The influence of welding on internal stresses

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The Influence of Welding on Internal Stresses.

Einfluß des Schweißens auf die inneren Spannungen.

Influence du soudage sur les efforts internes.

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The complex stresses set up in welding steel members resolve themselves in two directions, causing secondary stresses in the metal adjacent to the welded joint which are of an indeterminate nature.

It has for some time been thought that the shrinkage of the weld-metal, in passing from the molten to the plastic and crystalline, to its final condition at room temperature, provided accurate data for determining the value of the stresses produced.

The shrinkage of an arc welded joint is composed of a transverse and a longitudinal contraction; it is difficult to proportion the stresses due to contraction of the molten metal at the weld, and those due to the welded plates and sections, which are heated to a temperature approaching fusion and subsequently cooled more or less slowly to room temperature.

We will endeavur in the present paper to discriminate between these two phenomena, for a simple case in which a strip of weld-metal is deposited on a large plate.

In welding plates or steel members edge to edge, the contraction set up in the weld-metal may cause stresses in the parent-metal, near the joint, exceeding the elastic limit, and produce permanent deformations.

Under these conditions, considering only the measurement of the shrinkage at the joint, by means of two gauge marks placed symetrically about the axis of the joint, it would be distinctly wrong to maintain the original distance between the gauge marks by hammering. We have had the opportunity of demonstrating this matter in a communication to the Congress of Autogenous Welding at Rome in 1934. The hammering sets up graver defects; the weld-metal becomes subjected to a hardening in excess of useful limits.

The inspection of a welded structure should certainly refer to the reliability of the plates or sections in the neighbourhood of the weld, and we have developed during the last five years, a simplified method of providing gauge points.

1) *Method of marking the gauge points on the structure.*

This method of providing gauge marks was described in a communication to the Welding Congress in Rome in 1934, and we will limit ourselves to giving a brief description of it, asking the reader to be good enough to refer to the report mentioned for any further information he wishes.

In the course of numerous tests we have carried out to verify the shrinkage in welded structures, we have been able to establish, that the internal stresses resulting from the shrinkage were not equally distributed in the plates, but indicated a variable distribution; the stress being nearly constant at a certain distance from the joint, and commencing to increase at about 30 or 40 cm (12 or 16 inches), becoming a maximum at the joint.

It was curious to find that in certain cases, in the course of welding, a progressive internal tension is sut up, and whith a variation in the rate of elongation a reversal of stress is detected in the neighbourhood of the joint, where compression is substituted for tension. In most cases the final layers of the weld suppress this compression, putting the joint of the structure in tension.

We have thought that this change from tension to compression, and subsequently to a tension in the region of the joint, is explained by the fact that the resultant of the combined transverse and longitudinal contraction effectively determines the rate of variation of the internal stresses.

We will see later when testing large butt welded plates, what the action is of two welding strips and what is the distribution of stress in the neighbourhood of the joint.

We have emphasised as a consequence of these studies, the marking of plates to be welded and verifying the displacement of the marks during the operation of welding. These marks require care to establish, and it is extremely difficult to distinguish differences when measuring to the thousandth part of a millimetre.

2) *Description of R. Sarazin's tensiometer.*

This difficulty has been solved by our new method of marking, which comprises adjustable pointers used in an instrument which we call a „Tensiometer", and the use of a special system of indentations.

We propose to furnish the operator, inspecting the structure with a punch which clearly marks two points at a definite distance apart. Variations are registered on the scale provided by the instrument. It is evidend that a very sensitive instrument cannot be graduated over a long stretch, and the punch permits of planing the marks to within . 1 or at the maximum . 2 mm. We have chosen for our tests a distance of 25 mm (. 1 inch) between points.

After numerous trials, we have decided upon a system of indentations which permits of absolutely precise readings, and which consists of drilling small holes 2.5 mm (. 1 inch) diameter, and 1.5 mm (. 058 inch) deep, in the centred holes produced by the punch; on these holes we impress a ball 3 mm (. 11 inch) diameter; the ball produces a spherical seating at the edge of the hole, and the points of contact of the tensiometer being themselves provided with balls, it is seen that the displacement of the gauge marks will not introduce essential error, as the spherical bearing will be practically preserved throughout the elastic period.

The tensiometer consists of a fixed portion rigidly connected with an instrument box, and carrying a special comparator and a movable pivoted part forming an arm with increased leverage, resting against a stop on the comparator. The instrument gives precise readings; each division of the comparator represents one thousandth of a millimeter, and with a little practice, one can take readings with certainty to within one thousandth.

The distance of 25 mm between the points has been chosen so that one division of the scale represents an internal stress of . 800 kg/mm² (. 48 tons per sq. inch).

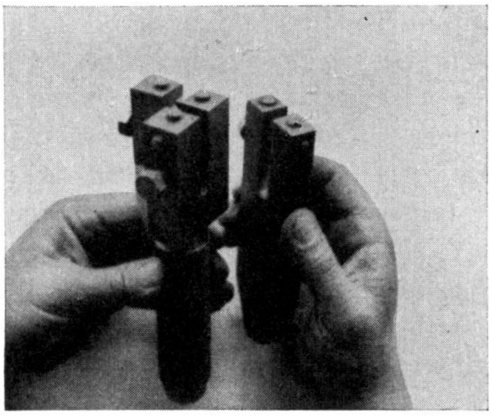


Fig. 1.
Marking tool with changeable ganging distance for the impression of test marks in two directions.

It is apparent that the instrument and the method of measuring are sensitive to variations of stress in the steel of 1 kg/mm² (. 63 tons per sq. inch) or at the maximum 2 kg/mm².

