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WELDED STRUCTURES FROM ALUMINIUM ALLOYS

T.M. Labur
E.O. Paton Electric Welding Institute of the NAS of Ukraine
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine. E-mail: office@paton.kiev.ua

Examples of modern lightweight structures from aluminium and its alloys are given. Their applications in different mechanical engineering sectors are shown. The structure diversity reflects the technological capabilities and forms of realization of unique properties of this material. Trends in world production and consumption of such structures have been analyzed. It is noted that appearance of more advanced alloys with the respective set of physico-mechanical and technological properties, as well as rational selection of the processes of their permanent joining, provide a high quality of welds and welded structure reliability. Presented examples clearly illustrate the fact that the effectiveness of lightweight structures is determined by functional requirements to products, weldability of the selected aluminium alloy and level of its joining technology, provided the expenses and production time are minimum. 20 Ref., 2 Tables, 6 Figures.

Keywords: aluminium and its alloys, welding methods, welded joints, light weight welded structures, physico-mechanical and technological properties, weld quality, reliability, service conditions

Products from aluminium and its alloys have now filled the goods market. They are widely used in many sectors of mechanical engineering, as well as civil and industrial construction [1–9]. Aluminium-based structural materials are traditionally used in flying vehicles. Their application sector is military, passenger and transportation aircraft. They are also used in rocket and space engineering (up to 80 % by weight). Aluminium alloys have a special status in the structures of land vehicles (car- and carriage building), river and marine shipbuilding. Irrespective of the welded structure application area common characteristics are used, which determine their service life (Table 1).

In **aircraft construction** the effectiveness of aluminium alloy application is well-known**.** Comparatively inexpensive, readily workable, strong aluminium alloys have proven themselves in aviation of the previous XXth century. They remain to be the main aviation structural materials both at the present stage and in the future. Creation of new models of flying vehicles in aerospace engineering is inextricably linked to solving three main problems of mechanical engineering: weight and cost reduction, and improvement of service properties. Weight reduction allows decreasing material content of the vehicle structure, promotes increase of the payload, and improvement of tactical performance at reduction of material costs for manufacture and service [10–12]. This motivates searching for alternatives to the main aerospace aluminium-based materials — D16, D19, V95 and V96, 1201, which are traditionally used in the airframe structure of civilian fleet aircraft. It has been estimated that reducing the civil aircraft mass by 1 kg allows saving 125–165 l of fuel annually, and during its entire service life the consumption savings are equal to 3.0–4.8 mln USD [9]. A new class of high-strength aluminium alloys, containing lithium, opened up broad possibilities in this direction.

Modern aircraft operate mostly under the conditions of intensive and extreme loading, so the main requirements, made of their materials, include the complete spectrum of aerodynamic conditions, environmental im-

Table 1. Characteristics determining the welded structure serviceability

Service properties	Types of tests	Studied characteristics
Deformability in the cold state	Tension	Relative elongation, uniform elongation
Weldability	Process samples (fishbone, cruciform samples, etc.)	Hot cracking susceptibility, fracture surface
Delamination resistance	Tension in the direction of thickness	Narrowing of sample cross-section
Fracture (brittle or tough)	Impact outward bending of notched samples	Work of deformation
	Outward bending of the weld	Fracture surface, bend angle
	Tension or outward bending of notched samples	Crack initiation temperature
	Fracture mechanics testing	$K_{1C}(K_C)$, $\delta_{1C}(\delta_C)$, J-integral

T.M. Labur — https:/orcid.org/0000-0002-4064-2644

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pact, flight safety and cost. In flight, use is made of the load-carrying surfaces of the structure to create the lifting and control forces in the air environment, as well as the power unit which maintains the aircraft flight using the energy of fuel on board the aircraft.

Correct selection of the material of structure elements can essentially improve the weight and tactical characteristics of the flying vehicle. Particular attention is given to satisfying the requirements on ensuring the needed strength and rigidity of the structure at minimum mass, mass efficiency of the material, which is determined by the ratio of σ_{add}/ρ to the cost of 1 kg of material. Increase of mass effectiveness of the welded structure depends on the perfection of prefabricated components and type of the joints of its elements that is determined not just by design goals, but also by technological potential of the material. In addition to weldability, structure designers make to the material the requirements of ensuring a high specific strength and ductility of its welded joints at maximum fracture toughness. This is exactly what allows continuing fulfillment of the flight tasks in case of damage. In view of the increasing speed of the aircraft and the accompanying increase of external panel temperature, aluminium alloys should also have high thermal stability and thermal cycle fatigue under service conditions. Creation of oriented space expresses, space shuttles, cosmoplanes is related to the need for materials, which, alongside good weldability and heat resistance, also have high quality at superlow temperatures.

