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Measurement by load cells of impact force which a human body receives by external force

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Properties

ABSTRACT

Purpose: By development of a robotics technique, the assisted living instruments which have intelligent functions are being developed. As a result, there is a possibility that the accident to which the assisted living instrument under actuation contacts a human body may occur. The purpose of this research is for the impact force measurement system which with load cells to build, and to evaluate performance.

Design/methodology/approach: The impact force measurement system was built by load cells and a data logger. Evaluation of the performance of the system was carried out to static loads and dynamic loads.

Findings: By covering the sensor part of load cells with shock absorbing material, it turned out that it is possible to measure impact load simple. Moreover, as a result of comparing the characteristic of shock absorbing material, it became clear that the impact-absorbing characteristic of cell sponge and organism soft tissue is in agreement.

Research limitations/implications: This research estimated the impact-absorbing characteristic of organism soft tissue for the skin, fat, muscles, etc. as a complex.

Practical implications: This paper cleared that the load which a bone receives by dynamic external force can be easily measured by load cells.

Originality/value: The objective of this research project was to develop the system by which impact force is measured and evaluated based on the damage which a human body receives. And we were able to complete the prototype.

Keywords: Non-destructive testing; Biomaterials; Viscoelasticity; Skin; In vivo; Rheometer; Bed sore

1. Introduction

By development of a robotics technique, the assisted living instruments, which have intelligent functions, are being developed [1]. As a result, there is a possibility that the accident to which the assisted living instrument under actuation contacts a human body may occur. Therefore, preparation of the safety standards of an assisted living instrument is hurried.

However, since many parameters, which should be taken into consideration in order to evaluate the strength of impact force from a viewpoint of personal injury, exist, quantification is difficult.

Moreover, the relationship between an impact load and an injury level has been eagerly studied in the police, in order to clarify existence of the murderous intent in murder cases and injury cases [2-8]. As a result, it has turned out that the injury levels by an impact load differ in the situation of organism soft tissues, such as the skin and muscles. Furthermore, as for the impact force which passes through organism soft tissue and is applied to a bone, it turned out that load loading speed falls very much. It shows that the impact force which a bone receives can be measured by a load cell, if the sensor part of a load cell is covered with suitable buffer material.

In this research, the quality assessment of two impact force measurement systems was performed. One system is a system with one load cell with a large measuring plane product developed for this research, and another system is a system with three load cells currently used at the police. Moreover, the impact-absorbing characteristic of organism soft tissues and buffer material was investigated. As a result, when measuring the impact force which a human body receives, the optimal buffer material was able to be selected.

2. Impact force measurement system evaluation test

2.1. Impact force measurement system 1

The impact force measurement system 1 is the structure which measures the impact load which the upside sheet steel receives by three load cells placed between the sheet steel (300×300×35 mm) of two sheets as shown in Fig. 1. As shown in Fig. 2, we have placed the center of three load cells at equal intervals (120-degree spacing) in position of 120 mm from the center of the sheet steel, respectively. A system figuration is shown in Figure 3 and a list of instruments is shown in Table 1.

Fig. 1. Three load cells are placed between two sheet steel

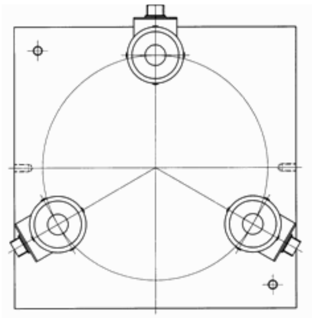


Fig. 2. Layout of three load cells

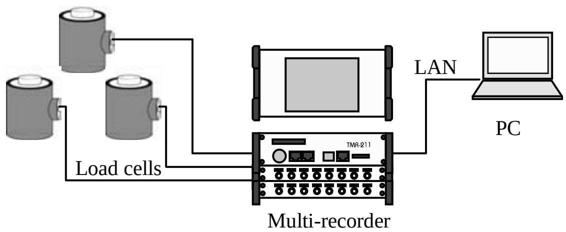


Fig. 3. Component of an impulse-force measurement system

Table 1.
Instrument list of impact force measurement system 1

Device name	Manufacturer	Type
Load cell	Tokyo Sokki Kenkyujo	CLP-10KNB
Multi-recorder	Tokyo Sokki Kenkyujo	TMR-211
Notebook PC	Panasonic	CF-R6

2.2. Impact force measurement system 2

The impact force measurement system 2 is the mechanism which measures impact load directly by one load cell (CLM-10KNS; Tokyo Sokki Kenkyujo) shown in Fig. 4. The same equipments as the impact force measurement system 1 were used except the load cell.

