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EVALUATION OF TRAFFIC DENSITY AND DYNAMIC PARAMETERS DURING VEHICLE COLLISIONS

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Abstract
This paper analyzes the relationship between vehicle traffic density and the dynamic parameters that arise during collisions. As traffic flow becomes denser, the likelihood of road accidents increases. Therefore, the study explores how key physical parameters—such as vehicle speed, acceleration, impact force, and deformation—are interrelated under varying traffic conditions. The research emphasizes the use of mathematical modeling and simulation techniques to closely replicate real-world scenarios. The findings provide a valuable scientific and practical foundation for enhancing road safety and developing technological solutions aimed at reducing the risk of vehicle collisions.

Keywords: Car collision, dynamic parameters, impact force, acceleration, deformation zone, passive safety, simulation, mathematical modeling, matlab/simulink, accident analysis, motion trajectory, traffic safety.

Introduction

The sharp increase in the number of vehicles in modern cities is leading to various problems in the traffic system, in particular, an increase in traffic density and an increase in road accidents (RAs). High density of vehicle traffic leads not only to traffic jams, but also to a decrease in driver reaction time, an increase in the likelihood of collisions and an increase in car accidents. This situation reduces the efficiency of the transport system, poses a threat to human life and health, and also leads to significant economic losses.

Dynamic parameters that occur during car accidents - for example, speed during a collision, impact force, acceleration and deformation levels - allow for a deep analysis of the physical nature of the event. It is by studying these parameters that it is possible to increase traffic safety, improve passive and active safety systems, and optimize traffic strategies.

Also, determining the relationship between the density of the flow of cars and the probability of collision plays an important role in traffic management and planning. Using statistical analysis, mathematical modeling and computer simulation, it is possible to predict dangerous dynamic situations that arise in cases of increased traffic density.

This article studies the interrelationship of the density of car traffic and dynamic parameters during a collision. The results of the study are of great importance in developing scientific and practical solutions aimed at a safer and more efficient organization of vehicle traffic, reducing the number of accidents on the roads, and increasing the stability of the transport system. The process of cars hitting fixed obstacles is covered in detail in scientific experiments. In particular, the mathematical model of the process of car collisions is expressed in the form of a law of change in the motion of elastic bodies with several degrees of freedom along the impact axis, and the contact force during the impact is shown as a function of the thickness of the cylindrical surface shell based on the Saint-Venant theory.

In real-life scenarios, when a vehicle unintentionally collides with road surface obstacles or roadside barriers, an impact force that reaches its peak value within a very short time interval is generated between the interacting objects. The direction of this impact force typically aligns with the vehicle's motion trajectory that leads to the collision.

If the obstacle is considered to be movable and not an absolutely rigid body, both the contacting parts of the vehicle and the elements of the barrier undergo deformation at the point of interaction. Additionally, various dynamic behaviors may occur, such as the displacement of the barrier along the direction of motion, its rotation around the center of mass, or even its deflection at a certain angle relative to the horizontal plane.

Thus, the maximum value of the impact force depends not only on the velocity of the moving object but also on the physical and mechanical properties of the colliding materials, as well as the nature of deformation and displacement. Accurate determination of the impact force magnitude enables the calculation of vehicle body structural strength and the design of automated safety systems that enhance operational safety.

In the study of traffic flow systems on roadways, one of the most important characteristics is traffic density. Traffic density is measured as the number of vehicles occupying a 1-kilometer length of a single traffic lane (vehicles/km). This indicator varies depending on the composition of the traffic, the speed of vehicles, and road conditions. For light vehicles, the maximum traffic density isv=0 km/h, while the optimal traffic density ranges from

25 vehicles/km.Transport oqimining zichligi oshib borgan sari transport vositalari oraliq masofasi kamayishi, tezlikning kamayishi hamda haydovchilarning psixologik ish rejimining qiyinlashishi umumiy yo‘l harakatining noqulayligiga olib keladi. Eng katta transport oqimining zichligi transport vositalarining to‘xtab qolish (“zator”) holatida kuzatiladi.

