APPLICATION OF WELDING TECHNOLOGIES AT REALIZATION OF EUROPEAN PROGRAM ON NEW RENEWABLE ENERGY SOURCES*

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Analysis of the strategy of EuroUnion outlined in the European Strategic Energy Technology Plan (SET-Plan) was performed. Design of high-power wind generators for application on land and at sea is described, as well as modern structural materials and design solutions of towers, blades and load-carrying structures of nacelles. Directions of investigation of modern welding technologies to be applied in manufacture of up to 20 MW wind generators are proposed.

Keywords: *welded structures, renewable energy, wind generators, European plan, new structural materials, new welding technologies, installation work*

At the end of 2010 the European Commission approved a new program «The European Strategic Energy Technology Plan» (SET-Plan) [1], the main objective of which is lowering the emissions of hothouse gases (CO_2) and development of effective energy technologies. This initiative is based primarily on cooperation with the European Industrial Initiatives and covers the following fields: bioenergy; CO_2 collection and accumulation; power networks, fuel elements and hydrogen; nuclear energy; solar and wind energy.

In each of the above-mentioned fields technologies of welding, surfacing, thermal spraying and cutting have an important role. These technologies, unfortunately, are usually not taken into account or treated as those of secondary importance. A group of experts was formed, including the author of this paper, the purpose of which is development of concepts of fundamental and applied investigations in the field of technology of materials for construction of high-power sea wind generators. Analysis of the documents of «SET-Plan Wind Energy» shows that modern welding technologies should have one of the leading roles in construction of sea wind generators of up to 20 MW power. In is anticipated that in 2030 in the EuroUnion wind power will generate electric energy of up to 280–400 GW. Under «SET-Plan Wind Energy» program for which approximately 6 bln Euros will be allocated, it is intended to built up to ten new generation test wind turbines of 10–20 MW power; not less that four test structures of high power sea wind turbines located in zones with different wind conditions, in the sea coastal strip and in open sea in deep waters that will require application of welding technologies.

There exists a multitude of national and international organizations and societies, which, in particular, coordinate cooperation between industry and research centers [2–25]. Denmark now is keeping the leading role in the world market among countries producing energy by wind power, where in 2010 already 20 % of the total energy was produced from wind power (in Poland it was just 2.6 %). By the data of Polish Society of Wind Power in 2010 about 1096 MW of electric energy was produced by ground wind power stations (0 — sea wind power stations), and based on 2020 prediction about 1.6 GW will be produced by 10,893 sea wind turbines and 14.4 GW will be produced by 2100 ground wind turbines, including 600 private turbines [26]. As predicted in the report by J. Beurskens, Director of WE@SEA Scientific Program of Dutch government [4], Poland so far is only a potential territory for construction of sea wind power stations and does not look good against the background of 2030 prediction for the countries of Baltic and Northern Sea regions. According to this prediction, it is anticipated that sea wind power stations in 2030 will produce electric energy of the following power: more than 4 GW (Denmark), 6 (The Netherlands), 4 (Belgium), 33 (Great Britain) and 25 (Germany).

Ground and sea wind generators, made in a wide power range from various structural materials, are given in Figures 1–5 and Table 1. Quite a lot of wind generator manufacturers are present in the world wind energy market, among which the following European companies have the leading role [13–19], %: VESTAS (Denmark) — 12.5–15.0; ENERCON (Germany) — 8.5–10.5; GAMESA (Spain) — 6.5–8.0; SIEMENS WIND POWER (Germany and Denmark) — 5.0–6.0; REPOWER (Germany) — 3.5–4.5; GE WIND ENERGY (USA) — 12.0–14.0; SINOVEL (China) — 9.0–11.0; GLODWIND (China) — 7.0–8.0; DONGFANG ELECTRIC (China) — 6.0–6.5; SUZLON (India) — 6.0–6.5.

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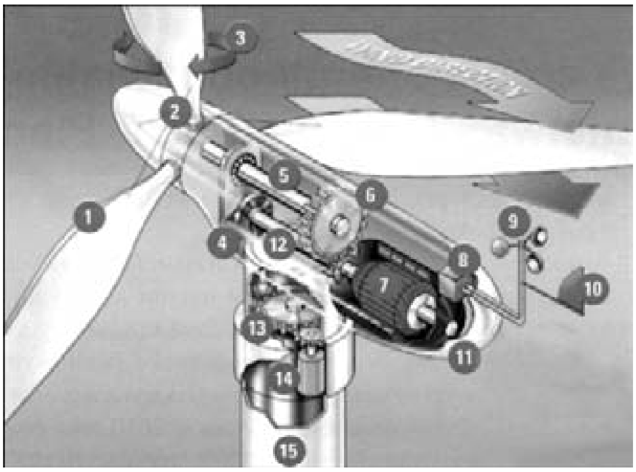

Figure 1. Schematic of a wind generator: *1* — blades; *2* — rotor; *3* — system of blade rotation in rotor bushing; *4* — system of deceleration of rotor rotation; *5* — drive shaft with low speed of rotation; *6* — transmission; *7* — generator; *8* — control system; *9* — wind speed measuring instrument; *10* — system of wind direction monitoring; *11* — nacelle; *12* — shaft with high rotation speed; *13*, *14* — drive and motor of nacelle rotation system; *15* — tower

