Contrivance and Modification of In-house Brinell Hardness Tester for BHN Determination of Soft Materials

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Abstract. The aim of this work was to design and invent Brinell hardness testing machine for in-house testing and used for evaluation of hardness properties of soft materials. In this representation, Coated-Wood-Free (CWF) paper with grammage at 300 grams were used as the sample, whereas, the indenter diameter and the dwell time of imprinting were used at 7.86 mm and 10 seconds, respectively. After that, the hardness values were determined by using the principle of Brinell Hardness Number (BHN). This report presented the mean and the deviation of quantification that measured by this equipment and the focused parameter were included active weight loading, imprinted diameter, and BHN, respectively. Finally, the consequences of this analysis were discussed for development of this apparatus.

1. Introduction

Regularly, the mechanical properties included that modulus, stress, strain, and etc, be the essential topic for material characterization. The hardness is the one majority of characteristics that could be used for the mechanical properties indication. This property described in the ability of materials to against deformation [1-3] and the principle of Brinell analysis be already explained by earlier report [4]. Additionally, the boundary that used for macro-micro identification, was focused on the applied loads. The macro-hardness defined as the applied loads more than 1 kg, whereas, less than or equal to 1 kg was referred to the micro-hardness [5].

In this report, this prototype was contrived for hardness measurement by using Brinell analysis associated with the initiation of macroscopic and be developed to microscopic range. The point of view of this work, was focused on the experimental analysis for soft materials such as Tin (Sn), Lead (Pb), paper-based fibrous composite, and etc. The characteristics design of this apparatus to use the triplet indenter in one process, and then, the imprinting be the same pattern as the equilateral triangles. Thus, three samples could be obtained by one-cycle process. Furthermore, the indentation diameter could be obtained by using the image digitization algorithm, which based on python language, associated with simple measurement by using Vernier calliper.

2. Methodology and methods

In this paper, the preparation of sample used the dimension of 4 cm × 4 cm. The meaning of CWF referred to the coated-wood-free paper and the value of 300 defined as their grammage in grams unit. The crucial hardware components, the experimental setting up, the measuring method, and the procedure of BHN calculation, were already described in the earlier report [4]. Furthermore, the active weight loading was defined as the using of force loading acted on one sensor which using quasi-static approximation. The characteristic design of this apparatus was the distance between each indented point that was fixed at 80 mm and the pattern be the same as the equilateral triangles. This configuration was the alignment of triplet force-resistive sensors that used the changing in electrical resistance when external force was applied. Generally, this sensor was called Force Sensitive Resistor (FSR). By the way, the force-resistive sensor acted on the position A, B, and C were defined as FSR1, FSR2, and FSR3, respectively. This alignment and the prototype of Brinell testing machine, were illustrated as Figure 1.

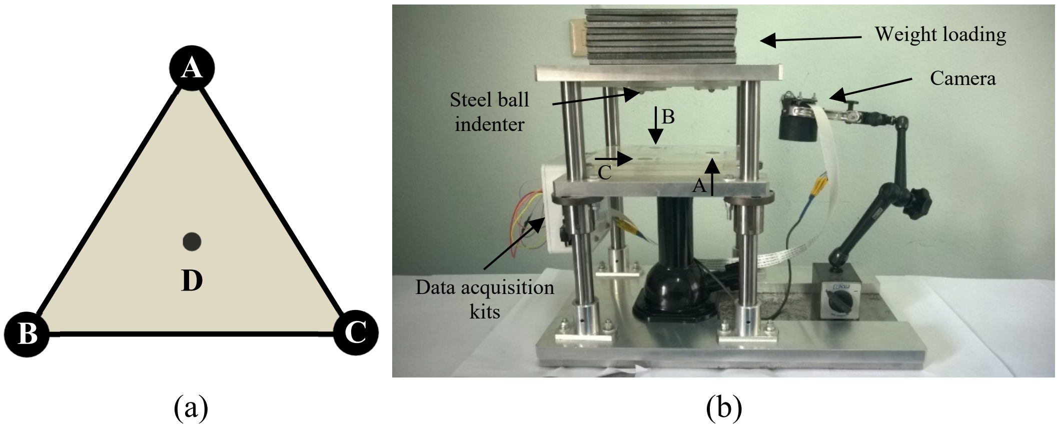

Figure 1. Schematic presented (a) the top view of triplet force-resistive sensor alignment. Point A, B, and C declared as the active weight loading while point D referred to the centre of gravity of the weight loading. (b) The prototype of Brinell hardness testing machine [4].