Tranport oqimining zichligi yuqori bo‘lgan paytlarda yo‘lning yuklanganlik darajasi ortishiga, shu bilan birga transport oqimining tezligini kamayishiga olib keladi. Bu xollarda tabiiy ravishda transport vositalaridan atrof-muhitga chiqayotgan ortiqcha zaharli moddalar soni kattalashishiga olib keladi. Transport vositalaridan chiqayotgan chiqindi gazlarning kamaytirishda transport oqimining zichligini kichik ko‘rsatkichga keltirish , buning uchun oraliq masofani saqlagan holda 40 dan 60 km/soatgacha tezlik bilan harakatlanishni ta’minlash kerak.

The purpose of conducting experimental observations on urban streets is to study the variation patterns of vehicle speed, to analyze how traffic density changes under different conditions, and to explore the interrelationships among the key characteristics of traffic flow.

Traffic density is also characterized by low travel speeds and irregular motion. To study traffic flow density, it is essential to investigate the influence of road conditions on density and to analyze the “speed–density” relationship.

Traffic density varies over time depending on the functional importance of the road. High traffic density values are most commonly observed on uphill gradients, near railway crossings, and on narrow streets within residential areas. As the intensity of movement increases on inclines, the density of the traffic flow also rises.

Before intersections, traffic density increases and reaches a peak level; however, it gradually decreases after the intersection as vehicles enter straight road sections. It has also been observed that traffic density tends to be higher approximately 150–200 meters after entering residential zones.

It has been determined that traffic flow density is more significantly affected by uphill road sections and sharp curves (with small radii) than by straight road segments. A diagram illustrating the variation of traffic density at different times on I. Karimov and Sh. Rashidov streets in Jizzakh city is provided.

Analysis of the graph shows that traffic density increases in proportion to traffic volume. When the traffic volume was at its lowest—2,725 vehicles/hour—the average traffic density was approximately 30 vehicles/km. Under similar road conditions, during other times of the day when traffic volumes reached 2,930, 4,300, and 4,600 vehicles/hour, the average traffic densities were found to be around 38, 40, and 43 vehicles/km, respectively.

At peak traffic volume, approximately 5,200 vehicles/hour, the highest observed traffic density reached around 48 vehicles/km.

Thus, it can be concluded that traffic density is closely linked to traffic volume. As traffic volume changes, so does traffic density. Moreover, it is evident that road conditions also significantly influence traffic density. Studying the characteristics of traffic flow is essential for ensuring road safety and for organizing effective traffic management.

Various scientific sources suggest different methods for assessing the technical condition of vehicles in motor transport enterprises. In our research, three evaluation methods were presented, and the operational performance of several enterprises was compared and assessed.

For this purpose, the second method—based on the age structure of the vehicles—is presented below. In this approach, the assessment is carried out using the actual values of the technical utilization coefficient and the theoretically derived values of continuous step size. This allows for the evaluation of the operational efficiency of motor transport enterprises.

To carry out such an evaluation, it is first necessary to provide information on the composition of the vehicle fleet within the compared enterprises, including vehicle types, models, and age distribution.

Conclusions

This study provides an in-depth analysis of vehicle traffic density and the dynamic parameters during collisions, aiming to understand the root causes and physical mechanisms of road traffic accidents. The results indicate that as the density of vehicle flow increases, the likelihood of collisions also rises significantly. Particularly in situations involving high-speed movement and insufficient inter-vehicle spacing, impact forces, abrupt acceleration changes, and deformation levels are more severe, leading to substantial harm to both human health and technical systems. The analysis of key dynamic parameters during collisions—such as impact force, velocity, acceleration, and reaction time—serves as a vital scientific basis for improving road traffic safety. Furthermore, the mathematical models and simulation results presented in the article yield realistic outputs and are of great practical importance. They can be effectively utilized in the fields of transport engineering, automotive design, road infrastructure planning, and the development of accident prevention strategies.

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Based on the research findings, it is recommended to maintain optimal traffic density, manage speed limits effectively, enhance vehicle safety systems, and implement automated control technologies to reduce the negative consequences of road accidents. Future research should focus on real-time data collection, AI-based analysis, and integration with autonomous control systems.

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