A Study of the Hot-pressure Welding of Steel

By W PANKNIN and M SODEIK*

Hot-pressure-welding finds wide application in the manufacture of welded pipes. The procedure consists in first bending a so-called split-tube out of the strip and subsequently welding it. The welding itself takes place as hot-press-welding. The heated edges of the strip are compressed so well that they fuse with each other. What is therefore involved is 'Rigid State Welding'.

For the heating of the strip edges, one has to distinguish between four different heating processes :

1. Resistance heating with 50 cps alternating current over electrode rollers.
2. Resistance heating with inductive coupling (1000 to 10,000 cps alternating current).
3. High frequency heating with 450 kcps over sliding contacts or inductors.
4. Fretz-Moon Technique.

In the procedures mentioned at (1) to (3), only the strip edges are heated and welded with each other. The depth of penetration of the heating is dependent on the frequency employed. In the process mentioned at (4) above, the entire strip is heated. The edges alone are then further heated and are welded together.

Although hot-pressure-welding is widely applied in the manufacture of pipes, it is not known exactly how the individual limiting quantities influence each other. The essential limiting quantities are :

1. Welding temperature
2. Deformation at the welding area
3. The state of the surface of the strip edges.

It should be therefore examined what the minimum conditions to be observed are with a view to obtaining a welded joint free from defects. That is to say, the welded joint should exhibit the same characteristics as the raw material both with regard to its rigidity as well as with regard to its ductility.

For the sake of simplicity, round test pieces were used in the investigations (Fig. 1). Two separate experimental tests were employed in order to be able to investigate the influence of the extent of the heated zones. Fig. 2 shows the schematic installation of the equipment required for the experiment. The test pieces were clamped to a small hydraulic press and were heated by passing arc electric current. While being heated, the test pieces were subjected to a slight advance compression. The pressure welding was done when the temperature necessary for the experiment was attained. Fig. 3 gives a view of the equipment necessary for the experiment. The power and the path of compression were registered during the experiment. The path of compression could be limited by means of limit stops, so as to obtain by this means deformations which are similar. The temperature was recorded by means of radiation pyrometers in infra-red range and was controlled by means of thermoelements in the individual experiments. Fig. 4 shows welded test pieces which

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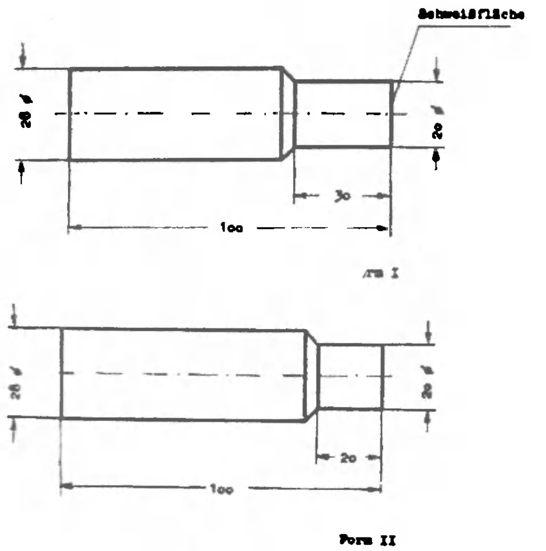

Fig. 1. Test pieces for welding.

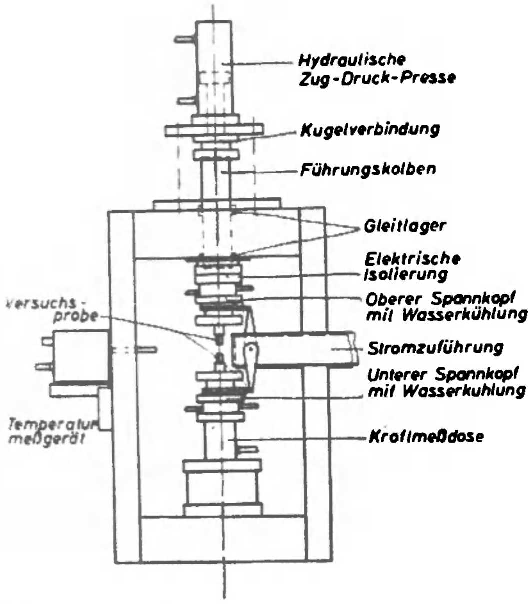

Fig. 2. Press-welding equipment (Schematic).

have become distinguishably deformed. The flow lines are clearly identifiable.

