Nitinol - Stainless Steel Compound Materials Made by Explosive Welding

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where E/M is the ratio of amount of explosive E and Mass M of flyer plate. According to Fig. 1 the following equations exist due to simple geometrical relations:

flyer plate velocity: $v_p = 2\ v_D \sin(\gamma/2)$ (2)

the collision angle: $\beta = \alpha + \gamma$ (3)

and

the collision velocity: $v_K = (\sin\gamma / \sin\beta)\ v_D$ (4)

$= (\sin\gamma / \sin(\alpha+\gamma))\ v_D$.

It is evident from these equations that explosives with different detonation velocities are required. In the case of a parallel arrangement between flyer plate and base plate the collision velocity is equal to the detonation velocity.

An explosive weldability window as established by R.Wittman[4] and later used often[5,6] to describe the weldability of different material combinations. Schematically it is shown in Fig. 2. In a plot of β vs.

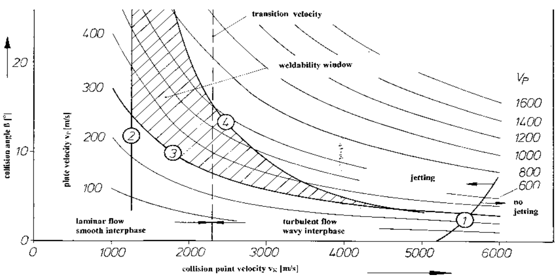

Fig. 2 Explosive weldability window, schematic

V_K there exist 4 boundaries for the welding parameters:

1) An upper limit of the collision point velocity Exists, up to which jetting occurs necessary for bonding. A good estimate for this upper limit is sound velocity, multiplied by 1.2
2) A further value of importance is the critical collision point velocity v_{Kt} which separates the regimes of turbulent and laminar hydrodynamic flow during cladding with the result of a wavy or smooth interphase. It can be estimated by

$$V_{Kt}^2 = 2R_t(H_1+H_2)/(\rho_1+\rho_2)$$

With H_i and ρ_i the Hardness and specific gravity of the two materials being welded and R_t the Reynolds number for viscus flow which has been determined for hydrodynamic flow under conditions of explosive welding at an accuracy of 17% and amounts 10.6

3) A minimum plate velocity is required for hydrodynamic flow to set in and is given by the equation:

$$V_P = \sqrt{(UTS/\rho)}$$

Where UTS = Ultimate Tensile Strength and
ρ = specific gravity of material

4) If the plate velocity v_p is too large, then excessive specific kinetic energy $K_{kin} = 1/2\rho v_p^2$ is transformed into heat and leading to molten material. Undesired amounts of intermetallic phases are created, then.

3 Experimental

The most imortant parameter in these investigations is the collision point velocity v_{Kt}, which describes the transition from laminar hydrodynamic flow at low velocities to turbulent flow at high velocities, or the transition from a smooth to a wave interphase.

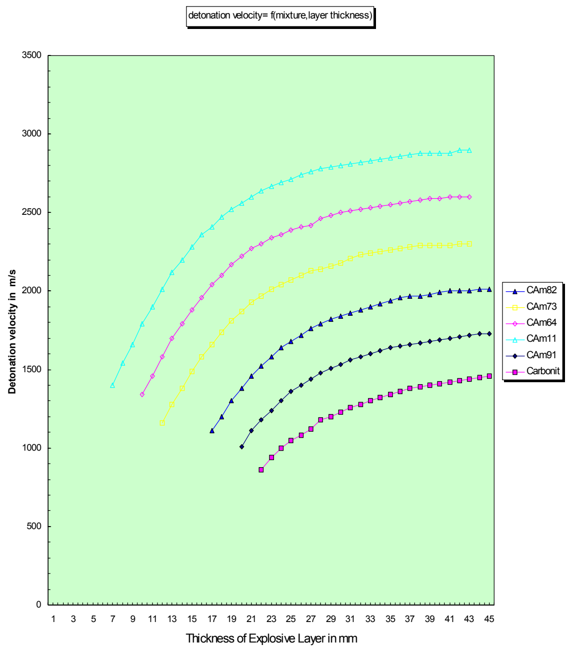

Figure 3 Detonation velocity of different kind of explosives as a function of layer thickness. CA91 = ratio of Carbonit and Ammonit = 9 : 1.

Low detonation velocity explosives are required for this evaluation. Fig. 3 shows these values . The explosives were made from commercially available explosives Carbonit, Ammont and RDX just by mixing the powder explosives in different ratios. The detonation velocity is dependent from thickness of explosive layer.

Explosive welding experiments were made in a tubular arrangement. Tubes of Stainless Steel with specification 1.4571 with the dimension 13.6∅x0.8x150mm were coated outside with explosive and upon initiation of detonation in axial

direction accelerated towards a concentrically arranged bar made of NITINOL® (SE508) with the dimension 12.7Øx150 mm.
Micrographs of metallurgical investigations were taken from cuts in a direction parallel to the axis of the compound material and reveal good bonding. Fig. 4 and Fig. 5 show the bonding area for a wavy interphase and a smooth interphase, respectively.

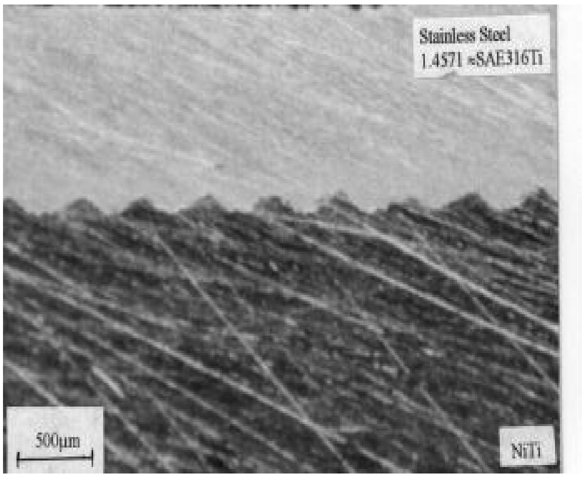

Figure 4. Wavy interphase of explosively welded NITINOL- Stainless Steel compound, welded at a collision point velocity of 2580 m/s

Figure 5. Smooth interphase of explosively welded NITINOL- Stainless Steel compound, welded at a collision point velocity of 2190 m/s

4 Discussion

From equation 3 with hardness data of stainless steel (240 HV_1) and NITINOL® (~200HV_1) a transition collision velocity of 2400 m/s is expected. The experiments are very well in accordance with these calculations.

References

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