The photograph opposite shows the tensiometer held in the hand, for measuring the gauge points of the plates. The instrument hardly weighs 1 kg (2.2 lbs.), is held conveniently in the hand in all positions, and allows the taking of measurements in most inaccessible places. It has been provided with a pro-

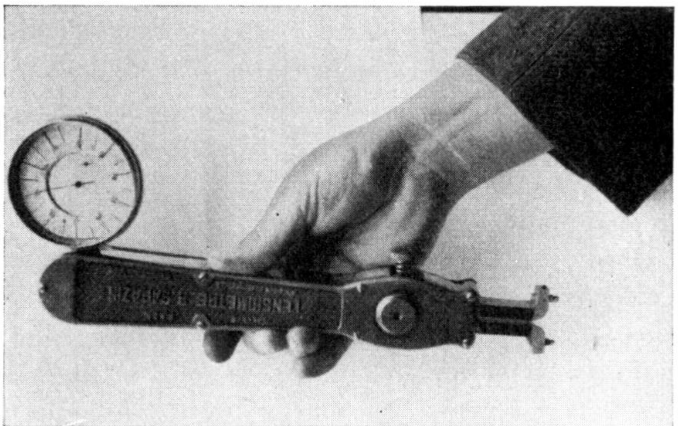


Fig. 2.
R. Sarazin's tensiometer held by operator.

jecting comparator in such a way that one is able without difficulty to work on a vertical wall where the first gauge points are situated at 15 mm (. 58 inch) from the base of the wall, as would be the case for example, in channel sections or joists.

We will further examine different cases in which the tensiometer has been used to measure the internal stresses set up by the shrinkage of the weld-metal, in order to ascertain what new phenomena are introduced by welding in the parent metal the neighbourhood of the joint.

3) *Tests carried out on a large plate after depositing a fillet of welding metal.*

The drawing opposite represents the simplest method of carrying out arc-welding, that is, the deposition of a fillet on a plate or large sheet. It is seen that the method of marking and the application of the tensiometer has furnished some very interesting facts.

Plate I shows that in forming a welding fillet on a large metal sheet 10 mm (. 39 inch) thick, a longitudinal contraction is set up amounting to a mean value of 50 thousandths of a millimetre over a length of 25 mm, which for a mild steel of 40 kg/mm^2 (25 tons per sq. in.) is in excess of the elastic limit.

This longitudinal shrinkage caused a contraction similar in direction along a line parallel to the joint and at a distance of 25 mm (1 inch) from it, which ranged from 20 to 25 mm corresponding to a local stress of about 8 kg/mm^2 (5 tons per sq. in.). In the transverse direction, the average contraction amounted to about 280 thousandths of a millimetre, considerably in excess of the elastic limit, and it is evident that in the case of a sufficiently long plate, this contraction puts the portion in the vicinity of the fillet under tension.

We have represented these several values graphically, (Curve A, Plate I), which represents the transverse deformation and (Curve C), which represents longitudinal deformation.

We have noted that in a plate 10 mm thick, the internal stresses measured on the back of the plate are of the same kind, but less in value, than those measured on the face; one can therefore say with certainty that a state of stress exists throughout the mass of the metal, which diminishes in value as the thickness of the plate increases.

We wished to observe wheter a plate 20 mm thick was similarly affected by the same phenomena, and we found that a neutral central zone existed, and the stresses on the side containing the welding fillet and on that remote from the weld, were reversed in kind.

The curve B represents the transverse variations in thousandths of a millimetre, that is, the difference between the two gauge points, when measured before welding and after the laying down of two superimposed fillets with an electrode 4 mm (. 15 inch) diameter, and a current of 140—150 amperes.

The welded specimen remained practically flat; moreover, examination showed compression in proximity to tension, which suggests a state of approximate equilibrium.

It was noticed that at the surface on which the welding fillet was deposited, a vigourous compression was set up on either side of the fillet, which despite of a thick layer of weld-metal exceeded the elastic limit, whilst locally on the side remote from the joint, a considerable tension was produced. The curves indicate the local values of the internal stresses.

It is certain that the phenomena which we have submitted, in depositing a layer of metal, are due in part, to the local heating of the plates to a temperature ranging from 1000 to 1200^0 C (1832 to 2192^0 F), and a subsequent cooling which induces contraction: The two contractions fix the value of the total compression.

The following tests will show to what extent the two phenomena interact in promoting internal stresses.

