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FE Modelling of Dynamic Indentation Test on AA6061

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Abstract—*The present study signifies numerical modelling and simulation of Dynamic Indentation test on Aluminum alloy material with high strain rate behaviour. Material behaviour in form of stress, strain and displacement due to impact have analysed for given loading conditions. FE modelling for nonlinear explicit analysis considering impact of indenter ball on AA6061 plate with contact behaviour was simulated. A 3D model is used the study the behaviour of the material. The plate material is considered to be isotropic and homogeneous. Simulation results are computed and discussed that are in good correlation with experimental and previous research data. It is also possible to study the deformed plastic zone. The research work can be further used for analysis of welded plated subjected to dynamic indentation.*

1. INTRODUCTION

Indentation testing is performed to measure the hardness of any material. Hardness of a metal is defined as the resistance to indentation [3]. The most widely used hardness testing method is the static indentation hardness testing method. In static hardness testing, an indenting sphere is pressed on the surface of the metal with a normal load, after sometime when equilibrium is reached, the load is removed. The diameter of the crater formed on the surface of the metal is measured. The hardness of the metal is measured as the ratio of the load applied to the area of the crater. Two types of hardness can be measured, Brinell hardness (ration of applied load to the cured surface area of the crater) and Meyer's hardness (ratio of the load applied to the projected area of the crater).

However, static indentation testing has a limitation as it only helps in computing static hardness and thus the effects of high deformation rate and high strain rate cannot be studied. High strain rates are encountered in cases of high speed machining, high velocity sliding and wear, impact of ballistics [2]. The order of high strain rates occur in the range of 10^3-10^5 s^{-1}. These cause large plastic deformation and may also cause structural vibrations in some field of applications.

Dynamic hardness is measured by various methods developed by Tirupataiah and Sundararajan [4], Richard Anton and Ghatu Subhash [8]. The most widely used method of dynamic hardness testing is the rebound method. In this method an indenting sphere is dropped on the metal and the height of rebound is measured to compute the hardness of the metal [8]. Most of the research done on dynamic hardness indentation testing is experimental, thus a lot of practical data is available which can be used to design a model and simulate results.

The present study focuses on FE Modelling and numerical simulation of dynamic indentation testing. The software used is ABAQUS. A 3D model has been used for numerical simulation. With a FE model it is possible to study the plastic deformation zone closely than in the experimental setup. Also, values of displacement and lip height can be accurately measured.

Through FE Modelling further research of dynamic indentation testing on welded plates can also be studied. These results can be used to linearly correlate the hardness to tensile strength.

2. MODEL DESCRIPTION

A 3D model has been created. The specimen is an AA6061 plate and the indenting ball is made of tungsten carbide. Both are assumed to be isotropic and homogeneous.

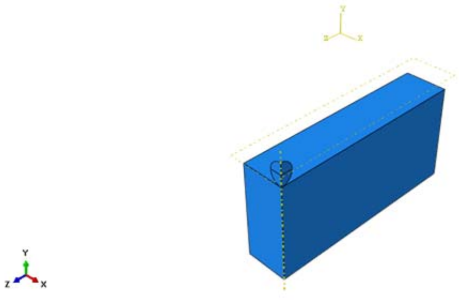

Fig. 1: FE Model

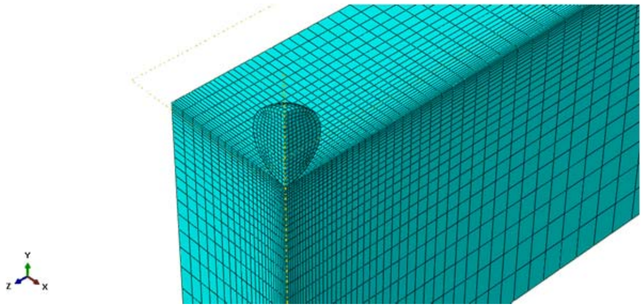

Fig. 2: Meshed Model

As shown in fig.2, single bias meshing is done on the specimen plate. Tangential interaction property is provided with a coefficient of friction being 0.15. For the initial step a general contact interaction is provided which is also propagated to step 1. Also surface to surface interaction is defined for step 1.

