

## INFLUENCING THE QUALITY OF HOSPITAL BEDS USING VIBRO-ACOUSTIC DIAGNOSTIC

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**Abstract** – Human health is one of the most precious gifts that each person has. This gift needs to be protected. The human, when he has health problems, seeks to restore satisfactory health condition with a significant contribution of medical care. Medical care has used various means to restore human health.

A hospital bed as highly sophisticated technical equipment is one of many such means used during treatment. Hospital bed allows appropriate positioning of the patient, so as to improve health status and complications occurred in the form of pressure sores. Also the patient comfort is one of the important tasks of a properly working bed. Patient's comfort can be compromised by increased vibration and noise levels generated by actuators of the bed and other movable parts of the bed assembly.

This paper describes the utilization of noise and vibration measurement in a particular case of Linet Eleganza hospital bed. Obtained results of measurements are used for the future redesigning of the actuator assembly. Influences of the taken changes are also enumerated.

**Keywords:** diagnostic, hospital bed, vibration, noise, patient comfort

### 1. INTRODUCTION

The World Health Organization (WHO) identifies health as a state of physical, mental, social, and aesthetic comfort. Health is not just the absence of disease. Therefore, to pay attention to the little which can have a major impact on human health is very important. This paper describes possibilities of noise and vibration measurement in a particular case of Linet hospital bed. Undesirable vibrations and acoustic load were transmitted to the patient's body while positioning the hospital bed. Obtained results of measurements are used for the future redesigning of the actuator assembly. The proposed solution is simple with a significant impact on the final vibrations and noise levels.

Accurate, easy and comfortable adjustment of the bed is important because when patients lie in bed for a long time, they risk bedsores. The bedsores (Fig. 1) are caused by pressure of the body on the bordered skin area against the bone protrusions [1]. The bedsores, if they occur, they are very difficult to treat [2]. It is important to pay particular attention to the prevention of these complications.



Fig. 1 Bedsores - stage II [4]

It is necessary that a suitable position of the hospital bed is reached by smooth movement. The suitable position can be controlled from several places according to the health condition of the patient and the requirements of hospital staff. These requirements mainly deal with ergonomics, that attention is devoted in many industries [3], [5], [6]. There is primarily monitored impact of vibrations to the operator's body and absorbed vibrations health influences (Fig. 2) [7], [8], [9], [10].

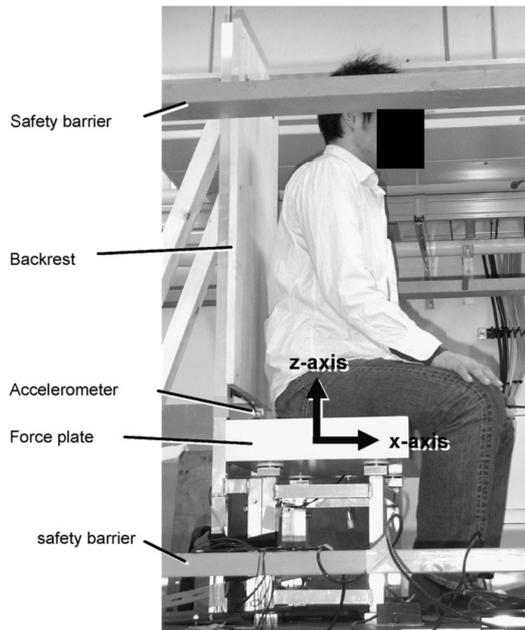


Fig. 2 Experimental set-up showing subject sitting in the 'back-off' posture [8].

The vibrations are generated by rotating parts of machines or directly moving parts. Among the major drivers of oscillations are also bearing [7]. First of all, regards bearing with defects [13], where it is successfully used fast Fourier transform to evaluate the causes (Fig. 3) [15]. The vibrations are evaluated during patient transport ambulance, from the medical point of view [13]. The vibration is not only undesirable, but on the basis of vibration analysis can be monitored functionality of certain organs or can be monitored breathing functions of the patients (Fig. 4) [12].

