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COMMUNICATIONS

FEASIBILITY INVESTIGATIONS OF THE POSSIBILITY OF MEASUREMENTS, OF THE ULTRASONIC TRANSDUCER POWER OUTPUT AT ULTRASONIC–THERAPY–DEVICES, WITH PIEZOCERAMIC SENSORS

Thomas LEKSCHA * — **Daniela ĎURAČKOVÁ** **

The paper shows the essential results for the investigation of a new ultrasonic power measuring method, in articular for measuring the sonic pressure of ultrasonic therapy devices, by using piezoceramic sensors. The aim of this work is to develop a new measuring instrument for the fast performance measurement at ultrasonic-therapy-devices.

K e y w o r d s: ultrasonic therapy, piezoceramic sensor, medical devices directive, measuring device

1 INTRODUCTION

This document is concerned with examining whether sound output levels from ultrasonic therapy devices, in particular their ultrasonic transducers, can be determined by means of piezoceramic sensors. The objective of this feasibility study is to compile basic information in respect of a measuring instrument, envisaged for the future, which should take the form of a hand-held measuring unit and be capable of measuring the ultrasonic output from the transducers of various ultrasonic therapy devices.

The background to this examination is based on the legally prescribed tests on technical medical devices. According to the Medical Devices Directive (MPBetreibV) [1], ultrasonic therapy devices must be subjected to regular safety inspections. These regular control measurements are taken on the respective medical devices at certain intervals by personnel trained in respect of medical equipment. The aim of regular tests is to detect any faults on the therapy devices at an early stage and prevent any consequential injuries to patients and/or device operator. Ultrasonic therapy devices are not only subjected to a function test and electrical safety checks but the output parameters and ultrasonic output at the transducers is measured and determined.

At present, the output level is completed using an extensive gravimetric procedure which, in practice, is relatively inconvenient to use. In addition, the purchase of a gravimetric measuring instrument involves high costs.

This study aims to examine whether piezoceramic sensors could be used to realise a measuring procedure which can be implemented to control ultrasonic output levels of ultrasonic therapy devices in everyday testing processes.

2 ULTRASONIC THERAPY

In order to implement ultrasonic for medical treatment, an ultrasonic therapy device is required. A wide range of such therapy devices is currently available on the international market. However, the structure of the basic modules used in these devices is always the same. In order to produce an ultrasound, one needs a high-frequency generator and an ultrasonic transducer with an integrated oscillating crystal (piezoelectric actuator). The high-frequency generator produces an alternating voltage which is transferred to the oscillating crystal. This alternating voltage causes the oscillating crystal to change its geometrical shape (due to the piezoelectric effect). The oscillating crystal oscillates, and sends sound waves in the ultrasonic range (20 kHz to 1 GHz) [2].

To achieve a broader range of application possibilities, the oscillating crystal can be excited either continuously or pulsed. The corresponding operating mode can then be selected on the ultrasonic therapy device according to the indicators.

The output frequency of most therapy devices is restricted to 1 MHz and 3 MHz. These two frequencies and their respective modulations are sufficient to treat numerous medical conditions. In order to be able to emit the sound waves on the human body, a coupling medium is required for the transfer (coupling the ultrasonic transducer to the human tissue). In practice, ultrasound gel or water is generally used as the ultrasound coupling medium. Since the various media (ultrasonic transducer, air, and tissue) conducts and absorbs the ultrasound differently, selection of the right coupling medium is of great importance.

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Table 1. Description of the series of voltage measurements, $M.A_1$ to $M.A_5$

Output power at the ultrasonic therapy device (W/cm²)	(W)	$M.A_1$	$M.A_2$	$M.A_3$ UDC (V)	$M.A_4$	$M.A_5$
0.0	0.0	0.00	0.00	0.00	0.00	0.00
0.1	0.5	1.24	1.17	1.20	1.15	1.20
0.3	1.5	2.64	2.58	2.54	2.55	2.50
0.5	2.5	3.83	3.71	3.75	3.74	3.64
0.7	3.5	4.83	4.80	4.74	4.61	4.42
0.9	4.5	5.46	5.27	5.35	5.26	5.26
1.1	5.5	5.70	5.66	5.67	5.72	5.47
1.3	6.5	6.06	5.90	5.97	6.01	5.97
1.5	7.5	6.20	6.26	6.20	6.09	6.05

Table 2. Description of the series of voltage measurements, $M.B_1$ to $M.B_5$

Output power at the ultrasonic therapy device (W/cm²)	(W)	$M.B_1$	$M.B_2$	$M.B_3$ UDC (V)	$M.B_4$	$M.B_5$
0.0	0.0	0.00	0.00	0.00	0.00	0.00
0.1	0.5	0.83	0.99	1.05	1.01	1.00
0.3	1.5	2.25	2.39	2.41	2.45	2.40
0.5	2.5	3.48	3.61	3.61	3.56	3.64
0.7	3.5	4.38	4.60	4.55	4.37	4.50
0.9	4.5	5.04	5.10	5.03	4.98	5.04
1.1	5.5	5.46	5.44	5.41	5.39	5.36
1.3	6.5	5.71	5.84	5.76	5.77	5.81
1.5	7.5	5.90	6.02	6.00	6.05	6.05