The material for the specimen plate is Aluminium Alloy 6061. The material is defined by the density, elastic property and rate dependent plastic property. The indenter material is Tungsten Carbide and it is defined by its density and elastic property.

The plate is fixed at the base in all directions. The ball is given a velocity of 30 m/s in the negative y direction and all the degrees of freedom are fixed. Fig. 3 and 4 show the boundary conditions applied on the plate and indenter.

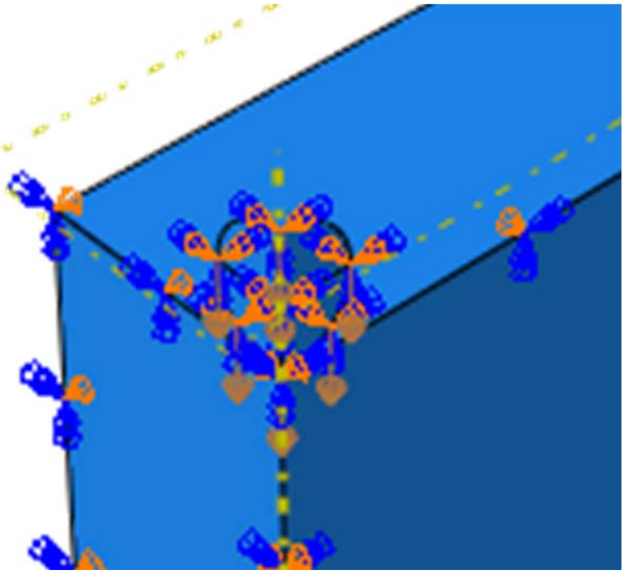

Fig. 4: Boundary Conditions applied on the indenter

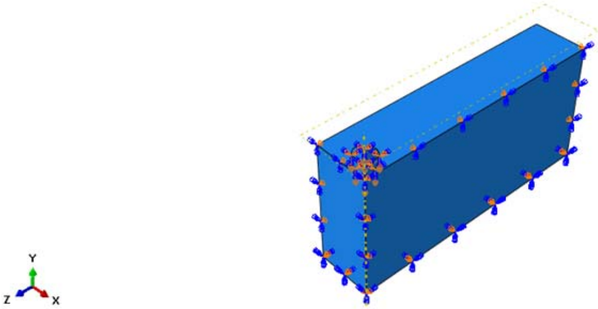

Fig. 3: Boundary Conditions applied on the FE Model

3. RESULTS AND DISCUSSION.

1. Indentation Crater Profile

When the indenter hits the specimen with a velocity of 30 m/s, displacement is caused in the affected area and a crater is formed.

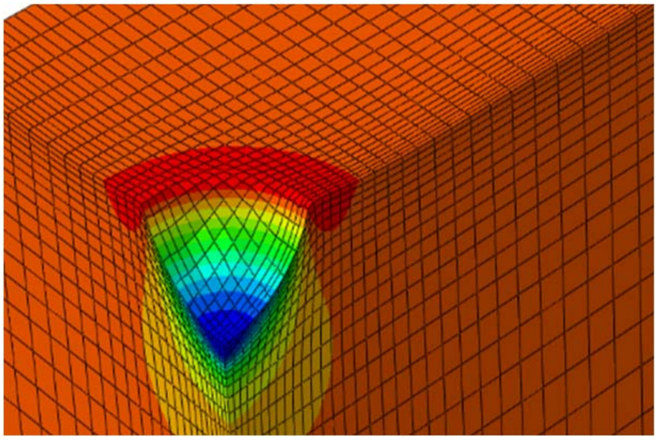

Fig. 6: Profile of Indentation

Fig. 6 shows the displacements caused in x, y and z directions. The radius of the crater can be measured by observing the displacement in x direction or z direction when the displacement in y direction is zero.

2. High strain rate behaviour of AA6061

The variation of displacement with the strain rate is plotted in Fig. 7.