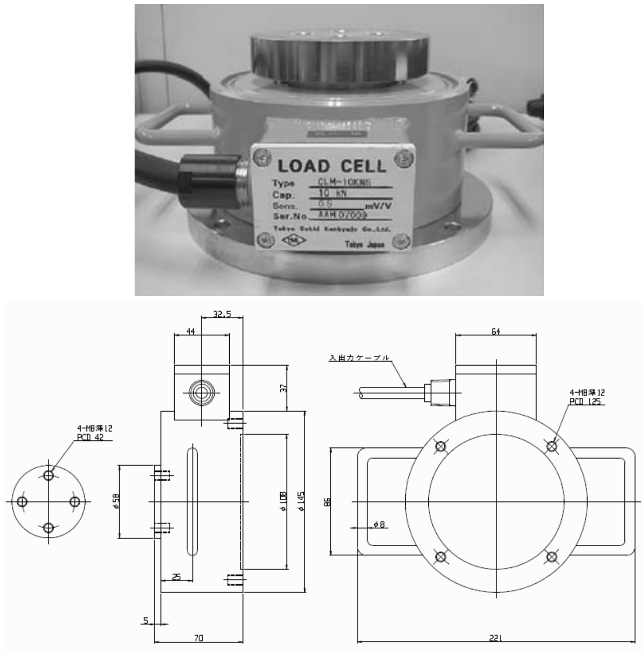


Fig. 4. Appearance and drawing of a load cell (CLM-10KNS)

2.3. Experimental procedure

The static load-test of impact force measurement systems was conducted with the material testing machine of maximum capacity 1MN. Placement of the load cells in the impact force measurement system 1 is shown in 1-3 of Fig. 5. A loading position is shown in A-C of Fig. 5, and load values are shown in Table 2.

The loading position in the impact force measurement system 2 is shown in No.1-5 of Fig. 6. No.1 is a central position of a load cell. No.2 is a position of 21mm distance from a load cell center. No.3 is a position of 40mm distance from a load cell center. No.4 is a position of 45 degrees from No.2 to a clockwise rotation. No.5 is a position of 45 degrees from No.3 to a clockwise rotation. The load value of a system 2 is shown in Table 3.

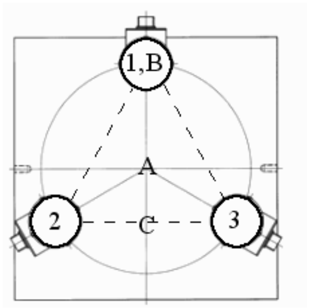


Fig. 5. Layout of load cells and load positions (System 1)

Table 2.
Static load-test conditions (System 1)

Loading position	Load value (kN)
A	0,5,10,15,20,25,30,25,20,15,10,5,0
B	0,2,4,6,8,10,8,6,4,2,0
C	0,4,8,12,16,20,16,12,8,4,0

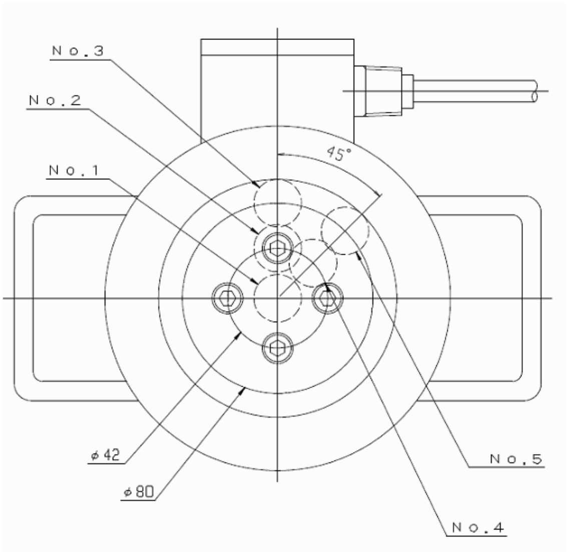


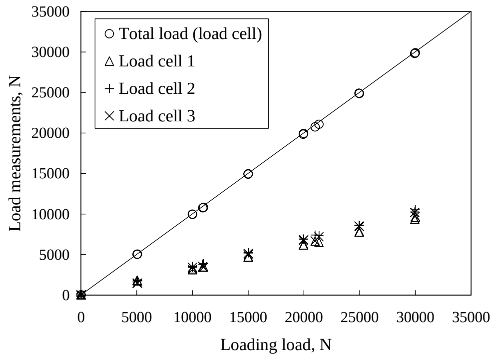
Fig. 6. Layout of load positions (System 2)

Table 3.
Static load-test conditions (System 2)

