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Biomedical Mechatronic Dynamometer to Support the Evaluation of the Effects of Leprosy Through the Palmar Holding Strenght and

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Abstract

The hand can suffer the effects of several diseases among the most serious, leprosy stands out, which is considered infectious and can generate loss of muscle strength, atrophy, deformity and physical, mental and social disability. For the World Health Organization (WHO) and also doctors and physiotherapists, it is necessary to evaluate the diseases in an objective, reliable and early manner in order to propose appropriate treatment and follow their evolution. This research proposed a biomedical mechatronic dynamometer in order to support the evaluation of the effects of leprosy by means of palmar grip strength and grip strength of tweezers performed by hand. The experimental research was developed at the Federal University of Mato Grosso do Sul and consisted first of all in the survey of the demands of the health area in relation to the biomedical dynamometer being consulted the following databases: Medical Literature Analysis and Retrieval System Online (Medline); US National Library of Medicine National Institutes of Health (PUBMED) e Institute of Electrical and Electronic Engineers (IEEE). The mechatronic biomedical dynamometer consisted of three fundamental parts: mechanical structure, electronic signal conditioning circuitry and digital information processing. The mechanical structure was designed to withstand a strenght of up to 700 N, developed in brass because this metal has low cost, has less mass and also because it is easier to machine than steel. The oval shape of the structure contains two lateral and thin regions that measure 2 cm thick, 3 cm wide each and aim to concentrate mechanical stresses in order to sensitize the strain sensor consisting of the four linear strain gages, model N2A-XX-S5262P-350/E4 and nominal resistance of 350 Ω, from the company Micro-Measurements, which showed accuracy of 98%. The mechanical structure also has a stainless-steel support that measures 1 cm thick and 3 cm wide located at the bottom and on which was glued a cushion to support the palm of the hand. This support can be replaced by other models that also contain a cushion that considers the presence of injuries or deformities in the hand. The mechanical structure also has a upper support that also measures 1 cm thick and 3 cm wide, to which four pressure sensors developed with rosette strain gages model N2K-XX-S5294R-350/DP/E4 with a nominal resistance of 350 Ω, from the company Micro-Measurements, were fixed and which showed an accuracy of 99.5%. The deformation sensor is stimulated by the application of palmar grip strenght while the pressure sensors are stimulated

Keyword: mechatronic biomedical dynamometer; hand; leprosy; evaluation; measure.

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Biomedical Mechatronic Dynamometer to Support the Evaluation of the Effects of Leprosy Through the Palmar Holding Strenght and the Tweezer Holding Strenght

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Abstract

The hand can suffer the effects of several diseases among the most serious, leprosy stands out, which is considered infectious and can generate loss of muscle strength, atrophy, deformity and physical, mental and social disability. For the World Health Organization (WHO) and also doctors and physiotherapists, it is necessary to evaluate the diseases in an objective, reliable and early manner in order to propose appropriate treatment and follow their evolution. This research proposed a biomedical mechatronic dynamometer in order to support the evaluation of the effects of leprosy by means of palmar grip strength and grip strength of tweezers performed by hand. The experimental research was developed at the Federal University of Mato Grosso do Sul and consisted first of all in the survey of the demands of the health area in relation to the biomedical dynamometer being consulted the following databases: Medical Literature Analysis and Retrieval System Online (Medline); US National Library of Medicine National Institutes of Health (PUBMED) e Institute of Electrical and Electronic Engineers (IEEE). The mechatronic biomedical dynamometer consisted of three fundamental parts: mechanical structure, electronic signal conditioning circuitry and digital information processing. The mechanical structure was designed to withstand a strenght of up to 700 N, developed in brass because this metal has low cost, has less mass and also because it is easier to machine than steel. The oval shape of the structure contains two lateral and thin regions that measure 2 cm thick, 3 cm wide each and aim to concentrate mechanical stresses in order to sensitize the strain sensor consisting of the four linear strain gages, model N2A-XX-S5262P-350/E4 and nominal resistance of 350 Ω, from the company Micro-Measurements, which showed accuracy of 98%. The *mechanical structure also has a stainless-steel support that measures 1 cm thick and 3 cm wide located at the bottom and on which was glued a cushion to support the palm of the hand. This support can be replaced by other models that also contain a cushion that considers the presence of injuries or deformities in the hand. The mechanical structure also has a upper support that also measures 1 cm thick and 3 cm wide, to which four pressure sensors developed with rosette strain gages model N2K-XX-S5294R-350/DP/E4 with a nominal resistance of 350 Ω, from the company Micro-Measurements, were fixed and which showed an accuracy of 99.5%. The deformation sensor is stimulated by the application of palmar grip strenght while the pressure sensors are stimulated by the realization of index, middle, annular and minimum finger gripping strenght. In addition, these sensors are connected to Wheatstone Bridges whose feeds and also the responses are processed by five signal conditioning circuits developed with operational amplifiers LF 356, OPA 27 and OP27 GP of the company Burr-Brown, whose structure consists of voltage oscillator, amplifier, band pass filter, buffer and peak detector that generates DC voltage that feeds the data acquisition board. The answers on this board are sent to the Inspiron 15 3000 microcomputer from Dell, which has installed Labview software from National Instruments, which processes the information, stores, plotts the palmar grip strenght and pinch grip strenght graphs and can also send the information over the Internet. This research has the potential to obtain accurate information on the effects of leprosy in the hand that can support the evaluation, diagnosis of health professionals, follow up the evolution of the disease and the treatment adopted.*