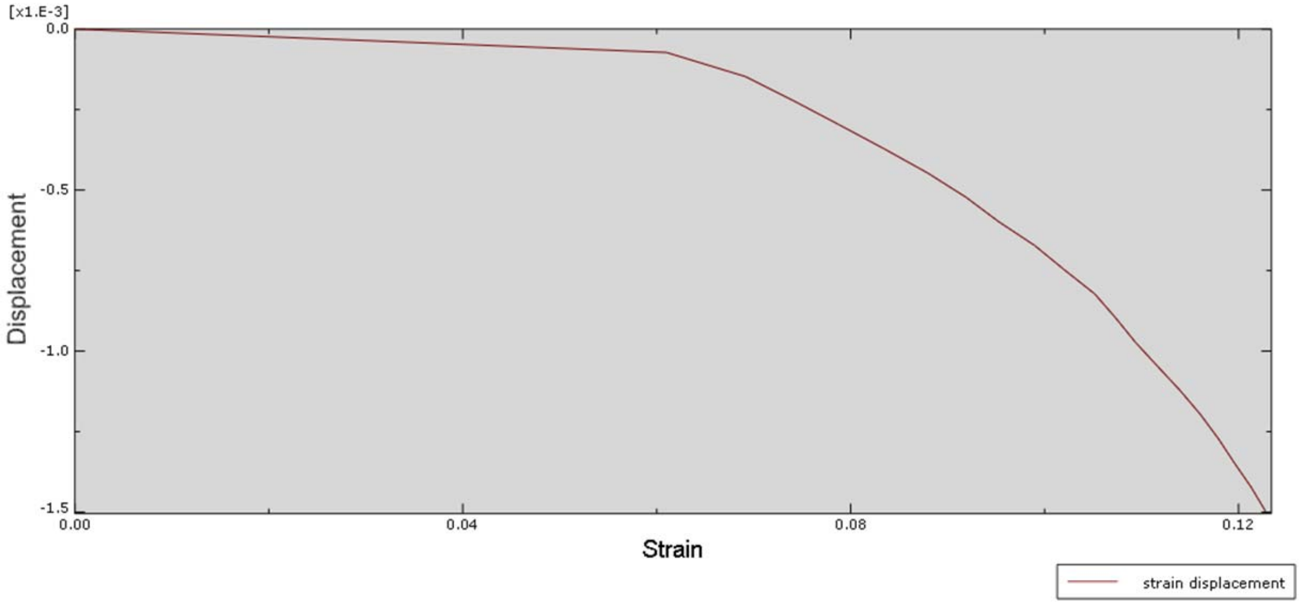

Fig. 7: Variation of strain with displacement

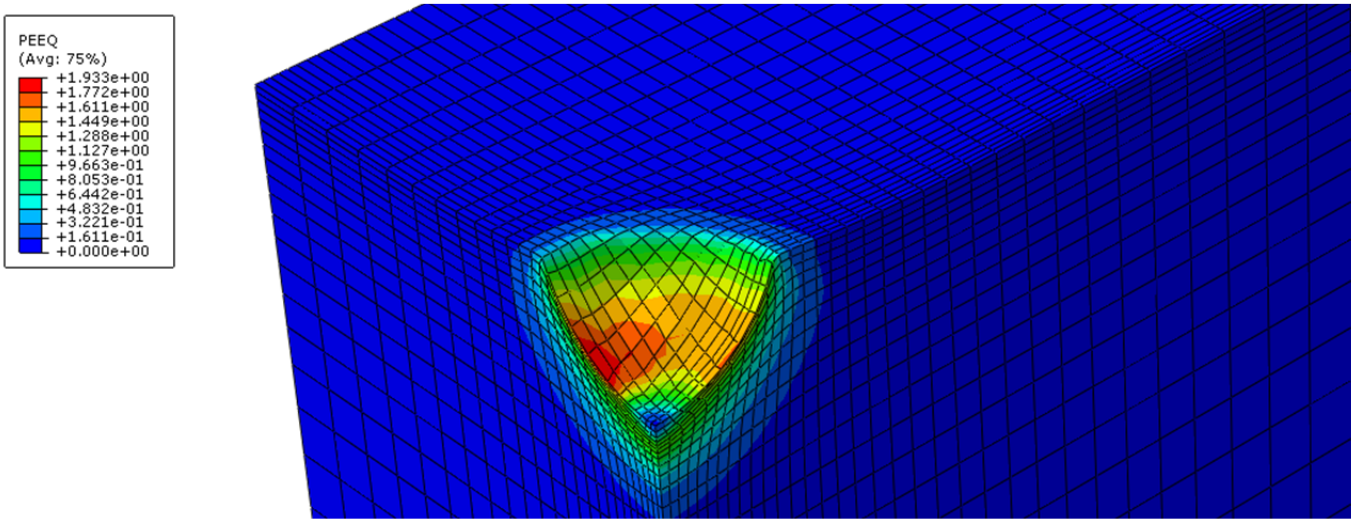

Fig. 8: Plastic strain along the profile of indentation

Fig. 8 shows the plastic strain developed in the plastic deformed zone. It is observed that the displacement increases with increasing plastic strain. The rate of deformation is higher than that observed in static indentation. Also, this behaviour is validated by the experimental results obtained in previous research.

4. THE STRESS STRAIN BEHAVIOUR OF AA6061 UNDER DYNAMIC INDENTATION.

The stress strain behaviour is shown in Fig. 9. On observation we can verify that the stress- strain plot obtained by numerical simulation complements the stress-strain plot achieved by previous research.

