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Quality Control in Welding.

Prüfung der Güte der Schweißungen.

Contrôle de la qualité des soudures.

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To obtain good results in welded structural work, control over the quality of the welds is essential, for the situation is one in which a relatively new method of forming connections has to defend itself against all possible risk of failure. The specifications and regulations which govern welding lay down certain tests which are designed to control the quality of welds as conveniently as possible. Since the quality of a weld depends firstly on the intrinsic qualities of the weld metal and secondly on the skill of the operator, there arises a need for the following tests, as laid down in the relevant French regulations.

a) *Tests of weld metal.*

These tests are for tensile strength and for resilience. The specimens are taken in the first place from the same metal as is used for the electrodes and are cast in a steel mould. The tensile tests are required to give the following results:

	Parent metal	
	Ac 42	Ac 54
Minimum tensile strength	38 kg/mm²	48 kg/mm²
Minimum elongation at fracture measured between gauge points	15 %	12 %

At the same time the resilience must not be less than 8 kg/cm³.

b) *Tests on welded joints.*

These tests serve to control both the quality of the weld metal and the proper execution of the welded work. They include tensile tests and bendig tests to be carried out on specimens made by butt welding flat plates to one another.

The tensile tests must give a value of not less than 42 kg/mm² if the parent metal is "steel 42" and not less than 54 kg/mm² if the parent metal is "steel 54". The fracture obtained from the weld must show neither air bubbles, dark zones, slag incusions nor scoria.

The bending test is made over two cylindrical supports 100 mm in diameter placed at 150 mm centres, the weld being at an equal distance from either support and the opening of the V being downward. By means of clamps applied on the right of the weld a press is operated and until the two branches of the welded plates form an angle of 60°. There must then appear no flaw or crack on the tension side of either the weld or the parent metal.

These different methods of control may be combined with the examinations for appointment of welding workmen. From a practical point of view the best guarantee is not to employ any workmen without adequate training, and to test their skill by periodical examinations.

Apart from the more or less official point of view described above, various attempts have been made to perfect direct methods of inspection which will serve the purpose of identifying such defects as are liable to arise in the miniature metallurgical operations which appertain to welding. The chief of these methods are the following[1]:

Radiographic examination.

Radiography is applied to welds by means either of radium or of radon. It may be recalled that radium is transformed into radon by the emission of α rays which consist of atoms of helium carrying double positive charges in rapid motion. The radon in turn is transformed into radium B, and thence into radium C, by the emission of β and γ rays respectively. The β rays consist of electrons in very rapid motion. The high velocity α and β rays are physiologically dangerous and cannot be used for purposes of radiography; they can be screened off by the use of copper, silver or platinum bombs which allow the γ rays to pass through. By means of radiography it is possible, for instance, to photograph welds in hollow bodies by placing a suitable capsule inside the piece to be photographed.

Magnetographic examination.

The magnetographic method of examination, due to Professor *Roux* of the Ecole Centrale des Arts et Manufactures, is based on the following principle. If a sheet of metal covered by a sheet of paper is placed over a magnet and iron fillings are scattered over the paper the result is to form a magnetic spectrum, the character of which is well known. If, now, the single sheet of metal is replaced by two sheets properly welded together — that is to say without air bubbles or defects of any kind — the line of welding is revealed by the spectrum, because the magnetic permeability of the weld metal differs from that of the sheet in consequence of the greater thickness of the latter. If the weld has been well made the spectrum of the line of welding is regular and is free from any kind of anomaly, but each of the common faults of welding may be recognised by a characteristic figure; for instance, if there is a lack of penetration, which is a fairly frequent fault, a black line appears, due to the increase in density of the lines of force in the thinner portions. Again, if there

[1] See «La soudure à l'arc électrique et la soudure à l'hydrogène atomique» by Dr. *Maurice Lebrun*' of the University of Paris.

is a complete absence of welding at the middle of the thickness intended to be welded, a more distinct black band appears.

The magnetographic method allows of welds bein examined in their actual positions provided that the piece to be examined is not too massive, but it is not possible, for instance, to examine in this way the hull of a large ship. In order to retain a record of such examinations use may be made of transparent paper covered with an adhesive solution on to which the filings are thrown. The method can be worked in any position, and portable apparatus has been developed for use in checking welded work on the site.

Magneto-acoustic examination.

The complement to the Roux method is the use of listening apparatus, and this nomises to yield results of considerable interest. The device consists in creating a magnetic field in a welded plate by means of an electro-magnet and inserting in this field a small coil to which a periodic motion is imparted. By this means a tension is induced in the coil, which is proportional to the variation in the magnetic field along the weld over which the coil is moved. Such induced tensions give rise to harmonic waves, and the latter are strengthened by an amplifier, similar to those used in wireless apparatus, and detected in a headphone. The disadvantage of the magneto-acoustic method is that the recognition of possible defects in the welds is made to depend on a personal factor.

Direct examination by boring.

This method consists in the use of a special form of milling tool to withdraw from the metal a small cylinder which may be subjected to macrographical examination. The Schmuckler tool has been specially devised for this kind of examination. The advantage of the method is that it gives a direct control which cannot be disputed; its disadvantage is that it can only be performed by drilling in depth.

Mention will now be made of two practical methods that can be applied to electric arc welding.

Control of the electrical characteristics of the arc.

A defect common to the methods explained above is that they afford a check only on *a posteriori*. It is possible, however, to control the welding while it is actually being performed, by reference to the characteristics of the arc and to the strength of current in amperes. (There is nothing to be gained by checking the difference in potential across the terminals of the arc.)

Without going so far as to use a recording ammeter, there are also portable apparatus, which do not involve any interference with the electric circuit but allow the current to be checked at any given moment. These instruments work equally well with direct and alternating currents.

If the current is correct in relation to the diameter of the electrode there is a certainty that all the metal which is deposited will be actually welded. There may still, of course, be discontinuities in the weld, but that is a defect which can easily be detected by an hydraulic test.

To adopt this method is to pass from checking the deposited metal to checking the workman who deposits the metal; a further step is to note the time it takes him to do so.

Control of welding time.

By means of a shunt an electric clock may be introduced into the welding circuit for the purpose of registering exactly how long the welder is at work. The time is measured in hundredths of an hour. The clock stops during the periods that the welder is not at work, and even during the periods that the electrode is short-circuited.

The control tests mentioned above relate only to the breaking strength against statical forces, and to measurements of resilience. For some time past a good deal of attention has also been given to fatigue tests on welded specimens. These tests are designed to throw light on the unfavourable effects from the point of view of resistance to fatigue that may be caused by welding.

The systematic researches of Mons. *Dutilleul*, a marine engineer, have shown that whenever a reduction in the fatigue strength has been detected in welds, by comparison with sound plate, the cause has nearly always been the existence of air bubbles in the welds, that is to say, porosity.

There is some tendency to look upon fatigue resistance as an absolute criterion. It would appear, however, that its chief importance is in relation to pieces which will actually be subject in service to alternating stresses repeated an indefinite number of times, as occurs in aeronautical and mechanical work; on the other hand, so far as contemporary structural engineering is concerned, the value of fatigue tests is open to a great deal of question. It may further be remarked, in this connection, that very often the fatigue strength and the resilience vary in opposite directions.