Keywords: mechatronic biomedical dynamometer; hand; leprosy; evaluation; measure.

1. Introduction

The human hand is a prehensile organ that constitutes the most distal part of the upper limbs and can be used to perform various daily activities of interest such as manipulating objects with the application of strenght and interacting during communication with other people [1]. There are two postures that define the strenghts applied by the human hand, the hand grip strenght (HGF), which applies strenght to a given object so that the thumb is added and positioned to oppose the finger pulps and gripping strenght clamp (GFC) which occurs between the flexor surfaces of one or more fingers with the thumb in opposition, being performed when the need arises for a refined movement of touch [2], [3] and [4]. However, the hand may suffer the effects of several diseases, and among the most severe is leprosy considered infectious and contagious and being feared by disabilities generated in the physical, mental and social aspects [5]. This disease is considered chronic, but curable and is caused by Mycobacterium Leprae - a mandatory intracellular host bacillus (tropism by nerve cells, Schwann's sheath) that affects the peripheral nerves located in the face, feet and hands, generating an inflammatory process characterized by acute pain due to compression and imprisonment of the swollen nerve that leads to loss of sensitivity in the distribution path of the affected nerve, atrophy and decrease in muscle strength may cause deformities and functional disabilities [6], [7] and [8].

Hand paralysis in people with leprosy is related to five important changes from the motor point of view, among them: muscle weakness in the flexion of the metacarpophalangeal muscles; loss of the ability to abduct and add fingers; weakness in the extension of the proximal interphalangeal muscles; weakness in the flexion and opposition of the 5th finger and the loss of the opposition of the thumb and consequently compromising the interaction of the affected person with the other people and with the environment [8] and [9].

In addition, since leprosy is a complex and highly severe neuropathy, it should be monitored by means of evaluation in order to verify its evolution in the nervous system. In addition to the inspection and tactile sensitivity examination by means of Semmes-Weinstein nylon filaments, a motor evaluation is performed respecting the degree of muscle strength that the individual can achieve, this test being extremely important to detect motor losses and obtain information from the health professional [8] and [9].

According to the World Health Organization (WHO), leprosy is a disease of sanitary interest due to its high level of disability that it generates, and control policies have been concerned with diagnosing it early in order to adequately treat the affected individuals. In addition, there is a need for physiotherapists and physicians to have early, objective and reliable information on the manual strenghts that can be related to their presence and consequently to the effects of various diseases, thus contributing to the adoption of procedures and the monitoring of the evolution of the situation [10] and [11].

Among objective methods that can be used to obtain information on the manual strenght produced by a person, the biomedical dynamometer (BD) stands out since its design considers the physical differences of the user, has adjustment between the supports for the hand, contemplates the anthropometric differences and is economically viable. However, in the specific case of this project, the proposed biomedical mechatronic dynamometer (BMD) also had to be able to generate information on the hand grip strenght (HGF) and gripping strenght clamp (GFC) simultaneously applied by the hand in order to relate to the effects of leprosy.

