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# A Review Paper on Stabilized Stretcher for Ambulance

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**Abstract***: This work deals with a scrutiny of the acceleration equal to which a patient is uncovered during ambulance transportation. A dynamic scrutiny of ambulance movements has been advanced considering some different operating circumstances of the vehicle, such as braking, driving over speed bumps and on uneven pavements. The tenacity of this study is providing sources for development of a system reducing vibration effects on the body when a patient is transported by ambulance.*
*a) Highlights*
*• The vehicle dynamic analysis simulated the behaviour of the ambulance during sudden braking, and driving over different types of road unevenness*
*• A full vehicle multi-body model with 16 degrees of freedom and 34 bodies was engaged in the simulations*
*• The results achieved provide useful inputs for the development of systems for dropping the vibration effects on the patient's body*

**Keywords:** patient

## I. INTRODUCTION

When a person is affected by unexpected illness or has suffered more severe injuries in accident, he/she must be transported quickly and safely to a place for providing proper care. The vehicles used in these cases are relatively denser and less comfortable than passenger cars. In Brazil, ambulances usually have been either tailored or adjusted from cargo transport vehicles, such as trucks or vans. As patients are carried in the back of the vehicle, they are uncovered to accelerations during the transportation, either by braking, in curves, driving over complications or uneven pavements that directly impact the movements of the vehicle [1]. The vibration produced by irregular surface can affect the vital function of the human body (cardiovascular system, skeleton, central nervous system, respiratory system), and may exaggerate still more the clinical condition of the patient [2]. In the case of patients who suffered heart attack, stroke, or have disabilities that cause chronic pain and distress (arthritis, multiple sclerosis, back pain), they require special care due to their increased sensitivity to vibrations generated during the transport, which may impact their health conditions [3].
The ISO 2631 standard labels how to evaluate human body experience to vibration [4, 5]. Patients transported in the recumbent position are more profound to vertical vibrations when matched to standing or seated position [6]. In addition, vibration of the human body is most painful for sick or injured patients.
Road bumpiness can be either separate or even prolonged for the road which an ambulance goes through. Evenness along the road may have either a sinusoidal or stochastic profile. The ISO 8608 standard categorises stochastic road roughness by power spectral density (PSD) for both paved and unpaved roads [7].
Regarding distinct unevenness, speed bumps are mounted on the roads in order to control car speed and avoid traffic accidents [8]. The Watts Profile is a kind of speed bump widely used in works about ride comfort Fig. 1(a) [9]. In Brazil, Contran (National Traffic Council) is a government entity which governs carrying out of a kind of speed bump similar to Watts Profile. However, in many streets there are speed-humps dissimilar to this pattern.
In the context cited above, this paper presents a dynamic analysis of an ambulance in view of many operating conditions, such as braking, and driving on bumpy pavement. As previous papers related to ride comfort usually do not focus on any particular kind of ambulance transport, the purpose of this study is to examine movements and their

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respective accelerations as it can affect the comfort of patients transported by ambulance. The results obtained provide inputs for the development of a system for dropping the vibration effects on the patient body.

## II. METHOD

In order to calculate the patient body experience to vibration during ambulance transportation, the CarSim software has been applied. It works a full vehicle multi-body model with 16 degrees of freedom and 34 bodies. The tippers are nonlinear and the elastic kinematic effect of the suspension is also considered. The calculated model of the tire is nonlinear too. The ambulance factors applied to the simulations are well- matched with Mercedes-Benz's Sprinter 415 CDI 7.5 m³ vehicle altered to the intensive care unit (ICU) model, widely used for patients transport in Brazil. Table 1 lists the ambulance factors practical in this study.

The dynamic inquiry simulated the conduct of the vehicle during sudden braking, and driving over four distinct hurdles Watts Profile, Sinusoidal Road Profile (with two different wavelengths) and Chassis Twist Road.

Sudden Braking: the tenacity of this manoeuvre was to simulate a condition in which the driver needs to perform a sudden braking, from the initial 50 km/h speed and 4 MPa extreme pressure in the master cylinder.

