DYNAMIC LOADING STRESS IN ANGULAR WELDED JOINTS

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Dynamic photoelasticity has been used to examine the effects of joint geometry on failure in explosive loading; the stress waves interact with the shape in a way that can be described as diffraction at dihedral angles formed by the plane of the plates and the surface of the metal fillet. Such joints fail in the reflected wave at the points of passage from the main metal to the strengthening fillet, as well as in the interference zones.

Angular joints are often welded, and they may be subject to dynamic loads in real structures. Specifications have been drawn up for the components of such joints but the stress distribution in the weld zone and the mode of failure under pulse loading are not well understood.

Polarization methods have been combined with high-speed cinephotography to examine the effects of joint geometry on the state of stress and failure in explosive loading.

The effects of the structure of the real joint (assumed free from defects) were eliminated by using a linearly viscoelastic material (polymethyl methacrylate) having the following physicomechanical characteristics: density 1.18 g/cm^3, yield points in compression, tension, and bending correspondingly 900, 600, and 1000 kgf/cm^2, elastic modulus $3 \cdot 10^4$ kgf/cm^2, Poisson's ratio 0.35, and Brinell hardness 19 kgf/cm^2.

Sheet of thickness 10 mm was used to make up joints in accordance with GOST 147771-69 with the joints denoted as U5, U7, U8, and U9 in accordance with that State standard. Table 1 gives the dimensions of the elements.

The loading was provided by 50 milligrams of PETN; the maximum load was 500 kgf/cm^2 and lasted for 20-25 μsec, with a rise time of 8 μsec. A planar wave front was provided by distributing the material uniformly over the loaded plate at 60 mm from the working region.

We found that the shape had a marked effect on the dynamic-stress distribution; as the joints were unsymmetrical, it was not equivalent to load them from opposite sides. For instance, joint U9 when loaded from side A (Fig. 1d) produced a state of stress at the start (Fig. 2, frames recorded at 1 million frames/sec, frames shown at intervals of 8 μsec), and wave diffraction at the dihedral angles formed by the surface of the joint root and the planes of the plate, so the maximum stress concentration arose there. The root of such a joint is most likely to have various defects on account of faults during welding, irregular perforation of the edges, and so on, so this region on dynamic loading produces conditions that may initiate failure.

TABLE 1

Symbol	Sizes in mm					
	$S=S_1$	K	g	l	l_1	K_1
U 5	14	10.5	—	—	—	3
U 7	14	—	2	13	—	—
U8	19	—	2	13	—	2
U9	14	—	2	22	—	—

Reinforcement favorably influences the state of stress; the lines of maximum tangential stress reproduce the geometry of the reinforcement (Fig. 3a). Conditions for failure are not set up at the points of transition to the reinforcement. The diffraction is accompanied by refraction and interference, which cause cracks to develop and grow in the loaded plate at a distance of 20 mm from the end face. The effect is similar to shattering.

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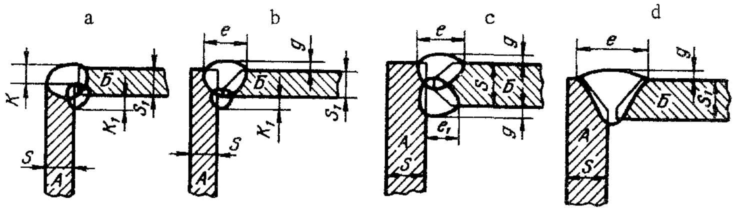

Fig. 1

Fig. 2

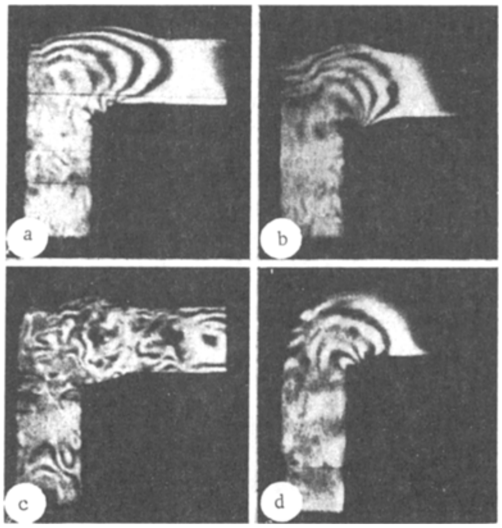

Fig. 3

When a U9 joint was loaded from the opposite side (Fig. 4) the above effects were accompanied by stress localization and failure at the point of transition to the reinforcement, i.e., reinforcement facilitated crack initiation and growth. This disposition relative to the wave propagation direction was hazardous even with comparatively smooth transitions to the reinforcement (reinforcement from factor 11.0). The cracks were initiated and grew mainly in the reflected wave, i.e., the latter is the most hazardous from the viewpoint of joint failure. The reinforcement in that case tends to favor shattering, since it lies in the wave interference zone when the load is on the plate B side. Stress waves of different types act on the vertex of a growing crack to alter the state of stress, which alters the path of the crack (Fig. 4). The initial growth rate is quite high (500 m/sec), but it gradually falls to zero. This is accompanied by failure at the root of the joint, i.e., on the internal contour, which begins much later than that on the outer edge.

The results for U7 joints showed that the effects on loading from side A were similar to those for U9 in spite of the difference in the reinforcement (fall factor 6.5). Waves propagating from plate B produced more marked stress concentration at the points of transition to the reinforcement, so the cracks formed and grew somewhat earlier than for U9. An important part in the failure is played by the disposition of the reinforcement relative to the wave interference zone, which to a large extent determines the crack growth rate and hence the joint strength. In the case of U7, the fillet reduces the sharp transitions and improves the root geometry, which produces a more favorable state of stress.

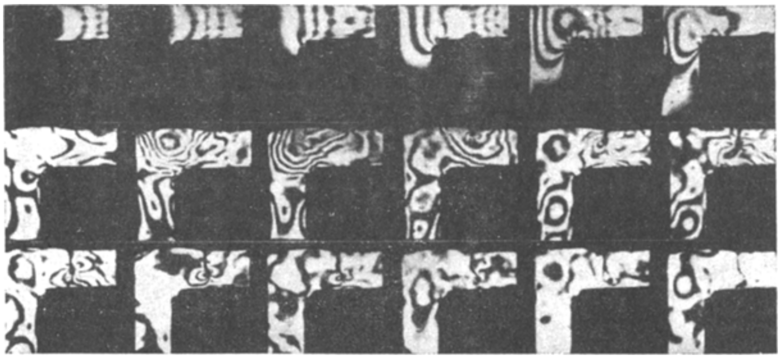

Fig. 4

The results for U8 indicated that a very unfavorable geometry is present, in spite of the bilateral reinforcement, and this leads to a very high stress concentration on the internal edge, which makes itself particularly felt when waves propagate from point A (Fig. 3b). The reason is that a dihedral angle close to 90° is formed on the internal edge, and this results at a certain loading level in failure even in the incident wave. Results show that failure occurs mainly as in Fig. 3c or in the reflected wave at points where the joint section changes sharply.

The U5 joints were the best as regards dynamic strength. The shape of these does not set up failure conditions on the outside edge, although the inner one remains hazardous (Fig. 3d). No shatter effects are seen for this type.

The results indicate that diffraction and interference in stress waves are responsible for the state of stress in such joints; in the general case, the stress waves interact with the geometry in a way equivalent to diffraction to the corners formed by the planes of the plates and the surface of the metal fillet.