The welded test pieces were then machined and were subjected to tensile tests. Fig. 5 shows various forms of test pieces. Forms I and II were used for tensile test while Form III was made ready for bending test. Form I showed itself up to be unsuitable as normally the fracture did not appear at the weld. No conclusions about the ductility of the welded seam could therefore be drawn from this test. As, however, hardness is not the only criterion for judging a welded seam, Form II was used chiefly for the tensile

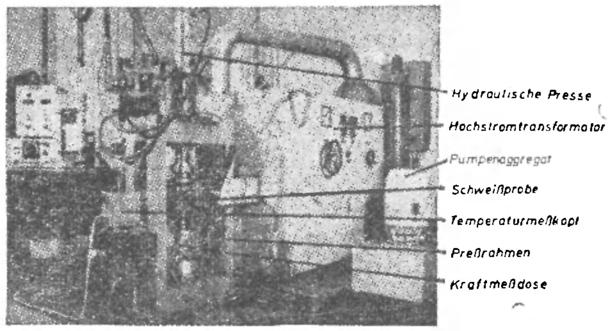

Fig. 3. Press-welding Equipment.

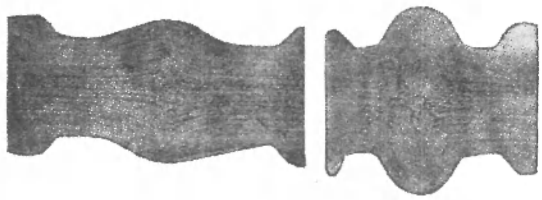

Fig. 4. Longitudinal Section of Press-welding.

test. In this test, the weld seam lay at the narrowest place of the test piece.

Fig. 6 represents several load-extension-diagrams and corresponding fracture patterns. A brittle fracture can be seen on the left side, which is given rise to by particularly bad welds. The stiffness lies frequently in the range of the initial hardness of the raw

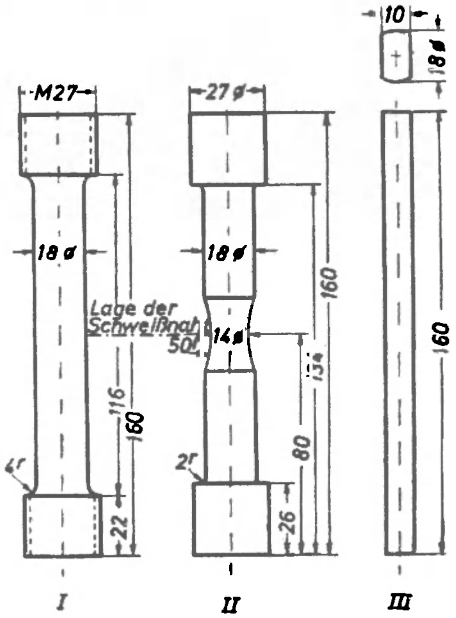

Fig. 5. Test pieces for the testing of raw material.
I. Tensile test according to DIN 50125.
II. Rounded off tensile test.
III. Test piece for bend test.

material. Very often it could even be observed that although the cross sections were only partially welded together the hardness of the initial raw material had been achieved. A ductile fracture can be seen on the right side in Fig. 6. This fracture was indicative of a defect free weld. Till the emergence of this fracture, the welds in the experiment in question were not considered to be good. On the other hand, the welds were not defect-free if a mixed fracture as shown in the middle of Fig. 6 appeared. This mixed fracture indicates a combination of brittle and ductile fractures.

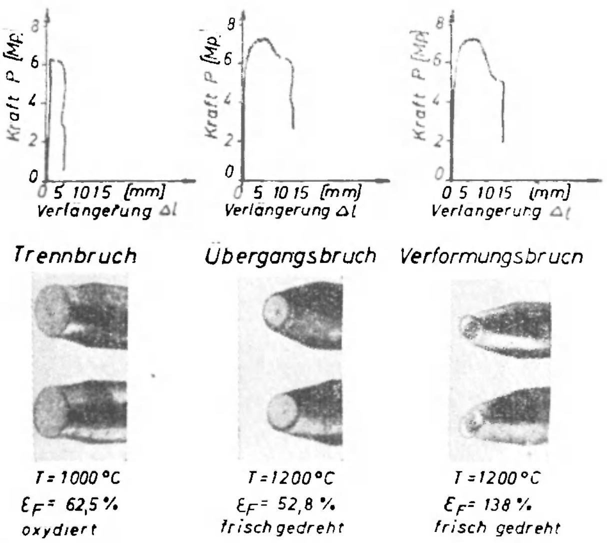

Fig. 6. Forms of fractures and the corresponding load extension diagrams of rounded tensile test 'pieces.