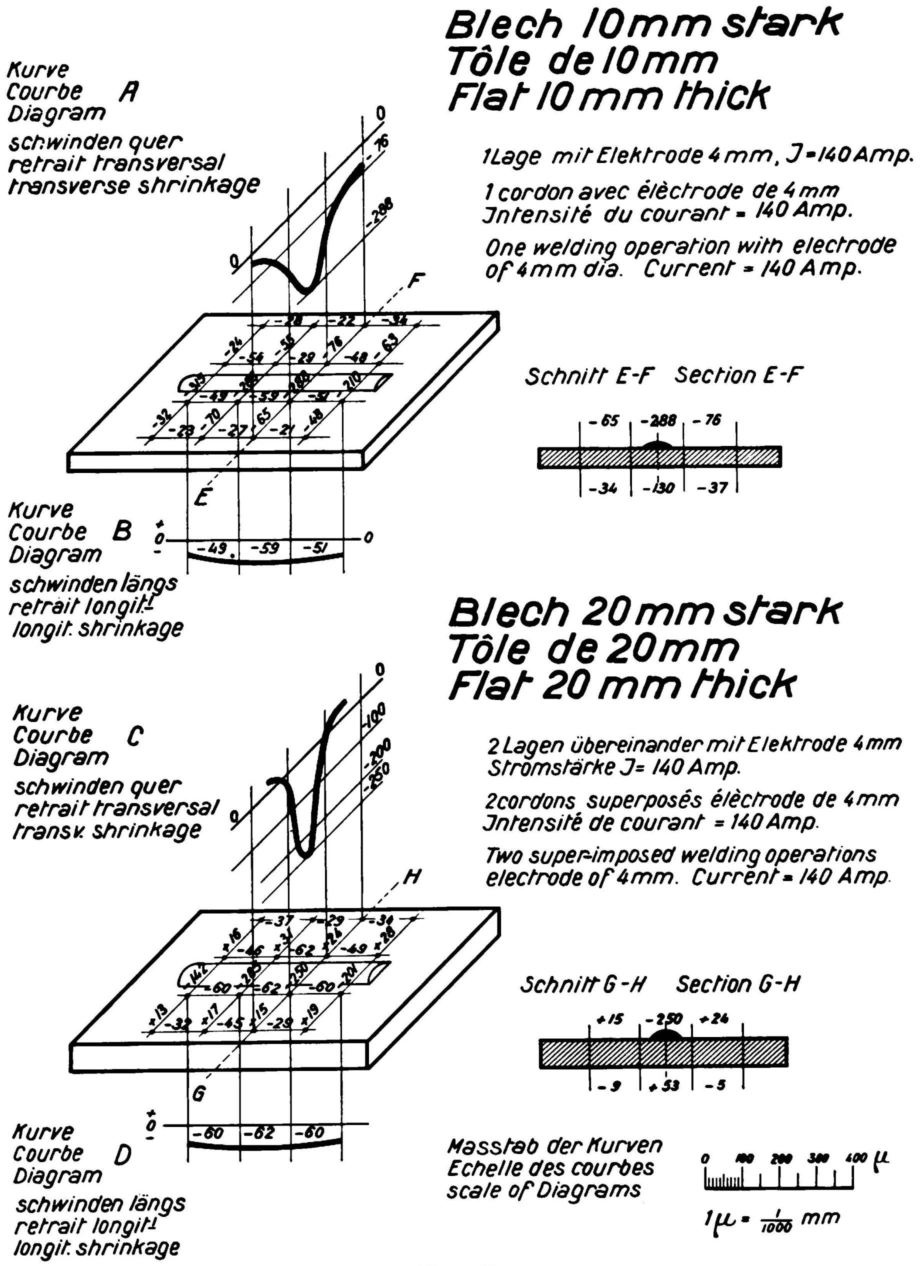


Plate I.

4) *Measurement of the shrinkage of specimens heated in electric arc, without having metal deposited upon them.*

A specimen from a plate 10 mm thick, similar to that previously used, was submitted to local heating by means of an automatically controlled electric arc, over a length equal to that of the previously deposited welding fillet.

By this procedure, the specimen assumed the same conditions as in the case of the welding fillet, and concerned only the heating of the plate, without the inherent contraction of the metal deposited by the electrode.

In order to take account of the quantity of heat absorbed in fusing the electrode itself, we reduced the current intensity of the arc from 140 to 100 amperes, used a carbon 6 mm (. 23 inch) diameter, and made a pass at the same speed as in the normal use of an electrode 4 mm diameter.

The results are given on Plate II, which indicates that the longitudinal shrinkage is of the order of 15 to 25 thousandths of a millimetre, instead of the 50 thousandths previously found, and the average transverse shrinkage is 200 thousandths as against 280 thousandths for a specimen on which a welding fillet had been deposited by the electric arc.

