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AUTOGENOUS WELDING IN AIRPLANE CONSTRUCTION

By Ludwig Kuchel

From Schweissen, Schneiden und
Metallspritzen mittels Acetylen, 1927

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In the original manufacture of airplanes from wood, the warping of the structural parts through the influence of the elements could not be entirely prevented, despite the careful selection of the wood. An improvement was made by using plywood for covering the fuselage and wings. Plywood was used in Germany during the war on most of the military airplanes.

The increased requirements of airplanes, especially in modern air traffic, called for a homogeneous building material of greater strength and reliability than wood, which is so easily affected by external conditions.

The advantages of steel for highly stressed parts, as discovered in engine building, led, in airplane construction, to the use of steel tubing, which also offers less obstacles to future structural development. Autogenous acetylene-oxygen welding was found to be the only practical way to join the steel tubes.

Lightness is an essential characteristic of the structural parts of an airplane. All the structural requirements which must be satisfied by the building materials must therefore be adequate without being excessive. While military airplanes are

*"Die autogene Schweissung im Flugzeugbau," from Schweissen, Schneiden und Metallspritzen mittels Acetylen, 1927, pp. 27-33.

not subject to considerations of economy, but only to those of maximum efficiency, commercial airplanes must be governed by both of these factors.

The structural parts of an airplane are the fuselage, wings, tail surfaces, engine mount and landing gear.

Figure 1 is the picture of a twin-engine Albatros commercial airplane. It has a full load of 3800 kg (8378 lb.) and an engine power of 480 HP.

Fuselage.- The steel-tube framework of a twin-engine Albatros commercial airplane (Fig. 2) for eight passengers and two pilots has a framework of approximately square cross section in the form of a lattice girder. The front part has K braces. The rear fields are crossed by brace wires with the exception of the next to the last field, in which there are welded diagonal tubes for withstanding the stresses produced by the tail skid in landing. The fuselage framework weighs 224 kg (494 lb.). The joints are autogenously welded in all the structural parts. The longerons consist of telescoped steel tubes of 40 mm (1.57 in.) diameter at the front end and tapering to 25 mm (0.98 in.) at the rear end. The ends of the tubes are joined by sloping welds. The requisite reinforcement is effected by muffs, which are driven on and welded. The attachment joints of the wings and landing gear, which are subject to great tensile or compressive stresses, are reinforced by strips of sheet metal driven into slots in the ends of the tubes and completely welded. The eyelets required for attaching the brace wires are formed by welded-in tubular loops. No tube in the whole fuselage has a wall thicker than 1 mm (0.04 in.), but the required safety factor of eight for the airplane is nevertheless exceeded.

Wings.- Figure 3 shows the whole wing structure, consisting of a middle section and two lateral sections. Figure 4 shows a wing in process of construction. The spars are full-walled box girders with open duralumin members. The fitted-in steel ribs have the form of lattice girders. The open spaces in the front part of the wings are intended for the reception of the fuel tanks.

The welded steel-tubing engine supports, which also serve as wing struts, are installed between the upper and lower wings on each side of the fuselage.

Figure 5 shows two of the ribs. The upper and lower flanges are made of steel tubing 6 x 0.5 mm (0.24 x 0.02 in.), while the welded-in lattices are made of steel tubing 5 x 0.5 mm (0.2 x 0.02 in.). A span of 19 m (62.33 ft.) requires 65 such ribs for each wing. These ribs are produced in quantity and are welded with the aid of formers.

Figure 6 shows the tail structures. The horizontal tail structures, consisting of the stabilizer and elevator, have welded frames with diagonal braces made from steel tubing of

5 to 25 mm (0.2 to 1 in.). The stabilizer is adjustable, and the elevator is hinged to it. The vertical tail structures, consisting of the fin and rudder, are likewise made of autogenously welded steel tubing.

The ailerons are likewise made of welded steel tubing with diagonal bracing. The hinge supports are made of steel tubing with triangular bracing and are autogenously welded to the wing structure.