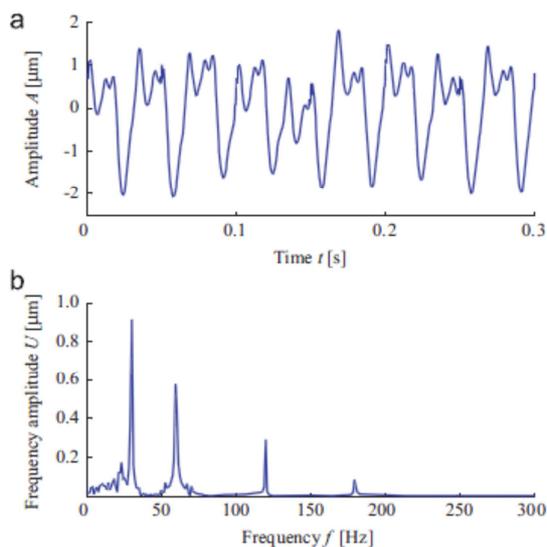


Fig. 3 (a) The wave format  
(b) The Fourier spectrum of the artificial signal  $x(t)$  [15]

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the patient's body while positioning the hospital bed. Obtained results of measurements are used for future redesigning of the actuator assembly. The proposed solution is simple with a significant impact on the final vibrations and noise levels.

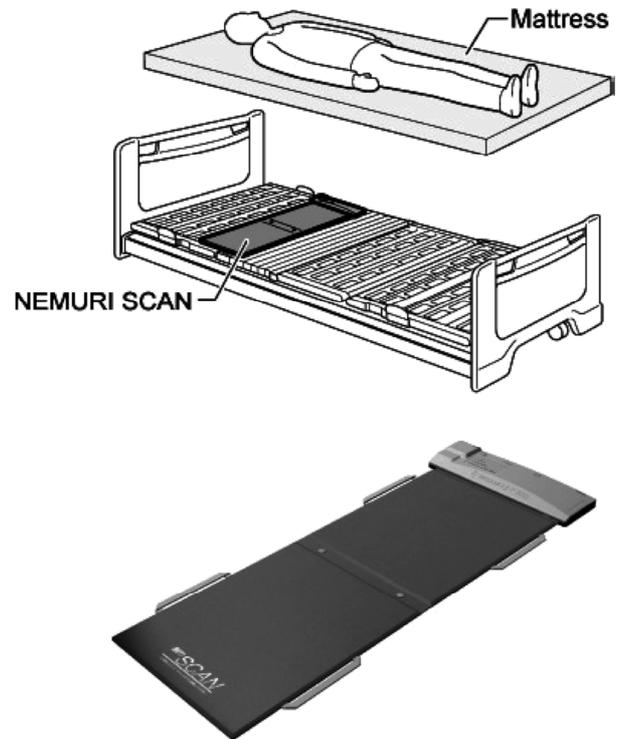


Fig. 4 Positioning of the NEMURI SCAN under a sleeping mattress [12]

## 2. MATERIAL AND METHODS

Linet Eleganza 3 bed (Fig. 5) has a positive effect on the treatment and convalescence of patients and also streamlining and facilitating the work of staff in acute care with unique functional features and properties. Improved ergonomics positioning is the result of special modifications Tonneau Ergoframe, which ensures maximum patient comfort and helps prevent pressure sores. Some users have complained of not too smooth movement and noise during bed position changes. Linet manufacturer responded quickly to complaints. It was found that the problem is the increased levels of vibration and noise while adjusting the position of the bed. Elevated sound and vibration levels were transmitted into the hospital bed from the telescopic pole when positioning (Fig. 5).

Therefore, the company Linet in its technical center focused on this issue, the company invited external expert to solve vibration and has set the following aims:

- check of the current design of telescopic poles,
- measurement of sound pressure and vibration performance analysis,
- draft implementation design of modifications to reduce sound and vibration level,
- final check of adapted telescopic poles in the test chamber of Linet manufacturer.