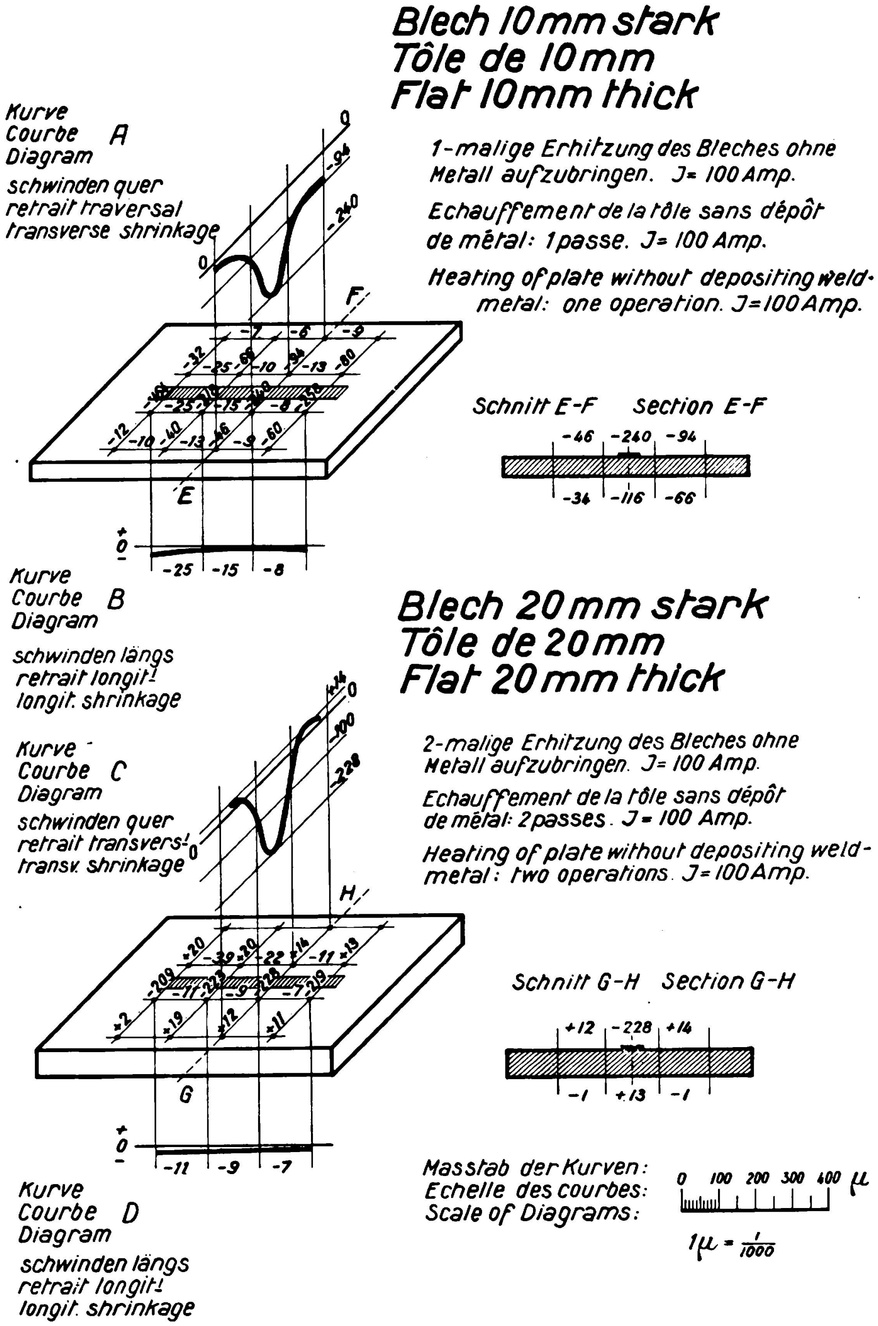


Plate II.

These figures indicate that the shrinkage of the 10 mm thick specimen represents a large part of total shrinkage set up by depositing the welding metal directly on the plate.

Two passes were also made in the manner above stated, over a specimen 20 mm (. 78 inch) thick, and it was observed that the average transverse shrinkage was 215 thousandths instead of 250 for a specimen of the same thickness, as shown on Plate I, on which has been deposited two welding fillets. The longitudinal shrinkage was only from 15 to 20 thousandths instead of 50 to 60 thousandths for the corresponding specimen.

At the back of the plate, tension was found in proximity to a slight compression.

Summarising, we can say that in depositing welding fillets on a plate, the fillet accounts for about 30 % of the deformation, the heating and cooling of the welded plate contributes the principal cause, this assertion needs verifying and is only applicable to this particular case.

5) *Determination of the shrinkage in the case of circular welding "plug" or "false rivet".*

In making this test, two specimens of steel plate 10 mm (. 39 inch) thik have been chosen, and at the centre of one of the test pieces a conical hole 30 mm

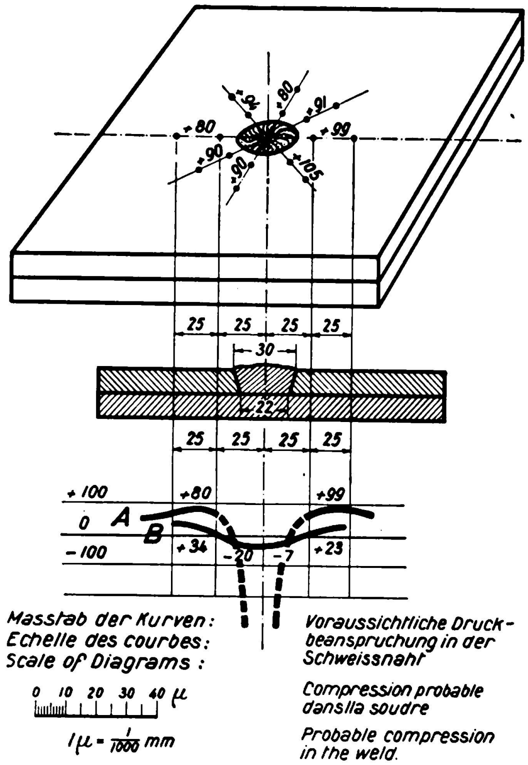


Plate III.

Welding of Hole.

Curve A: Measurements taken between marks on the front side.

Curve B; Measurements taken between marks on the rear side.

and 22 mm (1.17 and . 84 inch) diameter at top and base respectively, was drilled, the hole being thus shaped to let the arc reach the bottom plate. The welding was started with an electrode 3 mm (.11 inch), followed by an electrode 4 mm (. 15 inch) diameter, until the hole was filled.

This "plug" type of welding, or say "false rivet", is a task of precision and can give rise to many disappointents. However, it was interesting to note its behaviour from the point of view of shrinkage and see whether the axis of internal stresses followed a direction radiating from the centre of the hole.

For this purpose, the surface of the plate and the reverse side of the joint were marked as indicated. The curves given on Plate III embody the rusults.

The values recorded by *R. Sarazin's* tensiometer have given with precision the following reesults: —

On the surface the deformations consist of radial tensions and their values, ranging from 80 to 100 thousandths are consistent.

On the back of the specimen, the marks indicate at the centre a compression of 7 thousandths, and the majority of the neighbouring marks show a tension ranging from 25 to 30 thousandths. Some marks on the contrary, suggest considerable compression. (See curves A and B, Plate III.)

6) *Butt welding of two plates* (Plate IV).

The butt welding of two plates presents curious phenomena in the sense that the internal stresses are distributed in a manner dependent upon the ratio of the thickness of the specimen to its width.

