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NUMERICAL SIMULATION OF EXPLOSIVE WELDED STEEL WITH ALUMINUM USING AUTODYN 2D

Suraj Srivastava[1], Bir Bahadur Sherpa[2], Gurjeet Singh[3], P.J. Singh[3]
Abhishek Upadhyay[2] and Niraj Srivastava[2]

[1]PG Student, PEC University of Technology, Sector-12, Chandigarh-160012, India
[2]Terminal Ballistics Research Laboratory, Sector-30, Chandigarh-160030, India
[3]PEC University of Technology, Sector-12, Chandigarh-160012, India

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Abstract - *Explosive welding is the process in which a controlled energy of an explosive is used to generate a metallic bond between the same or different material. In this paper different material has been taken for simulation i.e. Aluminum plate as flyer plate and Mild steel as base plate. The simulation has been carried out using AUTODYN 2D, where various study such as flyer plate velocity, detonation velocity, pressure, effective plastic strain, temperature distribution across the material has been taken into consideration. There is different equation of state and strength model involved in the simulation process. JWL equation of state was used to study the effect of explosive material and Johnson cook for the mechanical behavior. Different graph has been plot against the parameters to shows the behavior of the materials with time, with the help of this simulation many factor can be correlated and find the feasible output of the process.*

Key Words: Explosive welding, ANFO, JWL, Mechanical, Plastic behavior.

1. INTRODUCTION

The Explosive welding is a well-define for its credential to directly join a wide heterogeneity of same and different metals combinations which cannot be join by any other convention methods. The set-up of the explosive welded plate is shown in the (figure 1), where the two plates to be join is placed parallel to each other separated by some distance called stand-off distance. In this process the flyer plate collides with such a high impact pressure that it forms a strong metallurgical bond between the two plates [1-2].

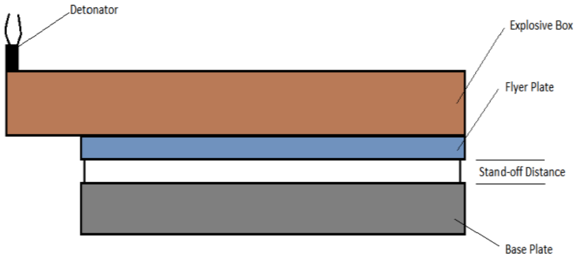

Fig. 1. Layout of Explosive Welding

Different types of energy assign, concentration, conversion and disbursement generate on the surface contact constantly. The explosion vibe (welding) is a complete phenomenon in a wink as the process happens in a very few microseconds.

Development and theoretical studies on explosive welding has been reported in the literature. In papers [3–7] authors have mention few research methods and results that previous researchers have used. Method of finite element (FEM) and the jetting phenomenon was arithmetically reproduced by [8]. Different testing and microhardness near the interface has been studied [9] experimentally which shows that hardness increase from the interface. The welded sample Interface wave was generated and arithmetical results agreed with the results development [10], but there is no any Performa of jetting propagate. Moreover, it is assumed that uniform or non-uniform flow of shear distribution was introduced in both the flyer and base plates. The tensile test of the welded sample has also been evaluated to check the strength of the welded specimen [11]. The flow of shear distribution was similar to the wake behind interference in fluid and the modeling was accomplished based on the hypothesis. In the paper [8–10] author have considered the solver of SPH processor. The materials at the point of collision were considered to behave like a wave, the straight wavy interfaces and jetting phenomena has been modeled, and the magnitude of the waves and velocity of jet were predicted. Furthermore, SPH computation can always be applicable for the plate impact but historical process understanding is to be difficult. EULER is a numerical grid or mesh Lagrangian hydrodynamics process and also using particles, unlike conventional Lagrangian techniques, it can also be applied to the astronomical science, hypervelocity strike and super-fast large deformation problems. EULER method to model the process of explosive welding was used by [12]. However, due to the explosion welding is a vast and complicated process; the physical phenomenon and a lot of mechanisms need to be researched thoroughly.