Power plant.- Figure 8 shows the engine mount on a one-engine commercial airplane. The autogenously welded steel-tubing engine mount is attached to the steel-tubing fuselage at four points, so that the whole can be detached by removing four bolts. The joints are reinforced by sheet metal, because of the great stresses to which they are subjected. The weight of the 220 HP. engine, with all its accessories, is 295 kg (650 lb.). It is separated from the pilot room by a fire wall.

Landing gear.- The streamlined struts are autogenously welded (Fig. 9). The landing shock is absorbed by the telescoping struts. The shock absorbers operate by compression of air, sealed and regulated by oil. In this way the kinetic energy of the airplane is converted into friction and heat, and the unavoidable springing in landing with rubber shock absorbers is eliminated. With a stroke of about 24 cm (9.44 in.), an energy absorption of about 45% of the total weight is attainable. The absorbed energy corresponds to a free fall of about 0.5 m (1.64 ft.) of the fully loaded airplane. The unabsorbed forces are transmitted to the fuselage.

Aside from the main structural parts, whose joints are almost exclusively welded, the gas-welding process is used to advantage in all kinds of fittings, connections, levers, etc. Properly welded parts satisfactorily replace parts cut out or forged in one piece. The welding process is simpler, quicker, and cheaper and saves much weight, which is a very important consideration in airplane construction.

For the different materials available for welding in aircraft construction, adaptations of the welding wire have been discovered, which render the welds, as improved by after-treatment, very nearly as strong as the unwelded tubes. The excellence of the weld depends largely on the skill of the welder, who should have some understanding of the physical process involved. In training welders, their individual qualifications must be considered first of all. The inspectors must be able to tell the difference between a good weld and one that simply adheres or is burned.

For testing the welds, portions are taken from the completed structures, from which samples are prepared for tensile and bending tests. A bending test is made of the finished part, in order to determine its buckling strength. This is a very good test of the excellence of the welds and exposes any defects in the welds.

It is generally assumed that the excellence of a welded structure depends on the strength of the weld seam, since this is ordinarily the weakest point. I cannot accept this assumption unconditionally, however, since the weld seam may be the strongest part of the structure under certain conditions. I will omit the discussion of the welding wire to be used, as being too far reaching. I will only mention that it is important to test the welding wire thoroughly for the different uses. Autogenous welding has now become very important in airplane construction. It facilitates the construction and shortens the time required.

The new industries of aircraft construction and autogenous welding constitute a timely coincidence. In 1903 the first flights were made with engine-propelled airplanes, and in the same year the first burners for acetylene-oxygen welding were put on the market.

Although the laws of statics are fundamental for construction, progress is made through the properties of the materials used, as determined by experience. The type of girder used for withstanding bending and buckling stresses in aircraft is already regarded with increased respect in other lines of construction. The autogenous welding industry is one of the few industries which can increase its usefulness through the discovery and appropriation of new fields of application. There are many such fields not yet aware of the fact that production can be cheapened by the use of autogenous welding.

D i s c u s s i o n

Mr. Herz.- I only wish to ask whether autogenously welded or seamless drawn tubes were used:

Dr. Kuchel.- Seamless drawn steel tubes, as obtainable in the market, are generally used in airplane construction. There is no need of producing them in the aircraft factory, because every kind of tube can be bought ready made in the market.

Mr. Herz.- My question was meant somewhat differently. In recent years quite an extensive industry has developed in the manufacture of well-made autogenously welded tubes for all purposes. Have these tubes yet been used in aircraft construction? I understand that such tubes were investigated in Italy in 1923 or 1924. I do not know, however, what the outcome was.

Dr. Kuchel.- I do not know of autogenously welded tubes being used in aircraft construction either in Germany or elsewhere. In a tour of investigation in the spring through France and England, I found, however, that this kind of welding is done with no such precision in either of these countries as in Germany.

Mr. Butz.- In the welding of thin-walled tubes, are there any data available on the effect of the purity of the welding gases?