### 3. RESULTS

#### 3.1 Design modifications results

Measured values of noise and vibration on a telescopic pole without modification proved to be unacceptable. These values are shown in Table 1. Based on this decision design of drive attachment has been changed. In the first step the change consisted in placing insulating pads with a thickness of 2 mm and 22 mm diameter prescribed hole for the electric motor and mounting screws. In the second step there was the cover of drive filled using sanitary silicone. Results are shown only for one of two telescopic poles, while results for the second pole is analogous.

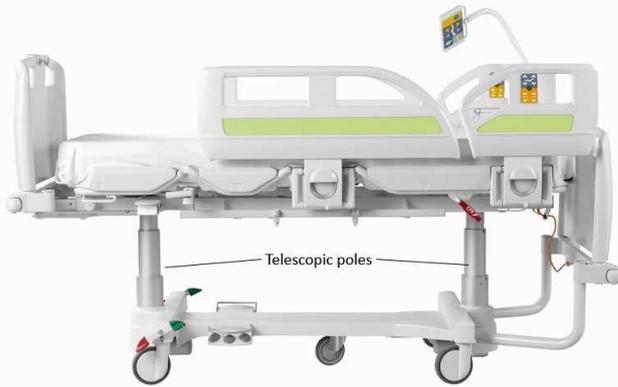


Fig. 5 Hospital bed Linet Eleganza 3 [unpublished]

Measurements points (Fig. 6) were appropriately chosen on the telescopic pole (Fig. 6) and were chosen following measurement methods, which were carried out in both UP and DOWN direction of the telescopic pole movement:

- measurement of speed vibrations in the range 10 - 1000 Hz,
- measurement of vibration acceleration in the range of 10-2 000 Hz,
- measurement of noise emission of the electric drive at the attachment to the telescopic pole.

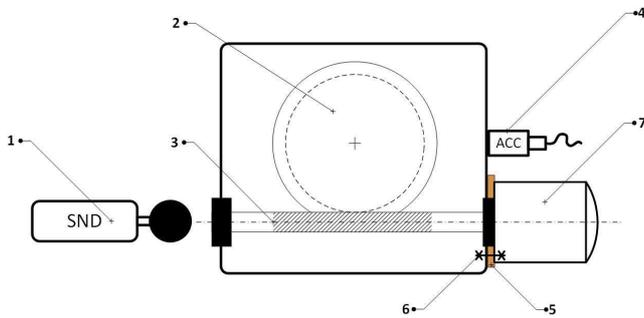


Fig. 6 Proposed solution with insulating pad: 1) sound meter 2) Saw toothed wheel telescopic pole, 3) worm wheel electric drive, 4) vibration sensor 5) insulating pad, 6) securing screws, 7) electric motor

Velocity and acceleration of vibrations were measured using Microlog CMVA60 vibration analyser, which, besides that, is able to overlap measured spectra and thus easier to detect the causes of vibration. Noise level of the telescopic pole movement was measured using a sound level meter Lutron SL-4023SD.

In order to reduce the noise and thus well-being of patients has been proposed several solutions. These solutions were chosen because of low cost of isolation pad and then isolating pad in combination with sanitary silicone filling.

Table 1 Measured data of vibration and noise on Linet Eleganza.

Measurement	Units	Before changes	Insulating pad inserted	Insulating pad inserted + silicon filling
ACC Velocity – UP direction	mm.s <sup>-1</sup>	0.54	0.26	0.14
ACC Velocity – DOWN direction	mm.s <sup>-1</sup>	0.48	0.31	0.19
Acceleration – UP direction	g(9.81m.s <sup>-2</sup> )	1.17	0.29	0.15
Acceleration – DOWN direction	g(9.81m.s <sup>-2</sup> )	0.69	0.31	0.25
Noise Level	dB	75.6	69.1	64.9

