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Pregnant women when riding in a motor car – selected issues

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Abstract
The issue of passive safety of pregnant women travelling by car has been discussed. The pregnant woman's body has been considered as a complex dynamic system subject to various impacts that take place during a car ride. In the field of motorization, much attention is paid (and rightly so) to the issue of safety of pregnant women travelling by car in consideration of road accidents. Motor vehicle accidents are the most important cause of death of pregnant women, according to data published by the National Highway Traffic Safety Administration (NHTSA). In the USA, about 130 000 pregnant women being in the second half of their pregnancy are annually involved in motor vehicle accidents. In this paper, some example solutions have been presented that are to improve the passive safety of riding in a motor car, including those proposed to minimize the injuries that may be sustained in result of an accident. The issue of the possible negative effects of a road accident or collision on a pregnant woman has also been raised. The application of virtual techniques has been discussed and examples of modelling a pregnant woman have been shown. Some research results concerning the deceleration values that might be dangerous for pregnant women have been given, with reference having been made to statistical data on fatal accidents.

Introduction

There are many areas of human activity where people are exposed to harmful impacts when carrying out their tasks. The man's environment continuously changes under the influence of new technologies and varying economic, social, and demographic conditions. This is also applicable to transport, including motor transport.

Among the vibrations caused by technical transport facilities, those occurring in motor transport impose the greatest hazard [1]. Although the ride comfort improves, the amount of time spent by people on car travels grows at the same time. In the motor transport, the driver and passengers not only must remain in a position that cannot be changed for a prolonged time and there is a need for continuous concentration providing adequate responses to driving situations [2, 3] but they are also exposed to noise and mechanical vibrations felt by them as most oppressive.

So far, the impact of vibrations on the human body during a ride in a motor vehicle was almost exclusively investigated with respect to the adults [4, 5].

Recently, however, particular attention has been increasingly often paid by researchers to children transported in safety seats as such children should be treated with no less care than "normal" passengers would, especially in the case of long-distance travels. Simultaneously, another problem has been noticed, i.e. attention begins to be paid to the issue of safety of pregnant women travelling by transport means, in particular motor vehicles, and to the safety of the foetus [6].

In this paper, the aspect of passive safety of pregnant women during car rides has been discussed, because the studies on these issues are still at an early stage.

Problem description

The body of a pregnant woman is a very sophisticated dynamic system which includes the bodies of an adult and a foetus). Obviously, it is highly susceptible both to the effects of a vehicle collision and to the impact of vibrations on the sitting woman during a "normal" ride. The research and experiments on the issues related to the safety of pregnant women and foetuses are carried out within a very limited scope. The high degree of complexity of the pregnant woman problem may be well illustrated by the works dedicated to the issue of eliminating or at least easing the pains felt by pregnant women. There is no simple but fully effective remedy (such as e.g. physical exercises) for the ailments of this kind [7, 8].

Studies are carried out with comparing pregnant and non-pregnant women at their work places as regards changes in the body positions assumed by them when performing their duties [9]. The issue of changes in the body mass and in the mass distribution during pregnancy was also explored. Publication [10] shows results of examination of 15 pregnant women, according to which the mass of the torso of a pregnant woman increased at a rate of 0.29 kg/week, on average, and the principal moment of inertia relative to the lateral axis grew by 0.0069 kgm^2. The issues of dynamic stability of the posture of a pregnant woman are being addressed as well. The authors of publication [11] have drawn readers' attention to the fact that pregnant women are exposed to an increased risk of a "routine" fall, especially when being in the second and third trimester of their pregnancy. They have simultaneously stressed that numerous anatomical, psychological, and hormonal changes take place during the gestation but their impact on the dynamic stability of woman's posture has not been explored yet.

Most of deaths of babies in the womb (in accidents) take place when the placenta is injured, which causes the oxygen supply to be cut off from the foetus. Therefore, a stress is put on the importance of correct use of seatbelts by pregnant women [12, 13]. In publication [14], the authors have revealed that merely 13% of pregnant women actually wore their seatbelts properly positioned according to the safety rules, i.e. in a way ensuring them to be properly protected from the effects of a shock. The pregnant woman and her foetus is best protected when her three-point seatbelt is properly placed (see Fig. 1). The seatbelt placed as shown in the drawing significantly reduces the risk of injury to the foetus. This is highlighted by authors of publication [15].