Additionally, the unique characteristic of sensor was used for the calibration procedure that would be as following: first, to revealed the holistic relationship between raw data with known weight loading for multi-sensor, and then, to declared balancing condition as reference. The calibration data in this step was obtained by the unbalanced condition. the ratio was defined as the reaction of one sensor divided by the sum of all sensor reaction, after that, the active weight loading presented by multiplied the weight loading with this ratio. Thus, the active weight loading that received by step one be declared as AWL1. Second, to discovered individual characteristic of sensor by using the association between raw data with the single sensor reaction, the active weight loading presented in this step called as AWL2. Third, used AWL2 to find the active weight loading ratio and used this ratio to simulated the data, the active weight loading in this step referred as AWL3. The last one, to expressed the mean of active weight loading by using the AWL1, AWL2, and AWL3, and then, used this mean as the resulting of calibration. Following that, used the CWF300 as the sample for this testing. Not only the indentation size could be observed by using the unassisted vision but also could be measured by using both of simple equipment like Vernier calliper associated with image digitization algorithm. Thus, the resulting of indented diameter was obtained by mean of Vernier measurement associated with image digitization. Finally, the analyzation of the active weight loading, the indented diameter, and the calculated BHN were summarized in Figure 2, repectively.

3. Experimental results

From Figure 2(a), the active weight loading presented by using three positioning of force-resistive sensor as following: AWL1, AWL2, and AWL3, respectively. Although the relation pattern of active weight loading be differed from the balanced FSR, BHN could be calculated. Consequently, the weight loading could be varying as 22.56 to 322.64 N. Following that, the active weight loading could be used for BHN calculation as following: 7.61 to 85.64 N for AWL1, 4.22 to 128.56 N for AWL2, and 8.10 to 109.18 N for AWL3, respectively. These might be occurred due to the unbalancing of weight loading in little bits. From Figure 2(b), the deviation was less than 1.0 N when the active weight loading in ranging as 7.30 to 53.49 N. Consequently, this range of active weight loading be selected for BHN analysis as previous research [4].

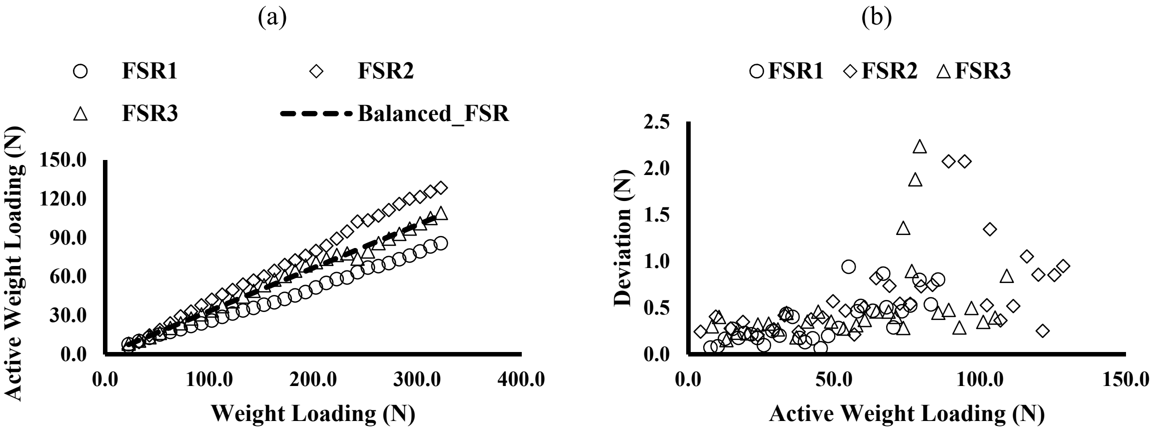

Figure 2. Characteristic curves of triplet force-resistive sensor including: (a) relationship between weight loading and active weight loading and (b) active weight loading with deviation, respectively.

