Influence of loading rate on strength characteristics of ultra high molecular weight polyethylene (UHMWPE)

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Abstract. Modern digital modeling of dynamic processes is impossible without verified models of materials. However, when creating a material model, it is necessary to consider the possibility of changing properties depending on the loading rate. In this paper we consider the influence of loading rate on the strength characteristics of modern polymer material – ultrahigh molecular weight polyethylene (UHMWPE).

1. Introduction

Nowadays, an important issue for the road construction industry and related fields is the enhancement of the road safety and counterterrorism actions. According to statistical data, in 2018, the monthly average number of road accidents is appr. 400-500 cases, the number of victims makes up appr. 7,000 persons, and the number of fatalities appr. 12,000 persons. These figures to a great extent (at least 70%) result from the absence of reliable safety systems (various guardrails) on roads or by totally absent guardrails, which is, first of all, caused by obsolete constructions, their material consumption and costs. This is also true for similar systems preventing intrusion into restricted territories, first of all terrorist intrusions; these systems also developed based on american models.

The use of digital modeling allows replacing of long and expensive field tests and accelerating of designing and implementation of modern constructions, as well as good understanding of and effective solving of road safety issues related to increasing of loads, traffic speeds, automation and implementation of intellectual systems for vehicle driving [1, 2]. The development of a reliable digital modeling system for crash situations occurred during car collisions with various-design and various-purpose road safety systems.

The developed, based on digital twins, of new systems using new materials and structures will allow designing of modern road safety systems, which will ensure rapid reducing of dangerous consequences of road accidents (zeroing of fatal cases) and prevent the vehicle intrusion into the restricted territories. However, the accuracy of conducted virtual experiments directly connected with the development of verified models both for whole constructions and for models of new materials [1, 2]. To obtain an accurate model of material, not only static, but also dynamic bench tests shall carried out, especially, bench tests required for the development of stress-strain diagrams for different loading rates [3-6].
2. Problem
This paper dedicated devoted to the investigation of the influence of loading rates on the strength characteristics of the modern, advanced material – UHMWPE, which is currently applied in many sectors [7-13]. UHMWPE mostly produced using two procedures: “dry-fiber” procedure, which ensures high strength characteristics, and solid-phase extrusion procedure, which provides high elastic properties.

This paper deals with specimens produced using the solid-phase extrusion procedure. The considered material has a number of performance properties [7, 11, 13], which can significantly improve the quality of the available constructions used for side feature systems, but the certification of new construction is directly connected with the conduction of new field dynamic tests involving vehicle collisions. To reduce certification material costs, virtual model experiments are useful, whereas for the development of verified models physical and mechanical properties of the material shall be determined, including obtaining of stress-strain diagrams considering dynamic loading.

3. Object of study and results
FE modeling is one method for solving engineering and research problems. The finite element model (FEM) used in the virtual test consists of a vehicle moving on a hard surface and a road fence being clashed with the vehicle (figure 3). The initial speed of the vehicle is 90 km/h, weight – 1200 kg, the angle of impact – 20°. The study carried out for flat UHMWPE specimens (figure 1, 2, 3). For their loading, a TIRA TEST 2300 multi-purpose test machine used. Based on conducted tests, the stress-strain diagrams for different loading rates obtained (figure 4).

![Figure 1. Test specimen (sketch)](image-url)
Figure 2. Test specimen

Figure 3. Test specimen (after test)

Figure 4. UHMWPE stress-strain diagrams for different loading rates
4. Conclusions
The analysis of the obtained results allows the following conclusions:
1. With increasing of the loading rate, the yield point rises from 16-17 MPa under static loading 20 mm/min to 20-21 MPa under loading 500 mm/min;
2. With increasing of the loading rate, the strength rises from 25-26 MPa under static loading 20 mm/min to 29-30 MPa under loading 500 mm/min;
3. During development of models of the virtual digital dynamic tests, the bench tests with the taking into account loading rates shall be carried out for the verification of the models.

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