**Table 1** Ambulance parameters applied in simulations

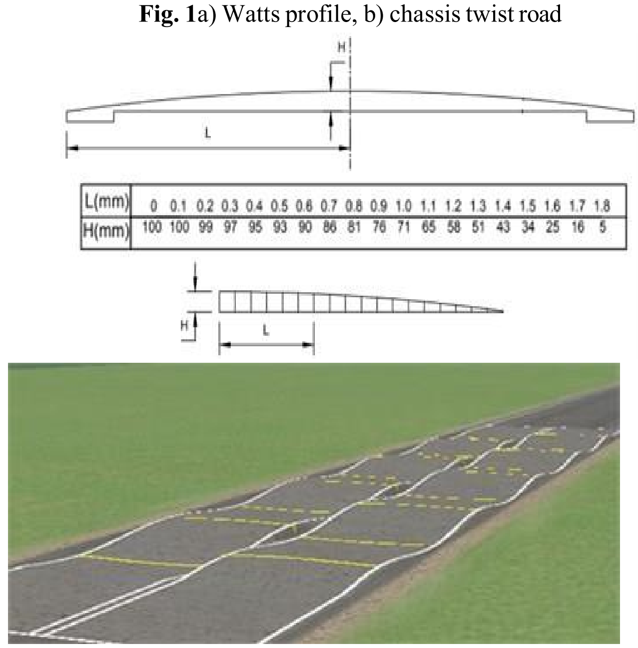
| Parameters | Values | Parameters | Values |
|---|---|---|---|
| Sprung mass [kg] | 2600 | Front unsprung mass [kg] (both sides) | 150 |
| Roll inertia [kg·m2] | 658 | Rear unsprung mass [kg] (both sides) | 150 |
| Pitch inertia [kg·m2] | 4174 | Wheel centers [mm] (front and rear) | 1550 |

Watts Profile: it was engaged in order to analyse the conduct of the vehicle running at 30 km/h speed through a identical speed bump, as shown in Fig. 1(a) [9].

Chassis Twist Road: this maneuverer, based on [10], pretend road excitations generated from the road profile inequality with the 0.05 m height elevations, as illustrated in Fig. 1(b). The vehicle speed during the replication was 45 km/h.

Sinusoidal Road Profile: two types of bumps were realistic to simulate the road bumpiness based on a sine profile. The maneuverer namely l indicates that the wavelength, λ in Fig. 2(a), is identical to the wheelbase of the simulated vehicle and the 2l indicates that the wavelength is twice the wheelbase. Both sinusoidal shapes of the road profile consist of three consecutive peaks of height equal to 0.1 meters. The vehicle speeds during the l and 2l manoeuvres were 15 km/h and 30 km/h, respectively. A sinusoidal shape of road profile is shown in Fig. 2(a)

**Fig. 1**a) Watts profile, b) chassis twist road



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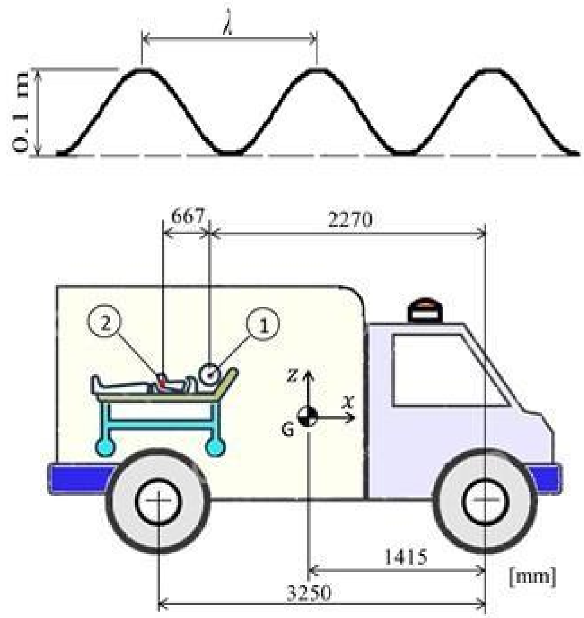
b) It is important to underline that the vehicle speed during the manoeuvres Watts Profile, Sinusoidal Road Profile, and Chassis Twist Road were select considering a typical speed of the ambulances when traveling through those bumps. Moreover, it was confirmed the grip between tires and pavement to provide the likely to control of the vehicle by the driver.

According to ISO 2631, the variables related to the patient distress are both translational and rotational accelerations. Thus, during the manoeuvres, roll and pitch accelerations were premeditated. Moreover, lateral and vertical accelerations were obtained for three different points: on the centre of mass of the vehicle, on the head (point 1) and at the abdominal region of the patient (point 2). The locations of points 1 and 2 were defined based on the anthropometric dimensions of a medium stature person, found from the work of Pheasant and Haslegrave [11]. Fig. 2(b) shows the locations of the points 1 and 2, and the centre of mass of the vehicle. The lateral coordinates of the points 1 and 2 are y1=y2= 40 mm.