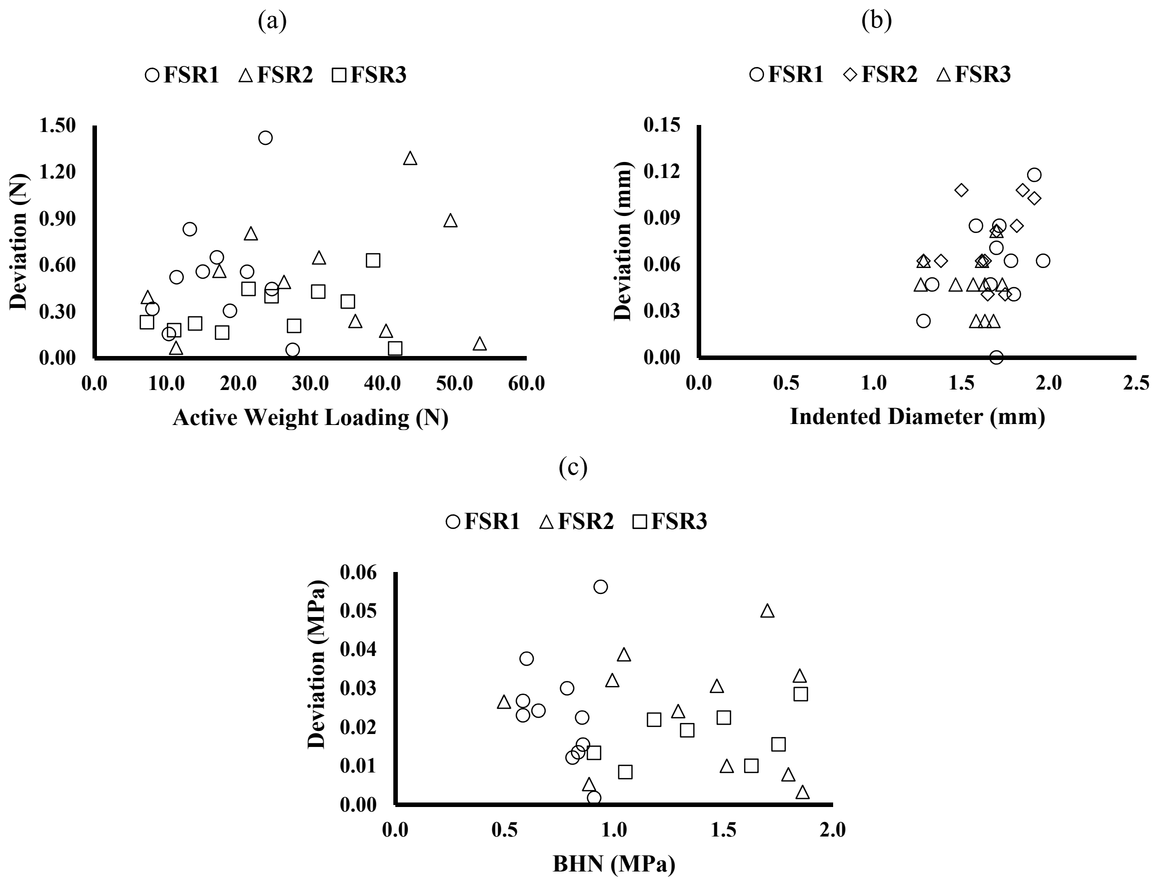

Figure 3. The experimental results of CWF300 testing illustrated the mean and the deviation that were summarized including: (a) the active weight loading with deviation, (b) the indented diameter with deviation, and (c) the BHN with deviation, respectively.

From Figure 3(a,b,c), the deviations of the active weight loading presented the maximum at 1.42 N, whereas, for the indented diameter measurement the deviations exhibited the maximum at 0.12 mm. Finally, for BHN, the deviations reported the maximum at 0.06 MPa. These experiment results were confirmed that BHN could be measured by using this prototype of Brinell hardness testing machine.

4. Conclusion

In conclusion, this research presented that the hardness of CWF300 paper could be measured by using this prototype of Brinell hardness testing machine. The calibration data presented in this representation, used the mean that combined on both of the individual characteristic and the holistic reaction. This equipment illustrated the characteristics of hardness measuring in the macroscopic range due to the applied force could be activated the single sensor which declared as the active weight loading in ranging as: 6.86 to 107.55 N, represented in Figure 2(a) as the balanced FSR, when using the weight loading as following: 22.56 to 322.64 N. Following that, the resulting of CWF300 was presented by using the active weight loading in ranging as 7.30 to 53.49 N and the deviation be maximized at 1.42 N, and then, the indentation presented in ranging as 1.3 to 2.0 mm when the deviation be maximized at 0.12 mm. Finally, BHN could be calculated and reported as following: 0.50 to 1.86 and the deviation be maximized at 0.06 MPa, respectively. These experiment results be used for the next development of this equipment.

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Acknowledgments

This work was financial supported by Research and Development Institute, Chiang Rai Rajabhat University for financial support (#B36001002). Thanks, Faculty of Education, Chiang Rai Rajabhat University for the facilitating and the sharing resources. The author would like to thank Asst. Prof. Dr. Waipot Ngamsaad, Dr. Ekasiddh Wongrat, Dr. Somrit Unai, and Dr. Sirikamon Saengmee-anupharb, Division of Physics, School of Science, University of Phayao for approving of the algorithm based on python and the instrumentation analysis. Thanks for Mr. Patipol Chaithep, Program in Materials Science, Faculty of Science, Maejo University, for technical discussion, calibration of force resistive sensor, and experimental assistance by using Digital Micro Vickers Hardness Tester. Finally, the author would like to thank all advisee including: Mrs. Chetthida Pinngeun for technical designing of Brinell hardness measurement by using the weight loading technique associated with the designing part of indenter mounting, Mr. Nattawat Singkom, Mr. Watcharapon Khamngam, Mr. Apisit Masum, and Mr. Teerapat Mungngam for calibration of force resistive sensor, experimental assistance, and data acquisition kits assembling.