2. Materials and Methods

The research was developed at the Federal University of Mato Grosso do Sul - UFMS and consisted of a DBM that can generate objective and reliable information on the manual strenghts produced by a person affected by leprosy, in addition to considering the needs of health professionals, as commented, in order to have relevant information during the tests, as shown in Figure 1.

The mechanical structure (2) was projected to support strenght of up to 700 N, with the use of brass with the objective of facilitating machining, for being of low cost and possess mass inferior to the stainless steel that in general is used in other DBs. This aims to make the equipment economically accessible to medical clinics, hospitals and also to not cause muscle fatigue to the patient. In addition, this structure (2) has an oval shape and the largest diameter is 20 cm while the smallest diameter is 14 cm, with the objective of concentrating the mechanical tensions on the two thin sides that measure 2 cm of thickness, 3 cm wide and where four linear strain gages (SG) model N2A-XX-S5262P-350/E4 with a nominal resistance of 350 Ω, from the company Micro-Measurements, were glued together to form a single strain sensor (8), which has the purpose of measuring the intensity of HGF during the static or dynamic test.

Four pressure sensors (7) were developed using four N2K-XX-S5294R-350/DP/E4 rosette type SGs that have a nominal resistance of 350 Ω, from Micro-Measurements. Each pressure sensor (7) has the purpose of measuring individually the intensity of GFC during the static or dynamic test when each finger applies strenght on its dome.

To allow the performance of GFC, the pressure sensors (7) were fixed on the stainless steel support (4) that measures 1 cm thick, 3 cm wide and 12 cm long. Tests involving people with leprosy will occur at a later stage because the conditions of protection are being created for the researchers involved and also for the laboratory in order to avoid contamination with the disease.

On the dynamometer presented was requested patent deposit n. BR 10 2019 005169 8 with the National Institute of Industrial Property (NIIP) in Brazil.