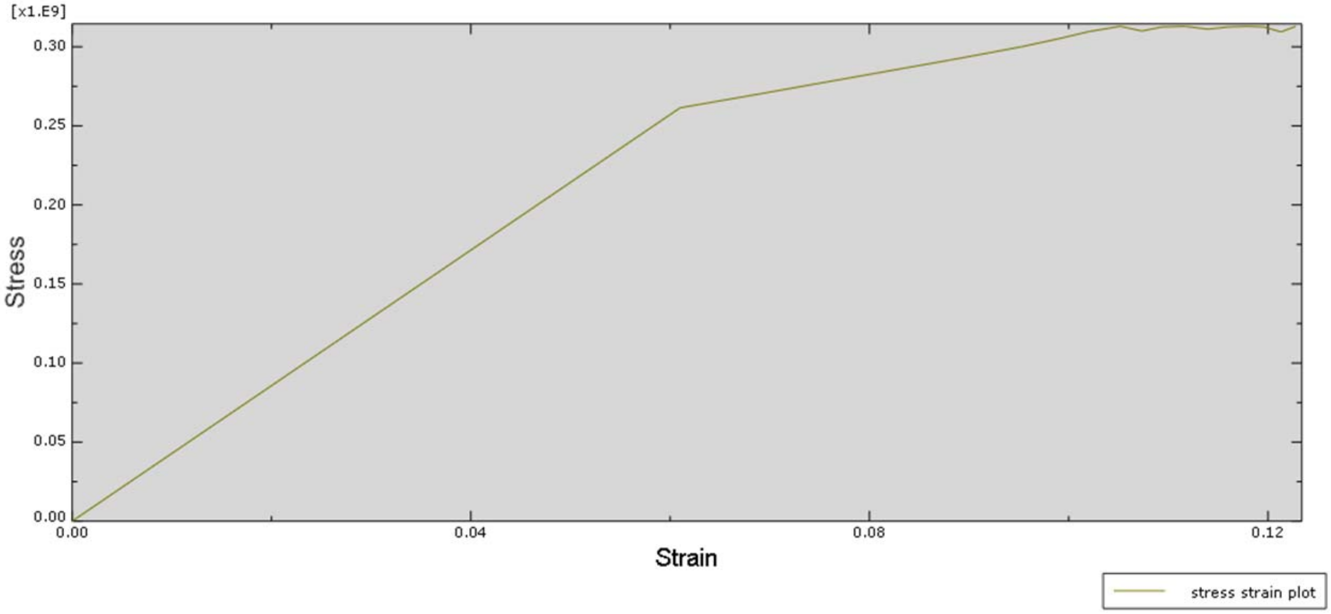

Fig. 9: Stress Strain behaviour of AA6061

5. CONCLUSION

The results obtained in the study of numerical simulation of dynamic indentation test are verifiable and validated by the previous research work done and experimental data already available.

The change in displacement along y direction, or the depth of the deformed zone changes much more rapidly in dynamic indentation in comparison to static indentation testing. This can be further verified by the experimental work done previously.

Thus the study can be further propagated to study the dynamic indentation testing of welded joints.

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