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PROCESS FOR EXPLOSIVE SURFACE BONDING OF METAL PARTS

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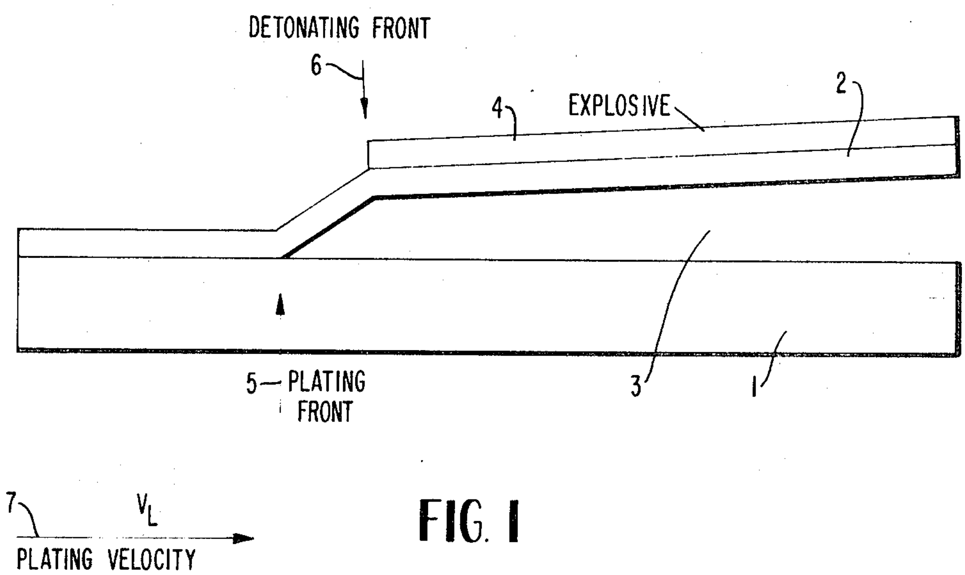

FIG. 1

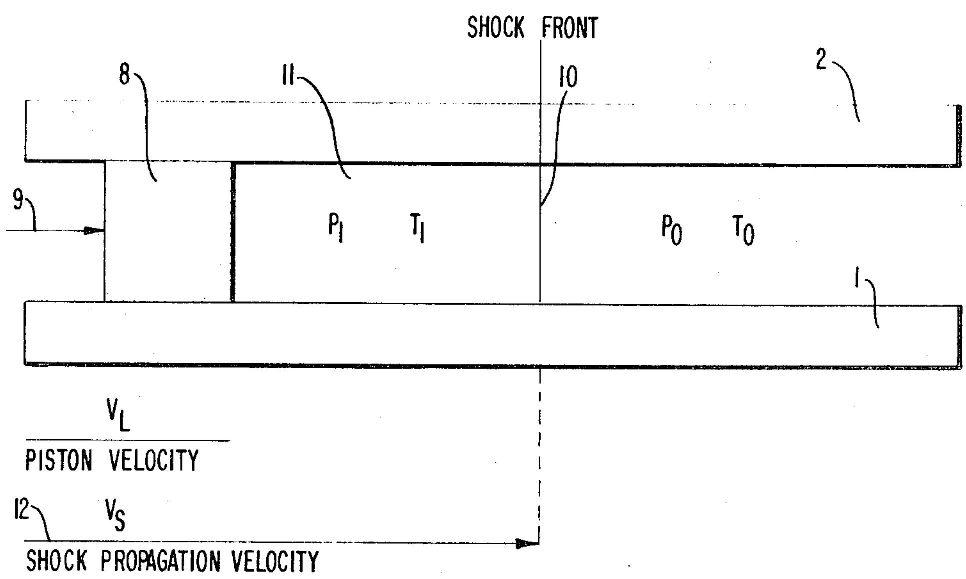

FIG. 2

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PROCESS FOR EXPLOSIVE SURFACE BONDING OF METAL PARTS

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ABSTRACT OF THE DISCLOSURE

Helium, hydrogen, or another gas having an acoustical velocity substantially greater than air is placed between the spaced non-parallel parts to be bonded prior to the ignition of the explosive contained on the outer surface of at least one of the parts.