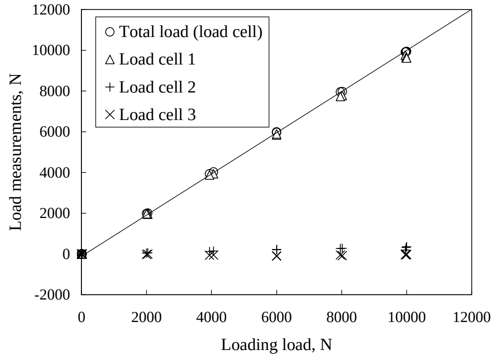
Load value (kN)
0, 2.5, 5.0, 7.5, 10.0

2.4. Experimental result and discussion

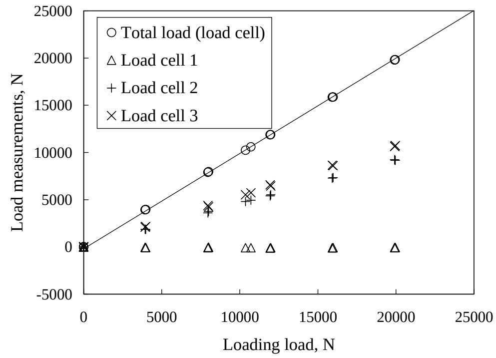
The relation between the loading load and the load (every load cell and the sum total value of three load cells) measured by the impact force measurement system 1 is shown in Fig. 7(a)-(c). The relation between the loading load and the load measured by the impact force measurement system 2 is shown in figure Fig. 8. In all the experiments, loading load and the load measured by the impact force measurement systems 1 and 2 were the almost same values.



a) Loading position A



b) Loading position B



c) Loading position C

Fig. 7. Relationship between loading load and measured load (System 1)

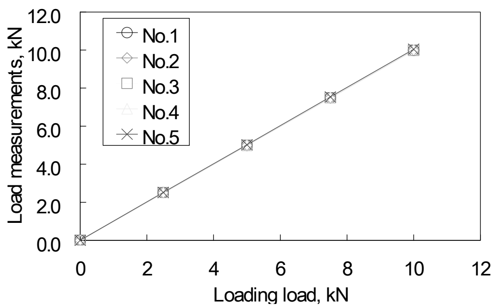


Fig. 8. Relationship between loading load and measured load (System 2)

3. Impact absorption characteristic evaluation of organism soft tissue and buffer material

3.1. Experimental procedure

The organism soft tissues and buffer material which were used for this experiment are shown in Table 4. As shown in Fig. 9, organism soft tissue or buffer material was placed on the sheet steel on three load cells of an impact force measurement system, and the experiments which drop 0.5 kg weight on it from height 0.25, 0.5, 0.75, and 1.0 m were conducted.

Table 4.
Test material:
a) Organism soft tissue

Name	Thickness (mm)
Pork tenderloin	31.5
Pork loin	57.0
Beef tenderloin	25.0
Chicken breast	21.0
Chicken thighs	11.4
Left arm (human body)	64.1
Right arm (human body)	73.9

b) Buffer material

Name	Thickness (mm)
Cell sponge	5, 10, 20, 30
Soft sponge	5, 10, 20
Rubber	5, 10, 20

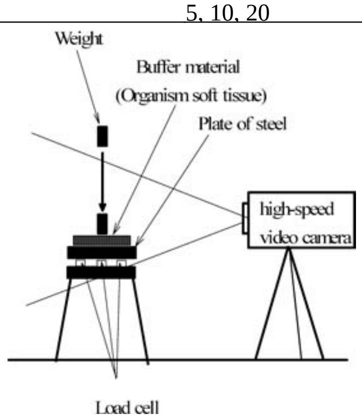


Fig. 9. Mimetic diagram of a test situation

3.2. Experimental result and discussion

The experimental results of the buffer material near the impact absorption characteristic of organism soft tissue and typical organism soft tissue are shown in Fig. 10. As shown in Fig. 10, in organism soft tissue, the relationship between weight falling height and a maximum-load value is not based on the type of soft tissue, but is expressed with the straight line of the same inclination. Moreover, it was confirmed that the measured maximum-load value is also in inverse proportion to the thickness of organism soft tissue. On the other hand, in buffer material, the relationship between weight falling height and a maximum-load value changed greatly with types.

Then, the impact absorption characteristic of buffer materials and organism soft tissues were compared. As a result, it was confirmed on all the conditions (weight falling height, buffer material thickness) that the impact absorption characteristic of organism soft tissue and cell sponge is nearly the same.

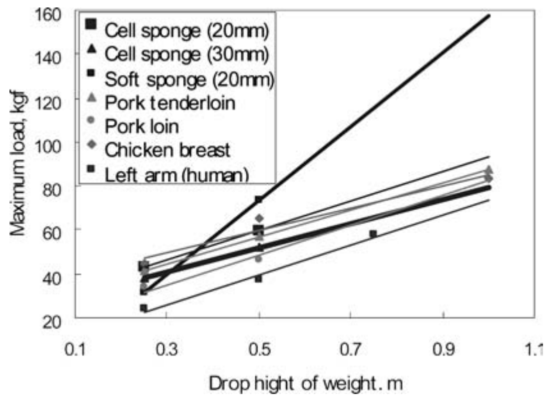


Fig. 10. Relationship between weight drop height and maximum load

4. Conclusions

It was confirmed that both the impact force measurement systems 1 and 2 can measure impact force with high precision in a large area.

Because a measurement part is only a load cell, the impact force measurement system 2 is easy to carry. Therefore, measurement of horizontal load and measurement in a narrow space are possible with this system.

The impact absorption characteristic of cell sponge is nearly the same as that of the characteristic of organism soft tissue. Therefore, it was confirmed that cell sponge can be used instead of organism soft tissue.

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