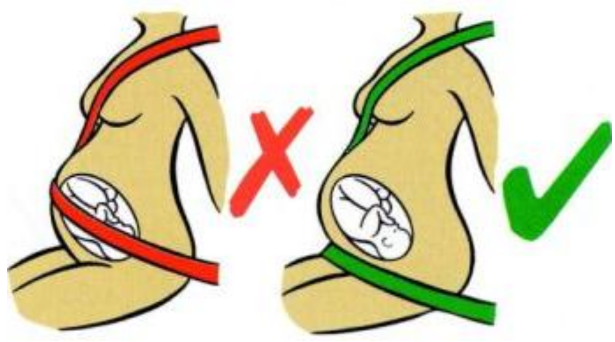

Fig. 1. Incorrect and correct use of a three-point seatbelt by a pregnant woman [16]

It is important to know that women in advanced pregnancy are not forced to fasten their seatbelts. However, this increases the risk of foetus's death in case of a road accident. It should also be remembered that before driving a car, a pregnant woman not only should correctly adjust the driver's seat but also should not forget about the headrest. In case of an accident, the force of inertia would cause the occupant's body to be pushed forwards and then to be rapidly thrown backwards.

The seatbelt may be well supplemented with the Tummy Shield system (Fig. 2 [17]), which is a special seat made of materials of high tensile strength and additionally reinforced with stainless steel, with a mass of 4.5 kg. Thanks to the Tummy Shield system, the lap portion of the seatbelt having been fastened is not placed under the abdomen but it just holds the thighs. The shoulder portion of the seatbelt goes as usual across the chest.

On the one hand, research shows that pregnant women are better protected from the effects of a frontal collision if the steering wheel is provided with an airbag [16]. At the same time, however, attention is drawn to insufficient distance between the woman driver and the steering wheel provided with an airbag. This may cause additional injuries when the airbag is activated. The selection of an appropriate shape of the airbag is also important (Fig. 3) [16].

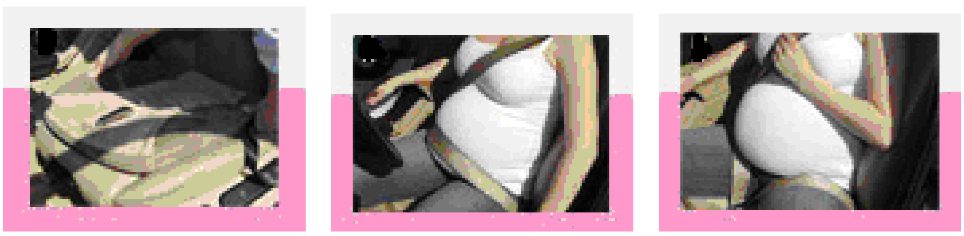

Fig. 2. Example of using the Tummy Shield seat [17]

Fig. 3. Example of a special shape of the airbag [16]

In consideration of specific features of the bodies of pregnant women, it is recommended that their physical dimensions and changes in their body shapes (anthropometric dimensions) should be specially taken into account (see Fig. 4).

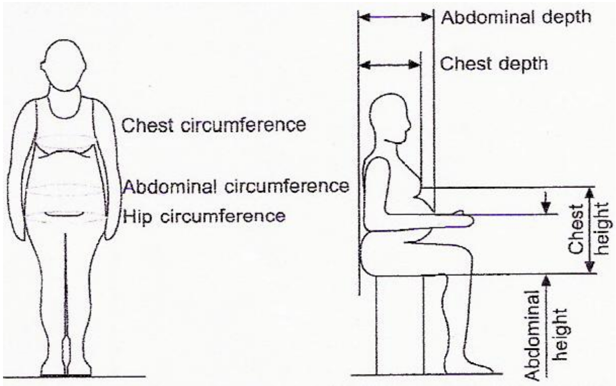

Fig. 4. Anthropometric dimensions of a pregnant woman, especially from the point of view of designing the seat belts [14]

The issue of the role played by the position of pregnant woman's placenta during a road accident that may result in a loss of the foetus has been addressed in publication [18]. The authors have put a stress on the need to compare results of numerical analyses with results of experiments carried out with a dummy representing a sitting pregnant woman. Computer simulation tests where a numerical model was transformed to represent situations with different positions of the placenta, showed a possibility of using the results of such tests at the creation of road safety systems (related to road accidents) and at the preparation of procedures to provide clinical first aid for pregnant women.