BACKGROUND OF THE INVENTION

It is known to surface bond metallic plates by means of an explosive by spacing the plates from each other, preferably non-parallel or inclined with respect to each other, and applying the explosive to the outer surface of at least one of the metal parts for ignition from one corner or one side. The shock of detonation will drive the plates toward each other at a great velocity, for example 1,200 m./sec. or higher. As the collision front progresses from one end of the metal plates to the other, a very high stress of approximately 10,000 kg./cm.^{2} is induced thereby, which causes plastic flow of the metal and welding together of the metal parts.

The spacing of the plates is maintained to obtain a sufficiently high collision velocity; however, this has the disadvantage that air is inherently present between the plates. During the impact bonding or joining of the plates, the air is displaced from the space between the plates and is subjected to a compression shock in the direction of advancement of the collision front. Thus, very high pressures and temperatures occur rearwardly of the compression shock, which have the disadvantage of forming plating faults particularly in the case of large surfaces to be plated or bonded and in the case of thin metal sheets. For example, undulating or corrugating effects can be produced in thin metal sheets by the pressure forces from the inside, that is, from the plate interspace, which undulating effects can in turn cause air inclusions. Another disadvantage is produced by the extremely high temperatures which can cause buckling, that is, deformation of the metal sheets.

In an attempt to avoid the above-mentioned plating faults, it is known to evacuate the space between the plates. However, this partial solution involves a great technical expenditure, especially if large areas are to be plated.

SUMMARY OF THE INVENTION

It is an object of the present invention to avoid the above-mentioned difficulties by filling the interspace between the plates with a gas having a high acoustical velocity, instead of air. Preferably, the gas employed is hydrogen or helium. The present invention has recognized the advantageous result that the pressure and temperature rearwardly of the compression shock wave in the gas employed according to the present invention are far below those resulting from the use of air in the interspace between the plates.

BRIEF DESCRIPTION OF THE DRAWING

Further objects, features and advantages of the present

invention will become more clear from the following detailed description of the drawing, wherein:

FIG. 1 is a schematic representation of two plates being surface bonded together by the ignited explosive; and

FIG. 2 is a schematic equivalent representation of the conditions existing in the plate interspace.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. 1, two metallic plates **1** and **2** are held at a spacing from each other in an inclined position, that is, non-parallel, with respect to each other. Such a positioning produces a plate interspace **3**, that is, a wedge-shaped space between the plates **1** and **2**. An explosive **4** is provided in a layer on the outside of at least one of the plates **2**. In the representation of FIG. 1, the explosive **4** has been ignited from its left end and partially burned toward the right. The arrow **5** indicates the plating front or collision front between the two plates, which is caused by the plates being driven toward each other into engagement by the detonation front indicated by arrow **6**, which corresponds substantially with the burning front of the explosive. The plating or collision front **5** will proceed from the left to the right at a plating velocity V_L, which is schematically represented by the arrow **7**.

A schematic equivalent illustration of the gas conditions within the plate interspace is illustrated in FIG. 2. In FIG. 2, the advancement of the bonding zone or plating front at a velocity V_L in the plating direction toward the right is schematically shown by piston **8** between the parallel plates **1** and **2**, in FIG. 1, which piston is moving in the direction of arrow **9** corresponding to the direction of the plating velocity V_L, to drive the gas in front of it. The moving piston **8** imparts a shock to the gas, which is propagated in the gas at a shock velocity V_S, indicated by arrow **12**. The shock velocity V_S is higher than the piston velocity V_L and in the same direction. Across this shock front or shock wave **10**, the pressure rises suddenly from P_0 to P_1, and the temperature increases suddenly from T_0 to T_1. The shock wave or shock front **10** has a very small thickness approximately equal to the diameter of several molecules. In the space **11** behind the shock front **10**, the high pressure P_1 and high temperature T_1 are preserved until the arrival of the plating front **5**.

In the following table, experimental values are set forth for V_S, T_1, and P_1, when employing air, helium, and hydrogen between the plates, for various plating velocities.