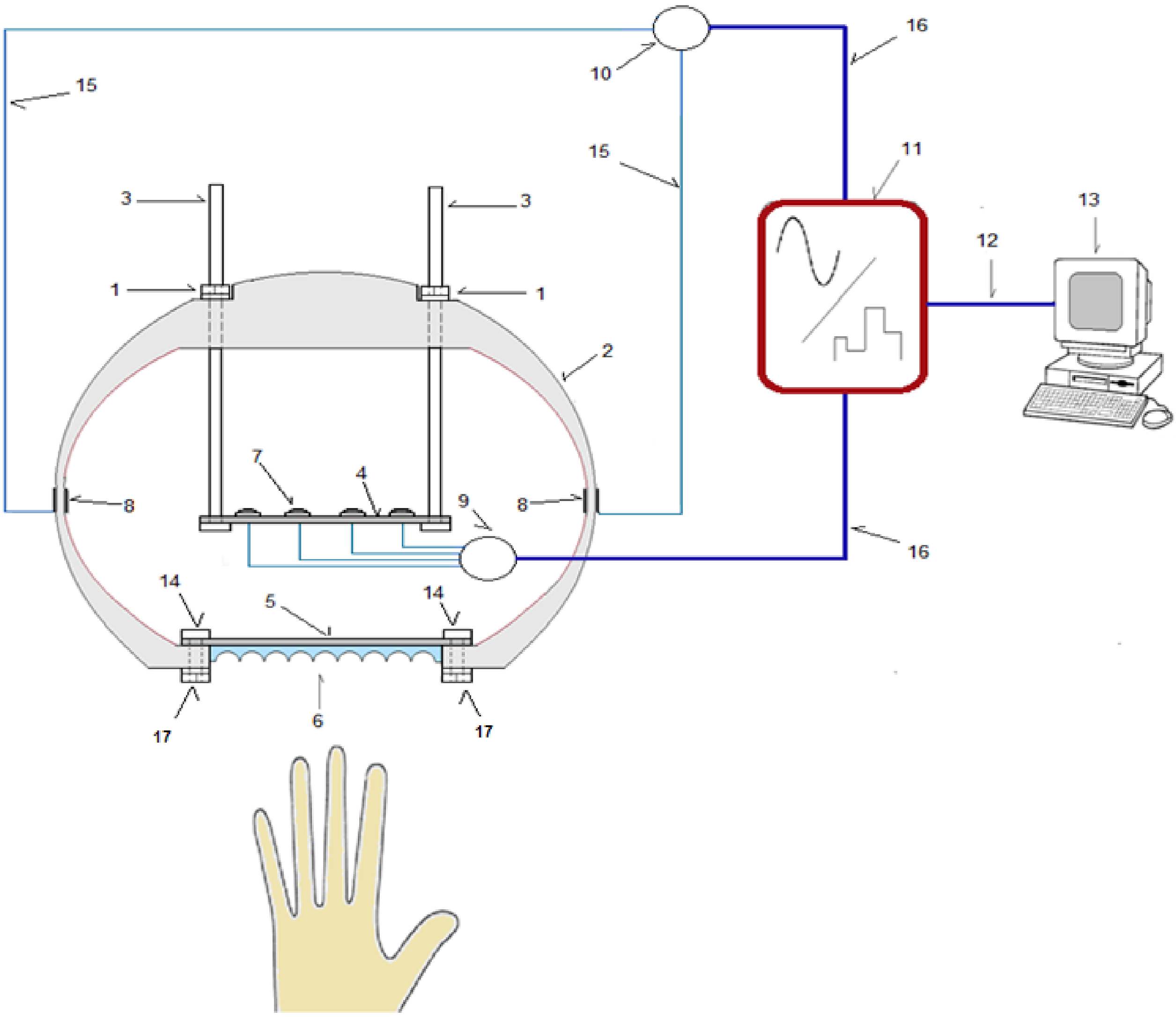

Figure 1. Mechatronic biomedical dynamometer.

Caption

1: Fixing nut.
2: Mechanical structure.
3: Screw.
4: Pressure sensor support.
5: Pillow holder.
6: Pillow.
7: Pressure sensor.
8: Deformation sensor.
9: Signal conditioning circuits.
10: Signal conditioning circuits.
11: Data acquisition board.
12: Network cable.
13: Microcomputer.
14: Screw.
15: Cables from the deformation sensors.
16: Cable.
17: Nut.

The support of the support (4) of stainless steel in the desired position is accomplished by two screws (3) that cross the mechanical structure (2) and the height is adjusted adjusting two nuts (1). The cushion (6) for the palm of the hand (PH) is fixed to the support (5) of stainless steel that measures 1 cm of thickness, 3 cm of width and 14 cm of length and its ends are fixed to the mechanical structure (2) by means of two screws (14) fixed by two nuts (17) that allow the replacement of this set by another model that has cushion that considers the presence of deformities or lesions in the PH.
When the PH compresses the cushion (6) and the four fingers: index, middle, annular and minimum compress the domes of the pressure sensors (7), the HGF and also four individual GFC appear. Each pressure sensor (7) is connected to Wheatstone Bridge (WB) while all four strain sensors (8) are connected in a single WB as shown in Figure 2.

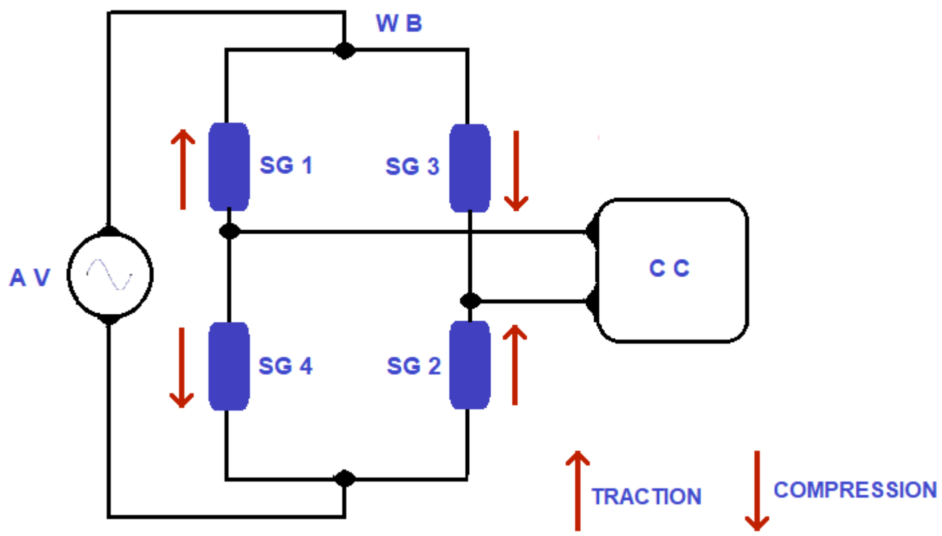

Figure 2. Wheatstone Bridge with strain gage.