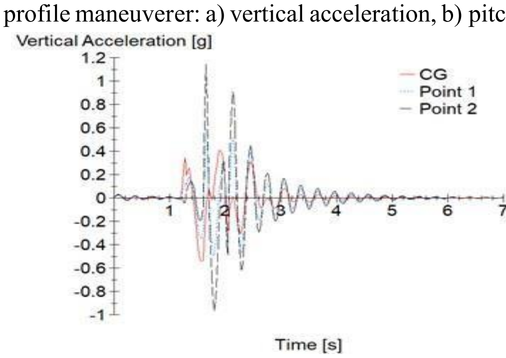
**Fig. 2** a) Sinusoidal road profile; b) locations of points 1 and 2 and vehicle's centre of mass G




## III. RESULTS AND DISCUSSION

During the maneuverer Watts Profile, vertical acceleration and pitch acceleration were studied (Fig. 3). The extreme and lowest values obtained at this maneuverer are represented in Table 2. These results are in harmony with the ones presented by Raemaekers [6].

**Fig. 3** Watts profile maneuverer: a) vertical acceleration, b) pitch acceleration



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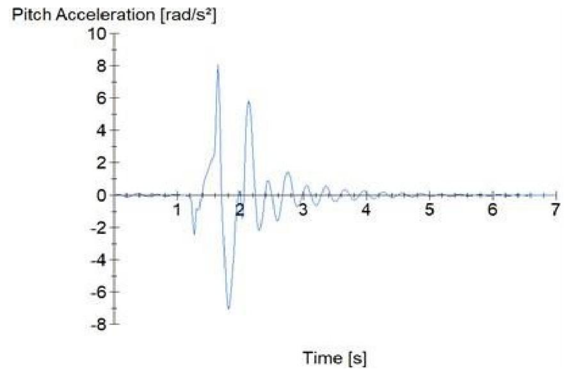


In the abrupt braking maneuverer, vertical, longitudinal and pitch accelerations were analysed, as shown in Fig. 4. The extreme and lowest values obtained during this maneuverer are shown in Table 3.

**Fig. 4** Abrupt braking maneuverer: a) vertical and lateral accelerations, b) pitch acceleration

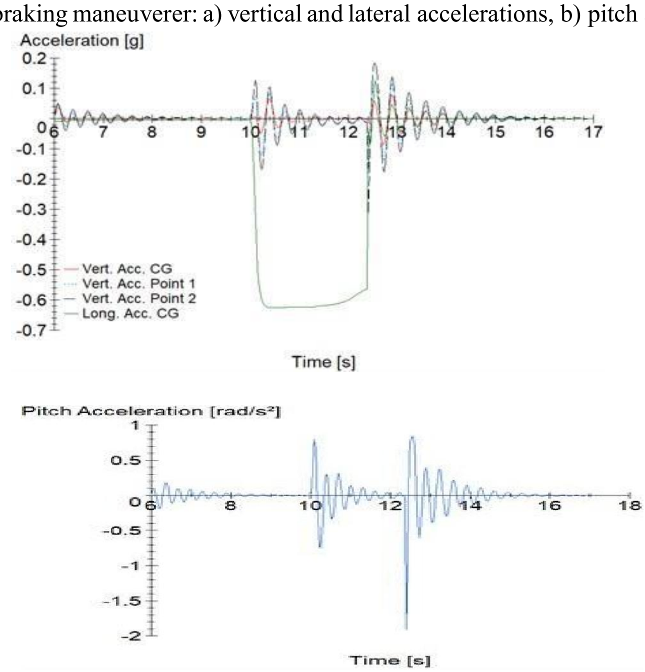


**Table 2** Maximum and minimum values obtained during Watts Profile maneuver

| Watts profile | Point | Maximum | Minimum |
|---|---|---|---|
| Vertical acceleration [g] | Point 1 | 0.59 | –0.49 |
| | Point 2 | 1.14 | –0.96 |
| | G | 0.41 | –0.54 |
| Pitch acceleration [rad/s²] | – | 8.08 | –7.07 |

When the ambulance flock through the Sinusoidal Road Profile, the vertical and pitch accelerations were analysed. The results from l maneuverer are shown in Fig. 5 and, Fig. 6 shows the results of 2l maneuverer. The extreme and lowest values obtained in these figures are listed in Tables 4 and 5, respectively.