1.2 JOHNSON COOK CONSTITUTIONAL EQUATIONS

Johnson cook define the mechanical behavior of metals and the strength of von mises model is a flexible-perfectly plastic strength model. It will be defined the using materials of shear modulus and yield strength. The von-mises yield stress is given as,

$\sigma = (A + B\varepsilon^n)\,(1 + C \ln\varepsilon_p)\,(1 - T^m)$

where ε is equivalent plastic strain ε_p is plastic strain-rate for $\varepsilon_0 = 1.0/s$, T is the homologous temperature $(T - T_{room}) / (T_{melt} - T_{room})$, and T is absolute temperature for $0 \le T \le 1.0$. The five constants are A, B, n, C, and m. The expression of the set of first brackets present the stress will be a function of strain $\varepsilon_p \le 1.0$ and T=0. The formulation in the second and third set of brackets express the conclusion of strain rate and temperature, respectively. Now the temperature melting (T =1) the stress will be draw on zero for all strains and strain rates. The material constants are resolved for straining tests execute in tension or torsion. Although there are various test techniques will be used to acquire the constants for as model, the following approach has been commonly used. First, the yield and strain hardening constants (A, B, and n) are acquired from isothermal torsion and tension tests at moderately low strain rate ($\varepsilon_p \le 1.0$). Now secondly strain rate constant C is resolved from torsion tests at different strain rates and for tension tests (Quasi-static and Hopkinson bar) at two strain rates. Finally, determined the thermal softening constant m from Hopkinson bar tests at varied temperatures. The model lay hold into account thermal softening, strain hardening, strain-rate hardening. The mechanical substantial of the materials used in this simulation with the help of Johnson–Cook module equation for this table [1].

2. EXPLOSIVE WELDING SIMULATION AND EULER METHOD

The experiment of numerical simulation described above was carried out using AUTODYN (2D) interpretation (AUTODYN CODE). Autodyn has been developed by century dynamics but at that time that is platform of ANSYS workbench. It is an explicit coding of hydro which includes exclusive different solvers such as Euler, Lagrange, Arbitrary Lagrange Euler (ALE) and Smooth Particle Hydrodynamics (SPH). Every solver will be our own strength and weakness and is also a suitable for resolve the problems. All of these methods can be scattered both in time and space allow to application problems to be solved [14]. The metals used in simulations was interaction between a steel 1006 base plate and flyer plates of Aluminum (Al), mild steel (MS) and Aluminum (AL). The processor of Euler in which the numerical meshing is fixed in every space and the physical material flows among which had been used. The point of materials which is collision were considered to act as a propagate wave. Although the formulation of Eulerian, the grid (mesh) is fixed and the material will be flow through the meshes, the mesh size plays an important role from the arithmetical timing view of point and stability. In simulation, modelling impact and explosive welding, the size of mesh which can also important to visualizing the wavy profile and profile of interface. A grid size has been maximum 0.2mm will be used in this study for the close areas in the collision zone. The data will be obtained from the simulations were authenticated by the explosive welding trials as well as test of impact welding. The size of particle plays a vital role in simulation due to the arithmetical timing points of command and stability; they all depend on the size. Therefore, the parent and flyer plate were modeled using about 50,000 particles. The conditions of initials were given in the form of the premier velocity. The flyer plate initial velocities taken 500–1000 m/s were chosen in this work and the initial velocity of base plate always set in zero. The free extent defines a regular free surface in which stress wave will be reflect back, but in other case of boundaries the stress wave is not permitted to reflect back. In this work, the free extent was workable in order to achieve a good effect and to be with the concurrency of practice conditions. Since the goal of this study act cell stress and strain distribution during the dynamic process of landing, the failure of cell is not take any interest here and the predicted stress and strain values are not being compared with the threshold values of failure with any cell. So there is no any mode of failure was set in this work. The analysis of time steps was automatically computed to ensure accuracy and stability of the solution. These parameters such as pressure, velocity, stresses and strains were studied for each particle and were available at the end of every step of time.

Table -1: Property of materials

Materials	Yield Stress (MPa)	Density (g/cm^3)	Shear modulus (GPa)	Hardness (MPa)	Temperature (k)
Al 7039	337	2.7	27.6	1800	877
Steel 1006	350	7.8	81.8	2200	1811
Mild Steel	1500	7.8	82	2100	1800
Steel 4340	792	7.8	81.8	2000	1793

3. RESULTS & DISUSSION

The shape of interfaces can be approximately classified into three ways straight, smooth wavy or wavy by vortex shedding in the experiment. The different combinations of flyer plate and base plate which can be modeled to attach the values of contact pressure and shear stress were passed. For the information of clarification to judge only some representative samples in the simulation experiment were presented here. (Figs. 2–5) clarify that material location, pressure contour and shear stress contours of combination. Whereas, smooth wavy which cannot clear in this simulation (Fig. 3). In order to conform the process will be more intuitively, where face-to-face points have been taken at the middle of flyer and base plate respectively in all cases. The shear stress is clearly shown in (Figs. 4) respectively.