A significant part of the experimental research was dedicated to the issue of avoiding the harmful impact of vibroacoustic effects on the foetus, e.g. [19, 20, 21]. Other research covered pregnant women and foetuses in road accidents, e.g. [22, 23, 24]. The work described in publication [25] was the first analytical study on the effects of vibrations on a sitting pregnant woman. The research into this subject was continued in the works presented in publications [26, 27, 28]. Twelve women having been 31 weeks pregnant were subjected to tests consisting in free fall from a standing posture. It was found from the experiments that the dangerous frequency of vibration of the pregnant woman's abdomen was 7.7 Hz. The authors of publication [26] have emphasized the importance of anthropometric data determined for a human body for the needs of reliable modelling of a human specimen.

According to estimates presented in publication [29], about 92 500 pregnant women are annually injured in the USA. In spite of wearing seatbelts, a large number of women are killed in result of "rear-end collisions." The authors of publication [6] carried out a research work where seatbelts with pretensioners were worn by pregnant drivers. In the experiments, a dummy representing a pregnant woman was used. The activation of the seatbelt pretensioning system resulted in a reduction of the intrauterine pressure by 30–60% and by 50–60% when the acceleration reached a value of 6.5 g and 4.5 g, respectively.

In consideration of specific characteristics of pregnant women's bodies, the investigations are based on computer techniques where, *inter alia*, the finite element method (FEM) is used. An example may be the work reported in publication [30] (Fig. 5).

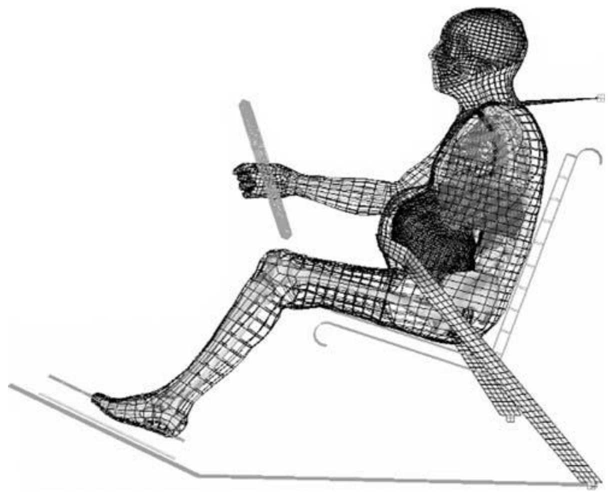

Fig. 5. Side view of a pregnant driver represented by a computer model [30]

The author of publication [30] has highlighted the good points of the use of virtual techniques in the field of research into the traumatology of pregnant women without a risk of possible adverse effects that might occur at the carrying out of experimental tests. It should be stressed here that significant importance should be attached not only to the anthropometric differences but also to the fact that the dangerous frequency of vibrations of the pregnant woman's abdomen in the vertical direction is 7.7 Hz.

An example of the modelling of a sitting pregnant woman has been shown in figure 6 [25]. A baby in the womb is a conspicuous "new element" of the model.

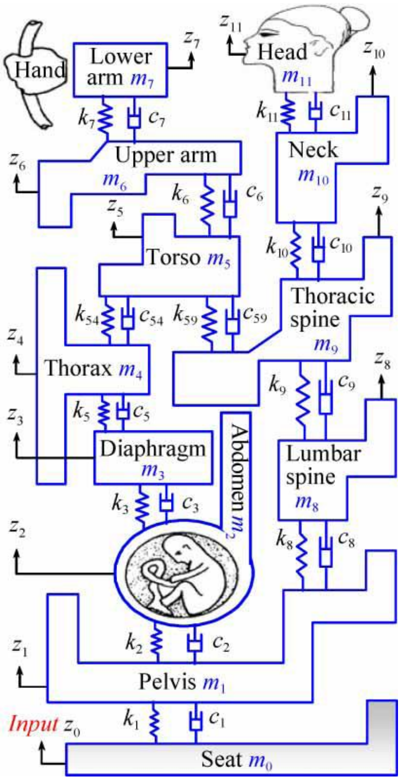

Fig. 6. Mechanical model of a pregnant woman [25]

In this case, it is interesting that the authors ignored legs when modelling the sitting posture. A more comprehensive discussion of biomechanical modelling issues may be found in publication [31]. It was emphasized there that biomechanical (biodynamic) models are necessary for any methodical analyses of the man-vehicle relationships, including the consideration of the impact of mechanical vibrations. However, the scope of application of such models should be limited to the area for which they have been validated.

