but for the time being there have not been developed enough materials for repairing and restoring components.

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Contact address:
Mitko Nikolov, 'Angel Kanchev' University of Ruse, Department of Repair, Reliability and Chemical Technologies, ul. Studentska 8, Ruse, Bulgaria, e-mail: mnikolov@uni-ruse.bg