Review on the Morphological Visualization of Physical Marks for the Traffic Accident Collision Speed Evidence Analysis

Abstract  Road traffic injuries still remain an important public health problem at global, regional and national levels while the speed is an important determinant of injury. This paper describes retrospection and future trends in physical marks in traffic collision speed analysis. Traffic accident speed estimation methods such as skid marks, deflection, thrown distances, visual techniques, computer simulation and physical marks measurement techniques are briefly mentioned. A special attention has been paid to interface with surface morphological analysis and optical methods. Selected problems of visualization and collection are described. The effects of collision on the speedometers are analyzed alone. Since collision marks for speed analysis are becoming both technologically and theoretically critical, their description is a problem of a great practical importance. And it will provide a new train of thought to study this problem in an integrated way.

Keywords: Forensic science; Traffic accident analysis; Speed analysis; Collision marks; Interface; Visualization;

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1. Introduction

With the social and economic development and the sharp increasing in the number of motor vehicles, traffic accidents have become the world's largest public nuisance. And road traffic injuries still remain an important public health problem at global, regional and national levels. As a major cause of the death and disability [1], the road traffic crashes are of direct relationship with the speed. Since the speed is an important determinant of the injury [2], the faster the vehicle is travelling, the greater the energy inflicted on the occupants during a crash, and the greater the injury.

For protecting human body, the travelling speed should be limited [3]. For limiting the speed, laws have been made to ensure safety and pinpoint responsibility. While for pinpointing the responsibility, the ability must be improved to determine the speed more and more accurately in the traffic accident analysis. Each country sets its own speed limits, however, rates are similar. Currently, a lot of useful methods have been accumulated to estimate and determine the speed in the traffic accident analysis.

From a physical evidence view, it needs not only to find out effective ways to determine the accident speed, but also to assess the results for expert testimony. For casualty treatment and safety design of vehicles, speed analysis is important, while for forensic science, it refers to more complicated aspects.

Collision speed, especially in the serious impacting situation, is of close relationship with the deceleration. And for accident scene detecting, the mechanical properties of the interfaces are important for mechanical analysis, since it is meaningful for physical evidence verification.

With new techniques and theories coming forth, it impels to take review on these fields for speed analysis on the physical evidence view, which including the necessary brief retrospection of collision speed analysis especially the physical marks on the scene, and the resent results of original researches on the surface analysis and morphological surface collision marks visualization and collection in the traffic accident field. More problems have been suggested unsolved here, and more impact marks should be studied for the traffic accident injury treatment and the scene reconstruction.

2. Speed analysis

No matter you searching for the skid marks on the road [4], or the deflection of the vehicles [5], or taking calculation of the thrown pedestrian [6] or objects [7], like most police officers still relying upon, real conditions are more or less limited [8] to interfere the old traditional methods to be the optimal approaches in real cases. Therefore, new experimental methods [9], the image [10][11][12] and video [13][14] approaches and the computer simulations [15][16][17][18] have been suggested. These new approaches have indeed improved the accurateness of speed determination [19], but their uncertainties have been critically analyzed [20]. And more, how can all the roads be covered with video recorders? Or how can such costly equipments be bought by everyone to collect data for simulation? So, it still needs to find more simple ways to solve the problem.

2.1 Skid marks

A primary technique is the estimation of vehicle speed from the length of skid mark. The technique of calculating speeds of cornering vehicles from the curvature of their tire marks is widely used, although misgivings have been expressed over its accuracy, given the way that cornering ability depends on individual characteristics. Controlled crash tests had performed by various workers [21][22][23] show that the relationship between impact damage and impact velocity is a remarkably simple function, and more scientists described the techniques for using their data in the more varied conditions of real accidents.

Experiments [21] have been performed in a range of motor cars to explore these effects, to establish the accuracy of the technique and to draw up a set of guidelines for accident investigators. The conclusions are that the marks must clearly indicate side slipping and a degree of yaw by the vehicle; that the measurement of radius should be taken directly from the road surface; that only the first part of the mark (usually about 15 meters) need be measured; that the yaw of the vehicle should not be large; and that the speed so found should be reckoned as being that at the start of the
marks $\pm 10\%$. The characteristics of an individual motor car may affect its ability to achieve a particular lateral acceleration without loss of control, but not the speed indicated by its tire marks.