Dr. Kuchel.- The welding section generally uses apparatus in which the gas is purified in the ordinary way. It is endeavored to keep the gas as cool as possible, to have it well washed and to have the purifying materials renewed often enough.

Mr. Butz.- I recently ascertained the effect of the purity of the oxygen in a large welding factory which produces thin-walled tubes and bicycle frames in large quantities. This factory undertook to use high percentage oxygen. The rejections were 30% greater than with oxygen under 98% pure. The demands on the skill of the welder increase with the purity of the oxygen, especially for thin-walled tubes.

Mr. Pothmann.- We found that the purer the gas, the more sensitive the flame was when wrongly adjusted. We also found that oxidation occurred much more readily with very pure gas. In ordinary welding poorer results were obtained with very pure gas (99.5%).

Dr. Streb.- According to our experiments, nitrogen up to 5% has no harmful effect on the quality of the weld. We have not yet determined whether a smaller amount of nitrogen has an actually favorable effect on the quality of the weld. There were some indications in other experiments that the presence of a small quantity of nitrogen in the oxygen prevented or substantially reduced the carbonization of the weld, when a slight excess of acetylene was used.

Dr. Vogel (the presiding officer).- It seems that the experimental results do not yet justify their adoption in practice. This remark applies also to the results thus far obtained by Dr. Streb.

Translation by Dwight M. Miner,
National Advisory Committee for Aeronautics.

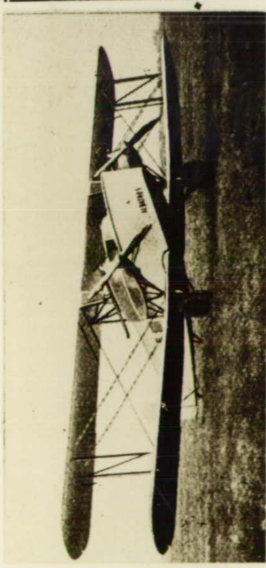


Fig.1

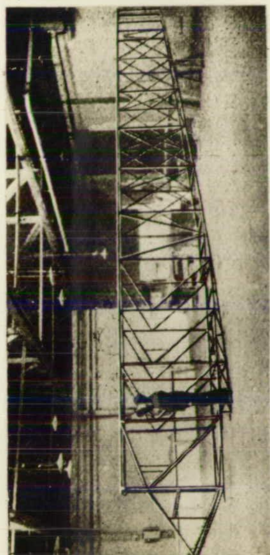
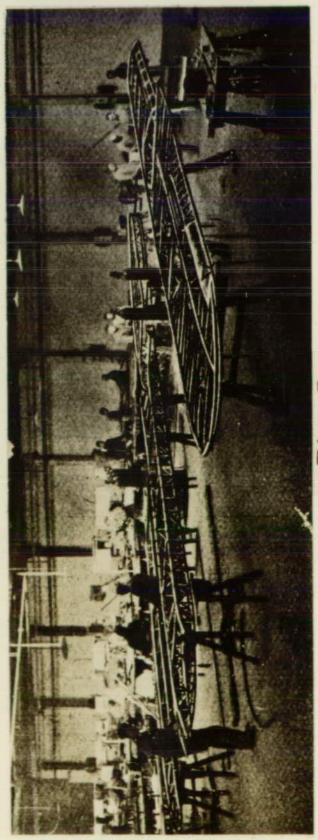


