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Cabin attendants' exposure to vibration and shocks during landing

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Abstract

The Scandinavian Airlines System (SAS) has noted that cabin attendants have reported an increase in health problems associated with landing. The European Union reports cover health problems related to neck, shoulder, and lower-back injuries. Moreover, analysis of these reports shows that the problems are often associated with specific airplanes that have a longer tail behind the rear wheels and appear more often in attendants who sit in the back of planes rather then the front. Against this background, this study measures and describes the vibration during landing in specific airplanes to evaluate the health risk for the cabin attendants.

Measurements were conducted on regular flights with passengers in the type of airplane, Boeing 737-800, which was related to the highest per cent of reported health problems. All measurements were performed the same day during three landings in one airplane with the same pilots and cabin attendants. The measurements were carried out simultaneously on the cabin crew seats in the back and front of the passenger cabin. Under the cabin crew's seat cushions, a triaxiell seat-accelerometer was placed to measure the vibration in three axes. The signals from the accelerometers were amplified by charge amplifiers and stored on tape. The stored data were analysed with a computer-based analyse system.

For the cabin attendants, the dominant direction for the vibration load during landing is the up-and-down direction although some vibration also occurs in the other horizontal directions. The exposure to vibration is higher on the rear crew seat compared to the front seat. For instance, both the vibration dose value (VDV) and the frequency-weighted acceleration in the dominant direction are more then 50% higher on the rear seat. The frequency-weighted acceleration and the VDV measured at the crew seats are below the exposure limits as described by the European vibration directive. The evaluation of the cabin attendants' exposure to multiple shocks during landing shows that the potential of an adverse health effect for the cabin attendants is low in the front of the airplane and increases to moderate in the rear. Although this is a limited study, it could be conclude that there could be a risk for cabin attendants due to the exposure of multiple shocks. Therefore, efforts should be spent to minimize their risk by developing a better seat cushion and back support to lessen the effects of shocks. In addition, attendants should be informed about the most suitable posture to take during landing.

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1. Introduction

In the European Union (EU) Member States, 150 airlines transport over 2 million passengers every day for a total of 740 million passengers per year [1]. These passengers are served by the flight deck crew and cabin crew. The crew works in reduced atmospheric pressure, low humidity, and exposure to sound, vibration, cosmic-radiation, and magnetic fields [2]. These occupational exposures present physiological challenges to the long-term health of the crew. Exposure to whole-body vibration is one of the factors that have been recognized that could cause discomfort, injury, or interference with activities [3]. However, only one study could be found in the scientific literature that has recognized the cabin crews' exposure to vibration [4]. The study concludes that the exposure to whole-body vibration for the cabin crews was low except during take off and landing.

The exposure to vibration could also include an exposure to multiple shocks. Examples of conditions that result in vibration containing multiple shocks include off-road vehicle travelling over rough surfaces, small boats in rough seas, and banking aircraft. These shocks generate transients with high peak accelerations that have been associated with adverse effects on lumbar vertebrae after long-term exposure [5]. Therefore, the International Standardization Organization has presented a standard for evaluation and guidance on the assessment of human exposure to whole-body vibration containing multiple shocks [5].

EU airlines have reported that cabin attendants have reported an increase in health problems associated with landing. The internal reports within Scandinavian Airlines System (SAS) cover health problems related to neck, shoulder, and lower-back injuries. Moreover, analysis of these reports shows that the problems are often associated with specific airplanes and appear more often in attendants who sit in the back of planes rather then the front. Against this background, this study measures and describes the vibration during landing in specific airplanes to evaluate if there is a health risk for the cabin attendants.

2. Method

The measurements were made on regular passenger flights in the type of airplane that had the highest per cent of reported health problems. For the measurements a Boeing 737 with the model number 800 were used. This type of plane has a longer tail behind the rear wheels and the model is about 8.5 m longer compared with the model 600. The Boeing 737 has been produced for a total number of more then 5200 and is common in the world fleet of commercial airplanes. All measurements were performed on the same day in one airplane with the same pilots and cabin attendants. During the flight, the winds were heavy and bumpy (roughly 10–12 m/s). The measurements were carried out during three landings simultaneously on the cabin crew seats in the back and front of the passenger cabin. During the landing, the seats were used by cabin attendants. Both the front and rear seats were mounted in the plane with the backrest in the travelling direction. Under the cabin crew cushions, a triaxiell seat-accelerometer (Brüel & Kjær 4322) was placed to measure the vibration in the three axes according to the international standard ISO 2631-1 [6]. Measurements were carried out for a period of 20 min during the landing sequences. The signals from the accelerometers were amplified by charge amplifiers (Brüel & Kjær 2635) and stored on tape (Sony PC 204A/208A). The measurement chains were calibrated using an accelerometer calibrator (Brüel & Kjær 4294). The data were analysed with a computer-based analyser system (Brüel & Kjær 3560). The time analyses were performed with a resolution of 0.025 s. The frequency analyses were done within the frequencies from 0.4 to 400 Hz during the 45 s that includes the approach, landing, breaking, and taxing.