Vehicles decelerate between brake application and skid onset. To better estimate a vehicle’s speed and position at brake application, skid-to-stop tests [22] were performed from four initial speeds (20, 40, 60, and 80 km/h) using three different grades of tire (economy, touring, and performance) on a single vehicle and a single road surface. Average skidding friction was found to vary with initial speed and tire type. The post-brake/pre-skid speed loss, elapsed time, distance travelled, and effective friction were found to vary with initial speed. Based on these data, a method using skid mark length to predict vehicle speed and position at brake application rather than skid onset was shown to improve estimates of initial vehicle speed by up to 10 km/h and estimates of vehicle position at brake application by up to 8 m compared to conventional methods that ignore the post-brake/pre-skid interval.

While there has also been a line-based skid mark segmentation and measurement system to solve issues related to randomness from pavement texture and measurement subjectivity at car accident scenes. The system was designed to operate along the longer straight lines that exist in boundaries between skid marks and pavement at the scene of an accident. The operational system consists of two processes: preprocessing and feature extraction. Preprocessing steps include skid mark positioning, slope angle detection, and segmentation, whereas feature extraction involves detecting light striations, striation segmentation, and calculating the widths of striations from images. Some experimental validation and objective measurements [23] have illustrated that this system saves operation time and cost while performing with accuracy similar to that of manual methods.

2.2 Deflection

The structural-deformation inhomogeneity of the surface layer has been assessed by the method of scratching with recording the variations of the tangential force of resistance to the motion of the indenter [24]. For the depths of penetration of the Vickers indenter comparable with the parameters of surface roughness, the function has been used to describe the inhomogeneity of structural-deformation properties of the material along the scanning path without making into account the influence of the surface topography.

What's more, the energy absorbed in deforming a vehicle's structure in an accident often account for a significant fraction of its original speed. Some Controlled crash tests [25] performed by various workers have shown that the relationship between impact damage and impact velocity is a remarkably simple function, and the techniques have been described for using their data in the more varied conditions of real accidents. And the process of calibrating a tachograph (3.3) makes use of a mechanical head drive unit and an electronic clock tester. Both these devices should be checked against a standard at 6-month intervals. The design of such a substandard, based on a highly stable 1 MHz crystal oscillator, has been researched, too.

2.3 Thrown distances

For reconstruction of pedestrian–vehicle accident being a worldwide problem, numerous previous studies had been carried out on accidents with vehicular skid marks or definite pedestrian throw distances. However, little could be done if marks or throw distances cannot be obtained in accident reconstruction. And a team work [26] first described the physical model of dynamic process of pedestrian head impact on windshield glazing. Some simplifications have been made to obtain a better and more practical model, including discussing the support boundary conditions. Firstly, the work modeled the relations between pedestrian impact speed and deflection of windshield glazing based on the impact dynamics and thin plate theory. Later, the relations of vehicle impact speed and deflection were discussed. Therefore, a model of vehicle impact speed versus deflection of windshield glazing has been developed. The model was then verified by ten real-world accident cases to demonstrate its accuracy and reliability. This model has provided investigators a new method to reconstruct pedestrian–vehicle accidents.

2.4 Visualization

For visual techniques, some researchers [27] presented
measurements have been proposed. And for computer simulations, it has been presented a vehicle-to-vehicle distance and speed control algorithm [30] using an electronic-vacuum booster (EVB). The EVB has been used as a brake actuator. The performance characteristics of the EVB have been investigated via computer simulations and experiments. Mathematical models of the electronic-vacuum booster developed in the study and a two-state dynamic engine model have been used in the simulations. Linear optimal control theory has been used to design optimal acceleration for the vehicle-to-vehicle distance control. A throttle/brake control law has been proposed. The throttle/brake controller forces the vehicle acceleration to converge to the desired acceleration. It has been shown via the simulations and vehicle tests that the control law can provide a vehicle equipped with the electronic-vacuum booster with good distance control performance in both high speed and low speed stop and go driving situations.