Caption

SG 1 and SG 2: Strain gage 1 on the right side and strain gage 2 on the left side of the outer surfaces of the mechanical structure (2).

SG 3 and SG 4: Strain gage 3 on the right side and strain gage 4 on the left side of the inner surfaces of the mechanical structure (2).

CC: Signal conditioning circuit.

AV: Power supply voltage.

The WBs are powered by the oscillators of the five signal conditioning circuits (DC) with 15 V peak sinusoidal voltage and 20 kHz frequency and when stimulated with static or dynamic HGF and GFC applications, they generate analog responses of voltage x time, which are modulated, amplified, filtered and transformed into DC voltage (direct current) by means of peak detectors. These CCs have identical configuration, being developed with operational amplifiers LF 356, OPA27 and OPA27GP of the company Burr-Brown.

Each response generated by CC is then scanned on the data acquisition board (11) and sent to Dell's Inspiron 15 3000 microcomputer via the network cable (12) to be processed and presented by National Instruments' Labview software. Figure 3 shows the layout of the signal conditioning circuit. Figure 3 shows the layout of the signal conditioning circuit.

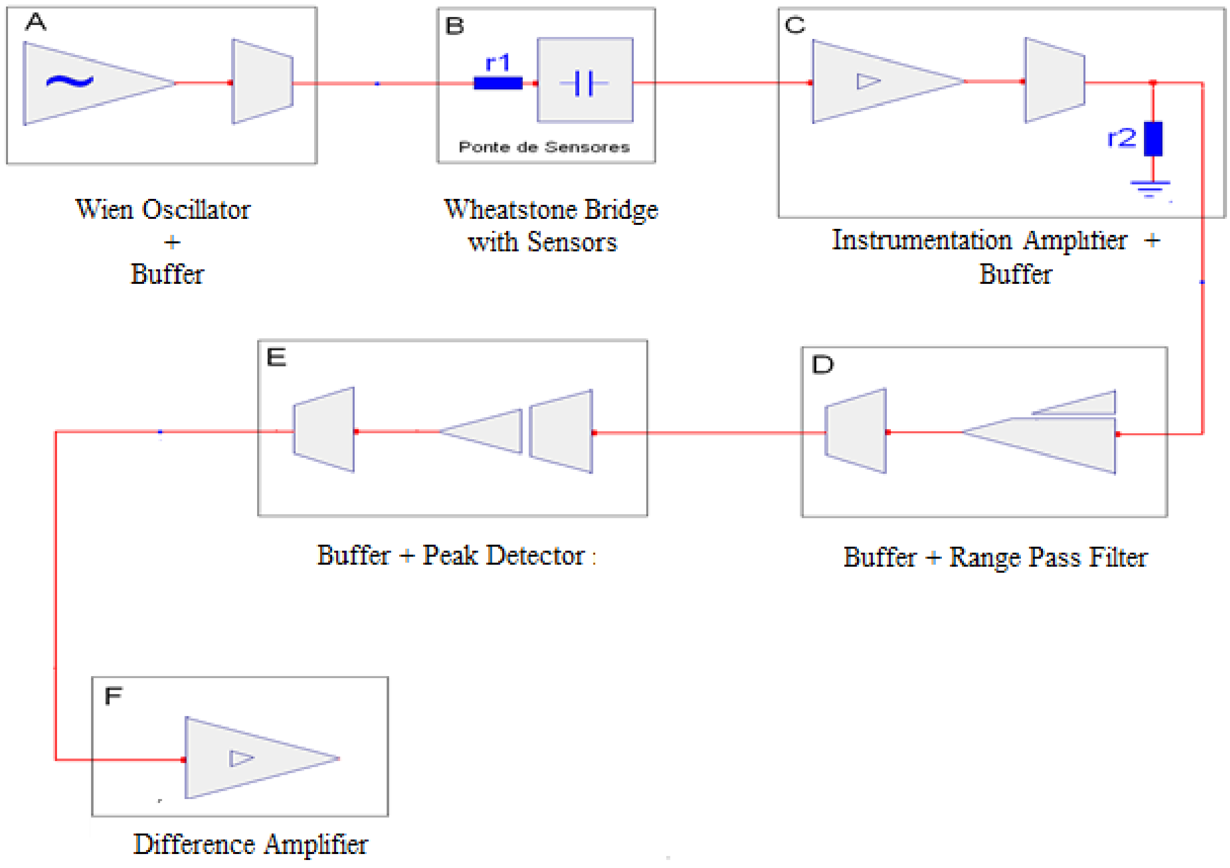

Figure 3. Signal conditioning circuit.