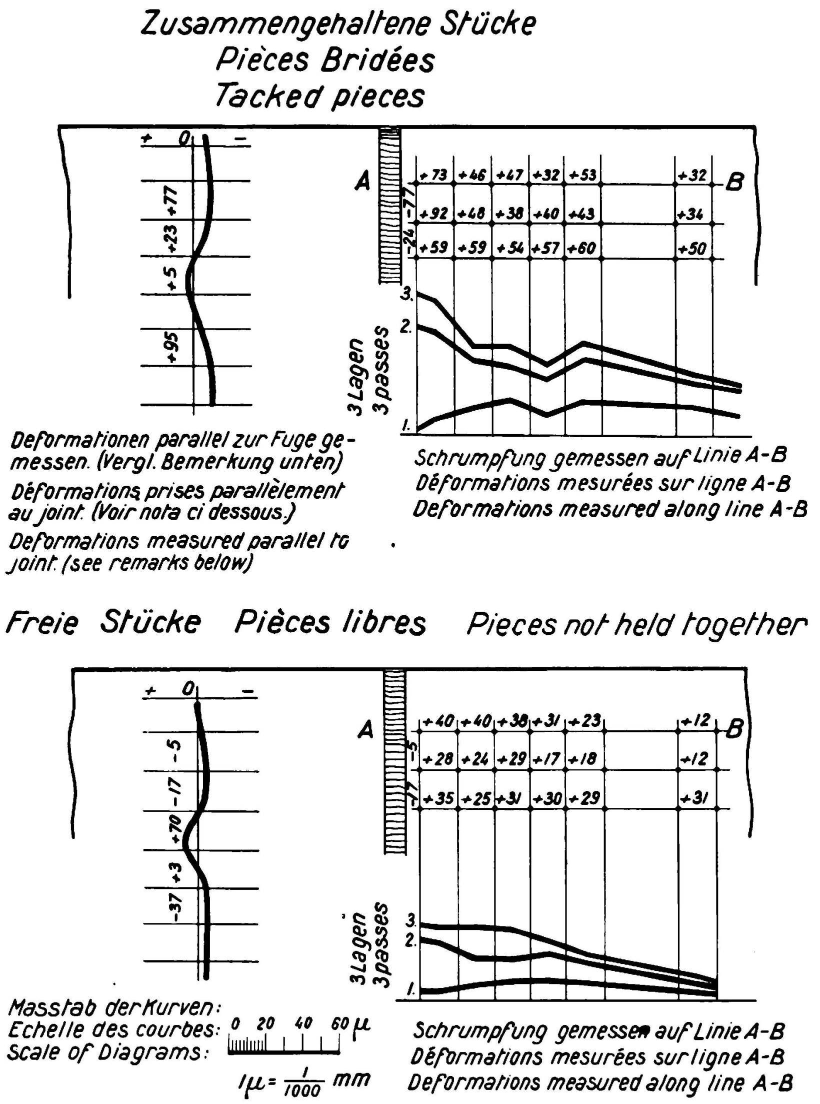


Plate IV.

Butt-welding of two plates of 250 mm width and 8 mm thickness. Note: The change from tension to compression is explainable by the small width of the test specimen.

The longitudinal contraction, in conjunction with the transverse contraction and the conditions of working, develop characteristic results.

In the case of plates 8 mm (.31 inch) thick and 250 mm (5 inches) wide, considerable difference in the stress and in its distribution occurs when the plates are free and when held together by welded tacks.

The curve on Plate IV shows the distribution of stress in free plates, and it is seen that at 25 mm (1 inch) from the joint on an axis perpendicular to the joint, a maximum tension ranging from 20 to 24 kg/mm² (12.6 to 15.1 tons per sq. in.) occurs. The first pass sets up a tension, increasing in the neighbourhood of the joint, reaching its maximum at the welding fillet.

At the second pass the tension increases and the curve is deflected in the region of the joint; this is no doubt due, as we have said, to the interaction of the longitudinal contraction, which neutralizes a portion of the tension.

At the third pass, the deflection of the curve is modified and emphasises the increasing value.

Summarising, it can be said that in a large plate 8 mm thick at a short distance from the joint, about 200 mm (8 inches) from the free welded joint, the general tension is about 8 kg/mm² (5 tons per sq. in.), at 100 mm (4 inches) the average tension is 10 kg/mm² (6.3 tons per sq. in.) and at 25 mm (1 inch) from the joint a maximum tension is reached of 20 kg/mm² (12.6 tons per sq. in.).

On similar specimens held together by welded tacks, that is, welded at the ends when rigidly held on a large slab, the values were much higher. At 200 mm the general tension ranged from 10 to 12 kg/mm² (6.3 to 7.5 tons per sq. in.), at 100 mm the average tension was 20 kg/mm² (12.6 tons per sq. in.) and at 25 mm from the joint. The maximum internal stress ranged from 30 to 35 kg/mm² (18.9 to 22 tons per sq. in.) which exceeds the elastic limit of normal mild steel.

The longitudinal deformation, on a line parallel to the joint and at a short distance from it, often shows inconsistencies, which will study more closely in future; we have noticed in fact, that the deformations occur where points, in close proximity to those under tension, are under compression. It will be interesting to determine a reason for these discrepancies, because an approximately uniform contraction has been found in specimens of greater thickness.

7) *Lap-welded plates* (Plate V).

This type of joint, known as "covered" or "lapped", reproduces the rivetted joint. It has been used since the early days of welding for joints in naval construction and is used in some cases for the welds in structural framework.

This joint is not always advantageous, because it subjects the weld to transverse shear and requires a heavy deposit of metal which makes it uneconomical.

However, it is interesting to see how the welded members react, and two large plates 10 mm thick have been welded, which were previously marked, as was done in the preceeding work. Plate V represents the welded specimen and between each pair of points we have inserted two values; the first refers to the reading taken after the weld AB had been made in three passes with electrodes 4 mm diameter and a current of 140 amperes.

The values arrived at after this first weld have shown that lapping the line of the joint set up a compression of about 40 thousandths of a millimetre along the edge of the specimen on the left and a compression of about 20 thousandths of a millimetre across the specimen on the right.

It will be noticed that the two compressions have added to the tension existing along a line perpendicular to the joint; this extension being due, on the one hand, to the transverse contraction of the joint, and on the other hand, to the longitudinal contraction of the deposited metal. In fact, this latter contraction in shortening the plate transversely, sets up an elongation in the immediate vicinity.