2.6. Collision marks

Since the road scenes are so easily to be influenced by external conditions, that why not to find an approach directly to the core of the problem? Being part of the accident scene, vehicles can provide the information of the travelling and collision. And there indeed some experts set foot in. Some experts [31] [32] utilized the score mark or scratches on the tires or bodies of the vehicles to estimate the speed as shown in Figure.1.

Although they have solved the problem in a numerous and complicated way, it has been suspected whether they could reduce the amount of calculation work in practice. Theories of the physical evidence have suggested to find useful traces or impressions to identify things. It enlightened
a new direction to scan the problem of speed identification. As traces left on the road were no longer novelty, traces or marks on the vehicle body or fittings were novel for accident analysts.

In collisions where there is contact between a plasticized polyvinylchloride surface and a vehicle, characteristic marks [33] arising from the plastic are deposited on the vehicle. These appear as (a) a series of ridges and depressions with embedding plastic filaments, or (b) dispersed droplets along with brown mass. The corresponding features noticed on the plastic are (a) melting and marks of stretching, and (b) dark brown discoloration and cracked film structure. These marks are dependent on whether the deformation in the collision is either melting or thermal degradation. The occurrence of the marks from melting has been reported [34]. In a recent case, different marks, namely, dispersed droplets along with brown mass caused by the thermally degrading plastic were observed.

The appearance of either of these kinds of marks on the vehicle together with corresponding features on the plastic material constitute physical evidence of contact and can be used as proof of a collision.

3. Interface

3.1 Physical properties of the solid surface

Mechanical properties [35] which describe how a material behaves when forces are applied. They depend on its structure, the strength of the bonds, and the type and number of defects present. (1) Strength: A strong material has a high ultimate tensile stress i.e. a high stress is needed to break it. (2) Ductility: A ductile material can be drawn into wires. (3) Malleability: A malleable material can be hammered into different shapes. (4) Stiffness: A stiff material has a high Young's modulus, i.e. a high stress produces little strain. (5) Toughness: A tough material will deform plastically before it breaks. It is not brittle, i.e. cracks do not easily spread. Since surfaces vary, their physical properties are different.

Since the early 1960s, techniques for the study of surfaces on the molecular level, which have provided the foundation for the rapid evolution of surface science, have become available in ever-increasing numbers. In the interim period, surface science has emerged as the frontier area of molecular physical chemistry on a broad front, ranging from nanoparticle structures to biointerfaces and selective catalysis of stereospecific molecules and reactions, and to chemical energy conversion.

Nowadays, many application [36] of the newly acquired knowledge of molecular surface chemistry is used in innovative technologies relying on metal, semiconductor, and polymer surfaces in order to achieve controlled chemical bonding, adhesion, friction, electron and atom transport, solar energy conversion and selective catalysis. Therefore, the challenge of modern physical is to understand macroscopic surface phenomena on the molecular level.

For forensic purpose, it mainly focuses on the physical marks on the surface.

Surface wear has been conventionally characterized by two-dimensional approaches primarily because historically there was a lack of proper three-dimensional measurement techniques and effective characterization methods. In recent years, many advanced three-dimensional instruments [37] for surface topography measurement have become available. This has had the effect of stimulating the demand for characterization of surface wear through the three-dimensional techniques. Since there is no well-defined approach, some researchers [38] have aimed to initiate an integrated approach based on three-dimensional techniques to the characterization of surface wear. The methods and techniques used in the qualitative characterization have been presented and described in conjunction with discussions of experimental results. Since qualitative characterization does not require relocation techniques during surface measurement and tribological testing, it is simpler and more economical to use. Furthermore not only is the proposed approach effective in surface wear characterization, but also it would be useful as a guideline to assist the functional design of surfaces.

Roughness is, among human sensations, just as fundamental as color or pitch, or as heaviness or hotness. But its study had remained in a more primitive state, by far. The reason was that both geometry and science were first drawn to smooth shapes. Thus, color and pitch came to be
measured in cycles per seconds, that is, have been reduced to sinusoids, in other words to uniform motions around a circle – the epitome of a smooth shape. A study of roughness had necessarily to wait until specific mathematical tools had been discovered and, much later, suitably interpreted. Fractal geometry began when it reinterpreted the flight from nature that had led mathematicians to conceive of notions like the Holder exponent, the Cantor set, or the Hausdorff dimension. They boasted of these notions being ‘monstrous’ but in fact it turned them over into everyday tools of science. It also added further tools that – taken together – made roughness quantitatively measurable for the first time. Acquiring a quantitative measure is the step that moves a field into maturity. And this move instantly led to a striking conjecture. The traditional measures of their roughness ranged all over. To the contrary, their fractal roughness varies very little not only between samples but also between materials. It checked the “universality” had been extended but not explained. The new intrinsic measure created a major intellectual mystery. The first major new tool that added to those contributed by the likes of Holder, Cantor, and Hausdorff was multifractality, for both measures and functions.