Figure 3. Mounting a powerful wind generator nacelle on wind generator tower

Weight fraction and fraction of costs for manufacturing of the main load-carrying assemblies of wind generator structure (rotor bushing, nacelle load-carrying structure and tower) not only depend on wind generator power and its dimensions, but also show how important is the component role in wind generator structure [1–25] (see Figures 1–3, Table 2). Towers of high power wind generators (more than 2 MW) are made by welding from steel with medium yield point, usually S355 NL. Load-carrying structures of the nacelle and rotor bushing are made in the form of heavy castings from spheroidized cast iron, one-piece or sectioned, welded by MAG-process, as well as from forged steel elements, joined by MAG, and sheet steel, most often S355 NL [11–20]. Generator rotor (bushing and blades) is a more expensive component of wind generator and at the same time a component, of which super high reliability requirements are made. Technologies of making rotor bushings from composite materials are developed [25]. Currently applied main production processes in manufacturing of wind generator structure elements are given in Table 3.

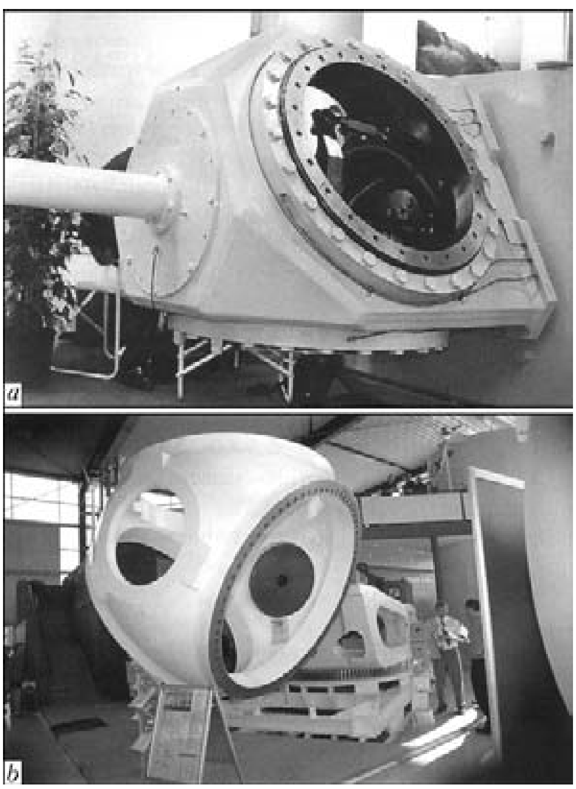

Figure 2. Appearance of a bushing of wind generator rotor: *a* — welded structure from sheet steel; *b* — casting from spheroidized cast iron of 15 t mass

Note that one of the main technological features of EurouUnion Program «SET-Plan Wind Energy» is construction of sea wind generators of up to 20 MW power at simultaneous lowering of energy production costs. Analysis of documents [1–9] shows that the fundamental and applied research in the field of materials technology should be focused on improvement of modern structural materials, and, therefore, also welding technologies and materials. Main structural elements of high-power wind generators (more than 2 MW), such as rotor, nacelle and tower, should be

Figure 4. Constructions of wind generators with their base in the sea coastal strip (*a*) and floating ones (*b*)

Table 1. Wind generators of maximum power from different manufacturers and their parameters [13–18]

Wind generator	Electric power, MW	Rotor diameter, m	Tower type	Tower height, m
VESTAS-V112-3.0	3.0	112	Steel pipe	Depending on location
ENERCON-E126	7.5	127	Tubular, steel	135
GAMESA-G128-4.5 MW	4.5	128	Tubular – steel or stressed reinforced concrete	120
SIEMENS SWT-3.6-107	3.6	107	Tubular, steel	80 or depending on location
REPOWER-6M	6.15	126	Same	100–117 on land 85–95 at sea
GE WIND ENERGY GE 4.0	4.0	110	»	No data
SET-Plan	20.0	160–250	No data	120–160

Note. Sea wind generator VESTAS-V112-3.0 has the following nacelle size, m: 6.8 height, 12.8 length, 4.0 width.

Table 2. Weight fraction and fraction of costs for the main structural elements of wind generators [1–24]

Structural element	Tentative mass of turbines of 2–3 MW power, t	Weight fraction, %	Cost fraction, %	Material
Tower	200	50–68	10–25	Steel, stressed reinforced concrete
Entire nacelle (load-carrying structure + transmission + generator)	70	25–40	40–65	Steel, copper, aluminium, special metal alloys, etc.
Load-carrying nacelle structure	11.5 (cast-welded structure)	6–8	No data	Steel, spheroidized cast iron
Rotor	40	10–20	20–30	Steel, spheroidized cast iron, fiberglass plastic or plastic reinforced by carbon fibre, wood and epoxy resins
Rotor bushing		6.5–7.0	No data	Spheroidized cast iron
Three blades		No data	Same	Fiberglass plastic or plastic reinforced by carbon fibre, wood and epoxy resins

made from materials with a high specific fatigue strength at simultaneous lowering of manufacturing costs. To fulfill these requirements, the purpose of fundamental and applied research should be lowering of the mass of rotor (bushing + blades), nacelle (drive shaft, transmission, generator, control system, rotor unit drive) and tower.

