Accelerated High Speed Water Erosion Test for Concrete Wear Debris Analysis©

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This paper contains investigations of wear particles generated during the erosive wear of four different concrete mixtures by high velocity water flow at velocities of about 700 m/s. The wear particles were collected, dried and analyzed by sieve experiments. Based on the sieve analysis, specific surface and average grain diameter of the particle samples were estimated. Using simple comminution relations, the specific crack length of every sample is calculated. It is shown that all estimated parameters exhibit a strong relationship to characteristic material properties, such as compressive strength, Young's modulus, and absorbed fracture energy. It was found by regression analysis that the average debris wear size can be effectively characterized by the absorbed fracture energy of the concrete sample. It is concluded that these relations are the result of different paths of fracture propagation through the materials during the generation of a microcrack network.

KEY WORDS

Wear and Failure, Erosive Wear Mechanisms, Materials, Properties and Tribology, Marine Tribology

INTRODUCTION

Since concrete is used for marine and hydraulic structures, pipe coatings and channel walls, its wear due to the attack of fast flowing water is a problem (*1*). The first systematic investigations on the resistance of concrete against wear in marine structures were carried out in the 1940s (*2*). Investigations carried out in the fields of water flow erosion, cavitation and abrasion have been reviewed in Refs. (*3*), (*4*).

Momber et al. (*3*)–(*10*) investigated the influences of interfaces, cracks, and inclusions on the failure of brittle multiphase materials due to fast flowing water attack at velocities up to 450 m/s. The predominant mechanisms of the material failure are propagation and intersection of pre-existing microcracks. It was found that the destruction process due to the water flow is introduced in the interface between the matrix and inclusions which are characterized by a high degree of porosity and pre-existing microcracks. The water is pressurized inside a crack; this leads to forces acting on the crack wall surfaces. If the generated stresses exceed critical material values, e.g., critical stress intensity factor, the crack starts to grow. The crack growth is controlled by the interaction between crack and aggregate grains. It was experimentally shown that inclusions in the material may act as crack arrestors and energy dissipators (*8*). The intersection of several single cracks leads to a macroscopical material removal. The model is illustrated in Fig. 1. In advanced versions of the phenomenological model, a computer-based simula-

NOMENCLATURE

a,b,c = regression parameters
C_M = sound velocity in the target material
d = sieve width
d_{AV} = average wear particle diameter
l_0 = maximum sieve width
d_U = minimum sieve width
E = Young's modulus
G = absorbed fracture energy
K = compressive strength
K_{lc} = fracture toughness

l_{cr} = specific crack length
p = applied pump pressure
S_{SP} = specific surface of a grain sample
v_{fl} = water flow velocity
V_M = removed material volume
$\dot{\varepsilon}$ = strain rate
μ = nozzle efficiency parameter
ρ = water density
ρ_M = target material density
ψ = particle shape parameter