It was motivated by the urge to model the intermittence of turbulence but also noted that the same techniques ought to apply to the intermittence in the variation of financial prices. It found unexpectedly quantitative truth to this adage by showing that both phenomena can be tackled with essentially the same tools. Roughness is everywhere therefore fractal geometry has little fear of running out of problems. It will sketch the fractal geometry of roughness and explore some new developments relevant to this field.

While for the fractal theory of roughness stand among the other branches of physics, quantitative measures of mass and size came early and mark the dawn of history. Visual signals led very early on to the vocabulary of bulk and shape, and of brightness and color; auditory signals, to the vocabulary of loudness and pitch, and to scales known to musicians since time immemorial. However, optics and acoustics did not fully arise as sciences until two hundred years ago, when concrete notions represented by ancient words were made quantitative, for example, when color and pitch could be measured by frequencies. Similarly, the first step in the theory of the perennial sensation of “hot” was well-recorded by history. It was the ‘invention’ by Galileo of the notion of bodies of uniform hotness, together with a proper intrinsic quantitative measure of hotness: the temperature.

Judged against this background, the sense of smooth vs. rough, which is a priori equally essential, remained in a primitive state. To accomplish this has been an awesome and humbling privilege.

Previously, the notion called either roughness or volatility was measured by a mean square deviation from a ‘norm’. For fluctuations in a perfect gas in equilibrium, this measurement happens to be formally proportional to temperature. But in the context of roughness or volatility, it proved an inappropriate borrowing. Instead, starting almost from scratch, it had to create a new tool-box specifically geared towards the study of forms of roughness that possess certain geometric scaling invariance. For each invariance intrinsically introduces one or more numerical invariants, it has reinterpreted one as the first of many quantitative measurements of roughness. Later, many additional intrinsic measurements were also brought up by fractal and multifractal geometry; it even made a set’s ‘degree of emptiness’ into a concrete and useful notion.

More generally, in the long road from raw sensation to science, a key moment has been marked by the successful identification of a proper ‘compromise’ between simplicity and breadth of applicability. Fractal dimension is the first agreed-upon quantity able to measure pure roughness the way temperature measures uniform hotness. This is analogous to the question of applicability of the notion of a system of uniform temperature. A growing and long list of widely diverse examples shows fractal or multifractal forms of roughness/fragmentation to be ubiquitous to an extraordinary degree in nature and culture. Specific applications cannot be discussed here further but the early illustrations of a multifractal measure have provided excellent models of the variations on financial prices and on the internet.

A co-existence emerges in physics, between the usual smooth or smoothly varying phenomena, and the fractal
ones. This raised a general issue. In responding, it has observed that numerical solutions of very familiar partial differential equations easily yield close approximations to fractals. For example [39], this happens under new but natural conditions that include movable singularities or boundaries. They occur for the Laplace equation in the case of interacting galaxies under Newton attraction, and for diffusion-limited aggregates. Solving the usual partial differential equations of physics can yield either the familiar and expected smoothness, or fractality.

3.2 Forms of surface collision

An excimer laser (KrF) operating at a wavelength of 248 nm has been used to modify the surface microstructure of 7075-T651 aluminium alloy. The aim was to improve both the corrosion resistance and the pitting corrosion fatigue resistance of the alloy by means of laser surface melting (LSM). The microstructure and the phases of the modified surface structure have been analyzed, and the corrosion behavior of the untreated and the laser-treated specimens were evaluated by immersion test. The fatigue resistance of the 7075 alloy has been presented in the form of S/N curves.

