Characterization of Therapeutic Ultrasound Devices for Rehabilitation and Physical Medicine

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***Abstract*— The study describes the results obtained in ultrasound power measurements carried out on physiotherapy ultrasound equipment in Department of Orthopaedics, Traumatology and Rehabilitation, AO Città della Salute e della Scienza, CTO Hospital, Torino, Italy.**

***Keywords*— Ultrasonic therapy, Mechanical effect, Quality control.**

I. INTRODUCTION

Therapeutic ultrasound, typically in the 1 to 4 MHz frequency range has been used in physiotherapy for 50 years to treat pain and edema related to acute and chronic inflammatory diseases such as tendinitis, bursitis, synovitis and traumatic events and for the clinical management of rheumatic diseases, neuritis, vasculitis. Most effects of ultrasound (US) depend on its ability to induce a local thermal increase, which elicits muscle tonicity, local vasodilation and toxic substance washout [1]. In the absence of a cogent regulation, both national or european, the periodic verification of the parameters of the ultrasonic beam, mainly the ultrasound power, P, is a quite uncommon procedure among the technical laboratories of the public hospitals in Italy [2].

This paper presents the ultrasound power values, measured using the radiation force balance method, emitted by the following devices:

TABLE I.

		Probe	
Name	Type	$f_0 = 1$ MHz	$f_0 = 3$ MHz
Device 1	SONOPLUS 434	X	X
Device 2	COSMOGAMMA F230	X	
Device 3	ENRAF NONIUS SONOPLUS 490	X	X

II. MEASUREMENT SYSTEM

A. Submersible load cell, SLC, measuring system

The system used for the ultrasonic power measurement is based on the radiation force balance method [3]. The ultrasonic power is determined from the measurement of the force exerted on a target by the sound field generated by the ultrasonic source (Device 1, Device2 or Device 3) [4].
The target is solidly connected to sensing element of the commercial load cell (Honeywell mod. 31) with a screw [5].
Fig.1 show the measurement apparatus, in the upper right box a detail of load cell and target.

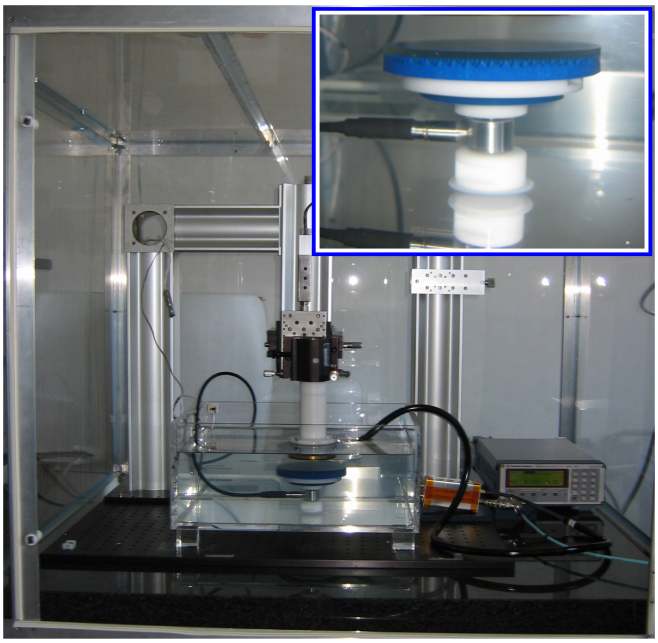

Fig 1. System set-up for ultrasound power measuremnts

The signal produced by the load cell pass through a strain gauge amplifier (Sensotec mod. UV-10) and then measured by a voltmeter (Agilent 34420 A). The load cell is placed on the

bottom of the plexiglass tank, with a volume of approximately 15 litres. The use of the load cell permit a short duration of the tone burst used for the measurement of the ultrasonic power emitted by the devices under test, P, allows the use of the absorbing target even for high values of ultrasonic power.
Assuming plane waves, and using a target that totally absorbs the incident momentum, the relationship between the ultrasonic power, P, and the radiation force, F, is:

$$P = u(T)F \qquad (1)$$

where: $u(T)$ is the speed of sound in water (measured during the experiment), depending on the water temperature.
The output voltage range of the load cell varies from few mV, for power near to 1 W, to nearly 10 mV, for an ultrasonic power up to 10 W.

B. Measurement procedure

In analogy with the measurement system based on a commercial balance, based on radiation force method, also for the SLC system a calibration (in measurements conditions) is strictly necessary before the ultrasound power measurements [6]. Calibration system is obtained measuring the output voltage of the load cell when charged with calibrated weights and calculating the linear regression curve relating weight and output signal. This calibration procedure allows to calculate the force induced by the ultrasound field, by measuring the variation of the output voltage of the cell. The computer program for the management and the control of the parameters influencing the measurement as, distances between transducer and target, water and air temperature, etc... is basically the same as the program used for the radiation force balance system and it is developed in LabVIEW 9.0 code[7].
In TABLE II the uncertainty as function of power level and frequency is displayed [8].

TABLE II.