Air-tight compartments of flying vehicles are stamp-welded structures, which consist of the sheath 1.5–3.0 mm thick with butt welded frames and flanges, produced by machining the 3D stampings with the preset direction of grain flow [13–16]. Parts from forgings are used in exceptional cases. This is related to the fact that on the frame caps, which are welded to the sheath, and on the flanges the metal thickness is just 2–3 mm. At unfavourable direction of grain flow of the semi-finished product, this zone can be not tight, that under the complex service conditions can lead to premature failure of the entire structure. The following alloys are used for these structures:

- V96 (7075), designed for parts which should have high static strength;
- D16-T (2024) — for parts, which should have high fatigue strength;
- special-purpose alloys (7175, 7050, 7150, 7475, 2124, 2224, 2324), i.e. almost all the available structural aluminium alloys.

Created in the last decade new aluminium alloys, together with other structural materials, opened up the way to appearance of structures with more perfect aerodynamic shapes [17–19]. Here, the welded structures are not only light and strong, but are also characterized by high reliability and safety of flying vehicle operation. Modern models of aircraft and rockets allowed mastering new tactical characteristics, which ensure the required cost-effectiveness of civil air transport, and high effectiveness of military aircraft. The general tendency of further development of such vehicles is associated with mastering the areas of high flight speeds and working temperatures of the structure. In the near future creation of supersonic flight vehicles is envisaged, which will have flight speeds $M = 5–7–10$ km/min.

Different concepts are being verified in order to solve these tasks. For instance, in order to create all-welded structures, the possibility of further improvement of the quality, reliability and service life of the product is envisaged due to application of new high-strength light alloys, welding methods, modern methodology of design and manufacture of welded components. Realization of such a concept is based on fabrication of welded finned panels of the wing, having considerable rigidity and minimum specific weight, fuselage elements, landing gear, etc. This envisages a significant saving of metal, reduction of the structure weight at replacement of mechanical joints by welded ones.

Traditionally used aluminium-based materials are replaced by those having improved composition and properties. As the main task of perfecting the aircraft structures for the next few years consists in weight reduction, improvement of the life and durability at the respective levels of strength, durability and cost-effectiveness, investigations are continuously going on, which will allow opening new reserves for performance improvement, and, thus, increase of their competitiveness, compared to other structural materials.

A vivid example of the policy of active upgrading of the structure is Boeing 777X aircraft. It collected the most promising developments in the field of materials science, technological processes and operations. A high-strength aluminium alloy, developed by Boeing and Alcoa companies— 7055-T77 alloy with yield limit of 640 MPa, is used for the upper surface of the wing, where static strength characteristics are the most important indices. The lower surface of the wing is made from 2324-T39 alloy of improved composition, with high strength and fatigue values. 2524-T3 alloy with high values of strength, fatigue and crack resistance is used in the fuselage.

At present, A-380 aircraft, which was developed in Europe (Figure 1), is a leader in application of new promising materials. It is designed for 555 passengers, which is by one third more than in its main competitor — Boeing 747. The world's first two-level (or two-deck) aircraft has four engines. Its length is 73 m, wing range is 79.8 m, and height is 24 m. The airliner is capable of flying 15 thou km without landing or refueling. High-strength 7055-T77 alloy is used for the upper surface of wing structure, and 2324-T39 alloy of improved composition is applied for the lower surface. 2524-T3 alloy is used for the upper part of the fuselage, and in the lower part weldable corrosion-resistant 6013-T6 alloy is applied. Empennage of the aircraft and wing center section are made from composite materials. Material replacement allowed reducing the structure weight and improving its adaptability to fabrication.

In Russian aircraft structures alloys of two alloying systems are extensively represented — Al–Cu–Mn and Al–Zn–Mg–Cu. D16-T alloy is used for the fuselage outer sheath and load-carrying side and lower surfaces of the wing, exposed to fatigue loading, and V96 (7075) alloy is applied for fuselage load-carrying elements (keys, stringers) and sheath of the upper load-carrying surface of wings, to which shrinkage stresses are applied. At present, developments based on the traditional alloys are performed, in order to improve their strength, toughness and fatigue properties.

