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SMALL PUNCH AND INDENTATION TESTS FOR STRUCTURAL HEALTH MONITORING

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Abstract

The microstructural and metallurgical changes due to high temperature and high pressure applications, irradiations etc. cause a significant degradation of the mechanical properties of materials in refinery industries, nuclear industries, power plants, oil and gas pipe lines, aging aircrafts etc. That's why materials of in-service components in these industries need periodic health assessment to evaluate the degradation of mechanical properties. In the present work Finite Element simulation of indentation technique has been done for refinery materials by using ABAQUS FEM Code and different mechanical properties has been obtained. For properties evaluation by indentation test technique, some material constants is to be required. After carefully studying it has been found that in case of service exposed components there is a large difference between actual value of these material constants and assumed approximate values, this may be due to the fact that material constants change due to change in microstructure with the exposure to high temperature for a long time. This incorporates inaccuracy in property evaluation by indentation technique. The present work shows that properties obtained by using small punch test are quite accurate and that's why these properties can be used to find out Indentation Technique constants. This methodology is also developed here for finding out Indentation technique constants by using the value of yield strength & equation of true stress-true plastic strain curve obtained by using small punch test. In this way accuracy of Indentation technique can be increased. Thus a new methodology has been developed to find out the mechanical properties of service exposed components by clubbing the two techniques i.e. indentation technique, small punch technique.

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Keywords Hardness; Miniature Specimen; Mechanical Behavior; Finite Element Technique; Small Punch Technique.

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1. INTRODUCTION

A fundamental requirement to assess the mechanical properties of materials using a small amount of test materials has got great importance in the research area for a long time. The necessity of a small specimen test technique has also arisen in the past few years for the development of materials for improved cladding and in core structures for fission type nuclear power plants. Other uses of this technique are assessment of materials for pressure vessels, turbines, thermal power plants, chemical processing industries, etc. The micro structural and metallurgical changes from irradiation cause a significant degradation of the mechanical properties of metals and alloys. In order to study irradiation damage, the scarcity of the material serves limitation on specimen size in irradiated material testing facilities. Small specimen techniques include a wide array of types and techniques as follows, tensile tests, micro hardness, creep, impact tests, bent tests, fracture toughness, and punch tests (ball, shear punch) [1].

In most of the cases, it is practically not possible to evaluate component integrity of in-service structures with traditional and well standardized test techniques because there is not available sufficient amount of material available from in service components to allow the determination of mechanical properties by the traditional tests. As a result determination of the properties of a material is a difficult task. In such cases indentation technique provides a way of obtaining accurate mechanical properties of components or structures while consuming small or almost no amount of material. However, we cannot be 100% sure that this technique can provide results which are as accurate and repeatable as the more commonly used conventional test methods, because the process is still in the development stage.

INDENTATION TECHNIQUE

Indentation test technique is a non-destructive technique, which consumes almost no amount of material for determining mechanical properties of materials. Among the many small specimen techniques for determining mechanical properties of materials, Indentation technique is one of the most promising techniques. For evaluating mechanical properties through indentation technique many theories and models have been developed. Tabor [2] gave an empirical relationship to find the representative strain of materials within plastic region while indentation is done through a spherical ball indenter. Now the effectiveness of a laboratory scale BI system has been established. Researchers have developed an automated ball indentation (ABI) set-up [3]. Using this set-up many research groups studied flow properties of different materials through the thickness variation/gradient in mechanical and fracture properties and found good agreement with the conventional test results.

SMALL PUNCH TECHNIQUE

In a small punch test, a specimen with the shape of a small disc or coupon is punched by a hemispherical head punch or spherical ball, up to failure. The load against displacement curve is recorded and used to derive the mechanical properties of materials or components. Load-displacement at failure was converted to an effective failure strain. Various types of specimen and corresponding punch dimensions have been used up till now. Based on the load-displacement curve obtained from miniature specimen tests, Baik et al. (1986) and Cheon et al. (1996) had noted that the deformation stages of a small punch specimen during testing can be classified into four stages i.e. elastic bending, plastic bending, plastic membrane stretching and plastic instability.

The main purpose of this study is to estimate the mechanical properties of the in-service component by indentation test and by small punch test separately, compare the results obtained from both the tests and choose the better one on the basis of values of different mechanical properties obtained from both the tests [11].

2. FINITE ELEMENT SIMULATION OF INDENTATION TEST

2.1 *Geometric Modelling*

A specimen and an indenter ball assembly has been modelled in Fig.1. the load conditions and the boundary conditions have been applied and after that FE analysis has been done. Modelling of following parts is done in ABAQUS/CAE to make required assembly. 1. Specimen (Deformable) and 2.Indenter ball (Analytical Rigid)