The major characteristic of an explosively has been produced weld and the profile of the weld interface often has been an appearance of regular wavy. For combination, a greater strike velocity of the flyer was chosen and facilitate wavy can be normally seen in our simulations. The shear stress profiles are shown in (Figs. 9), respectively. In Figs. (3-4) to check the formation and variation of pressure and shear stress with the help of simulation to check flyer plate velocity and pressure.

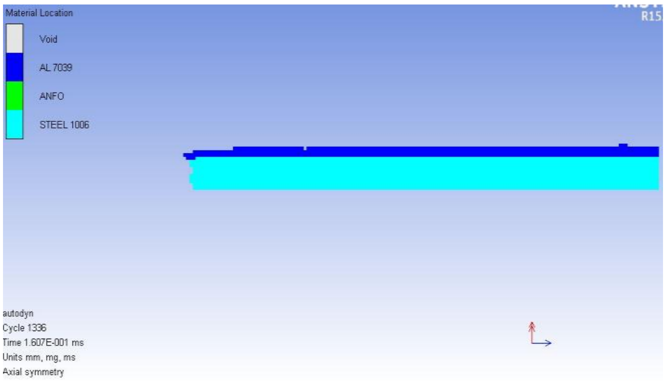

Fig. 2. Explosive welding simulation of material location in AUTODYN

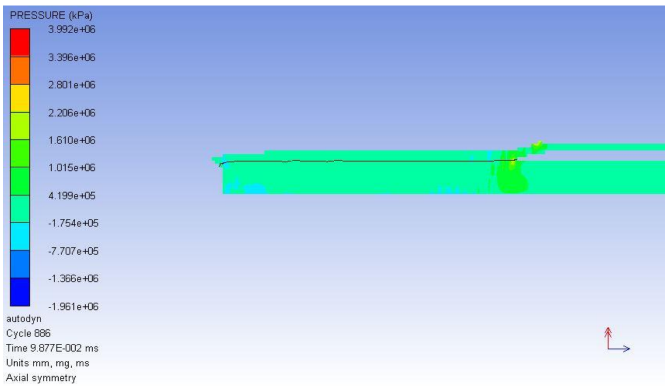

Fig.3. Explosive welding simulation of Pressure in AUTODYN

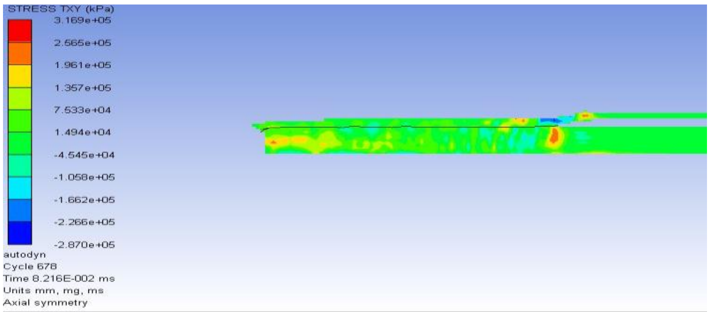

Fig.4. Explosive welding simulation of Shear Stress in AUTODYN.

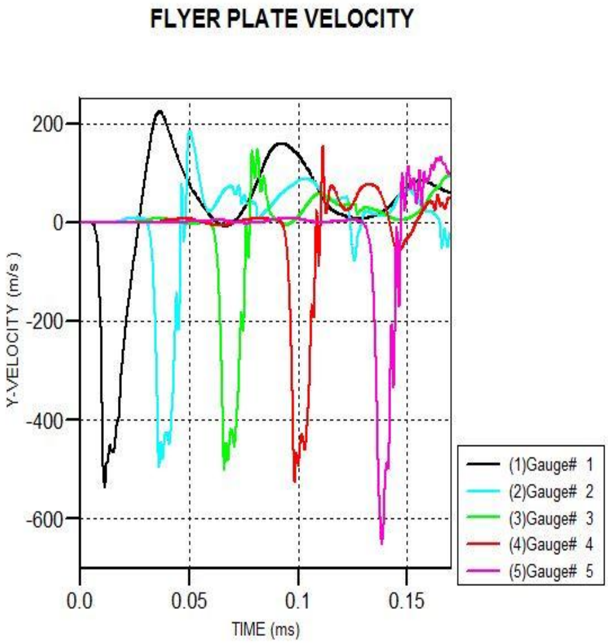

Fig.5. Profile of flyer plate velocity (aluminum)

