Statistical character of the failure of multiphase materials due to high pressure water jet impingement

A.W. MOMBER[1] and R. KOVACEVIC[2]
[1] *WOMA Apparatebau GmbH, Germany, Feodor-Lynen Scholar of the Alexander-von-Humboldt Foundation, Bonn, Germany, at the University of Kentucky*
[2] *Center for Robotics and Manufacturing Systems, University of Kentucky, Lexington, KY 40506, USA*

Abstract. In this study, fracture experiments on multiphase material samples have been carried out using high speed water jets. Based on fracture geometry measurements and on grain analyses it was found that the fracture of this type of materials by water jet impingement is a highly localized process at low pressure ranges. Beyond a critical pressure range of about 30 times the material's tensile strength a change in the material behaviour was observed. This result is in agreement with a theory suggested by Powell and Simpson. To explain the local character of the failure process, a simplified fracture model is introduced which resulted in a relation between a fracture probability parameter and the fracture width in the damaged materials.

1. Introduction

High energy plain water jets have been used to process brittle multiphase materials, such as rocks and concretes, in the mining and quarrying industry and in civil engineering for some years. Typical applications are recently described by Fowell and Martin [1], Vijay [2], Summers [3], and Momber [4]. Regardless of the wide range of application, the mechanism of destruction of brittle multiphase materials due to plain water jets is not well understood.

The general structure of a plain continuous water jet can be assumed as a three region jet. According to [5], [6] and [7], one can discern a core region, a transition region, and a droplet region. In practice, the jet core region is used to cut and remove materials with pressures greater than 100 MPa. In this region static loading due to a stagnation pressure p_s predominates. The stagnation pressure, which is distributed over the loaded surface, can be estimated using the equation

$$p_s = \tfrac{1}{2} \cdot \rho \cdot \nu_0^2, \tag{1}$$

where p_s is the stagnation pressure, ρ is the fluid density and ν_0 is the jet velocity. The stagnation pressure is distributed over the loaded area after a Gaussian curve. This distribution which is shown in Fig. 1 can be described according to [8] as follows

$$p_s(r) = p_s(0) \cdot e^{-\alpha^2 \cdot r^2}, \tag{2}$$

where $p_s(0)$ is the stagnation pressure on the jet axis, r is the radial distance from the jet axis and α is a constant depending on the jet diameter. For a jet diameter of 1.0 mm, which is a common value for rock and concrete processing, the pressure is distributed over an area of about 0.8 mm². This value suggests that integral macroscopic material properties, such as compressive strength and Young's modulus, can not be used for the evaluation of material resistance against water jet attack. The local conditions, and so the local properties, at the