The calibration of the strain sensor (8) was initially performed by gradually placing standardized masses of 10 kg, in the range of 0 to 70 kg, in a basket hung from the support (5). In the opposite direction, it was performed the gradual removal of the masses of 10 kg of the basket until returning to 0 and this process was repeated four times in which Figure 4 shows the response in Volts of the DBM.

The calibration of the pressure sensors (7) was initially performed by gradually placing standardized masses of 10 kg, in the range of 0 to 70 kg, in a basket hung from the support (4). In the opposite direction, the removal of the masses of 10 kg was gradually performed until returning to 0 and this process was repeated four times for each of the four pressure sensors (7). However, as these sensors are identical and consequently their responses, Figure 5 shows the response in Volts of DBM for only one pressure sensor (7).

In Figure 6 shows a dynamic test with HGF and GFC application by hand. This test aimed to verify the response in Newton of the DBM.

3. Results and Discussion

In Figure 4 shows the linear behavior of the graphs when placing and later removing masses of 10 kg, showing an accuracy of 98%; however, in the interval between 20 kg and 60 kg, there was a small variation between the straight lines, caused by the stiffness of the glue used to fix the four SGs in brass.

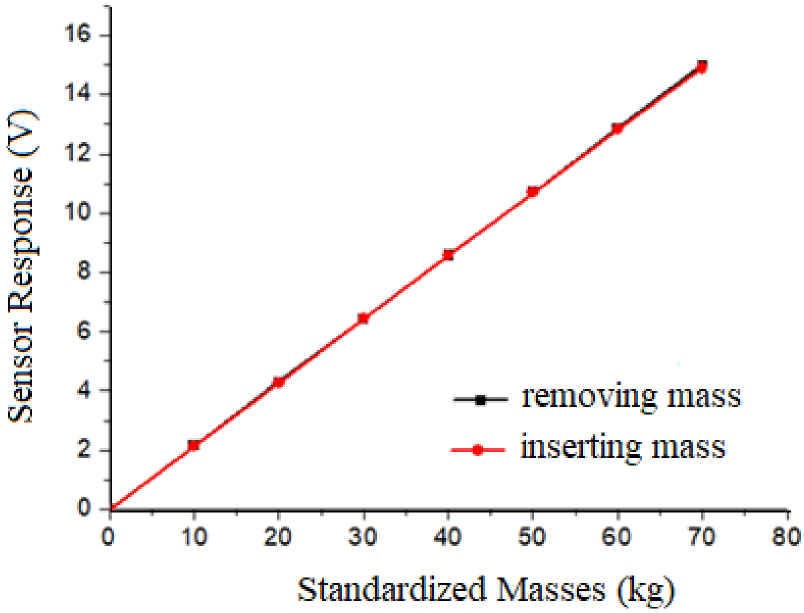

Figure 4. Calibration of the strain sensor.

In Figure 5 also shows the linear behavior of the graphs, when placing and later removing masses of 10 kg with an accuracy of 99.5%. It is understood that the result was caused by the adequate relaxation of the glue used to fix GSs in this second phase.