Perfect production technology is one of the important prerequisites, in order to reduce the machine mass. In addition to thermal, mechanical and plastic treatment, it includes effective welding processes. Although they feature low productivity, high equipment cost in manufacture of flying vehicles, at the same time they provide high reliability of the joint and ability to resist stringent service conditions. Gas-shielded consumable electrode arc welding belongs to such processes for joining typical elements from aluminium alloys. It did not become widely applied in aerospace industry, as it does not provide sufficiently high mechanical properties of the joint and the required level of reliability. Nonetheless, this method of joining aluminium alloys is the main one in welding outboard compartments for fuel and oxidizer in rockets of various classes.

For instance, in manufacture of the structure of Saturn-V rocket tank from 2014 and 2219 aluminium alloys, gas-shielded tungsten electrode arc welding had the greatest advantage. Welded structures of rocket engine bodies and rocket fuel tanks from aluminium alloys were made using arc welding technology. The reliability of the joints was ensured by providing effective heat removal behind the arc that greatly reduced the residual stresses and deformation of the joints [5].

When manufacturing elements of Space Shuttle reusable vehicle, the technology of plasma welding (Figure 2) with alternating polarity of the arc was widely applied, which was optimized at Hobart Brothers Company. The method was specially developed for welding thick profiles from aluminium alloys, which are used for outboard fuel compartments of Shuttle type vehicles (Figure 3). The thermal cycle in the following mode turned out to be the most effective: reverse polarity current pulse of 15–20 ms, straight polarity current pulse of 2–5 ms; straight polarity current here was by 30–50 A higher than the reverse polarity current. This creates the conditions for concentrated heating of the base metal that allowed reducing the angular deformation of the welded joint.

Figure 1. A-380 aircraft at takeoff

In aircraft of Airbus 318 and 380 series laser technology is used as an alternative to riveted joints for joining stringers to the sheath [15]. In welding the fuselage of F-22 fighter plane, electron beam welding was used instead of the riveted structures [10]. Diffusion and electron beam welding, as well as the combined process of friction stir welding are the most extensively used [17–19]. The main requirements to technology are the high joint quality, ensuring minimum risk under the product service conditions, and admissible production cost.

Integrated technology of treatment of aluminium elements and their joints allowed the Boeing Company to manufacture a tank for liquid oxygen and fuel compartment of booster of Delta series carrier

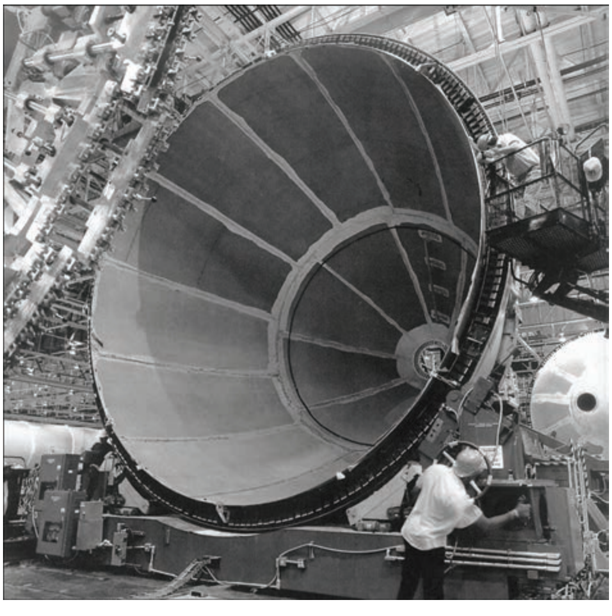


Figure 2. Welding of the dome of external fuel tank of Space Shuttle vehicle (USA)