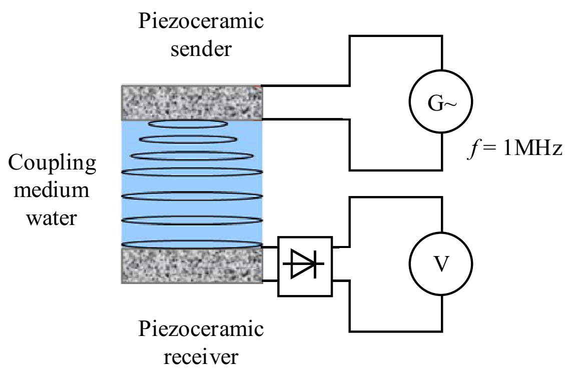

Fig. 1. Schematic testing equipment layout of the lab experiments

3 EXPERIMENTAL DETAILS

To conduct the laboratory experiments, an ultrasonic therapy device from ERBE was selected as sender. The device, of the type Erbogalvan e2plus, has a maximum ultrasonic output power of 7.5 W and was operated in continuous mode [3]. Continuous mode provided the maximum effective output power and, thus, the maximum heating of the oscillating crystal and transmission medium (water).

The maximum values were tested in order to be able to draw conclusions related to reliable operation of an envisaged measuring procedure. The effective application area of the ultrasonic transducer was 5 cm^2. The sound frequency of the device was 1 MHz. The ultrasound coupling medium, water, was degassed prior to the experiments [4, 5] and dosed at 50 ml for each respective series of measurements.

As detector, we used an Oscillating crystal type P502 as disc form [6], from Sonox P5 series from CeramTec AG. The distance (l_Q) between the oscillating crystal (Piezoceramic Receiver) and effective heat radiating surface of the ultrasonic transducer (Piezoceramic Sender) was 5 mm for all the series of experiments. The measuring time (measuring time per parameter setting) and the pause time (time between each measurement) were varied. Attention was paid, however, that the ultrasonic transducer and oscillating crystal were aligned exactly parallel to each other. The schematic test setup is shown in Fig. 1.

4 RESULTS AND DISCUSSION

Subsequently three expressive measurements, of a great number of measurements, were represented in order

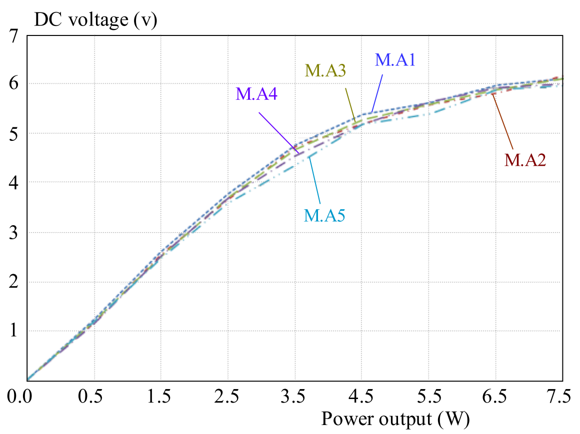

Fig. 2. Graphical illustration of the series of voltage measurements $M.A_1$ to $M.A_5$

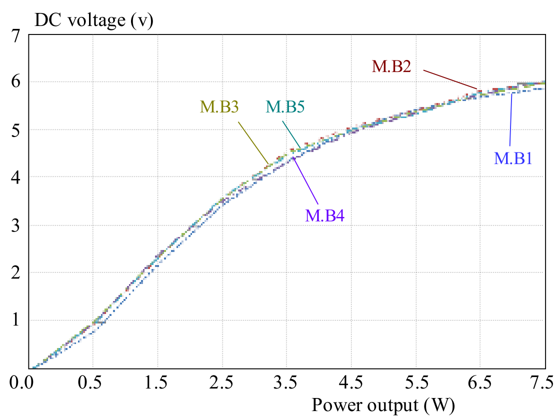

Fig. 3. Graphical illustration of the series of voltage measurements $M.B_1$ to $M.B_5$

Table 3. Description of the series of voltage measurements, M.C_1 to M.C_5

Output power at the ultrasonic therapy device (W/cm²)	(W)	M.C_1	M.C_2	M.C_3 UDC (V)	M.C_4	M.C_5
0.0	0.0	0.00	0.00	0.00	0.00	0.00
0.1	0.5	1.10	1.04	1.04	1.09	1.05
0.3	1.5	2.39	2.28	2.28	2.37	2.38
0.5	2.5	3.48	3.39	3.37	3.42	3.39
0.7	3.5	4.35	4.34	4.31	4.29	4.30
0.9	4.5	5.03	5.06	5.01	5.01	5.00
1.1	5.5	5.40	5.47	5.48	5.46	5.45
1.3	6.5	5.73	5.71	5.75	5.71	5.77
1.5	7.5	6.06	6.07	6.09	6.03	6.07

