Ultrasonics Sonochemistry 21 (2014) 354–359

Contents lists available at SciVerse ScienceDirect

Ultrasonics Sonochemistry

journal homepage: www.elsevier.com/locate/ultson

Cavitation intensity of water under practical ultrasonic cleaning conditions

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ARTICLE INFO

Article history:
Received 21 May 2013
Received in revised form 25 June 2013
Accepted 10 July 2013
Available online 18 July 2013

Keywords:
Cavitation
Ultrasonic cleaning

ABSTRACT

When measuring cavitation during cooling of thermally degassed water cavitation maxima are frequently observed at various temperatures. Relations between this phenomenon and frequency and power of ultrasounds as well as air content in water have been examined. It was found out that the secondary water regassing with air is the reason.

1. Introduction

The title of the present article harks back to a former author's work "Observations of water cavitation intensity under practical ultrasonic cleaning conditions" [1] published in Ultrasonics Sonochemistry. In that work cavitation intensity of water with various gas content was examined, both under winter (tap water temperature 5 °C) and summer (temperature of water about 20 °C) conditions.

It was found out that water gassed with dissolved air cavitates most intensely at the highest gas content and the highest cavitation was observed at 7–20 °C depending mainly on the height of water column sonicated from underneath. During heating gasified water above 30 °C, abrupt decrease of its cavitation intensity takes place, the lower the ultrasounds level, the deeper and longer lasting the decrease. All the experiments described in that work dealt with cavitation intensity of water during its heating.

Also works [2,3] are devoted to measurements of cavitation intensity of water.

It is known that during heating water degasifies because solubility of air in water decreases (e.g. at 10 °C it amounts to 23 cm^3/L and at 30 °C: 16 cm^3/L) [4].

By heating water up to 70–80 °C, preferably with its simultaneous sonication with ultrasounds, almost complete degassing of water may be reached.

Such method of degassing for practical purposes in ultrasonic cleaning was described in many works, for example in [5]. During cooling degassed water cavitates more and more intensely as the temperature decreases reaching a maximum around 35 °C. This maximum, however, is not sharp and there are no big differences in cavitation intensities of water during cooling in the 30–40 °C range [6,7]. Typical plot of cavitation intensity of water vs. temperature during its heating up from 20 °C and subsequent cooling is schematically presented in Fig. 1.

In practice, however, such shape of the plot during cooling, as the one in Fig. 1, is not always observed. On the cooling plot there appear maxima between 40 and 65 °C more distinct when the power of ultrasounds is bigger. At first it was attributed to the height of the water column not corresponding with the standing wave with a whole number of wave halves. More accurate measurements, however, show that this is not the reason of the anomalies on the cavitation – temperature plots during cooling of water. The present work is devoted to the explanation of this problem.

2. Experimental procedure

In the experiments it was checked how the shape of cavitation – temperature plot during cooling is influenced by:

- frequency of ultrasounds,
- ultrasounds power density,
- degree of air content in water.

Ultrasounds of frequencies 40, 38, 36 and 34 kHz were used. 40 kHz is one of the frequencies most frequently used in ultrasonic cleaning. Frequencies 38 and 36 kHz were chosen because, as follows from the previous author's works, solutions of some substances at elevated temperatures cavitate at these frequencies more intensely than water what may have something to do with

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http://dx.doi.org/10.1016/j.ultsonch.2013.07.003

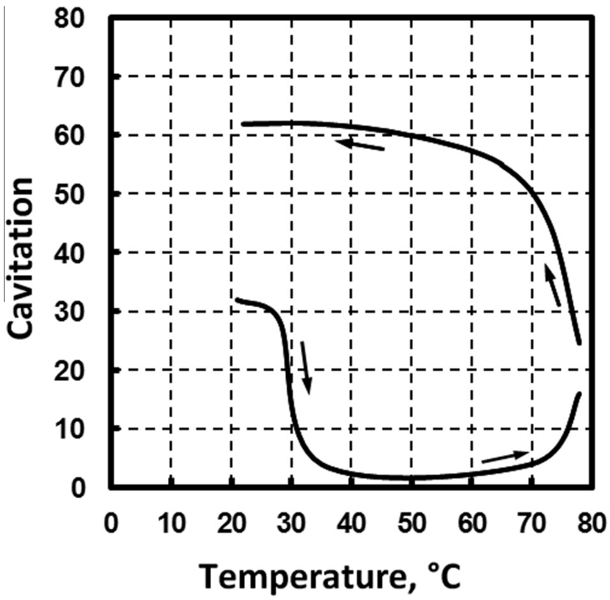

Fig. 1. Typical cavitation vs. temperature curve during water heating and cooling.

the problem under investigation [8,9]. From these works it follows also that at 34 kHz these differences in cavitation are not observed, and therefore this frequency was also included.

For the 40, 38 and 36 kHz an Elmasonic S180H cleaner of 18 dm^3 capacity from "Elma" Hans Schmidbauer GmbH (Singen, Germany) was used. This cleaner nominally operates at 37 kHz but in fact it has a 40 kHz generator. It was found out that its four transducers do not have one common resonant frequency and the cleaner operates simultaneously at different frequencies in the range 36–40 kHz. Therefore its internal generator was disconnected and another, more powerful generator of variable operating frequency was used instead.