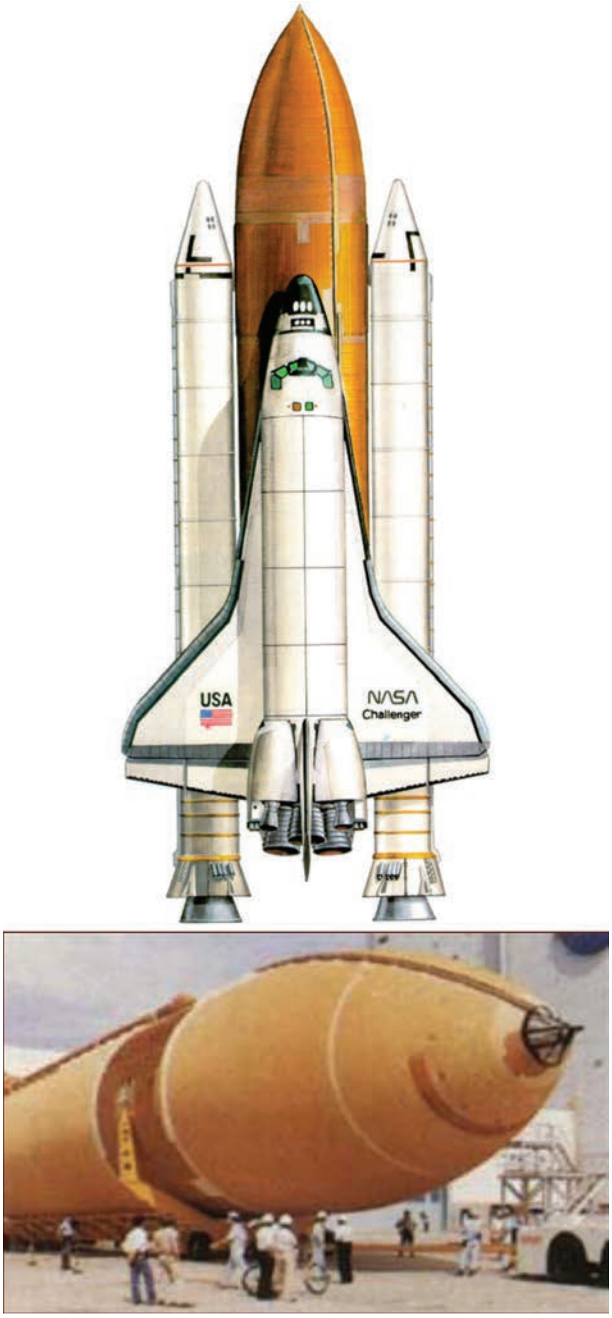


Figure 3. Appearance of base fuel compartment of vehicles of Space Shuttle type

rocket. The structure of the tank, which is loaded by cryogenic fuel, takes up a considerable part of flying vehicle overall dimensions. The booster compartment consists of two types of tanks of 12 and 8.4 m length, as well as intermediate cylinder of 4.8 m length and 2.4 m diameter.

Now preparations for launching Delta-VI rocket are underway. It is planned to make the tanks for it for aluminium alloy 2598. As the tank has considerable dimensions, it is envisaged to weld it in the vertical position. Here, the tank will move relative to the platform with the welding unit. Boeing Company developed such a technological process and anticipates an increase of commercial launches of satellites using rockets of Delta series and plans to produce 100 tanks per year. In addition, the Company conducts wide-scale investigations of service properties of welded joints and new technological documentation is being developed. Such a production strategy is due to expansion of the sphere of application of advanced welding processes for manufacture of welded structures in the civil and military factories.

Work on welding curvilinear joints is also actively pursued. In order to make superlight outboard compartments of reusable aerospace vehicle of Space Shuttle type, NASA (Figure 3) used the technology of friction stir welding for joints of 2 to 5 mm sheets of 2198 alloy of Al–Li system. Such elements of the structure are used for containing the fuel components, and usually they are of 47 m length and 8.38 m diameter. Results of studying the quality of welds confirmed that this technology can completely replace the plasma and electron beam welding methods when working with aluminium alloys [12, 13]. The low value of welding energy input creates the thermophysical conditions, required for weld formation, i.e. conditions are in place, under which a solid solution is deformed, that has a positive effect on the values of physico-mechanical properties of the joints, degree of metal softening in the heating zone and welded item deformation.

The method of friction stir welding was verified also for joining new aluminium-lithium alloy — C458 (Al–1.8Li–2.7Cu–0.3Mg–0.08Zr–0.3Mn–0.6Zn), which is characterized by a lower density (0.026 kg/cm^3), compared to other aluminium-lithium alloys and high modulus of elasticity, than 2219 alloy. Obtained results of investigation of weldability and physico-mechanical properties of welded joints allow predicting that owing to replacement of the traditional alloys by new alloy C458 in the structure of reusable vehicle fuel tank, it is possible to save from 2 to 4 mln USD for 400 flights, in terms of production and maintenance costs.

Prospective analysis (up to 2020–2030) of application of aluminium-based materials in flying vehicles is indicative of the fact that these alloys will retain their leadership in the structures of planes, for instance airframe, of about 80 %. The main tendency of their development, based on increase of strength and decrease of the alloy specific weight, will continue to grow. At the same time, it should be noted that increase of the above characteristics is usually based on complication of the alloy chemical composition, need to optimize the heat treatment modes and other technological measures, including also the welding processes, which cause lowering of the material ductility and life properties. Therefore, fabrication of sound permanent structures from new aluminium-based materials is a major scientific and technological problem, which necessitates large-scale investigations and mastering new methods of welding aluminium alloys, taking into account the fact that the welded joints should be able to perform with a high reliability under the complicated service conditions.

