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Non-Destructive Evaluation of Elasto Plastic Properties of Inconel alloy through Microindentation

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Abstract

Indentation tests are the most commonly used non destructive tests in the metal industry to evaluate the mechanical properties of the new materials , In indentation test a plane test surface is plastically indented, are widely used to provide quickly a measure of the elastic-plastic properties of a material. This approach is the best alternative, when there is insufficient material for a stress-strain specimen for machining and bulk deformation of the test piece is undesirable or impossible. In the present study we extracted the elastic-plastic properties of the Inconel 600 alloy and studied the indentation behavior of the material like effect of pile- up sink -in on properties and effect indentation depth , radius of the indenter on the pile up and sink in behavior of the.

Keywords: *Micro indentation, Hardness, young's modulus, elastic plastic properties, reverse analysis.*

1. Introduction

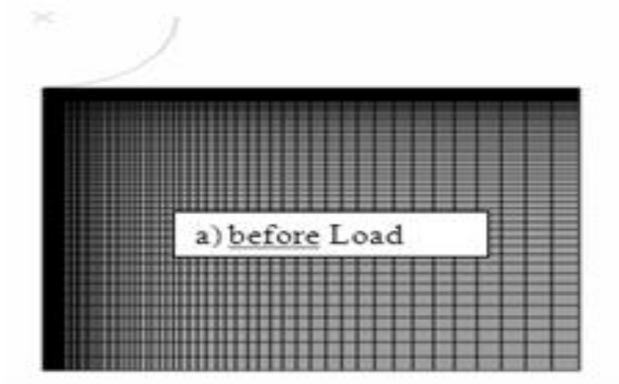
Indentation hardness tests, in which a plane test surface is plastically indented, are widely used to provide quickly a measure of the flow stress of a material. This approach is the best alternative, when there is insufficient material for a stress-strain specimen for machining and bulk deformation of the test piece is undesirable or impossible. Indentation tests are the most commonly used testing procedures in the metal industry and in research because they provideeasy, inexpensive and reliable method of evaluating basic properties of existing and newly developed materials.

Micro-indentation tests are used to measure hardness of test samples that are too small in size to be measured by conventional macroscopic methods or micro hardness testing using very small of the order of 10 Newton force. These tests are based on new technology that allows precise measurement and control of applied loads and indentation depths. By measuring the depth of the indentation, progressive levels of forcing are measurable on the same piece. This allows the tester to determine the maximum indentation load that is possible before the hardness is compromised and the film is no longer within the testing ranges. This also allows a check to be completed to determine if the hardness remains constant even after the indentation is made.

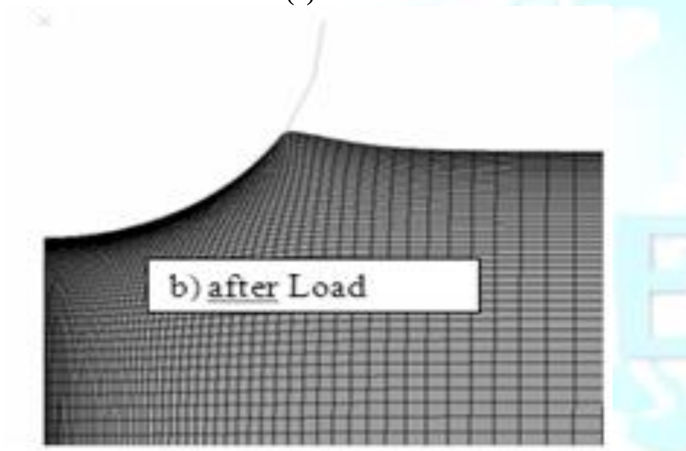
Micro indentation is especially useful in probing small volumes of material,Their mechanical properties can be extracted from the experimental indentation data by a reverse analysis if the relationship between the mechanical properties and the experimental indentation data is known. Among the several types of mechanical properties, elastic property is the most easily determined by micro indentation because analytical solutions exist relating the applied load, the indentation depth and the elastic modulus. However, plastic properties can rarely be determined by a unified approach due to the difficulty in finding an analytical solution.