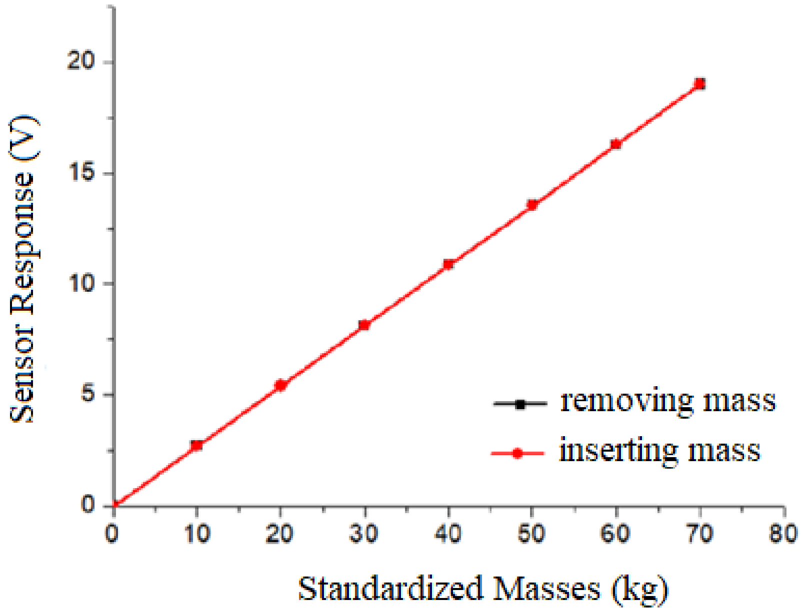

Figure 5. Pressure sensor calibration.

In Figure 6 shows a small difference in the amplitudes of the DBM responses due to the fact that the strain sensors (8) and the sum of the responses of the pressure sensors (7) have different sensitivities as presented in the previous calibration graphs. However, these sensors have reliable responses and high accuracy.

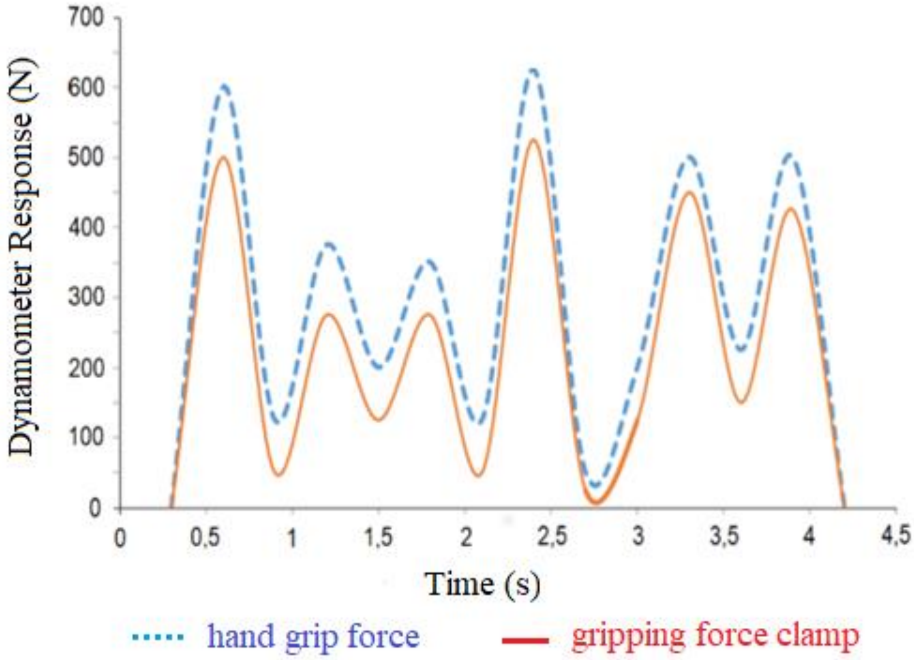

Figure 6. DBM dynamic response.

4. Conclusions

In this research, a biomedical mechatronic dynamometer was presented that has the potential to objectively and accurately measure both static and dynamic HGF and GFC, whose behaviors may be related to the effects of leprosy when they affect the hand. This device sought to contemplate the demands of the health area such as ease to adjust the spacing between the rigid supports (4) and (5) in order to accommodate hands of different dimensions, replace the cushion (6) for the PH, considering the presence of lesions or deformities that cause difficulty in performing the tests.

Another relevant characteristic refers to the use of brass in the mechanical structure in order to facilitate machining, reduce its mass so as not to cause muscle fatigue in people with the disease and also reduce the cost of the equipment, to make it accessible to clinics and hospitals. In addition, the information processed by the microcomputer can be plotted, stored in a database or sent through an internet network to other places of interest in the health area.

For future developments it is suggested to develop the mechanical structure using polymer instead of metal because the polymer besides being an insulator has an even smaller mass.

Finally, this device will provide relevant information about the effects of leprosy on the hand, allowing the health professional to adopt appropriate treatment and to monitor its evolution over time. In addition, the equipment will have strong social appeal since the tests are easy to perform and non-invasive.

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