A similar tendency promising for application of new welding processes is also observed in the **ship-building sector**. The main structural material in construction of high-speed vessels for operation under the conditions of sea and river basins are aluminium alloys of 5XXX group of Al–Mg–Mn alloying system. Compared to steel, they have essential advantages — high corrosion resistance in sea water. In addition, aluminium hulls are not overgrown by shells that allows preserving the flow around the ship and increases the passage speed in the overhaul period, thus lowering the operating and painting costs. This way, the conditions required for operation in aquatic environment are created (Figure 4). Earlier, different fusion welding processes, particularly consumable electrode welding, were widely used in ship-building. Over the recent years, a considerable increase of the interest to introduction of friction welding technology is observed in this mechanical engineering sector. Here, all the types of welded joint are used: butt, tee, fillet, etc. This welding process became the most developed in the Scandinavian countries of Europe.

The wide introduction of friction stir welding technology was facilitated by successful development of welding equipment by ESAB Company, Sweden, under a license purchased from The Welding Institute, Great Britain. In keeping with the data provided by ESAB Company, development of a series of SuperStir units is based on application of standard machines of modular type. Such a production strategy allowed development of a typical line of welding equipment for joining different groups of aluminium alloys. The units of modular design cover the entire range of working space parameters for overall dimensions of the welded panels from 0.5×1.5 up to 10×20 m. The equipment set includes special clamping devices with gear mechanism for movement, welding machine and computer control system. Welding is performed in the automatic mode. Welding process parameters are recorded due to a built-in operational control system.

One of SuperStir units was tested by a Norwegian shipbuilding Marine Aluminium Company, when making the hulls of high-speed launches and large hull ferries from aluminium panels of 6×16 m size. Here, evaluation of service properties of welded joints of 6082 and 7108 alloys was performed, and the possibility of application of aluminium panels produced by friction stir welding for sea vessel sheathing was determined. Obtained results showed that after cleaning from corrosion products and further tension, the welded samples had high anticorrosion resistance under the conditions of cyclic testing in a chamber with sea environment for 1000 h at the humidity of 98 %, as well as 50 °C and higher temperature. Welded joints of 2519-T87 alloy made by friction stir welding, demonstrated high properties at ballistic testing. They allowed General Dynamics Land Systems Company in cooperation with the Edison Welding Institute, welding aluminium plates of 1219×121×31.8 mm size to create a new generation of amphibious marine armoured vehicles [15].

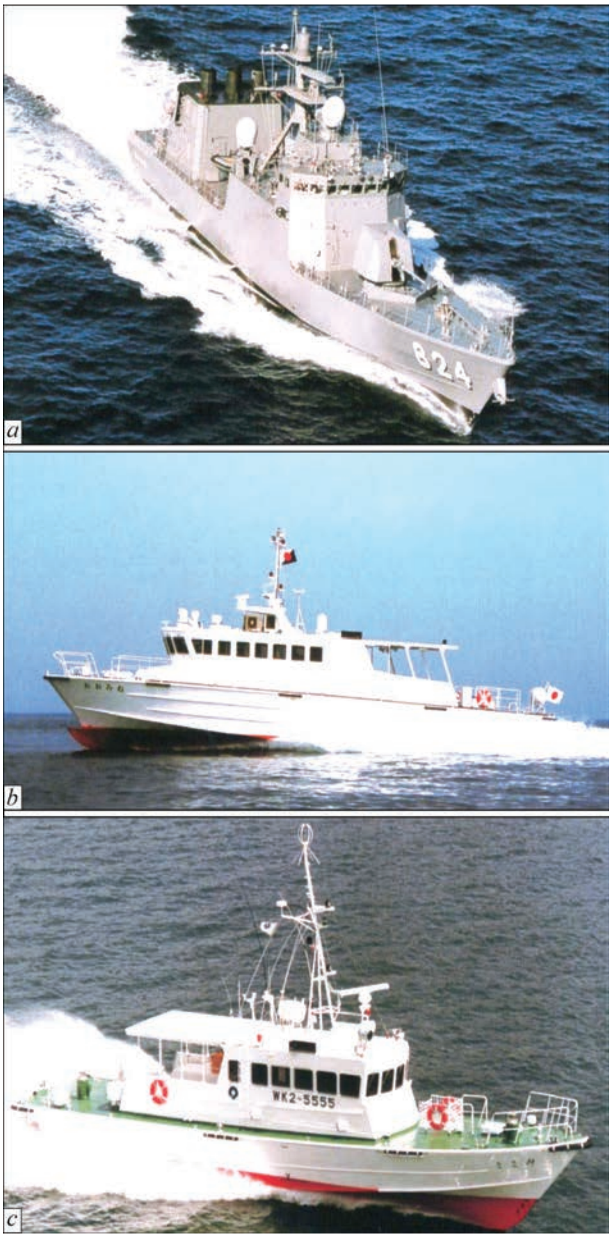


Figure 4. Examples of aluminium alloy application in shipbuilding structures (Japan): *a* — border guard boat; *b* — pleasure boat; *c* — small fishing boat