Experimental tests

The issues related to the impact of vibrations on the occupant of a moving motor vehicle have been investigated for many years at PIMOT (Automotive Industry Institute) [31, 32] and these research works have been described in many publications, e.g. [4, 5, 33, 34, 35].

Within the experiments, the impact of vertical vibrations on motor vehicle occupants was measured during tests carried out on a road with rough surface. During the tests, time histories of vertical vibration accelerations were recorded and the power spectrum density (PSD) values were determined for the said acceleration signals. Then, an analysis was carried out by comparing the PSD values of the signals recorded by sensors placed in the torso (H2B) and head (H2G) of a HYBRID II test dummy and on the vehicle floor (P). An example comparison between the PSD values of the vertical accelerations has been presented in figures 7 and 8.

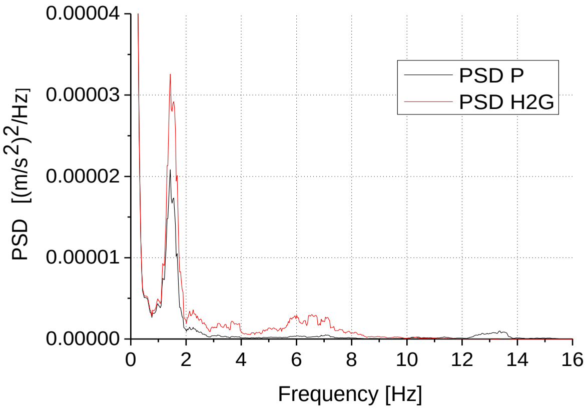

Fig. 7. Comparison between the PSD values of the vertical accelerations of the vehicle floor (P) and the dummy's head (H2G)

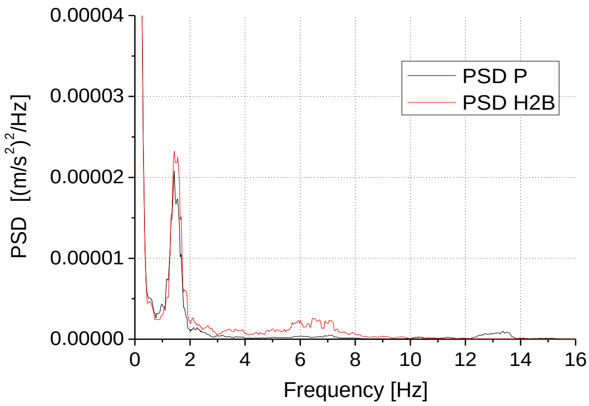

Fig. 8. Comparison between the PSD values of the vertical accelerations of the vehicle floor (P) and the dummy's torso (H2B)

The above graphs show that the highest PSD values occurred in the frequency range 1.5–2 Hz and that for the dummy's head (H2G) and torso (H2B), they exceeded those determined for the vehicle floor by about 50% and about 20%, respectively. For the frequencies rising from 2 Hz to 8 Hz, the PSD values generally decreased but those of the dummy (H2) were many times as high as those of the vehicle floor (P). This indicates that in this frequency range, the human body will be particularly susceptible to the absorption of vibrations. This frequency range includes the value of 7.7 Hz, i.e. the one indicated in publications [26, 27, 28] as the most dangerous frequency of vertical vibration of pregnant woman's abdomen.

It should be noted here that the test dummy used at the experiments was not an "equivalent" of a pregnant woman; instead, it rather represented a "standard" adult and this is the reason for the differences between the frequencies determined at the tests carried out at PIMOT and the research results revealed in publications [26, 27, 28]. However, considerable similarity of these results should be emphasized.

Conclusions

Based on the above, a statement may be made that the evaluation of the impact of vibrations during a motor vehicle ride on pregnant women, whose anthropological characteristics differ from those of other adults, is still an open issue.

The undertaking of research on the impact of vibrations on a pregnant woman riding in a motor car is fully reasonable from the point of view of both scientific exploration of this subject and practical effects produced by such factors on a baby in the womb. The minimizing of the loads caused by vibrations is an important task the vehicle designers must cope with. It should be remembered, however, that the construction of a vehicle that would be considered "good" in terms of the impact of vibrations generated during a vehicle ride and transmitted to vehicle occupants' bodies would not necessarily result in the obtaining of "optimum" running characteristics of the vehicle in terms of safety [35, 36].

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