2. Experiments

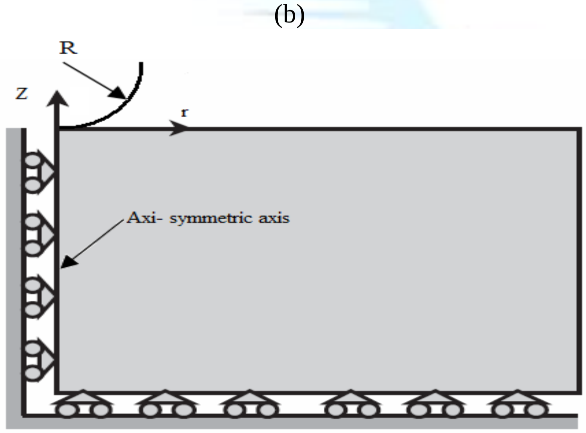
2D axisymmetric FE model with a spherical indenter is constructed as shown in Fig.2.1 to simulate the microindentation of Inconel alloy. In order to ensure the numerical accuracy, a finer mesh near the contact region and a gradually coarser mesh away from the contact region are designed. The size of the specimen is 2000nm × 2000nm and it was modelled using 4900 four noded quadrilateral elements. While a rigid line element was used for the indenter with radius 500nm. The horizontal displacement of the work piece and the indenter were fixed on symmetricboundaries and the vertical displacement was fixed on the work piece bottom. The static analysis including deformation was carried out using the ABAQUS.



(a)



(b)



(c)

Fig 1 2DAxisymmetric FE model (a)Before Load(b) After Load (c) Boundary conditions

Since uncertainty of the friction between the mating surfaces makes it difficult to measure the contact friction coefficient, it was assumed to be 1.0 as per the coulomb's law of friction. During loading, the indenter can be controlled either by displacement or by force and during unloading; the indenter comes back to initial position. In the present investigation, displacement controlled mode has been employed to characterize the indentation behaviour of the alloy. The load-displacement curve is drawn by means of the vertical reaction and the displacement from the rigid indenter.

3. Results and Discussions

3.1 Load and displacement curves

The load-displacement curves obtained from finite element modelling are shown in Fig 2 for Inconel 600 alloy. During loading, the curves steadily shifted upwards with increasing depth, indicating that, the resistance of the materials to indentation increases with depth

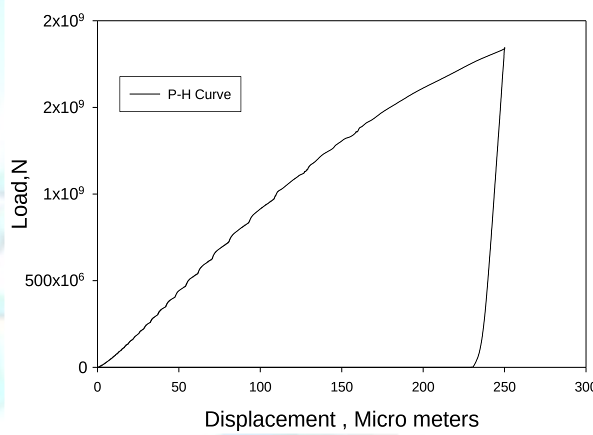


Fig 2 Load and displacement curve

3.2 Elastic properties of Inconel 600 alloy

The Young's modulus and hardness of Inconel 600 were caluculated from the oliver phar method, values given in Table 1.

Table 1 Elastic properties of Inconel600

S no	Material	Hardness (MPa)	Young's modulus(GPa)
1	Inconel 600	432	210

Table 2 plastic properties of inconel600alloy

S no	Material	Yield stress(MPa)	Strainhardening exponent
1	Inconel 600	295	0.7

3.2 plastic properties of inconel600alloy

The yield strength and work hardening exponent were extracted from the loading–unloading curves, using the model of Dao.The plastic properties were given in Table 2

3.3 Effect of friction on pile-up

To examine the influence of the friction coefficient between the indenter and the specimen on the pile-up/sink-in behavior, the indentation profiles in the loaded state were compared for four different friction coefficients (f =0.1, 0.2,0.3and 0.5), the height of the pile-up increases with decrease in f .The main reason for this effect is that a friction contact (f =0.1) for materials having high plasticity and low strain hardening exponent leads to more flow around the indenter leading to significant pile-up. The frictional effects on the extent of pile-up are dominant or f =0.1but the profiles tend to converge at f = 0.2 and above. Clearly, frictional effects on pile-up are most significant in materials that do not strain harden (low'n') and non zero frictional value acts to reduce the pile-up