Swedish Company SAPA together with The Welding Institute (Great Britain) developed and put into production welded panels for quick freeze refrigeration units [14]. Higher requirements of weld tightness are made of welded joints of these panels as they are containing cold substances, dangerous for man and environment. The sample company, using friction stir welding, mastered manufacture of welded panels for stations of fish mass precompression before freezing. The structure of such a station consists of 17 panels of up to 30 mm thickness with total weld length of 16 m. Equipment of SAPA Profil Plant, Sweden, allows welding from pressed profiles the extended and wide panels of 14.5×3.0 m size for fabrication of ship decks, covers and side parts of carriages of railway and metro trains.

In the **automotive sector**, the attractive qualities of aluminium alloys for designers are: reduction of the car weight and fuel consumption, accordingly; replacement of deficit copper and corrosion-resistant steel; wider raw material possibilities, compared to other metals; high efficiency of processing (recycling) of aluminium fragments and parts after vehicle life is over. Specialists have calculated that each kilogram of aluminium used in the car structure, allows saving 7–10 l of fuel during the car life.

Figure 5. Examples of aluminium alloy application in passenger cars: *a* — Feardi Z33; *b* — Skyline V35

Analysis of the dynamics of growth of the volumes of application of aluminium and its alloys in cars of EC countries and the USA show that already in 2000 the total weight of aluminium components and parts was equal to 120–150 kg or around 10 % of the car total weight. An example of promising applications of aluminium alloys is Porsche 928 car, which has almost 300 kg of aluminium parts in its design that is equal to approximately 20 % of the car total weight. Ford Motor Company developed a new model of Synthesis-2010 car, the structure of which is mainly made from aluminium that ensures its practically complete recyclability. Welded aluminium load-carrying body has the weight, which is by 46 % smaller than the respective body made from steel. The car has a three cylinder engine with an aluminium cylinder block.

Aluminium alloys are widely used in the structure of bodies of cars of Audi-A8, Lotus, Expedition (Ford), Navigator, and other classes. The above-mentioned car models belong to the high class of sports cars or the so-called SUVs (Figure 5). The volume of manufacture of such cars does not exceed 0.1–0.2 % of the total car output in the world.

The most widely accepted components and parts of cars from wrought and cast aluminium alloys are the frame, heat exchangers (radiator and heater), bumper, doors, trunk and hood covers, body, wheel discs, cylinder block, pistons, profiles of the car exterior and interior, cab bodies and sides of trucks, fuel tanks (Figure 6). In foreign car brands of frame structure extruded aluminium alloy profiles are used for frames and other elements. So, AOS/APC Car Company reported wide introduction of friction stir welding method into manufacture of a welded car frame from aluminium profile.

Table 2 gives the main types of welded joints and welding processes, which became widely accepted in fabrication of elements of the car structure from aluminium and its alloys. Their realization in car manufacture was due to solving a whole number of production processes. They include: absence of aluminium alloys of an optimum composition for manufacturing bodies of trucks and cars; low yield limit of the alloys, compared to steel; absence of a serial technology of stamping automotive blanks, particularly thin-walled items, preparation of aluminium semi-finished products for welding (laser, contact, arc) and further deposition of protective coatings. Today, new design-technological, metallurgical and organizational measures are being developed, which are mainly aimed at further reduction of the body weight and fuel consumption, improvement of ecological indices, high reliability and extended service life, as well as high level of comfort and safety during car operation.

Analysis of modern tendencies of development of automotive industry shows that today three main directions are noted in application of aluminium alloys in manufacture of car bodies. First, these are parts and components of the body in the cars with monocoque bodies. Second, these are add-on parts and components of hoods, boot lids, hatches, removable wings, doors, fuel tanks, front and rear bumper power beams, exhaust systems, etc. Third, these are parts and components of cars with frame design of the body. The last direction was particularly widely accepted in the USA and Europe. Aluminium alloys of Al–Mg, Al–Mg–Si, Al–Zn–Mg alloying systems, alloys 5083, 5456, 5556, 6061, 6013, 7033 are widely applied for this purpose. In Russia, their analogs are used: AV, AD33, AD37, AMg2, 1515, 1523. Alloys of Al–Mg and Al–Mg–Sc systems: 1535, 1545, 1570, AMg6 are widely used for load-carrying structures and components of cars; for exhaust systems these are 1419, SAP-3, 1151 alloys; and for load-carrying levers of torsion bars, rods — 1970, AK6, 1460, 1933, 1973 alloys.