The experiments were carried out with a carbon steel with 0.15% carbon. Fig. 7 gives the tensile strength of test pieces after different and varying degrees of upsetting during pressure welding at a welding temperature of 1000°C. Different surface conditions were noted as additional limiting quantities. The test pieces shown as freshly turned were welded with least lapse of time, the maximum being eight hours. The test pieces so treated attained the strength of the raw material for proportionally small upsetting. In the case of test pieces stored for four weeks after the turning, which outwardly appeared to retain metallic lustre without displaying any rusty coatings, an upset of about double the magnitude was necessary before the strength of the raw material could be attained, as can be seen from the figure. On the other hand, the hardness of the raw material can never again be attained if test pieces are used which have been left for about one hour at a temperature of 300°C and which consequently display oxide layers identifiable by means of the oxidation tints.

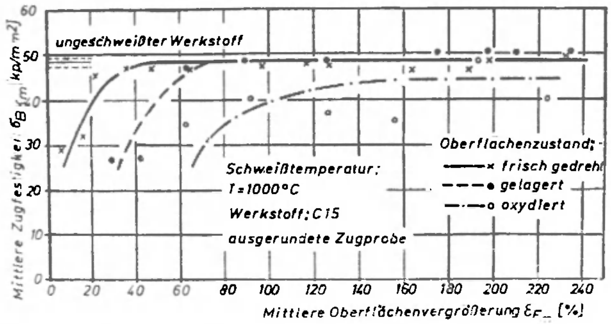

Fig. 7. Relationship between the tensile strength and the degrees of upset for different initial states.

When the welding temperature is raised from 1000 to 1200°C, relationships similar to the ones in Fig. 7 and Fig. 8 are obtained. The strength of the raw material is however obtained by smaller upsetting.

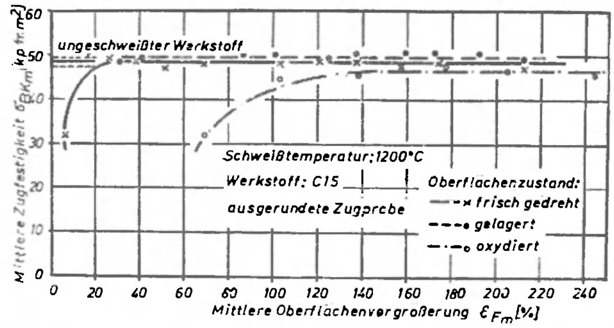

Fig. 8. Relationship between the tensile strength and the degrees of upset for different initial states.

It can however be seen from both the figures how the strength of the pressure-weld is adversely affected by thin oxide layers. If in addition we observe the percentage reduction in area at the weld, the adverse effect can be seen more clearly. The reduction of area and the form of the fracture are represented in Fig. 9, with reference to test pieces welded at a temperature

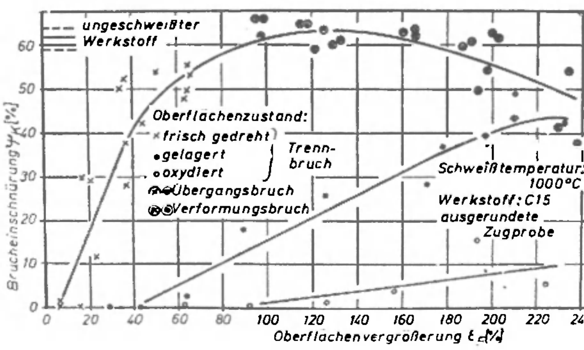

Fig. 9. Reduction in area of cross section at the fracture in relationship with the degrees of upset for different initial states.

of 1000°C. It can be seen that the freshly turned test pieces yield a defect-free fracture only by an upsetting as great as 100% while according to Fig. 7 the strength of the raw material had been attained by a surface enlargement of only about 40%. In view of the deformation characteristics, the minimum upset must therefore amount to 100%. By looking at test pieces stored for four weeks, it can be seen that the first deformation fractures do not appear until after the upsetting is about 240%. On the other hand, it was not possible to produce a defect-free weld with the surfaces provided with oxide tints. An almost similar situation is encountered when the welding temperature is raised to 1200°C (Fig. 10). The raw material with the oxide tints alone is somewhat raised in its absolute values for the percentage reduction in area at the fracture. Still the form of the fracture and the extent of its reduction allow of a defective weld being identified.