3. Results

Fig. 1 shows typical time history recordings of the acceleration during landing measured on the crew seat in the back of the plane. The landing is divided into four phases. During the first phase, for about 11 s, the plane approached the landing strip using banking manoeuvres to counteract turbulence. During the second phase (after landing), which takes about 2.5 s, the acceleration on the crew seat reaches the maximum level. During the third phase, the brakes are applied causing shaking for about 20 s. During the fourth phase, the plane is taxing on the runway. The acceleration peak value is close to 10 m/s^2.

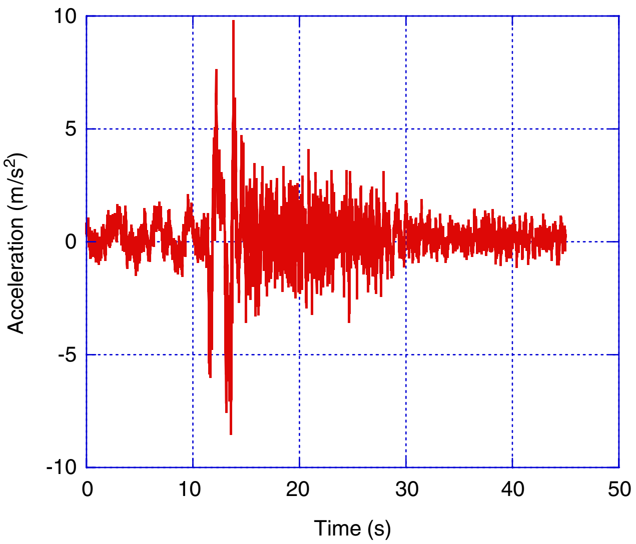

Fig. 1. Original recordings showing the peak acceleration as a function of the time on the rear crew seat in the up-and-down direction (*Z*-direction).

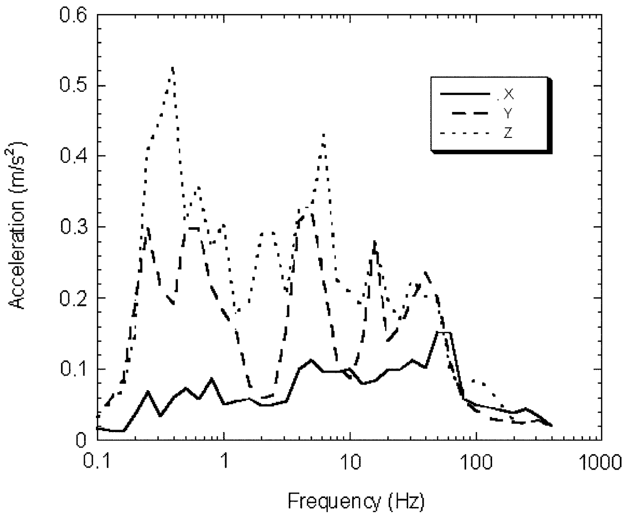

Fig. 2. Measured acceleration for the three orthogonal vibration directions (x, y, z) as a function of the frequency (1/3-octave band) on the rear crew.

Fig. 2 illustrates the mean magnitudes of the measured acceleration in the three orthogonal vibration directions as a function of the frequency (1/3-octave band) at the crew seat for one typical recording. The maximum acceleration on the seat is concentrated to frequencies below 1 Hz.

Table 1 presents the mean frequency acceleration (weighted and un-weighted) according to the international standard ISO 2631-1 for the measured acceleration on the crew seats during the landings for the three vibration directions (x, y, z). The table provides the calculated mean vibration dose values (VDV) and the mean crest factor. The table also presents the calculated acceleration dose values (ADV) [6] for the 45 s that includes the approach, landing, breaking, and taxing. The table presents the calculated equivalent daily static compressive stress on the lumbar vertebrae. For these calculations, we assume the cabin attendants land 5 times/day.