For measurements at 34 kHz a 30 dm^3 UM cleaner manufactured by ITR (Warsaw, Poland) was used.

In order to get various power densities both cleaners were connected to the mains via an autotransformer and the generators operated at 180 V, 200 V, 230 V and 260 V.

In order to exclude the influence of small amounts of salt dissolved in water on its cavitation, deionized water was used. 10 L of water was poured into the Elmasonic cleaner and 15 L into the UM. Water levels in the tanks were correlated with the cavitation maxima (standing wave). These were 116–124 mm in the Elmasonic cleaner and 124 mm in the UM cleaners. The levels were kept constant during all the experiments by replenishment of evaporated water.

Cavitation intensity was measured by a Model 200 Cavitation Meter from Branson with a measurement probe from Alexy Associates Ultrasonic Cleaners, SwanLake, NY, USA [10]. This meter measures so called 'white noise' resulting from implosions of the cavitation bubbles. A probe with a piezoelectric sensor at its end is inserted in the cavitating liquid. A weak electrical current pro-

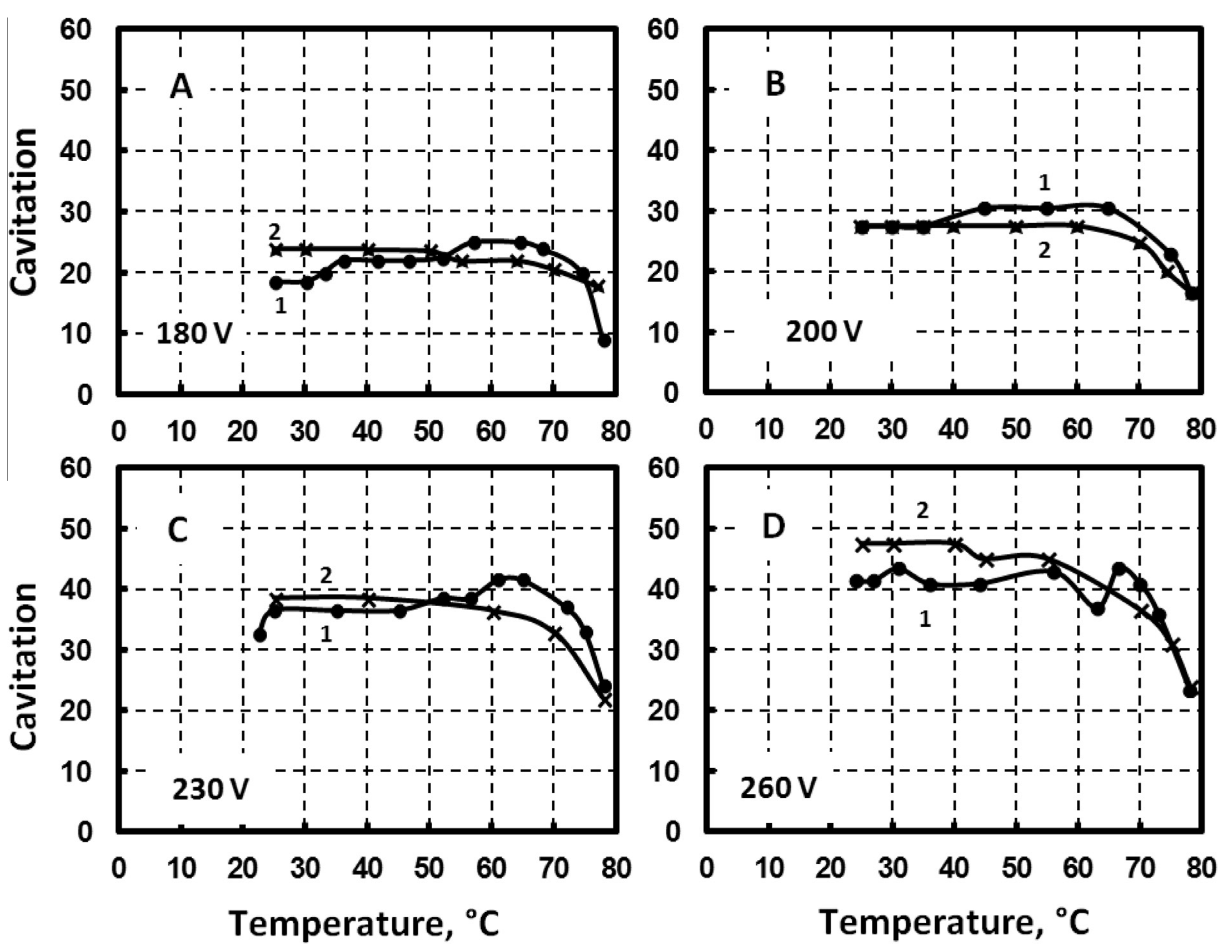

Fig. 2. Cavitation vs. temperature during cooling of water for 40 kHz and four generator output power levels obtained by changing voltage. 1 – plots for deionized water, 2 – plots for deionized water with 0.5% Na_2SO_3. Obtained power densities in W/L: A1–17, A2–17, B1–20, B2–19, C1–22, C2–21, D1–27, D2–27.