V_L (m./sec.)	Air (c_0=333 m./sec.)	Helium (c_0=997 m./sec.)	Hydrogen (c_0=1,330 m./sec.)
1,500:			
V_S, m./sec	1,850	2,200	2,500
T_1, ° C	1,800	300	200
P_1, at	40	6	4
2,500:			
V_S, m./sec	3,000	3,300	3,500
T_1, ° C	4,800	620	400
P_1, at	100	12.5	8
3,000:			
V_S, m./sec	3,600	3,850	4,000
T_1, ° C	6,800	860	520
P_1, at	140	17.5	10.5
4,000:			
V_S, m./sec	4,800	5,050	5,150
T_1, ° C	11,800	1,450	850
P_1, at	245	30	17
5,000:			
V_S, m./sec	6,000	6,159	6,300
T_1, ° C	18,000	2,159	1,280
P_1, at	380	45	26

It can be seen, for example, that with a velocity V_L of 3,000 m./sec., there is produced a temperature T_1 of 6,800° C. and a pressure P_1 of 140 atmospheres when employing air between the plates. With otherwise identical conditions, except for the employment of hydrogen between the plates instead of air, the temperature T_1 is only 520° C., and the pressure P_1 is only 10.5 atmospheres. Thus the pressure and temperature values behind the shock front are reduced approximately by one power of ten when hydrogen is employed instead of air.

In contrast to the high pressure produced when air is used, the low shock wave pressure when employing hydrogen is, for example, incapable of exciting resonance oscillations which will cause the undulatinng or corrugating phenomena observed particularly in thin metal sheets in the past with respect to air. These resonance oscillations are actually enhanced by the fact that, due to the shock wave in the gas between the metal plates preceding the plating process, there is first produced a pressure thrust from the inside and immediately thereafter a shock from the outside is triggered by the detonation.

The process according to the present invention may be employed in practice in a very simple and advantageous manner, for example, by enclosing the metal sheets to be plated and the explosive in a bag of synthetic material or the like; thereafter displacing the air present therein by purging with the gas intended to be used in connection with the process of the present invention. Therefore, no complicated and expensive structures are needed for enclosing the plates. Also, it is contemplated that the plates may be sealed on one or more sides by means of adhesive strips or the like to seal off the interspace between the plates for the admission of the filling gas, which will thereby displace the air; the filling gas may be supplied from the ignition side until the plating process has ended. The side opposite from the ignition side may be partially sealed off to allow escape of the air being purged by the filling gas supplied from the ignition side, and to allow escape of the filling gas during the plating process.

When employing hydrogen in the process of the present invention, it is particularly advantageous to completely expel the air to avoid the production of oxyhydrogen gas in the plate interspace, which may damage the components to be plated.

It is particularly advantageous to employ a filling gas that has an acoustical velocity of at least twice and preferably three times the acoustical velocity of air under the same conditions, for example, under atmospheric conditions at sea level.

A single preferred embodiment of the present invention has been described in detail for purposes of illustration; however, further modifications, variations and embodiments are contemplated within the spirit and scope of the present invention as defined by the following claims.

It is claimed:

1. The process of surface bonding metallic parts spaced

from each other by means of an explosive, comprising the steps of: spacing the parts from each other with the corresponding surfaces to be joined facing each other; placing an explosive adjacent the side of at least one part that is opposite from the surface to be joined of said one part; filling the space between said parts with a gas having an acoustical velocity greater than the acoustical velocity of air under similar conditions; thereafter, igniting said placed explosive to force said spaced parts into bonding engagement while displacing the filled gas from therebetween.

2. The process of claim **1**, wherein said explosive is applied on the surface of said opposite side of said one part.

3. The process of claim **2**, including removing substantially all of the air from between said parts prior to igniting said explosives.

4. The process of claim **3** wherein, said step of filling employs helium as the filling gas.

5. The process of claim **3**, wherein said step of filling employs hydrogen as the filling gas.

6. The process of claim **1**, wherein said step of filling employs a gas having an acoustical velocity at least twice the acoustical velocity of air.

7. The process of claim **1**, wherein said step of filling employs a gas having an acoustical velocity at least approximately three times the acoustical velocity of air.

8. The process of claim **1**, wherein said step of spacing holds said parts with the surfaces to be bonded nonparallel.

9. The process of claim **1**, including removing substantially all of the air from between said parts prior to igniting said explosives.

10. The process of claim **9**, wherein said step of filling employs helium as the filling gas.

11. The process of claim **9**, wherein said step of filling employs hydrogen as the filling gas.

References Cited

UNITED STATES PATENTS

3,194,643	7/1965	Ma et al.	29—470.1 X
3,377,694	4/1968	Simons et al.	29—470.1
3,434,197	3/1969	Davenport	29—470.1

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29—470.1, 494