Selection of child seats in terms of vibration comfort

D Frej*, A Zuska¹, P Kubiak ²

¹ Department of Automotive Engineering and Transport, Kielce University of Technology, Avenue Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland;
² Department of Transport, Warsaw University of Technology, Plac Politechniki 1, 00-661 Warsaw, Poland
* dfrej@tu.kielce.pl

Abstract. The article presents the results of laboratory and road tests of the impact of the method of fastening child seats on the vibration comfort of children transported in them. The tested child seats were mounted facing the direction of travel on the rear seat of a passenger vehicle. Two child seats were used in the work, the first (red) was attached to the rear seat behind the driver's seat using the ISOFIX base. The second child seat (grey) is attached to the rear seat behind the passenger seat with standard seat belts. During the measurements, the child seats were loaded with the mass of 5 kg, 10 kg and 15 kg, simulating the mass of a child fastened in a child seat. The child seats used can be mounted both forward and rearward facing. In the conducted research, they were installed in a passenger vehicle facing the direction of travel. Laboratory and road tests based on registered vertical accelerations showed a negative impact of using the ISOFIX base in terms of vibration comfort.

Keywords: vibration comfort, child seats, vehicle safety

1. Introduction
Choosing the right child seat is a difficult task. Before purchasing a child seat, one should measure it according to the child and the vehicle [1-5]. Otherwise, it may turn out that the selected seat is not compatible with one’s vehicle. The problem may be too high an ISOFix system hitch, the design of the rear seat of the vehicle and the inability to remove the headrest in the rear seat [2,3]. A very important element in choosing a child seat is matching it to the vehicle seat. The height of the rear seat of a passenger vehicle has a great influence on the placement of the child's feet, which in turn translates into the overall comfort in the vehicle. Furthermore, the seat cushion of the child seat may be longer or shorter than the seat cushion of the rear vehicle seat, and consequently a situation may arise in which the child has no limited foot space. The second important issue in choosing a child seat is its backrest [2,3,5]. The upright backrest may cause the child to tilt over when traveling forward. In addition, in some vehicles, it is impossible to remove the headrest or raise it to the appropriate height, so the backrest of the child seat will stick out from the backrest of the passenger vehicles [2,3].

In terms of safety, there are other aspects to check. The length of the seat cushion must match the length of the child's legs. If the seat of the child seat is too long, the child will maybe slide out, which is very dangerous. In a forward-facing configuration, the child's legs must have a space of 15 to 20 cm between the extreme point of the child seat and the front vehicle seat [6,7]. The most common difficulties when fitting a child seat to the vehicle include [3,6]:

- short seat belts in the rear seat of the vehicle,
• the shape of the child's seat does not match the shape of the vehicle seat,
• too short support stabilizing the ISOFIX base of the child seat,
• the ISOFIX brackets in the vehicle are positioned at a different height than the brackets in the child seat.

The above problems in the installation of a child seat in a passenger vehicle mean that the child is not safe in the seat while driving and during a possible collision. In a road collision, the child seat may come out of the vehicle seat. Improper installation of the child seat will affect the child's posture during the journey, making it uncomfortable and unsafe [7-10].

The approval tests of child seats are mainly focused on the safety of the transported child during a vehicle accident and protection against the harmful effects of such events [7,9]. During the safety tests of ADAC (Allgemeiner Deutscher Automobil-Club) vehicle seats are carried out in laboratory conditions and simulating of a side impact at 50 km/h and a frontal collision at a speed of 72 km/h [10,11]. The child seats are only tested for overall comfort. The position of the child's seat is checked, the softness of the upholstery as well as whether the seat belt and other elements of the child seat do not put pressure on the child during the journey. Child seats are also checked and evaluated for use and cleaning. Unfortunately, approval tests and ADAC child seat tests do not include the impact of vibrations (vibration comfort) on the child's body [3,10,11].

The greatest threats to humans, caused by the impact of vibrations related to the movement of vehicles, occur in road transport [11,12]. The driver and passengers of the passenger vehicle assess the discomfort from driving based on the acceleration influencing them. The harmfulness of these vibrations depends mainly on the amplitude, frequency of vibrations and the duration of this phenomenon. The permissible values of vibrations acting on the adult human body are the subject of many studies, both in terms of comfort and ergonomics [7,9,12]. Vibration measurement methods and their values have been regulated in ISO 2631-1 [13] and British Standards BS 6841 [14]. Unfortunately, there are no relevant standards developed for measurements and vibration values affecting a child's body.