A microscopical examination and the transmission electron microscopy (TEM) study [40] have revealed that LSM caused a reduction both in number and size of constituent particles and a refinement of the grain structure within the laser melted zone. As a result, the corrosion resistance of the aluminium alloy has been improved. There was a significant reduction in the number of corrosion pits and shallow attack occurred. The fatigue test results showed that under dry fatigue conditions, the total fatigue life of the laser treated specimens, in which the crack initiation period is of considerable significance, was lower than that of the untreated specimens. However, after shot peening, the fatigue life of the laser treated specimens was recovered. This was primarily attributed to the elimination of surface defects, but also be in part, due to the introduction of compressive residual stresses in the surface layer of the specimen. The fatigue resistance of the shot peened laser-treated specimens, tested in 3.5 wt% NaCl solution with 48 hrs prior immersion, was greater than the untreated specimens with an increase of two orders of magnitude in fatigue life. This was primarily due to the elimination of surface defects and the reduction of corrosion pits.

The problem of surface instability of a right circular cone with an arbitrary opening made of a hexagonal single crystal (the cone axis coincides with the crystal's axis of isotropy) has been investigated. The surface of the cone is free from normal and tangential stresses, but in the layer near the surface initial constant tensile or compressive stresses act in the hoop direction and in the direction of the cone's generators. Surface instability is analyzed by the use of weak nonstationary disturbances which propagate along the surface of the cone in the form of the two types of surface waves: the nonstationary Rayleigh waves polarized in the sagittal plane, and the nonstationary wave of the whispering gallery type polarized perpendicular to the sagittal plane. The weak nonstationary surface waves are interpreted as the lines of discontinuity (diverging circles) on which partial derivatives of the stress and strain tensor components with respect to coordinates and time have a discontinuity, but the components of these tensors are continuous. Each of the lines of discontinuity propagates with a constant normal velocity along the cone's surface in the direction of its generators and is obtained as a result of the exit onto the cone surface either of two conic complex wave surfaces of weak discontinuity intersecting along this line (Rayleigh wave) or of one real conic wave surface of weak discontinuity (wave of the whispering gallery type). The analysis [41] has been carried out within the framework of the theory of discontinuities based on the kinematic, geometric and dynamic conditions of compatibility; using them the velocities of the surface wave propagation and their intensities have been found. It has been shown that the surface wave velocities are dependent only on the initial stress acting in the direction of the propagation of a surface disturbance whereas the damping coefficients for the intensities of the surface waves are dependent not only on this stress but also on the initial stress acting in the hoop direction as well. The relationships for two critical magnitudes of the force compressive in the hoop direction have been obtained, and it has been shown that under the hoop compressive forces in excess of one of these magnitudes the intensity of the Rayleigh wave or the surface.
wave of the whispering gallery type begins to increase without bounds during its propagation, i.e., the surface of the cone loses stability with respect to either of two types of weak nonstationary disturbances.

The atomic force microscope (AFM) [42] was used to monitor changes in surface features of an acrylic melamine coating that was exposed to a variety of conditions. Exposure to ultraviolet (UV) radiation and high relative humidity caused general roughening of the surface and the formation of pits. Further, the damage of the coating surface was much more substantial for exposure to high relative humidity compared to exposure to dry environments. This difference in degradation rates correlated with measurements of chemical degradation determined using infrared spectra that were acquired along with the AFM images.

For a variety of products, presenting different industrial sectors, the quality of the product surface is quite often an important factor. The product surface may go through a sequence of finishing processes in order to improve the surface quality. Thus a very smooth punch surface is usually required for optimum tablet making. In the case of cellular phones high quality plastic covers are obtained using electro-discharge machining for injection mold surfaces. Plastic melt copies the mold surface and if wanted a relatively rough surface matte can be obtained. However, the tool is subject to wear and may cause local surface quality variation in the plastic product during a long duty cycle of the tool.

It is obvious that in some sectors of the industry [43] there is a desire to get as smooth a product surface as possible, whereas in some other sectors a relatively high surface roughness is the measure of the quality of the product. A common factor for all such industrial branches is to get information of the surface roughness of the product, and also on the finishing marks and their orientations. The role of the manufacturing process and, for instance, the condition of the tool has great importance in finding the optimal process in order to gain optimal product surface condition. Optical measurement techniques for ultra smooth surfaces are of great importance especially in the optimization of the surface quality of devices based on semiconductors and other high tech products.