	$f_0 < 1.8$ MHz	1.8 MHz ≤ $f_0 < 6$ MHz
0.5 W ≤ $P < 4.0$ W	$U(P) = 8\%$	$U(P) = 8\%$
$P \geq 4.0$ W	$U(P) = 4\%$	$U(P) = 6\%$

III. RESULTS

Figures 2 to 11 show the results of the measurementens carried on the aforementioned devices. The experiment consisted of two separate measurements on each apparatus [6].
At first, the device was set up at its nominal output level and the power emitted by the probe was measured n times in order to evaluate the repeatability of the ultrasound emission. The number of repetitions was set to 5. The absorbing target was used. The second measurement aimed at evaluating the stability in time of the output: with the same device set up, the power was measured over a 300 s period, a time typical of a clinical treatment. In this case it was not possible to use the same absorbing target, as the energy absorbed would lead to an excessive heating and thermal dilatation, with an increase of the buoyancy and therefore a measurement error. A reflecting target was used instead, and it has to be noted that the SLC system allows the use of this kind of target at high power levels without unwanted movements, because the target is firmly connected to the sensing element.

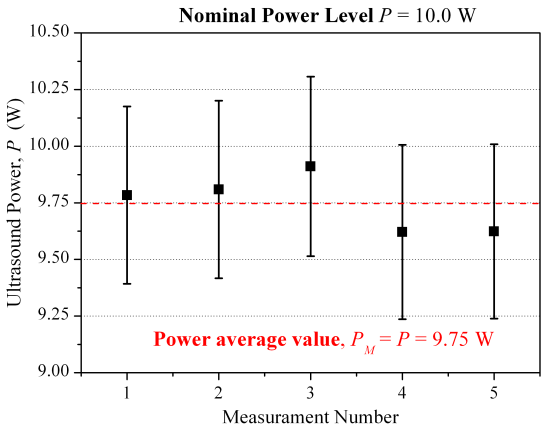

Fig 2. Ultrasound Power emitted from Device 1 Probe 1 MHz

