Numerical modelling of occupational accidents caused by falls from a height

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Abstract

Falls from heights are among the most common events from approximately 90 thousand accidents at work which take place in Poland each year. Efficient prevention of this type of accidents requires broad knowledge with regard to their causes and process in order to conduct training courses for employees, develop better safety procedures and improve work organization. Reproducing the detailed course of a fall from heights is generally difficult due to insufficient information provided from the place of accident, usually leading to indication of a number of accident versions which are mutually exclusive, thus making it difficult to evidence fault during a court proceeding etc. In many fields of study, numerical simulation is used in similar cases to model the physical phenomena in order to reproduce their actual course in the function of time, e.g. numerical models of the human body are used to research and reconstruct road accidents. However, they are validated in terms of particular road incidents and are quite limited when it comes to using them for reconstruction of other types of accidents.

The aim of this study was to develop a numerical model of the human body useful for reconstructing accidents involving falls from a height. A thesis was adopted that numerical modelling will allow to conduct a cause and effect analysis for this type of accidents at work, which constitutes an improvement when compared with the methods used currently.

Developing a numerical human body model consisted in expanding and adjusting the existing human model, i.e. the *Pedestrian* (available in the MADYMO package database) for the purpose of work biomechanics, in particular falls from heights. To this end, it was necessary to develop the following:

- a numerical model of upper limbs with the possibility of simulating fractures,
- a numerical model of the head with a protective helmet,
- a set of initial conditions for simulating a fall from heights.

In order to develop the author's own model of the upper human limb, the meta-analysis method was used. The collected experimental data of research results available in scientific literature regarding forces and moments of forces where fractures of the humerus or the forearm bones take place, were used to build this model.

For the purpose of developing a numerical model of the head with a helmet, own experimental research was completed, applying an actual and commonly used industrial protective helmet as well as a head phantom of the Hybrid III dummy. The phantom with the helmet was dropped from various heights with measuring the acceleration of its centre of gravity.

In order to generate the initial conditions necessary to start simulation of the fall process, broad experimental tests (on a sample of 30 people) of the initial phase of a fall from heights were conducted. For this purpose, an own-design tilting platform was used, which when tilting, caused the tested people, who did not expect the above, to lose balance. The platform base where the tested people were standing, was located 40 cm above ground; the tested people wore a harness for working at heights with an attached securing line. To create the impression of working at a height, a method of immersive virtual reality was used. To this end, the tested people wore a Head Mounted Display where the virtual view was played, showing a perspective from a scaffolding platform located approximately 20 m above ground. The course of experiments was captured using the VICON system for 3D motion analysis. On the basis of the results, 28 sets of initial conditions were developed, which included reaction of the human to loss of balance.

Partial models of the upper limbs and head in a protective helmet were developed using the method of multibody systems. This enabled their easy implementation into the *Pedestrian* model. The initial conditions were incorporated into the *Pedestrian* model thus creating a hybrid kinetic and dynamic model for reconstruction of the initial phase of a fall. As a result, a new numerical model of the human body was obtained, which is useful for reconstruction of falls from heights, thus achieving the objective of this study.

In this analysis, a new model for reconstruction of an actual fall from heights was used. Among the 28 sets of initial conditions, the author used the set whose application enabled reconstruction of the most probable version of the event. Selection of the version consisted in comparing the reconstruction results with the information contained in post-accident documentation. The results, in the form of estimated injuries, correspond to the actual injuries suffered by a fall casualty. Thus, the thesis of the study was evidenced.

The analysis is concluded with a summary of the main results, and indication of the needs and perspectives for further research.