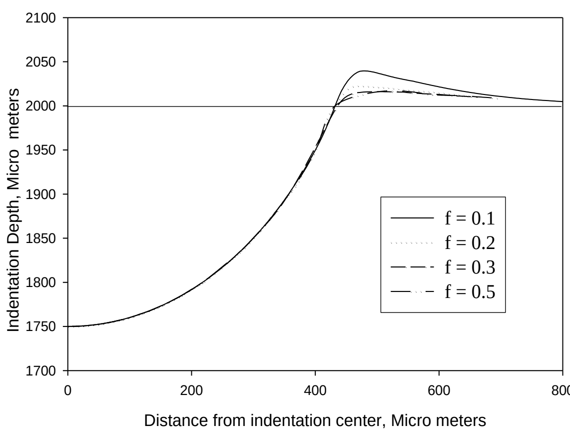


Fig 3 pile up due to friction

3.3 Effect of indentation depth on pile up

Fig. shows how the pile-up and sink-in behavior depends on the penetration depth for Inconel 600 material , the indentation profiles in the loaded state were compared for four different indentation depths (h = 100, 150,200 and 250),the height of the pile-up increases with increasing the indentation depth because the indentation depth increases the plastic zone increases and spreads outwards so pile up increases and at the small indentation depth the plastic zone decreases and pile up also decreases.

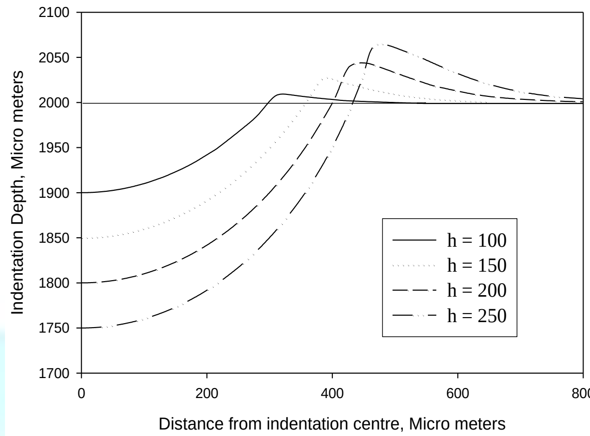


Fig 4 Indentation profiles at different indentation depth

3.4 Effect of indenter radius on pile up

To study the influence of the indenter size on the pile-up/sink-in behavior, the indentation profiles in the loaded state were compared for four different indenter sizes (R = 300,350,400,450), The height of the pile up is constant for different indenter sizes at the constant depth because the plastic zone for the different indenter sizes is constant, so the indenter size do not effect the pile up behaviour of the material

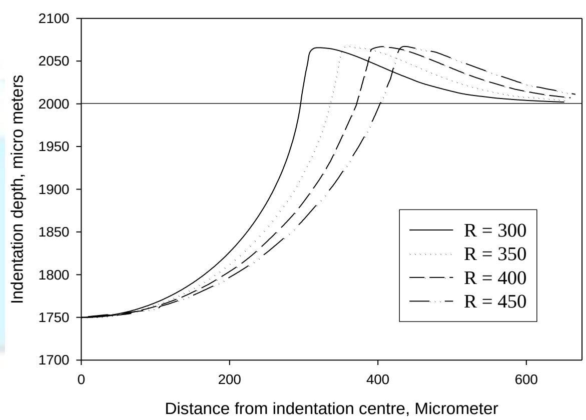


Fig 5 Indentation profiles at different indenter radii

4. Conclusions

In this paper we, extracted the elasto plastic properties of the Inconel 600 alloy using the dao and studied the mechanical behaviour through Microindentation and also studied the effect of pile up sink in behavior of the material and its effect on the mechanical properties of the material,when the friction decreases between indenter and substrate the pile uo increases. The height of the pile up is constant for different indenter sizes at the constant depth, the height of the pile-up increases with increasing the indentation depth because the indentation depth increases the plastic zone increases and spreads outwards so pile up increases.

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