Fig.2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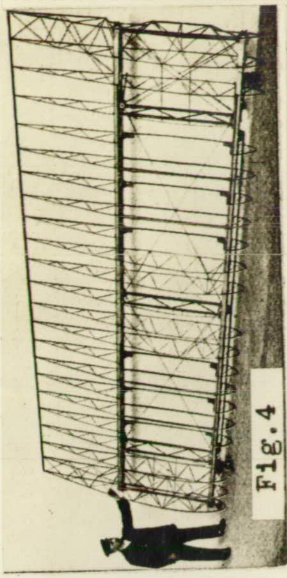
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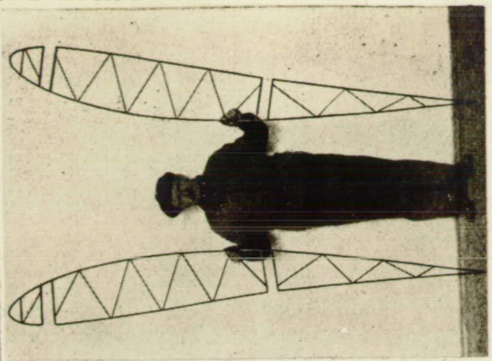
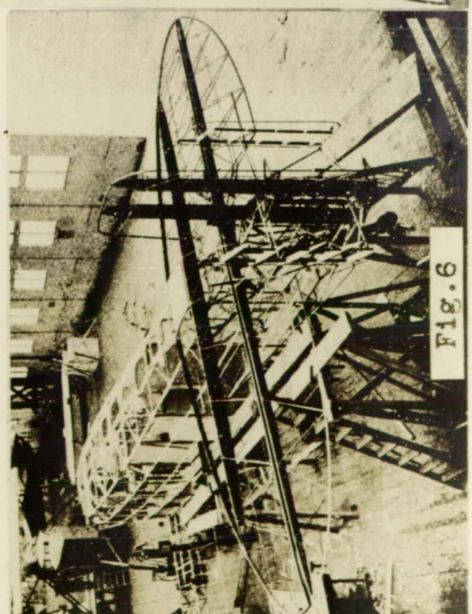


Fig.5 →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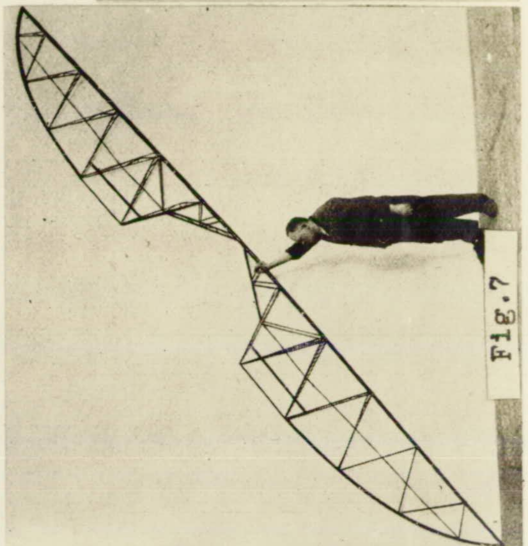
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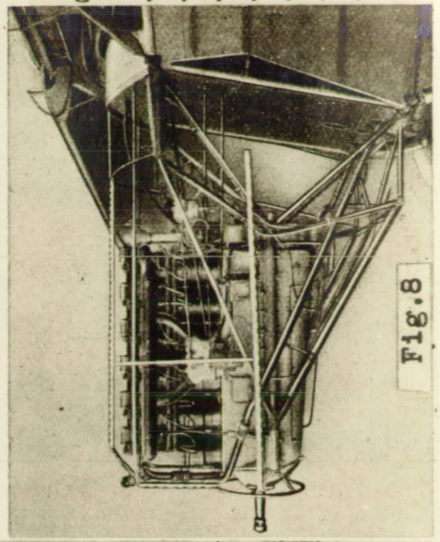
Fig.8

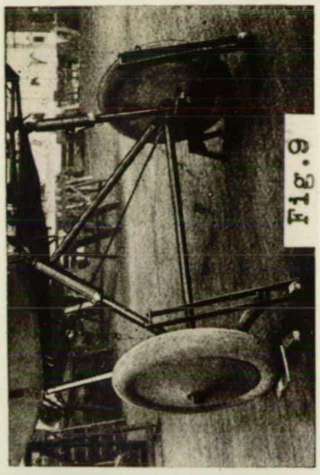
Fig.9