In the literature, one can find several normative acts and scientific publications describing the impact of vibrations on the human (adult) body [3,15]. Unfortunately, such studies are not carried out in the case of children. And the development of child seats is aimed solely at improving safety and ergonomics [3,4,9].

2. Research object and research methodology

The tests were carried out in laboratory conditions and in real road conditions. During laboratory tests, the wheels of the rear axle of the tested vehicle were made to vibrate using the measuring plate of the EUSAMA SA.640 device. This plate is used to test shock absorbers using the EUSAMA method and is part of the Bosch Beissbarth diagnostic line. The EUSAMA SA.64 device stimulates the road wheels to vertical vibrations with a constant amplitude of 6 mm and a frequency varying from the initial value of about 25 Hz to zero. The Bosch Beissbarth diagnostic line played the role of a vibration generator in the experimental tests.

Road tests were carried out on three sections of asphalt, gravel, and cobblestone roads. The speed of the passenger vehicle during the tests was kept constant at 50 km/h. The research used an Audi A6 passenger vehicle with air suspension, which could assume four positions: raised, comfortable, automatic, and dynamic. Two child seats were used in the experiment: Avionaut AeroFIX (Red) and Avionaut Pixel (Gray). The view of the tested child seats is shown in Figure 1. During road and laboratory tests, the child's seats were loaded with a mass imitating the mass of a child, which was 5 kg, 10 kg, and 15 kg, respectively.
The aim of the experiment was to measure and analyse the distribution of vertical vibrations in two subsystems. The first consisted of a rear vehicle seat and a child seat with a classic fastening system. The second subsystem consisted of a rear passenger vehicle seat and child seat attached with the ISOFIX base. The view of the ISOFIX base is shown in Figure 2.

The recorded waveforms of acceleration for the seat of the Avionaut Pixel seat and the Avionaut AeroFIX seat are similar in terms of the maximum acceleration values. It should be noted, however, that higher values of vertical acceleration on the child seat were recorded on the child seat fixed with the ISOFIX base.
Figure 3. Vertical accelerations recorded on the basis of ISOfix and the seat of the Avionaut AeroFIX child seat, mass loading the child seat 5 kg.

Figure 4. Vertical accelerations recorded on the rear seat of the passenger vehicle and the seat of the Avionaut Pixel child seat, mass loading the child seat 5 kg.

Figure 5. Vertical accelerations recorded on the basis of ISOfix and the seat of the Avionaut AeroFIX child seat, mass loading the child seat 10 kg.

Figure 6. Vertical accelerations recorded on the rear seat of the passenger vehicle and the seat of the Avionaut Pixel child seat, mass loading the child seat 10 kg.
Figures 9 to 14 show the vertical accelerations recorded on the tested child seats during road tests. During the tests on gravel and cobblestone surfaces, the highest acceleration values were recorded on the seat of the child seat fixed with the ISOFIX base, they were significantly higher than the accelerations recorded on the seat of the child seat fixed with the classic method (with the use of seat belts).

Figure 7. Vertical accelerations recorded on the basis of ISOFIX and the seat of the Avionaut AeroFIX child seat, mass loading the child seat 15 kg

Figure 8. Vertical accelerations recorded on the rear seat of the passenger vehicle and the seat of the Avionaut Pixel child seat, mass loading the child seat 15 kg

Figure 9. Vertical accelerations recorded on the basis of ISOFIX and the seat of the child seat Avionaut AeroFIX (red), loaded with a mass simulating the mass of a child of 10 kg, vehicle traveling on an asphalt road

Figure 10. Vertical accelerations recorded on the rear seat of a passenger vehicle and the seat of the child seat Avionaut Pixel (grey), loaded with a mass simulating the mass of a child of 10 kg, vehicle traveling on an asphalt road
4. Conclusions

The laboratory and road tests carried out have shown that the highest acceleration values occur on the base ISOFIX used to attach the child seats and they differ from the acceleration curves recorded in other areas. The use of the ISOFIX base for mounting a child seat is a great help for the parents of the child in terms of ergonomics. However, it should be noted that when traveling, the greatest attention to the manufacturers of child seats should be on the comfort of the child. A child placed in the child seat should feel safe and comfortable. The use of the ISOFIX base causes the child seat to be separated from the
rear passenger vehicle seat. The vibrations transmitted from the road surface through the body to the seat of the child seat are not absorbed sufficiently in the case of the ISOFIX base, therefore higher vertical accelerations in the seat of the child seat are recorded than in the case of a seat secured with standard seat belts.

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