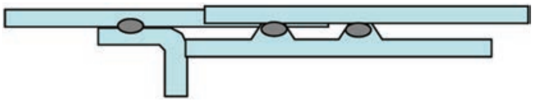
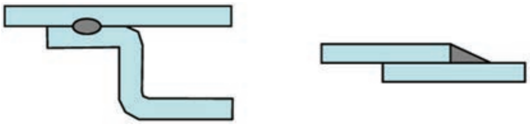
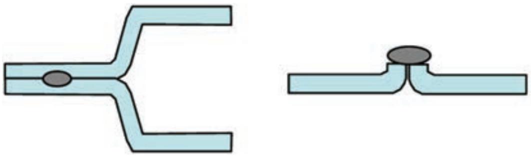
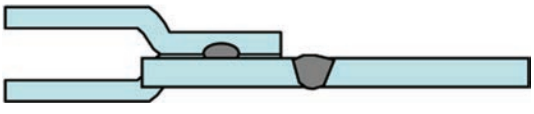
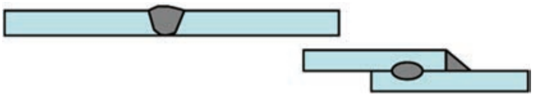
Aluminium and its alloys are also used in agricultural vehicles, including manufacture of animal transport trucks, refrigerators, flour trucks, specialized bodies of cars and trailers for transportation of mineral fertilizers. In addition to reducing the car body weight and increasing the payload that lowers the transportation costs and saves fuel, a high hygroscopicity and extension of operating life are ensured. Welded structures of all-aluminium flatbed and tipper platforms have also been introduced, which are used in international transportation of passenger cars have also been introduced. Structures of semi-trailers with sideboards and bars for awnings from aluminium profiles, general purpose box semi-trailers, refrigerated semi-trailers of different capacity have also been developed.

Welding technology arsenal is constantly growing. Alongside welding of plates from aluminium-magnesium alloys 0.5–1.5 mm thick by CO_2-laser (up to 5 kW power) and Nd:YAG-laser (up to 6 kW power), hybrid laser-arc technologies (laser + MIG) began to be used, which allow reducing power consumption and requirements to the accuracy of fit-up of the butts between the structure elements. The requirements to the quality of edge preparation, accuracy of butt fit-up for welding of aluminium alloys include the following: presence of strictly rectilinear edges without burrs at not more than 0.04 mm waviness. The gap in the butt between the edges of 0.5–3.0 mm thickness should not be larger than 0.08 mm. Some USA plants and companies operate new units for realization of the technology of electron beam welding without vacuum [19]. In Japan studies are under way on application of welding of sheet (0.8–1.5 mm) aluminium and its alloys for automobile production. Selection of the process of welding at organization of production is based on analysis of their technological capabilities. Cost is an important consideration, depending on type and volume of production.

Figure 6. Examples of aluminium alloy application in trucks: *a* — Toyota FCHV; *b* — superlight truck FU with aluminium frames; *c* — aluminium alloy body of a dump truck

In **railway transportation** aluminium and its alloys are used in the form of stamped and extruded blanks when making carriage axle-boxes [20]. The axle-box weight is here reduced two times. Damping properties of aluminium promote 10 % reduction of the load on the rails and elements of the carriage structure. Owing to high corrosion resistance and good weldability of aluminium, it is used with success in manufacture of tank cars for transportation of concentrated nitric acid, milk, wine materials, mol-

Table 2. Main types of joints and processes of welding aluminium alloys in fabrication of car structure elements