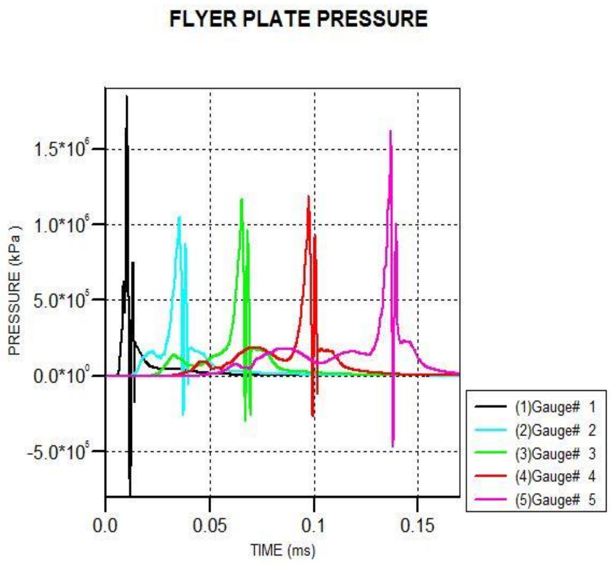

Fig.6. Profile of flyer plate Pressure (aluminum)

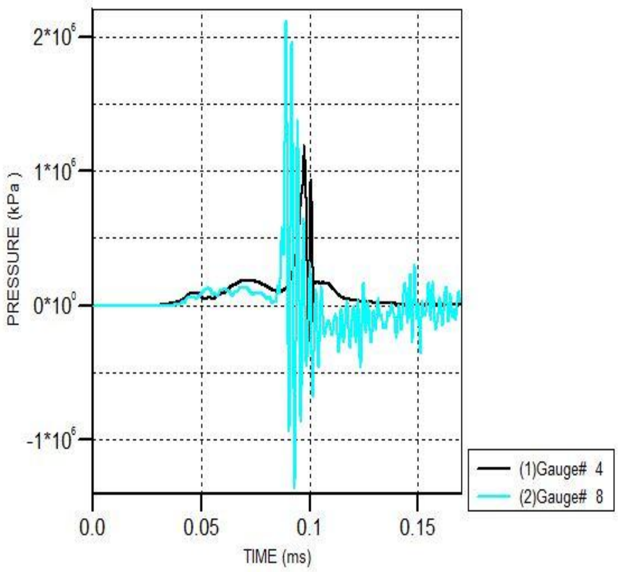

Fig.7. Pressure profile in flyer and base plates combination.

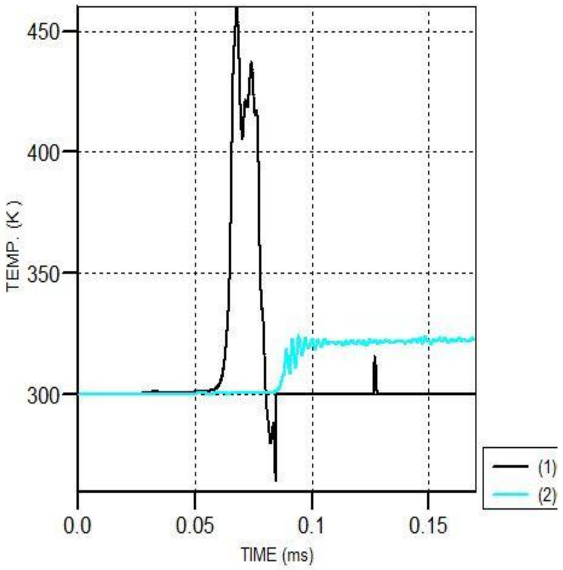

Fig.8. Temperature profile in flyer and base plates

Johnson-cook equation was used as strength of model in simulations and the temperature transformation was showed in the process and also discussed in papers [5,7,8,15], which is a good way to have a better understanding process of welding, but some kind of phenomena of the welding such as jetting and the interfacial waves were not conceptual. According to the graph (Fig.6), calculate the pressure of flyer plate 1.4 GPa (approx) with respect of time. In (Fig.7). we can also check the pressure between both the plates.