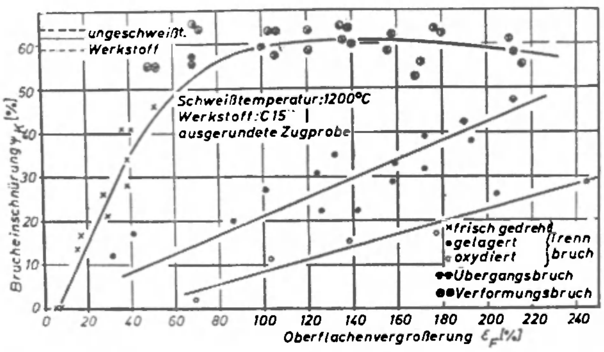

Fig. 10. Reduction in area of cross section at the fracture in relationship with the degrees of upset for different initial states.

To be able to comprehend the influence of the welding temperature on the quality of the welding, the reduction of area determined in the testing of the raw material was plotted over the upsettings, in the case of the freshly turned test pieces (Fig. 11).

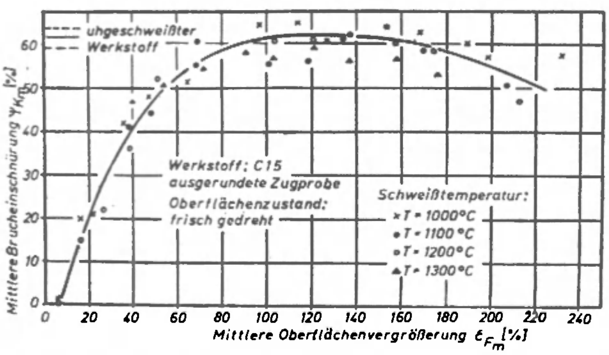

Fig. 11. Reduction in area of cross section at the fracture in relationship with the degrees of upset for different welding temperatures.

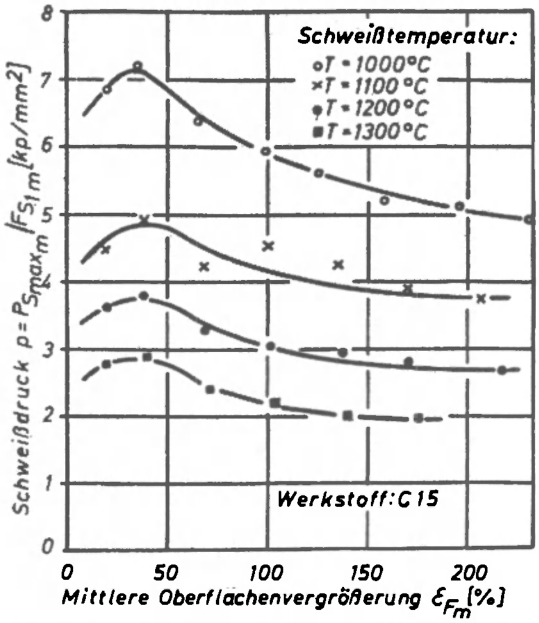

Fig. 12. Relationship between the welding pressure and the degrees of upset for different temperatures.

From the figure it can be understood that the welding temperature appears to have essentially no influence in the investigated range of 1000°C to 1300°C.

It can be concluded therefrom that in the first place the cleanliness of the surface and the deformation at the welded area are important for a defect-free joint. Unclean surfaces do not yield a defect-free and ductile weld even at high welding temperatures. In spite of an adequate degree of strength, such welds are to be regarded as defective. It follows therefore that it is very important that the strip edges are free of dirt and oxides immediately before welding so that the weld-seams will be without defects and besides, the welding will take place after relatively slight deformations.

The welding pressure is often looked upon as a factor which is important. It should therefore be examined whether in addition to the relationships already explained, the welding pressure also exerts any influence. Fig. 12 plots the welding pressure over the upsetting for different welding temperatures. From this it is seen that, as was to be expected, the welding temperature is in the first place basic for the value of the welding pressure. As however it can be seen from Fig. 11 that the welding temperature has no particular influence on the quality of the welded seam, it can be deduced that the welding pressure appears to have little or no effect on a welded seam.

