PPG-EM
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA MECÂNICA

ADIABATIC SHEAR BAND (ASB) AS A MECHANISM OF EROSION BY IMPACT OF SOLID PARTICLES IN DUPLEX STAINLESS STEEL UNS S32205 – CHARACTERIZATION AND NUMERICAL SIMULATION

Author: Maria Augusta Minguta de Oliveira[1] *maria.uerj@gmail.com.br*
Advisor(s): Antonio Marinho Junior[1]
[1] State University of Rio de Janeiro

PPG-EM Seminars: season **2016**
December 15, 2016 www.ppg-em.uerj.br

Keywords: ASB, ABAQUS, Erosion, Dynamic impact.

Introduction

Due to economic losses related to the deterioration of engineering materials in-service, the study of Tribology has been receiving increasing attention from researchers in the field of mechanics and materials. In the case of wear by erosion, that caused by the impact of hard particles on surfaces of ductile metallic materials still offers opportunities for research, especially on the mechanisms that can explain the phenomena related to the loss of mass that characterizes erosion.

This project aims to simulate erosion on a flat UNS S332205 duplex stainless steel surface, by means of individual and successive impacts of spherical and rigid Alumina particles, using a commercial software ABAQUS. The target material, the impacting particles and the software where chosen due to previous experimental and simulation works [MOLTER, 2014][SANTOS, 2015].

Erosion

Several models were formulated to explain the behavior of metal surfaces with both ductile and brittle behavior under hard particle impacts. For ductile materials, a well-accepted model presently predicts that the initial impact of a particle may cause only localized plastic deformation on the surface of the material. However, successive impacts at the same point may produce a hardening of the material at the bottom of such craters, also forming edges or lips on the sides of the craters or on the side opposite the impacts. In the end, removal of these lips would characterize erosion, i.e. loss of mass.

A suggested mechanism for the final detachment of these parts was based on ballistic studies, on what projectile impacts initially create a condition of localized dynamic compression on the affected surfaces (Figure 1). In the subsurface of the impact areas, structural transformations occur, with the formation of the so-called Adiabatic Shear Bands (ASB). The presence and coalescence of voids in these bands would give rise to cracks along them, which are precursors of fracture. This is one of the most accepted mechanisms to explain mass loss.

Much of the contributions made in this field come from experiments in laboratories, which can be very costly and time-consuming. Using the finite element method and the Johnson Cook's failure criterion [JOHNSON, 1985], it is possible to model erosion in materials, saving time and money.

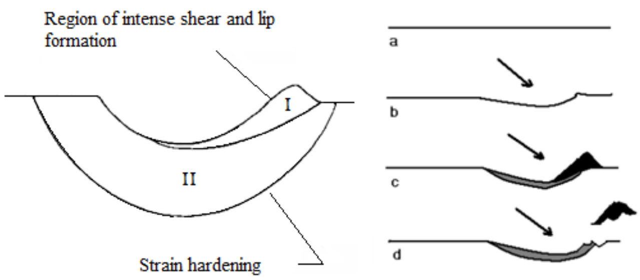

Figure 1: crater formed by dynamic impact of particles. Fonte: SHEWMON e SUNDARARAJAN, 1983.

Results of the simulations can be validated by those of some previous experimental studies, where the presence of ASB was observed by SEM in the eroded surface of that material, impacted by alumina particles. In this way, graphical outputs of the software can confirm the resulting plastic deformation in the craters of the eroded material, its hardening and the lip formation at the edges of the craters, besides to show the stress and strain values that characterizes the formation of the shear band, which is precursor to failure and a possible mechanism for this type of erosion.

Materials and Methods

Target material

Duplex stainless steel is a relative new material that has been replacing other stainless steels, mainly the austenitic ones, in diverse applications, as in the industry of oil and gas. However, concerning its behavior under erosion, a very few amount of information is available in literature. In the previous experiments, the chemical composition and the mechanical properties of the target material are:
- yield stress (0,2 %): 586 MPa;
- ultimate tensile stress: 784 MPa;
- elongation in 50 mm: 34 %;
- hardness: 20 HRC .

In simulations, the parameters of the Johnson & Cook formulation were as closer as possible to those of this material.

Impacting Particles

It is being considered Alumina particle as erodent once, it promotes a higher rate of material removal due to its high density, hardness and angularity, when compared to particles of quartz and silicon carbide for the same test conditions [DESALE, 2006].

The erodent particles were polyhedral alumina, with variable morphology and 150 micron average size (100 mesh). In simulations, erodent particles were spherical, rigid, 10 mm diameter.

Software

Modeling of the erosion process was performed using a finite element solver ABAQUS^{TM}/EXPLICIT version 6.12-1.

Methodology

Numerical simulation will be carried out in ABAQUS software in order to study the ASB formation and to predict the UNS S32205 stainless steel behavior in erosion, using the Johnson & Cook constitutive model. The Johnson & Cook failure criteria is based on the elastic-plastic material behavior [JOHNSON, 1985], and considers ductile failure and the effects of temperature, strain and strain rate.

The Johnson & Cook parameters to be considered in this work are respectively: A (550 MPa), B (750 MPa), n (0.20), m (1.0) and C (0.0014), adapted from [SANTOS, 2015]. Values of melting temperature (1700k) are from [JOHNSON, 1985] and reference temperature (293k) is the room temperature. These values approximate those of the UNS S32205 duplex stainless steel.

The working sample of the target will be a plate with 100x100x10THK (mm) and the erodent particle a rigid sphere of 10 mm diameter, velocity of 50 m/s and impingement angle of 30 degrees. Successive and individuals impacts will be simulated and results are expected to be in graphics form or in images.

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