Structural element	Alloy	Thickness, mm	Welding process	Main type of joints
Front and rear wings of a car	AMg2, alloys of Al–Mg–Sc system (1523)	1.0–2.5	Laser; resistance (spot or seam)	
Doors	AMg2, AD37, AMg4, 1523, 1535	1.0–2.0	Laser, resistance (spot or seam), spot arc, manual arc	
Hoods, lids	AMg2, AMg4, AD37, alloys of Al–Mg–Sc system (1523, 1535)	1.0–2.5	Laser, resistance (spot or seam), spot arc, manual arc	
Fuel tank	AMg2, AMg4, AMg6, alloys of Al–Mg–Sc system (1523)	1.5–2.5	Laser, resistance (spot or seam), spot arc, manual arc, automatic argon-arc	
Gas exhaust system	1419, 1151, SAP	1.2–1.8	Laser, resistance (spot or seam), spot arc, manual arc, automatic argon-arc	
Load-carrying elements, spar, bumper	AMg4, AMg6, AD37, alloys of Al–Mg–Sc system (1535, 1545, 1570)	1.5–3.0	Laser, resistance (spot or seam), spot arc, manual arc, automatic argon-arc	

ten sulphur and other chemicals. Profiles and other semi-finished products are widely used in the interior of passenger cars. Pipes with inner cladding from corrosion-resistant aluminium alloy are used for the systems of water supply and heating of the carriages. Their service life is ten times larger than that of monometal ones, that eliminates the need for system repair during the operating period. At present, the possibility of application of large-sized panels from aluminium alloys up to 800 mm wide as load-carrying structural elements in the carriage structures is considered. Aluminium shipping containers of all types, have considerable advantage over the steel products. Their weight is two times smaller than that of the steel ones, and corrosion resistance is much higher, they are more durable and cost-effective in service, as they accommodate higher payload and require no painting.

In **building of civil and production facilities** the base for application of aluminium alloys of Al–Mg, Al–Mg–Si, Al–Mg–Zn, Al–Cu–Mg system are the high strength, absence of cold brittleness threshold, low density, high ductility, good corrosion resistance, absence of sparkling upon impact, antimagnetic properties, high seismic resistance, bactericidal activity, as well as good appearance of the structure [15–18]. Aluminium building structures are not like steel ones. Flat plates turned out to be the most cost-effective, sometimes 3D parts and extruded rods, which together make up spatial systems.

Nonconsumable and consumable electrode arc welding, and automatic arc welding over a layer of flux became widely accepted. Over the recent years wide application of pulsed-arc welding is observed, at which the voltage and current change by a certain law, that allows producing sound welds in different positions in space, during fabrication of structures of a complex shape.

It should be noted that despite the advantages of aluminium structure application, search for rational engineering solutions of their fabrication increases the design costs several times, compared to steel ones. This is due to the need for thorough verification of the design schematics and cross-sectional shapes of the elements and conducting full-scale testing of individual samples, in order to determine the life and corrosion properties of the products. At the same time, considerable design costs are paid off by operating life of such structures, as the minimum cost of the welded product, incorporating individual elements from aluminium alloys, is inversely proportional to the costs of project optimization.

Operation of aluminium structures has its special features. The main expenses are to ensure systematic observation of the condition of structure element surface and areas of their joining to the parts from other materials, which it is desirable to properly insulate from aluminium. In the absence of aggressive environments (haloids or alkali), the aluminium structures do not require any funds for repairs for 20 to 50 years.

Application of weldable aluminium alloys is particularly effective in facilities, located in the Arctic, Antarctic, mountain regions and deserts. This is related to the ability of the alloys to increase their strength under the conditions of low and cryogenic temperatures, while preserving the ductility which they have at room temperature (20–25 °C).

Considerable cost effect is obtained from aluminium alloys in construction or reconstruction of bridge overpasses. In the latter case, it is possible to not only preserve the architectural appearance of the bridge, but also increase the traffic flow. Despite the considerable difference in the structure of aluminium and concrete, aluminium and ferrocement which are used, the base is a comparatively low modulus of elasticity of these materials that allows their use in the designs of spatial ferrocement and concrete structures.

Thus, the presented examples of mastering welded lightweight structures in different engineering sectors in the world are indicative of the diversity of technological capabilities and forms of realization of unique properties of aluminium and its alloys. They reflect the tendencies of world production and consumption, which widen the spectrum of their application by improvement of the welding processes and development of new joining technologies. The structure effectiveness is determined by functional requirements to products, weldability of the selected aluminium alloy and level of its joining technology at minimum costs and fabrication terms. Appearance of more perfect alloys with the respective physico-mechanical and technological properties, alongside the rational methods of their permanent joining provides the high weld quality and welded structure reliability.

A similar process also takes place in Ukraine. However, the pace of its realization is very slow. Intensification of lightweight structure fabrication requires mastering the recent high technology achievements, including welding, by industry. This will ensure higher productivity of welded structure fabrication at reduction of manual labour, lowering of labour content, improvement of ecological conditions in manufacture of typical structural elements, that will open up the prospect for creation of new samples from aerospace engineering to land and water vehicles, as well as effective building and bridge structures with wide application of welded parts and components from aluminium alloys.

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