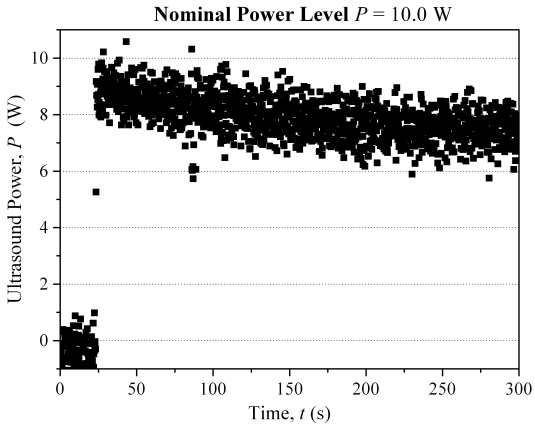

Fig 3. Ultrasound Power vs. time Device 1 Probe 1 MHz

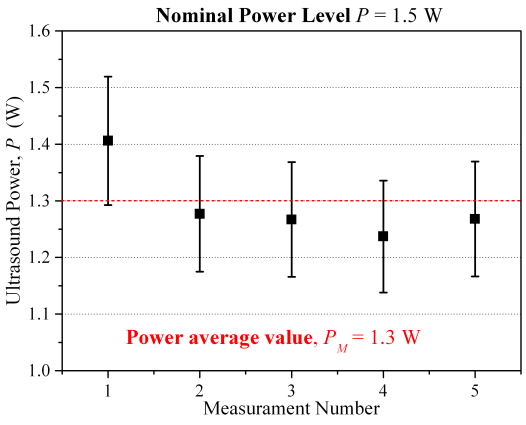

Fig 4. Ultrasound Power emitted from Device 1 Probe 3 MHz

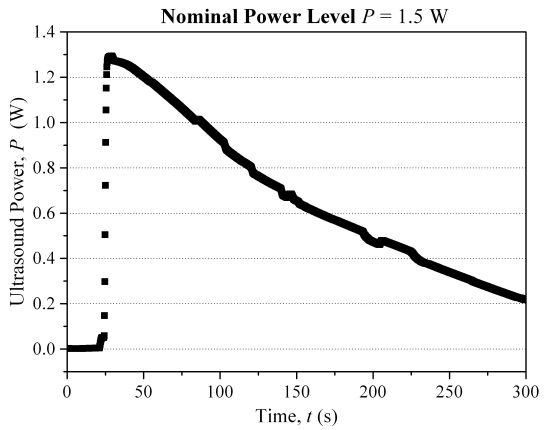

Fig 5. Ultrasound Power vs. time Device 3 Probe 3 MHz

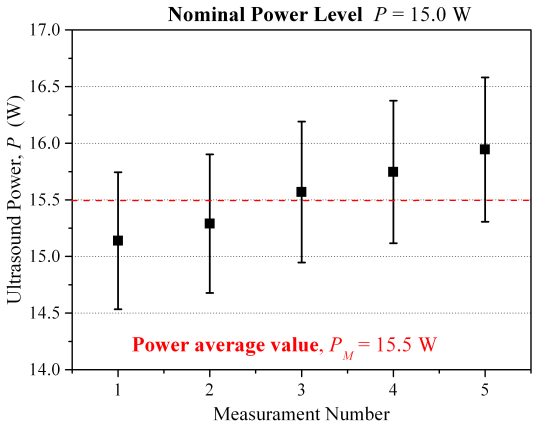

Fig 6. Ultrasound Power emitted from Device 2 Probe 1 MHz

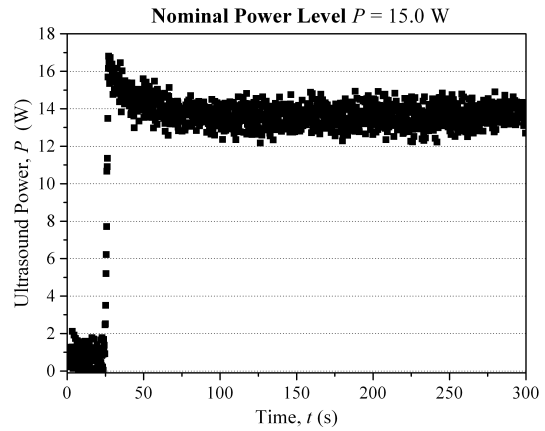

Fig 7. Ultrasound Power vs. time Device 2 Probe 1 MHz

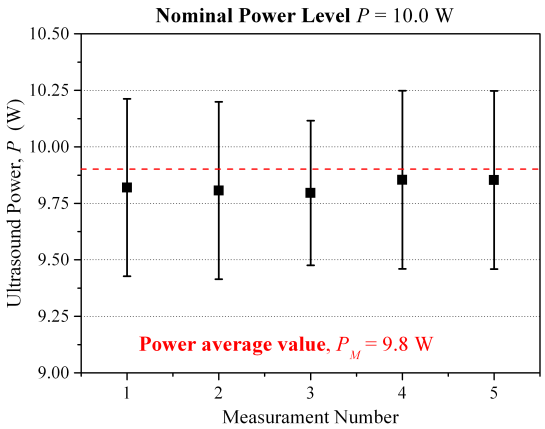

Fig 8. Ultrasound Power emitted from Device 3 Probe 1 MHz

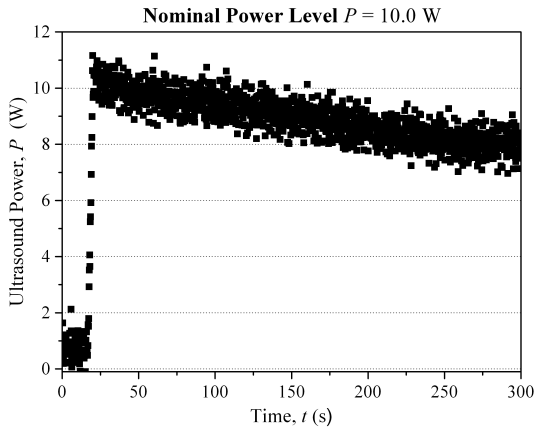

Fig 9. Ultrasound Power vs. time Device 3 Probe 1 MHz

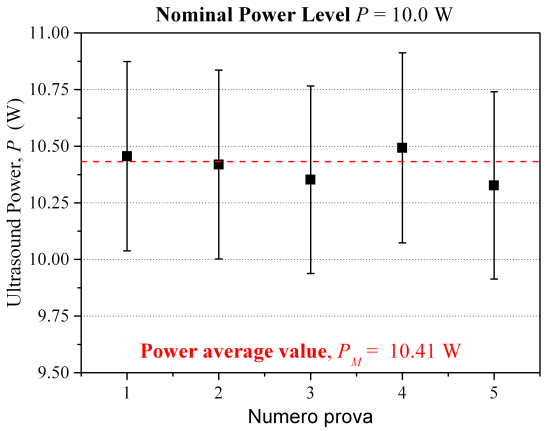

Fig 10. Ultrasound Power emitted from Device 3 Probe 3 MHz

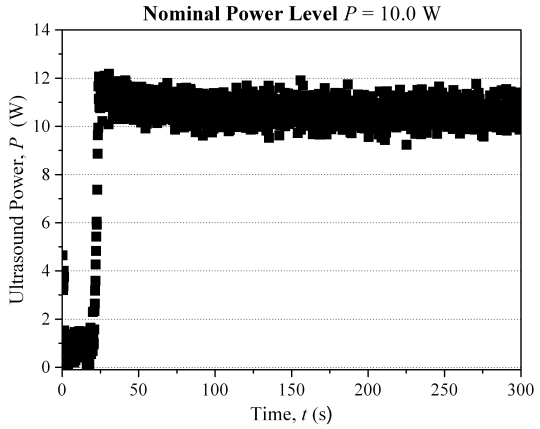

Fig 11. Ultrasound Power vs. time Device Probe 1 MHz

IV. CONCLUSION

Measurement data show a fairly good agreement with the nominal power levels set on the devices. With the exception of the device 1 in combination with probe 3 MHz, the stability in time of the power level is such that the effectiveness of the typical therapies, which these apparatuses are used for, is not affected.

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