Figure 5. Appearance of the first free-floating wind energy turbine of Siemens and StatoilHydro installed on September 8, 2009 in the North Sea

Towers of powerful generators, both sea and ground, are an element subjected to the highest fatigue load. At present towers are built from thick-walled pipes of a conical shape with a about 3 % convergence, more seldom with a truss structure (made by RUUKI in Europe» [19]), as well as hybrid structure (reinforced concrete or completely concrete) [18–22]. When mounting sea wind generators, one of the most complicated technological problems is development of the technology of mounting tower elements and their base structure on the sea bottom, as well as technology of fastening to the bottom at great depth, or realization of floating tower structure (see Figures 4 and 5). All the world and European programs are focused on applied studies to find tower design solutions, mounting its elements, as well as development and application of composite materials with very high yield point, providing an essential increase of strength properties, lowering of wind tower mass and product cost [1–26]. More than 90 % of the constructed towers of powerful wind generators are made from low-alloyed steels, mainly, of type S355 NL ($\sigma_{0.2}$ = 345–355 MPa) [11–23]. The basic technology of producing welded joints

Table 3. Main production processes of fabrication of wind generator structural elements and technological tasks

Structural element	Base material	Manufacturing processes	Ttechnological tasks
Tower	Steel	Continuous casting with controlled rolling, welding	Production of higher quality steel with better weldability, high-quality welding consumables, lowering of production costs, development of high-quality welding technologies
Load-carrying nacelle structure	Same	Continuous casting with controlled rolling, welding, casting	Production of steel of a higher quality and better weldability, high-quality welding consumables, lowering of manufacturing costs. Mastering the technology of casting cast iron large-sized billets, improvement of their quality
	Cast iron		
Rotor bushing	Steel	Forging, casting, welding	Production of steel of a higher quality with better weldability, high-quality welding consumables, lowering of production costs. Mastering the technology of casting cast iron large-sized billets, as well as technology of fabrication of high-quality structures from composite materials
	Cast iron		
	Composite materials		

in the processes of manufacturing powerful wind generators is automatic submerged-arc welding [29–35]. At the same time, also investigations on welding technology are performed for mounting tower steel elements instead of expensive bolted joints [27, 28], although steels with good weldability with 1100–1300 MPa yield point (WELDOX 110 and WELDOX 1300) and up to 25.4 mm plate thickness are available in the European market.

It is expedient to complement the EuroUnion «SET-Plan Wind Energy» Program, which is now at the stage of development of basic and applied research, with the following: investigation of the technology of laser hybrid welding of butt and tee joints of plate metal from steel with a high yield point both in the shop and in the conditions of tower section mounting (instead of bolted joints) [36–56]; investigations on development of high-quality filler materials for laser hybrid welding of steels with a high yield point [52–56]; investigations on the technology of rotational friction welding of butt and tee joints of plate metal from steels with a high yield point in the shop conditions of mounting tower sections (instead of bolted joints) [57–63]; investigations of technology of MAG welding with self-shielded flux-cored wire (SSA method) of butt and tee joints of thick-walled high-quality castings of rotor bushings and nacelle load-carrying structure from steel castings and cast iron; investigations of technological conditions of laser and hydroabrasive cutting of plate metal from steels with a high yield point.

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INCREASE OF STRENGTH CHARACTERISTICS OF SPIRALLY-WELDED PIPES OF STRUCTURAL DESIGNATION

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Influence of high-temperature thermomechanical treatment (HTTMT) on strength properties of welds on spirally-welded pipes made from 08kp (rimmed) steel of 1 mm thickness was studied. It is shown that HTTMT of welds in low-carbon steel joints allows producing sound welded joints of pipes with high service properties.

Keywords: *high-frequency welding, spirally-welded pipes, weld, weld strength, blank of structural designation, calculation technique, tread rings, samples*

High requirements made to manufacture and operation of hulls from seamless pipes operating under pressure is a well-known fact [1]. A prime cost of manufacture of the seamless pipes, however, is higher than that of the welded ones, therefore, it is reasonable to evaluate the perspectives of application of spirally-welded pipes (SWP) for manufacture of pressure vessel hulls. High-frequency welding (HFW) as a high efficient and low waste process of joining is applied for manufacture of SWP of various diameters [2].

Usage of HFW in SWP manufacture allows:

- produce various diameter pipes from a strip of equal width due to change of angle of weld inclination in a welded joint;
- produce large diameter pipes and tubular welded structures using relatively simple technological process in comparison with manufacture of longitudinally-welded pipes;
- produce thin-wall pipes of large diameter with high accuracy;
- provide low investments.

A tendency of increase of the requirements to quality of welded pipes, in particular, on index of strength