If instead of the welding pressure the compression power needed for pressure-welding were to be plotted

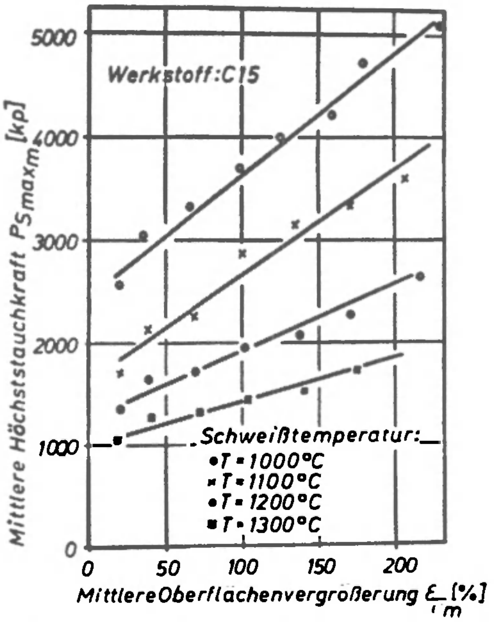

Fig. 13. Relationship between the maximum compression load and the upsetting for different welding temperatures.

over the upsetting, then we get a linear interrelation according to Fig. 13. As however the upset is the quantity which governs the welding, it may be possible to achieve a constant upset over a constant compression power, if the other conditions are constant. The compression power can therefore be used as standard factor for controlling the process, in order to nullify measurement variations. But the compression power renders itself suitable to be so used only when the other welding parameters such as, for example, temperature and the speed of deformation are held constant.

Metallographic investigations showed that when freshly turned and welded test pieces are used, the

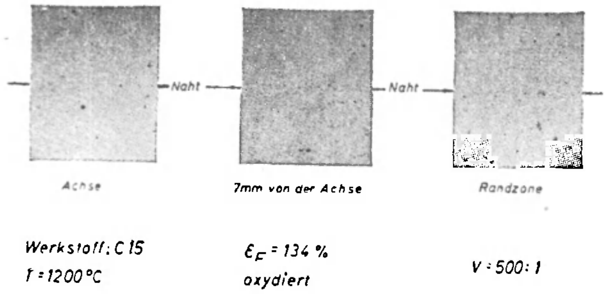

Fig. 14. Oxide distribution at different places of the joint.

oxide inclusions in the welded seam are very slight. The inclusions were more when test pieces were used which had been stored for four weeks. Fig. 14 shows longitudinal sections of a test piece which has been stored for one hour at a temperature of 300°C. A difference in the presence of inclusions between the core and the edge is clearly manifest. The reason for this lies in the fact that a greater deformation takes place at the core than at the edge and consequently the oxide gets more widely dispersed at the centre.

Summary

The foregoing investigation was aimed at ascertaining what are the controlling factors for attaining a defect-free weld with reference to low carbon steel. The welded seams were subjected to tensile tests and the strength and the deformation behaviour at the weld joint were judged. It was seen that in the investigated range the quality of the weld is not affected by the temperature and that on the other hand the upset and the surface cleanliness are very important for the welding process. The welding pressure does not appear to affect the quality of the weld.

Notes :

Schweisfluche — Welding surface
Kugelverbindung — butt joint
Fuhrungskolben — shaft
Gleitlager — bearing
Elektrische Isolierung — electric insulation
Oberer Spannkopf — top pressure head
Mit Wasserkuhlung — with water cooling
Stromzufuhrung — electric connection
Unterer — lower
Kraftme*B*dose — load measuring container
Versuchs probe — test probe
me*B*gerat — equipment
Hochstromtransformator — High current transformer
Pre*B*rahmen — press frame
Lagederschwei*B*naht—Position of the weld
Kraft — load
Verlangerung — elongation
Trennbruch — brittle fracture
Ubergangs bruch — mixed fracture
Verformungsbruch — ductile fracture
Oxydiert — oxidised
frischgedreht — freshly machined
Mittlere — medium
Zugfestigkeit — tensile strength
Ungeschwei*B*ter Werkstoff — Unwelded material
Schwei*B* — Welding
ausgerundete Zugprobe — cylindrical test piece
Oberflachenzustand — Surface Condition
gelagert — stored
Oberflachenvergro*B*erung — degree of upset
Bruchenischnurung — reduction in area
Schwei*B*druck — Welding pressure
Hochststauchkraft — Compression load
Naht — joint
Achse — axis
Randzone — edge.