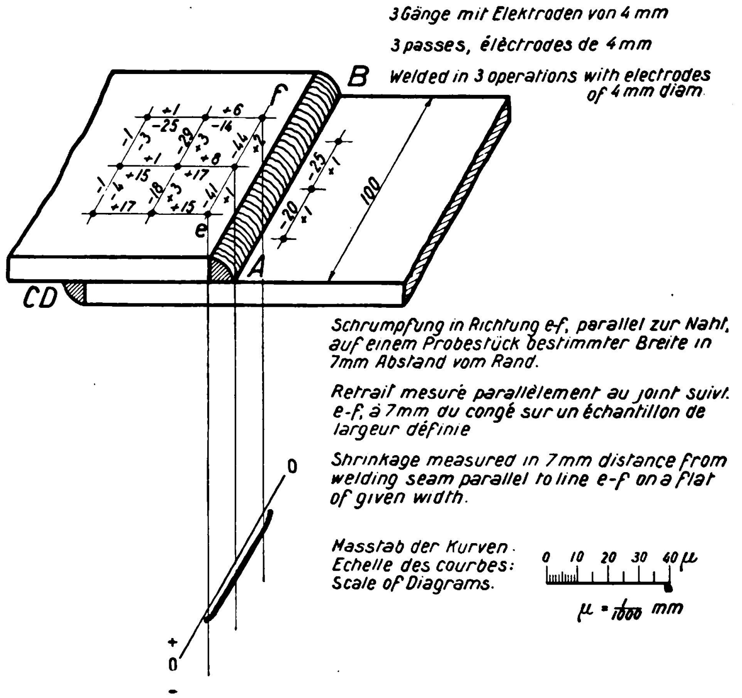


Plate V.

Welding of a lap-joint of two plates 10 mm thick.

Remark: The 1st figure between marks indicates the longitudinal deformation after execution of weld AB. The 2nd figure stands for deformation after welding of line CD. The 2nd figure has to be added to the 1st to obtain the final state.

After the weld AB was finished, that on CD was made under similar conditions, and fresh measurements made, which have formed the object of our preceeding readings.

We have noted a fresh discrepancy which has slightly modified the first readings. It will be seen that this must be added arithmetically to the value already existing, to give the final state of the joint after welding.

The measurements made on a line parallel to the joint have shown that the compression was fairly regular as is shown by the curve (Plate V).

8) *Welding two plates at right angles to each other* (Plate VI).

Plate VI shows this particular case, which is the one most generally met with in structural framework. It was interesting to ascertain the distribution of stress over the different members.

For this purpose the base was marked on the front and back surfaces, and similar marking was effected on both sides of the plate forming the web. The marks were uniformly spaced 25 mm apart by means of the special punches.

The tensiometer, being adjustable about its base it was possible to place marks 15 mm (. 58 inch) from the angle, that is, 5 mm from the edge of the fillet; thus the measurements have been so much the more characteristic. In a general way it does not appear that this type of joint gives large deformations in the web and upper surface of the base, but the back of the base plate, that is, the surface remote from the weld shows considerable tension, which is, moreover, noticed by a tendency of the plate to deflect.

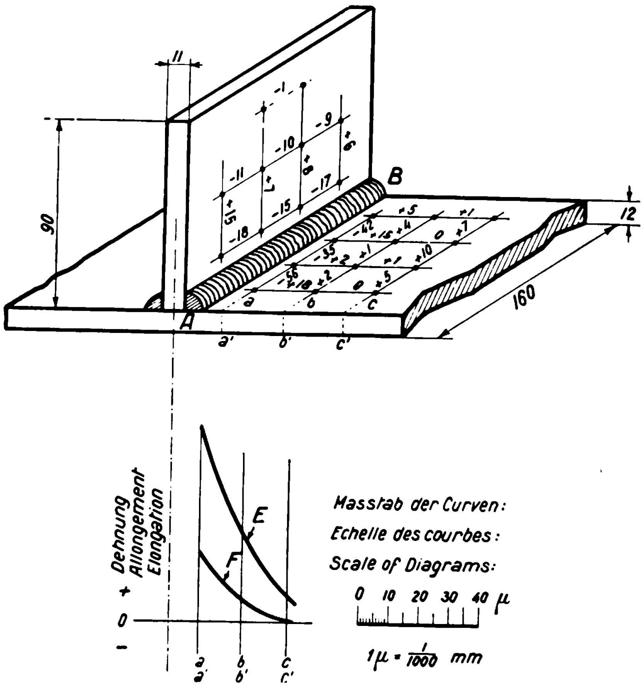


Plate VI.

Fillet weld connection of two steel plates, 3 lagers, 4 mm electrodes. Amperage 140 amps. The welds AB and CD have been made in turn.

Note: The base plate was marked on both sides. The curves E and F show values of deformations.

E: for deformations measured on the rear side at right angles to AB.

F. for deformations measured on the front side at right angles to AB.

The angles containing the welding metal tend to close up, but for rigid pieces this difficulty does not occur.

From an examination of the values recorded on base plate and web, one notices that the contraction is not so great on the latter. It would be necessary to make further experiments on plates of various thicknesses, to ascertain the cause.

9) *Use of the tensiometer for the determination of stresses in a welded structure.*

From the evidence we have put forward, it may be thought that the investigation of the internal stresses of a structure involves a very precise and costly system of marking. It is not so, because for industrial use one is not obliged to make numerous markings, and from our experience in the use of the instrument, 3 or 4 imprints of the punch in 3 directions set out along the line of the joint suffice to give 12 distances, therefore 12 measurements, which amply suffice to determine the magnitude of the phenomena.

In practice, for the investigation of stresses it will not be necessary to make the imprints on the face and reverse surfaces of the welded plate, because we have seen that if the plates are less than 10 mm (.39 inch) thick, the deformations will be less than one half of those recorded for the surface on which the weld was made, and that if the plates are more than 20 mm (.78 inch), these deformations may be reversed in kind but their value will be very small.