The achievement of welding that can be believed when their formation of jetting phenomenon in the process occurs, which is are required condition for welding [3,7,18].

The consist of forces between the atoms are attractive and repulsive forces and equilibrium of certain distances of these two forces will be equilibrium [7]. So the energy of potential must transfer its minimum value to overcome the forces of repulsive between atoms. In theory, if the collision velocity point were remains subsonic, the occur of jetting at any oblique angle. However, a minimum angle is required to satisfy the requirements of pressure and the pressure must be of adequate magnitude to overreach the dynamic elastic limit of the material to clarify the deformation of metal surfaces through a jet. The reason of main phenomenon may be due to the differences of density and hardness between metals and it appears that metals which can be high density and hardness contribute to little of the jet source. The velocity of jet which can be obtained from the simulation was 15–20% lower than that acquired using the standard equation [15] $V_J = V_P / \sin\beta(1+\cos\beta)$ where V_j is the velocity of jet. The highest vaticinated values of jet velocity by calculated and the equation were about 4000 and 4890 m/s, respectively. The attributed difference was to the fact which will be particle velocity is dependent of mesh size. If the size of mesh is large than they produced lower jet velocity.

The shear stresses magnitude was predicted for the bonded regions to higher than those for non-bonded zone. According to simulations in which combinations lead to successful welding, the shear stress sign faces to face will be opposite (Fig. 4). That kind of results were consistent with [3,16]. And if the contact area of shear stress was of the same sign in combination of two plates, bonding did not clearly to take place. The arbitrary value of shear stress in the flyer plate was always higher than in the base plate. The results of simulation were indicated that a fine band of plastic strain and high values of shear strain which will formed at the collision region, which is in line with the auguring of MPBondar [18].

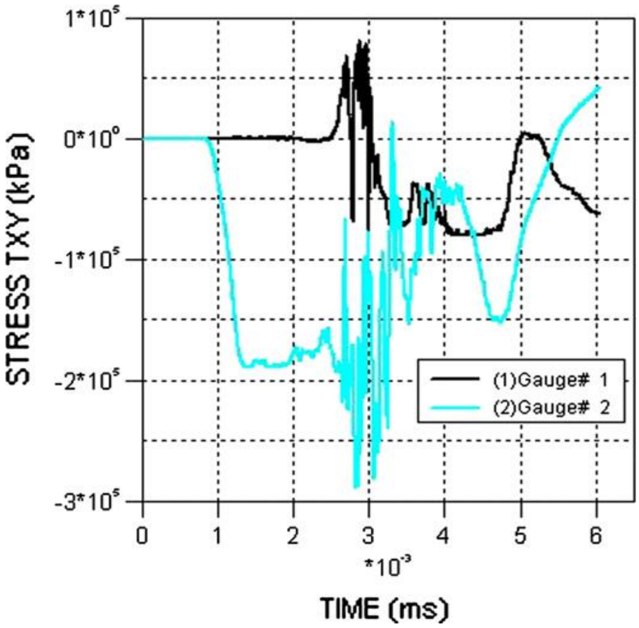

Fig.9. Profile of shear stress in flyer

3. CONCLUSIONS

This examination has made it possible and clarifies the model main features of the explosive/impact welding process. The major material parameters such as shear stress, temperature which can be arbitrated the success or failure of the welding was clearly distinguished.

The shear stresses showed that in the flyer and base plate must be of opposite sign for good bonding to take place in combinations different metals and the same time effective plastic strain and shear stress must precede a minimum value. According to change the parameters with the help of JOHNSON COOK and JWL to find the flyer plate velocity and pressure between both the plates. The interface would be greater obtained and the plastic strain and shear stress values were higher in the waves were present.

The confirmation of this paper is that in most of the cases bonding are more likely to be a fusion and solid state welding process. In this study, with the help of AUTODYN software numerically analyses with EULER 2D method is used to model the explosive welding process, the objective modifies the processes of shear stress, pressure and temperature were clearly checked in the simulations. Therefore, EULER is a quite suitable method for modeling and simulates the any kind of material in explosive process of welding.

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