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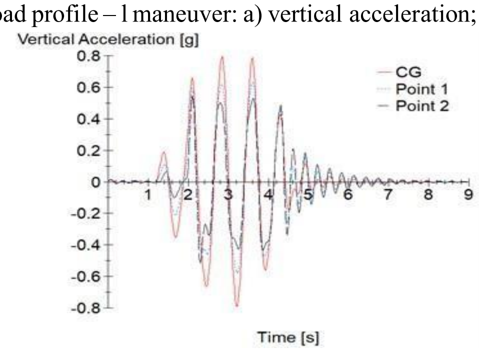
**Table 3** Maximum and minimum values obtained during sudden braking

| **Sudden braking** | **Point** | **Maximum** | **Minimum** |
|---|---|---|---|
| **Vertical acceleration [g]** | **Point 1** | **0.13** | **–0.18** |
| | **Point 2** | **0.18** | **–0.31** |
| | **G** | **0.08** | **–0.09** |
| **Longitudinal acceleration [g]** | **G** | **0.12** | **–0.63** |
| **Pitch acceleration [rad/s²]** | – | **0.84** | **–1.91** |

**Fig. 5** Sinusoidal road profile – l maneuver: a) vertical acceleration; b) pitch acceleration



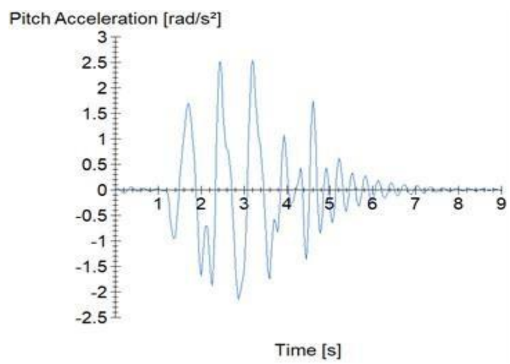




**Table 4** Maximum and minimum obtained during l maneuver

| l maneuver | Point | Maximum | Minimum |
|---|---|---|---|
| Vertical acceleration [g] | Point 1 | 0.64 | –0.58 |
| | Point 2 | 0.54 | –0.51 |
| | G | 0.80 | –0.79 |
| Pitch acceleration [rad/s²] | – | 2.55 | –2.15 |

Based on the results offered in Tables 5 and 6, it can be noted that the vehicle achieves the utmost vertical acceleration during the maneuverer l, while during the maneuverer 2l the pitch acceleration reaches the maximum value.

During the Chassis Twist Road technique vertical, lateral, pitch and roll accelerations were unwavering. Fig. 7 shows vertical, lateral and pitch accelerations. Results of roll acceleration is presented in Fig. 8. Table 6 lists the extreme and lowest values of the graphs presented in Fig. 7 and Fig. 8.

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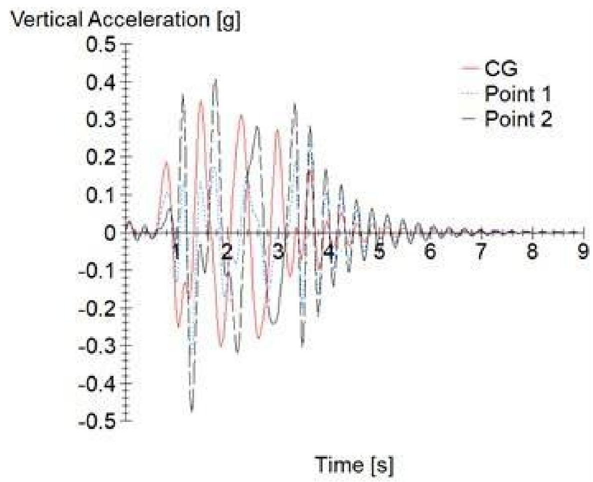
**Fig. 6**Sinusoidal road profile – 2l maneuver: a) vertical acceleration; b) pitch acceleration



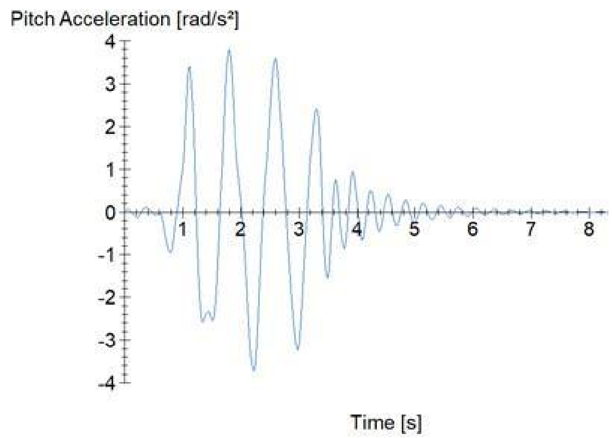




**Table 5** Maximum and minimum obtained during 2l

| 2l maneuver | Point | Maximum | Minimum |
|---|---|---|---|
| Vertical acceleration [g] | Point 1 | 0.23 | –0.32 |
| | Point 2 | 0.40 | –0.48 |
| | G | 0.35 | –0.30 |
| Pitch Acceleration [rad/s²] | – | 3.79 | –3.73 |