The use of the tensiometer in the course of welding a structure will avoid the troubles arising from the shortening of a line of joint, especially if it is a long one, in which it may lead to a diminution of 1 mm per metre, which for a bridge girder 10 metres long (33 feet) would be a shortening of 10 mm (.39 inch) in some places. This can be prejudicial to erection or to the proper distribution of the load.

Controlling the stresses in course of construction will avoid putting parts of the structure which should work in harmony, under different conditions of stress, and for example, in a symmetrical structure, we think that by this method the welded structure could be left in such a state that the shrinkages would be judiciously distributed.

It is evident that for the calculation of tensions set up by the welding, elastic deformations only should be accounted for and these are easily calculated by Young's formula.

Summarising, we might say that there are usually some points in the elastic welded structure in which the metal is stressed beyond the limit. In our opinion, this point is not important because the structure rapidly attains a state of equilibrium in consequence of the stresses produced by its normal working loads.

Some authors contend, no doubt with reason, that exceeding the elastic limit has the advantage of orientating the crystals in the direction of stress and it can be easily shown that the slight hardening which results is without practical effect on the mechanical properties of the steel.

10) *Modification of the internal stresses.*

The method of marking that we propose, and the instrument we have described, serve to demonstrate in a precise manner, the distribution of internal stresses in the members of a joint and in varions parts of the welded structure.

There often exists means of decreasing the internal stresses, and we will endeavour to bring forward in the future some methods of welding, which will reduce them to a minimum.

We can, in fact, make the following recommendations which are of a general character:

In welding a structure, the members forming it should first be assembled, and the start made by welding those members which can be butt welded in such manner that the deformation is a minimum, such as is shown on Plate IV when the pieces are free.

Right-angled welds are then made which, for example, concern the connection of flange and web, and as a general rule the right-angled welds are made of just sufficient strength for the stresses to which they are subjected, so as to avoid a considerable longitudinal shrinkage. Concerning this subject we have noticed that the right-angled welds are often so much too heavy and represent a degree of safety so much too high, that it justifies the preceeding remark.

When a long length of weld has to be made, it is always advisable that several welders should work along the same line of the joint and if the pieces are thick and access to both sides possible, it will be useful to provide a double chamfer by setting the welders to work on each side of the joint. This practice will be advantageous from the point of view of decreasing deformation.

Some engineers are concerned, by the magnitude of the internal stresses set up by welding, but we reply that rivetted structures are not exempt from internal stress and that often the use of a drift or faulty rivetting will set up stresses which we consider analogous to those indicated by our tests. We feel compelled to mention these facts.

There is occasion to draw the attention of welding engineers to a particular point which concerns the weldability of steel used for structures. As a general rule, all the usual commercial steels can be easily welded. However, for structures having a large margin of safety, as for instance, bridges, it will be well to insist that the steel should be weldable in conformity with the researches carried out in this particular branch, and in deciding between two steels suitable for use on a contract, preference should be given to the one which, after being stressed beyond its elastic limit and submitted to a fresh tensile test, is further elongated before rupture. This property must, of course, be considered in conjunction with the mechanical properties, specified for the type of work to be welded.

There are various means of decreasing the deformations, such as: — the choice of electrode, the choice of current intensity for a given electrode and lastly, for a given type of electrode, the choice of diameter to be used.

In welding with electrodes of small diameter, the welding metal is deposited in small successive deposits, giving rise to a series of shrinkages, which set up considerable stresses in the neighbourhood of the plate.

In welding with electrodes of large diameter and high intensity of current, a large area is heated and the concentration of metal too localised; the member is red hot for a longer time, the metal expands and an insignificant local shrinkage can be detected; probably due to the fact that a large area has been annealed by the immense heat of the arc and this presents some difficulties. The choice of the best diameter of the electrode will therefore merit some preliminary tests on the lines we have suggested.

Lastly, there exists another method of drecreasing the internal stresses; that of hammering after each layer of deposited metal. The hammering being methodically carried out in such a way that the amounts of shrinkage recorded by the gauge marks is modified at each pass to the preceeding values or a value approximating to it. We have shown in our report to the Congress at Rome (1934) that such hammering can neutralize almost completely the internal stresses provided that the hammering is carried out with care to prevent a useless hardening of the deposited metal.

We have also shown that a slight hammering of the edge of members welded together, effectively neutralizes the stresses, and we have given exact indications of the work expended for given test pieces.

From our experiments an important point arises as to the quality of the welding metal. The electrode should yield a sound and homogenous deposit, possessing good ductility and resilience; the metal deposited should not show cracks when forged hot or when cold-hammered.

11) *Use of the tensiometer to determine the working stresses in structural framework.*

A number of experiments have been carried out to discover under what other circumstances the tensiometer could be used similarly to an extensometer of the usual type. Possibly our instrument may be a little less exact than certain

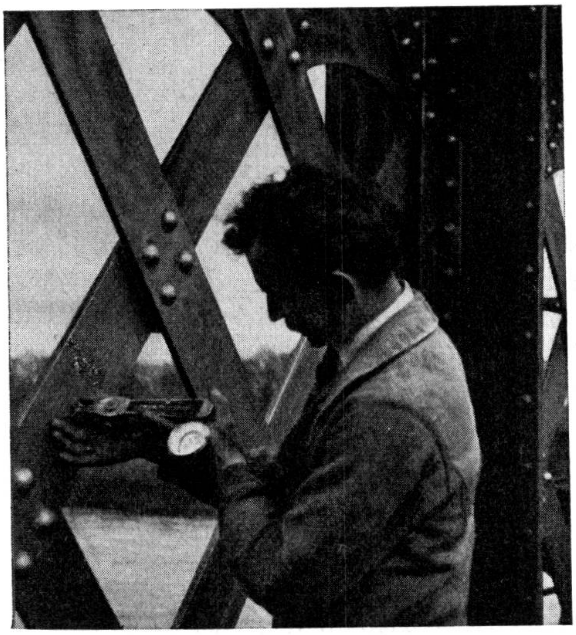


Fig. 3.
Fixing of Tensiometer to diagonal of a riveted bridge for measuring stresses under traffic.

extensometers, but on the other hand it has the great advantage of being able to be mounted at any point of a frame and in any position, when using it in conjunction with the method of marking as proposed and with a system of imprints.

