Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 87 (2016) 16 – 23

Physics Procedia

44th Annual Symposium of the Ultrasonic Industry Association, UIA 44th Symposium, 20-22 April 2015, Washington, DC, USA and of the 45th Annual Symposium of the Ultrasonic Industry Association, UIA 45th Symposium, 4-6 April 2016, Seattle, WA, USA

# Correlating inertial acoustic cavitation emissions with material erosion resistance

I. Ibanez[a], M. Hodnett[b], B. Zeqiri[b], M. N. Frota[a]*

[a]*Postgraduate Programme in Metrology (PósMQI), Catholic University of Rio de Janeiro, RJ, 22453-900, BRAZIL*
[b]*Acoustics and Ionising Radiation Division, National Physical Laboratory (NPL), Hampton Road, Teddington, TW11 0LW, U.K.*

**Abstract**

The standard ASTM G32-10 concerns the hydrodynamic cavitation erosion resistance of materials by subjecting them to acoustic cavitation generated by a sonotrode. The work reported extends this technique by detecting and monitoring the ultrasonic cavitation, considered responsible for the erosion process, specifically for coupons of aluminium-bronze alloy. The study uses a 65 mm diameter variant of NPL's cavitation sensor, which detects broadband acoustic emissions, and logs acoustic signals generated in the MHz frequency range, using NPL's Cavimeter. Cavitation readings were made throughout the exposure duration, which was carried out at discrete intervals (900 to 3600 s), allowing periodic mass measurements to be made to assess erosion loss under a strict protocol.

Cavitation measurements and erosion were compared for different separations of the sonotrode tip from the material under test. The maximum variation associated with measurement of cavitation level was between 2.2% and 3.3% when the separation (λ) between the transducer horn and the specimen increased from 0.5 to 1.0 mm, for a transducer (sonotrode) displacement amplitude of 43.5 μm. Experiments conducted at the same transducer displacement amplitude show that the mass loss of the specimen —a measure of erosion— was 67.0 mg (λ = 0.5mm) and 66.0mg (λ = 1.0 mm).


Peer-review under responsibility of the Ultrasonic Industry Association.

*Keywords:* Metrology; Cavitation erosion; Ultrasound, CaviMeter; engineering materials; Standard ASTM G32-10.

* Corresponding author. Tel.: +55 (21) 3527 1542; fax: + 55 (21) 3527-2060.
*E-mail address:* frota@esp.puc-rio.br


Peer-review under responsibility of the Ultrasonic Industry Association.
doi:10.1016/j.phpro.2016.12.004

## 1. Introduction

Cavitation erosion in engineering materials is amongst well-characterized problems identified in the industry. Searches for solutions to understand the phenomenon and to lessen its detrimental effect have stimulated studies and research on the subject (Choi et al, 2012; Da Silva et al, 2013). In particular, this paper summarizes a more comprehensive work (Ibanez, 2014) recently developed to investigate the resistance to cavitation erosion induced in specimens of aluminium-bronze alloys. The study was developed in line with well-established specification standards that describes a test method for cavitation erosion using vibratory apparatus (ASTM G32:2010). The erosion process was assessed via measuring the mass loss of the specimen while measurements of cavitation were performed by a variant of NPL's cavitation sensor (Zeqiri, et al, 2003).

## 2. Theoretical background

### *2.1. Cavitation erosion*

The phenomenon of cavitation results from the formation of vapour in a liquid when the latter is subjected to a reduction in pressure. The cavitation induced by an acoustic field (ultrasonic cavitation) occurs when an acoustic wave propagates in a fluid undergoing a reduction in pressure (rarefaction) with respect to the saturation vapour pressure (King, 2010). An acoustic wave can be generated by an ultrasound transducer driven by a power supply.

The acoustic cavitation develops in two regimes: inertial and non-inertial (Young, 1989). The first occurs in the absence of bubble collapse (bubbles may increase or decrease in diameter in response to the driving ultrasonic field) (Tiong, 2012) and the latter occurs with the eventual collapse of the bubbles. Fig. 1 illustrates both regimes and Fig.2 the progress of cavitation erosion.

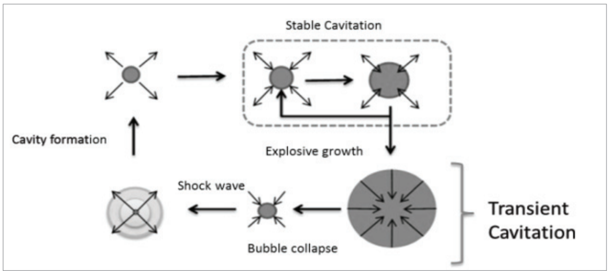


Fig.1. Cavitation sequence. Source: modified from (King, 2010)

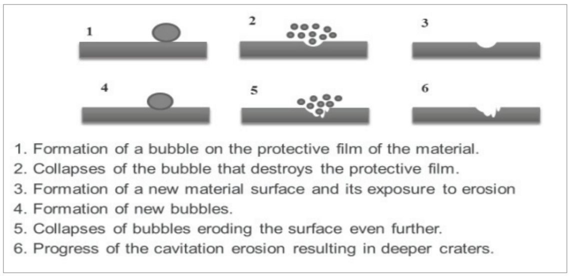


Fig. 2. Cavitation erosion progress.

It is well-known that acoustic cavitation changes material surfaces through various mechanisms (Young, 1989), and this is exploited by the applicable standard, ASTM G32:2010. It states that erosion develops in stages (ASTM G32:2010):

- *Incubation stage:* erosion rate is negligible at the beginning of the process;
- *Acceleration stage:* erosion rate increases until reaches a maximum value;
- *Deceleration stage:* erosion rate is reduced as a result of change in roughness at the eroded surface.

### *2.2. Measurement of cavitation*

Hodnett and Zeqiri (2008) describe the instrumentation and technique developed by the NPL for measurements of cavitation. Fig. 3 illustrates a variant of the cavitation sensor applied for (quantitative) measurements at driving frequencies above 20 kHz (Zeqiri, et al, 2003; Hodnett, 2006). The sensor operates via detecting the acoustic emissions from bubbles using a piezoelectric (PVDF) element, 110 microns thick, coated with a special rubber to isolate it from the fluid medium.