**Fig. 7** Chassis twist road procedure: a) vertical and lateral accelerations; b) pitch acceleration

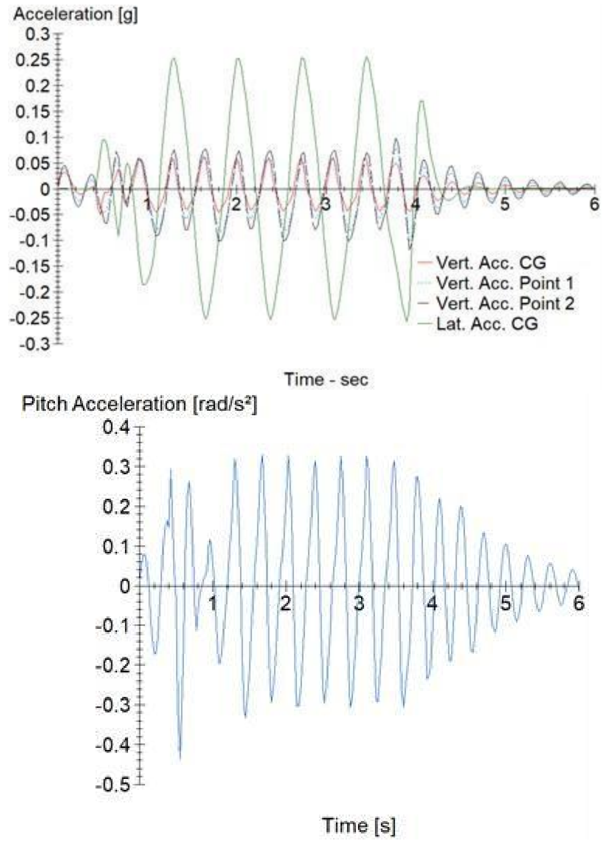
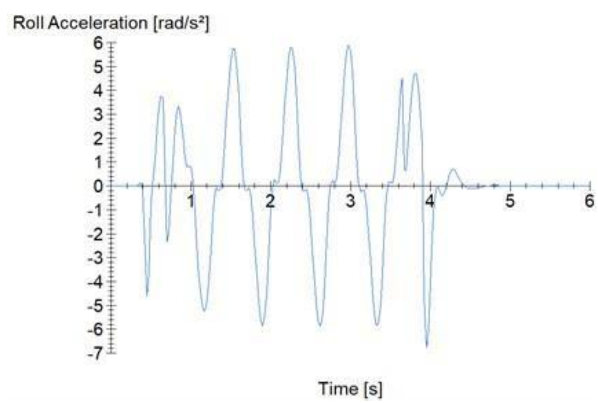



**Fig. 8**Roll angular acceleration




| Chassis twist road | Point | Maximum | Minimum |
|---|---|---|---|
| Vertical acceleration [g] | Point 1 | 0.08 | –0.10 |
| | Point 2 | 0.10 | –0.12 |
| | G | 0.06 | –0.05 |
| | G | 0.26 | –0.26 |
| | – | 0.33 | –0.43 |
| | – | 5.90 | –6.76 |

**Table 6** Maximum and minimum values obtained during Chassis Twist Road procedure

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## IV. CONCLUSION

This effort presents how the acceleration affects a patient transported by ambulance. Translational acceleration was considered on body regions such as the head and abdomen of the patient considering the vehicle implementing five dissimilar maneuvers. Moreover, roll and pitch accelerations were taken into description too. According to earlier works, the acceleration results obtained here may be damaging to the physical integrity of patients transported in the ambulance, which indicates the need to reduce vibrations in the ambulance stretcher. Vibration effects on the patient body could be reduced either by an active suspension system gathered between all wheels and the body of the ambulance or by a mechanism installed under the stretcher. The next step of this work may be a blend of a mechanism for reducing vibrations effects in both translational and rotational movements of the ambulance stretcher.

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