Table 1
The mean frequency (weighted and un-weighted) acceleration (m/s^2) as well as the calculated VDV (m/s^{1,75}) and crest factor on the front and rear crew seat, respectively, during the different landings in the three vibration directions (x, y, z)

	Crew seat front				Crew seat rear			
	x	y	z	S	x	y	z	S
Acceleration	0.6 (0.0)	0.4 (0.0)	0.9 (0.0)		0.5 (0.0)	0.9 (0.2)	1.4 (0.1)	
Acceleration (weighted)	0.3 (0.0)	0.1 (0.0)	0.6 (0.0)		0.2 (0.0)	0.4 (0.2)	0.9 (0.1)	
VDV	2.6 (0.3)	1.8 (0.1)	3.2 (0.1)		2.1 (0.3)	3.4 (0.3)	5.2 (0.6)	
Crest factor	7.1 (0.3)	7.6 (1.0)	10.2 (0.4)		7.0 (0.5)	7.0 (1.2)	7.8 (2.3)	
ADV	5.7 (0.6)	3.9 (0.2)	7.4 (0.3)	0.3 (0.0)	4.5 (0.5)	7.4 (0.4)	11.8 (2.4)	0.5 (0.1)

The table presents the calculated ADV (m/s^2) and corresponding calculated equivalent daily static compressive stress (S) in the lumbar vertebrae (MPa). The standard deviation is in parenthesis.

The highest values for all variables were measured in the z-direction. Furthermore, it could be seen from the table that there are differences in the results between the rear and front crew seat. The rear seat showed higher values on all measured variables compared to the front seat except for the crest factors.

4. Discussion

The vibration during landing depends on many factors such as type of airplane and landing strip, weather condition, maintenance, and the pilots' skill. Moreover, the number of measurements and landings in this study is limited. Therefore, the data should be interpreted carefully although the pilots and the cabin crew considered the landings to be "normal". Some general conclusions could be drawn from the results.

The dominant direction for the vibration load for the cabin attendants is the up-and-down direction although some vibration also occurs in the other horizontal directions. This is quite natural since the airplane direction is downwards during the landing, but the exposure of the cabin attendants depends on how the pilots manage to put the back wheels of the plane on the landing strip. Under some circumstances, for instance during bad weather, the landing could be accomplished on only one of the back wheels, which will result in strong side movements. The fore-and-aft movements are most likely related to the braking experienced during the landing.

The results also very clearly show that the exposure to vibration is higher on the rear crew seat compared to the front seat. For instance, both the VDV and the frequency-weighted acceleration in the dominant direction are more then 50% higher on the rear seat. Therefore, it is reasonable that the reported complaints from the cabin attendants are more frequent with reference to landing when sitting in the rear part of the airplane.

The EU has approved a directive [7] that covers minimum health and safety requirements regarding the exposure of workers to vibration. In the directive, two exposure values are stated, action value and daily exposure limit value, which are expressed as the frequency-weighted acceleration or as VDV. Although the directive does not address the exposure limit value for air transport, the prescribed limits could be used for guidance. Under normal circumstances, the exposure limit values are not exceeded for the cabin attendants because most of the vibration load occurs during landing, and exposure lasts less than 5 min/day. During the rest of the working period the vibration load have been shown to be low [4] also in comparison with other exposed workers [8].

For evaluating the cabin attendants' exposure to multiple shocks during landing, the international standard ISO 2631-5 could be used. It is assumed that multiple shocks cause transient pressure changes at the lumbar vertebral endplates that over time may result in adverse health effects arising from material fatigue processes. Exposure related factors are the number and magnitudes of peak compression in the spine. Adverse health effects of long-term whole-body multiple-shock exposure include an increased risk to the lower lumbar spine and the connected nervous system of the segments affected. According to the appendix of ISO 2631-5, the calculated equivalent daily static compressive stress indicates a low-to-moderate adverse health effect for the cabin attendants that are exposed to these conditions during their whole working life. The potential of an adverse health effect for the cabin attendants is low in the front of the airplane and increases to moderate in the rear part of the cabin. Since the measurements were conducted under circumstances that were defined by the crew as ''normal'' landings, one could suspect that under ''hard'' landings, when the pilots have to ''drop'' the plane towards the landing strip, the potential of an adverse health effect will increase. Moreover, the assessment is based on upright posture, and a bending forward or twisting posture is likely to increase the adverse health effect. However, the assessment methods described in ISO 2631-5 have not been epidemiologically validated.

These results indicate, however, on a limited number of landings, that there could be a health risk for cabin attendants due to the exposure of multiple shocks. Efforts should therefore be spent to minimize their risk by developing better seat cushions and back support to lessen the effects of shocks. In addition, the crew should be informed about the most suitable posture to take during landing.

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