We have been able to read, for example, during the passage of a train, the changes of stress in a diagonal, and it was found that at a certain moment the working stress varied from 5 kg/mm^2 (3.1 tons per sq. in.) below the stress due to dead load, to 7 kg/mm^2 (4.4 tons per sq. in.) above the stress due to same.

The instrument was not effected by the considerable vibration set up by the passage of the train, and we have been able to use it when held in the hand, and when placed on a small support of a type represented in the photograph opposite.

The tensiometer could therefore be used to determine the working stress in structures or even in machine parts, and we can cite the example of taking the stresses in the swan neck of a steel press, where each compression caused a deflection of the scale pointer indicating a maximum range stress of 10—12 kg/mm^2 (6.3 — 7.5 tons per sq. in.).

This shows that we can also on welded machine bodies investigate into the nature of stresses at places subject to important forces. These stresses are mostly very difficult to calculate and consequently remain practically uncontrollable, therefore the research offices demand always increased sections.

By the use of the tensiometer in this case, any part of a machine can be exactly proportioned to the stresses for which it is calculated, and at the first trials of the machine, it can be ensured that the ranges of stress do not exceed those which have been provided for.

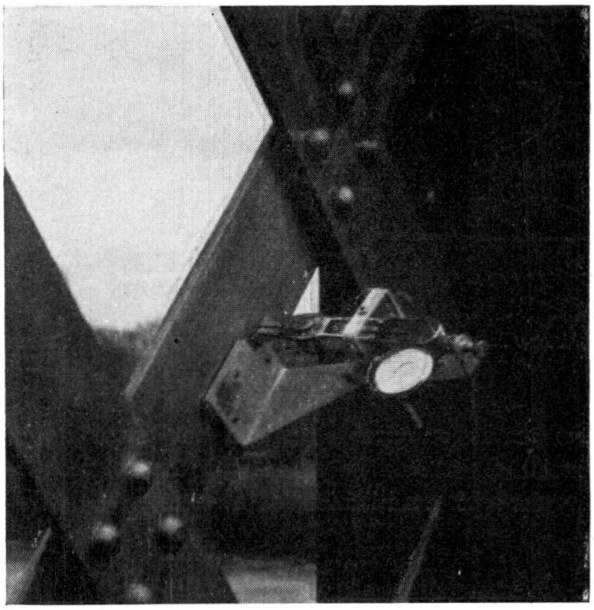


Fig. 4.
Fixing of tensiometer to diagonal by means of angle iron bracket, to give instrument increased stability.

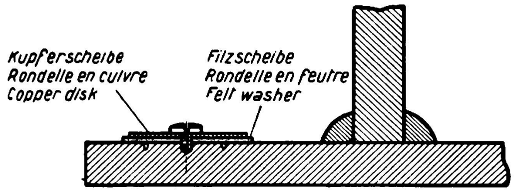
12) *Maintenance of metal structures.*

The system of gauge marks which we recommend for the construction of bridges, trusses and other structures, ought not to be neglected after the structure is finished. In fact, if the precaution is taken to cover the indentations immediately they have been made by a simple device consisting of an oiled washer of felt and a screwed metal cap, in such a way that the indentations are well hidden, one can periodically take fresh measurements by opening out and cleaning the indentations.

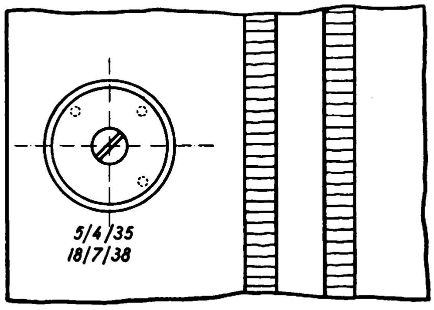
The tensiometer can then be applied successively at various points of a structure, and the values between the gauge points tabulated.

In taking fresh measurements periodically every two years, it can be ascertained whether the stresses at any point are dangerous and whether any parts require special attention.

We hope that this small study will contribute to the improvement of arc-welding, because we consider that with a better understanding of the factors which control this process of welding, engineers who can make use of it will appreciate and recommend more warmly its use.



Bemerkung: Die Messtellen können beliebig angeordnet werden.
Nota: Les pièces peuvent être repérées dans une position quelconque.
Note: The test-marks can be arranged in any direction.



Angaben des Aufsichtsdienstes.
Indications placées par le service de surveillance.
Periodical inspection mark.

Plate VII.

Preparation of test marks on steel structures for inspection purposes. Note: Periodical measurement will be taken with the original test marks for the examination of stresses.

Summary.

The author describes in his report an apparatus of his own invention, based on the principle of comparison, for measuring deformations. Before welding is done a measured length is marked by small impressions. Before and after welding the tensiometer is placed on these impressions, which are in pairs. The report contains the descriptions of experiments carried out with different types of welds. The deformation due to heat and cooling are measured parallel and at right angles to the welds. The measured values are plotted and shown in diagrams, the stresses brought into relation with the distance from the weld, for which the deformation can easily be measured.

The *R. Sarazin* tensiometer can also be employed for taking measurements on existing steel structures; and it has the advantage compared with other instruments of easy application, that it can be used without special fixing arrangement. The measuring marks can be covered by oiled felt pieces and a protecting metal disc, so that they can be used for taking measurements at later dates.