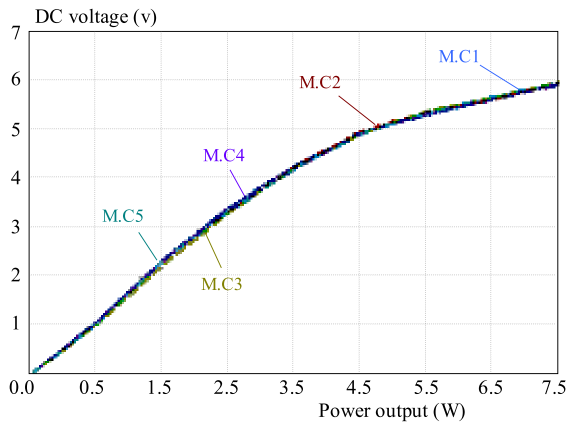

Fig. 4. Graphical illustration of the series of voltage measurements M.C_1 to M.C_5

to document the course of the measurements an results. All series of measurements were carried out with the same measuring instruments. Only the specifications of the lab testing equipment layout were distinguished.

Specifications for the series of measurements M.A_n:
50 ml degassed water as coupling medium, 10 seconds measuring time (t_M) per parameter setting, 1 minute pause time (t_P) between each measurement, 5 mm distance between effective heat radiation surface of the ultrasonic transducer and surface of the sensor, 1 MHz sound frequency.

Specifications for the series of measurements M.B_n:
50 ml degassed water as coupling medium, 8 seconds measuring time (t_M) per parameter setting, 3 minutes pause time (t_P) between each measurement, 5 mm distance between effective heat radiation surface of the ultrasonic transducer and surface of the sensor, 1 MHz sound frequency.

Specifications for the series of measurements M.C_n:
50 ml degassed water as coupling medium, 5 seconds measuring time (t_M) per parameter setting, 5 minutes pause time (t_P) between each measurement, 5 mm distance between effective heat radiation surface of the ultrasonic transducer and surface of the sensor, 1 MHz sound frequency.

In contrast to Fig. 2 and Fig. 3, the Graph in Fig. 4 clearly shows a relative conformity of the individual series of measurements. The used measurement specifications from the measurement experiments in Tab. 3 gave very good results. A difference < 0.2 V between the individual measurements with the same settings is sufficient and acceptable for further processing of the measured values. The processing and evaluation of these measured values by a microcontroller would be possible due to the small voltage differences < 3.3 % between the individual series of measurements. The optimized result were achieved by reducing the acoustic irradiation times to 5 seconds and increasing the pause times (time between the individual measurements) to 5 minutes. The modified times ensure that the oscillating crystal remained relatively stable during the measurements. The measuring results in Table 3. were repeatable over the entire output range from 0 W to 7.5 W. Comment on this series of measurements: An improvement in the measurement results can certainly be achieved if the production tolerances of the piezoceramic components, currently up to ± 20 % [7], can be reduced. Minimizing production tolerances can only be achieved, however, with a great deal of technical effort and at great expense due to the extensive, diverse production steps.

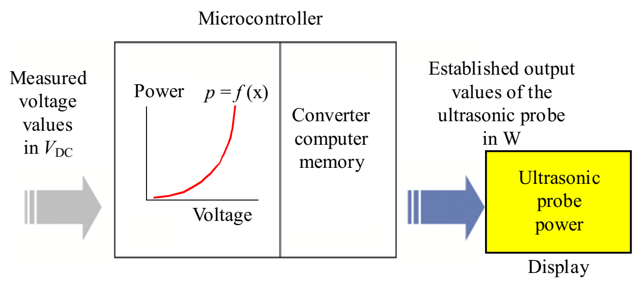

Fig. 5. Schematic block diagram of a new possible measuring instrument

5 CONCLUSIONS

This study aims to examine whether piezoceramic sensors could be used to realise a measuring procedure which can be implemented to control ultrasonic output levels of ultrasonic therapy devices in everyday testing processes. At present, the output level of ultrasonic-therapy-devices is measured by using an extensive gravimetric procedure which, in practice, is relatively inconvenient to use. In addition, the purchase of a gravimetric measuring instrument involves high costs. The results, in particular of Table 3, show, that a method of measurement with piezoceramic sensors is feasible.

If the measured values from Table 3 can now be used to establish an idealized function of the graphs, the trend curve can be used for programming a microcontroller and, thus, to evaluate and implement the results of the measurement. A schematic block diagram is pictured in Fig.

5. The main task of the microcontroller will be to compile the direct current values measured and convert them to output values according to the preprogrammed functions (trend curves). Different preestablished, ultrasonic-transducerspecific output curves could be stored according to the ultrasonic therapy device. In addition, it should save and record the measured values. It should be possible to call in a record for later documentation. A timing of the measured cycles and display-controlled user guidance could be programmed for optional implementation [8].

This feasibility study shows, however, that even using "standard (no project-related, custom-made components) piezoceramic sensors, measurement and ascertainment of ultrasonic output of ultrasonic therapy devices are possible. The results could be improved, if specially developed sensors for specific ultrasound-transducers and there frequency bandwidth, were used. But this will be only profitable, if the new measuring method will be mass-produced. The examined method of measurement is a good alternative to the -at this time used- extensive gravimetric method of measurement.

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