Table 2 Decrease of the measured values expressed in percentage

Measurement	Insulating pad vs. original state (%)	Insulating pad + silicon vs. original state (%)	Insulating pad + silicon vs. Insulating pad only (%)
Velocity – UP direction	52	74	46
Velocity – DOWN direction	35	60	39
Acceleration – UP direction	75	87	48
Acceleration – DOWN direction	55	64	19
Noise Level	9	14	6

When using insulating pad thickness of 2 mm it was also necessary to change holding screws. New screws were about 2 mm longer. From the measured values of vibration and noise is apparent that there was a decline in values and in the case of vibrations at least by 45% and sound level by at least 8% (Table 1, Table 2)

In the second case, where in addition to insulating pad were used silicone filling, the drop in the measured values is obvious. Vibration values dropped by at least a further 20% and the total reduction is thus achieved more than 65%. Noise level decreased by 6% and the total drop is about 14% (Table 1, Table 2).

#### 3.2 Vibration analysis

Fig. 7 shows FFT acceleration spectrum and Fig. 8 shows FFT velocity spectrum of measured data. Both of spectra includes comparison of the original state and two of design modifications of the drive unit. It is visible that there is a gradual decrease in overall vibration level.

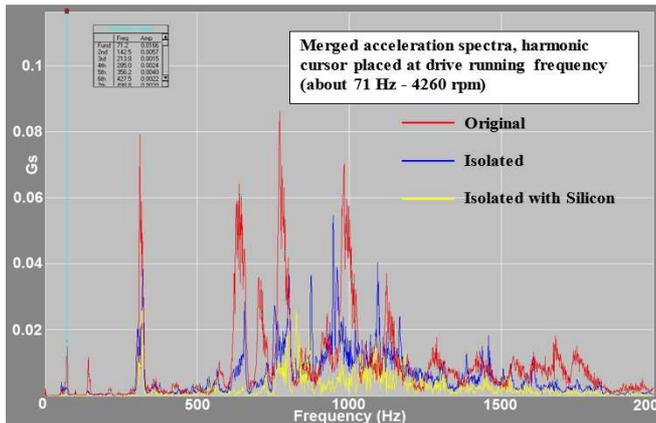


Fig. 7 FFT- Merged spectra.

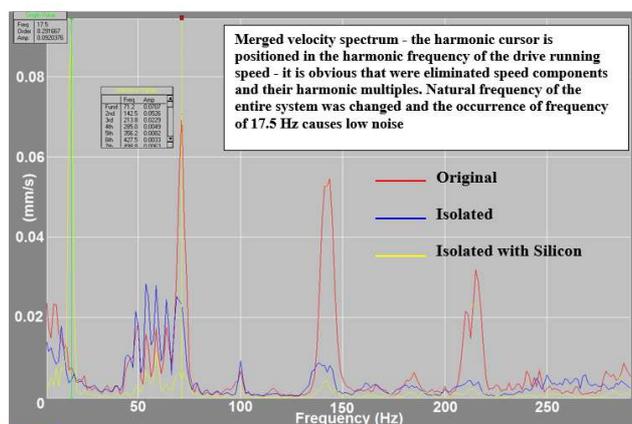


Fig. 8 FFT- Velocity spectra.

#### 4. CONCLUSIONS

According to measured data and spectral analysis of vibration it was found that the main cause of vibration and associated noise is the electric drive of the telescopic pole. Measured vibration levels corresponds to electric drive equipped with worm gear.

In order to reduce the noise and thus well-being of patients has been proposed several solutions. These solutions were chosen because of economic of isolation pad and then isolating pad in combination with sanitary silicone filling. Overall patient load was reduced in case of vibrations by more than 65% and in case of noise by 14%.

The paper noted how can technical diagnostics help in the field of medical disciplines and especially how is possible to support the health of patients. Based on suitable modification of hospital bed there was successfully reduced their vibrations and noise levels. We can conclude that significant contribution to the long-term well-being of patients bedridden has been achieved.

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