Chemical mechanical polishing (CMP) process is commonly regarded as the best method for achieving global planarization in the field of surface finishing with ultra-precision. The development of investigation on material removal mechanisms for different materials used in computer hard disk and ultra-large scale integration fabrication are reviewed [44]. The mechanisms underlying the interaction between the abrasive particles and polished surfaces during CMP are addressed, and some ways to investigate the polishing mechanisms are presented.

The surfaces of polybutadiene rubber (BR) and styrene-butadiene rubber (SBR) subjected to different degrees of abrasion have been specially studied [45] by scanning electron microscopy (SEM). In the case of SBR it has been shown that abrasion begins with marks in the direction of rotation which are followed by fine ribbing and then by the formation of coarse, angular and prominent ridges. Prolonged abrasion produces folding and cavities on the surface. This change in abrasion mechanism has been explained as a result of heat build-up and high crack growth rate in SBR which occur beyond a certain stage. These help in softening the matrix and removing the surface. On the other hand, fractured surfaces of BR show that ridges begin to form at about 250 revolutions and there is no characteristic difference between the abraded surfaces at lower or higher degrees of abrasion.

With the application of the photogrammetric analysis of microphotographs obtained with the help of a scanning electron microscope to the evaluation of the sizes of three-dimensional objects on anisotropic surfaces., the surface of a sintered carbide (WC + TiC + Co) subjected to electrochemical grinding and the surface of an abrasive diamond strip was studied [46]. The analysis of stereo pairs for different inclination angles of the surface makes it possible to reproduce the stereometry of objects formed after treatment for different anodic polarizations and pressure and determine the roles of the electrochemical and mechanical factors.

The causes of foxing, a rust-red spotting of engravings, books and archive documents, are not yet completely understood, but they are usually ascribed to mould growth.
and/or heavy-metal-induced degradation of cellulose and sizing materials. In the present work [47] some experts reported the use of attenuated total reflection Fourier transform infrared spectrometry, image analysis and atomic force microscopy as non-destructive tools for the surface analysis of foxing stains in respect of their chemical and physical characteristics.

An abelian differential on a surface defines a flat metric and a vector field on the complement of a finite set of points. The vertical flow that can be defined on the surface has two kinds of invariant closed sets (i.e. invariant components) — periodic components and minimal components. Some researchers [48] have given upper bounds on the number of minimal components, on the number of periodic components and on the total number of invariant components in every stratum of abelian differentials. These bounds are tight in every stratum as shown in Figure 2.

![Figure 2. A genus 3 flat surface with three invariant components in H (2, 1, 1). The boundary of M1 is a slit with identified points. The boundaries of M2 and M3 are slits [48].](image)

Surface acoustic wave (SAW) devices can be turned into identification and sensor elements, so called SAW transponders. Identification elements transmit an individual ID number and sensor elements measure physical quantities such as temperature, pressure, torque, acceleration, humidity, etc. The SAW devices do not require any power supply and may be accessed wirelessly. The complete sensor system consists of such a SAW transponder and a local radar transceiver (reader unit). An RF burst transmitted by the radar transceiver is received by antenna of the passive SAW transponder. The passive transponder responses with an RF signal, like a radar echo, which can be received by the front-end of the local transceiver. Amplitude, frequency, phase and time of arrival of this RF response signal transmit information about the SAW reflection and propagation mechanisms which in many cases can be directly attributed to the sensor effect for a certain measurement value. Due to the high delay time of the SAW transponder in the order of a few microseconds, usually no intersymbol interferences due to environmental reflections occur when the system operates in harsh indoor/outdoor environments. The functional principles of such wireless SAW transponder systems and the reader systems have been pointed out [49], including the design requirements for SAW transponders, such as identification tags and radio sensors, several application examples and their state-of-the-art performances.

In addition, multi-process textures are very important from functional point of view. Various methods of their description have been compared [50]. Surface texturing as a means for enhancing tribological properties of frictional pairs started to be extremely popular from for about last 10 years. The effects of surface texturing on improving tribological properties of sliding assemblies have been analyzed.

For cutting marks, fossil bones from the Lower Pleistocene site of Venta Micena bear cut-marks in a small proportion of specimens, similar to that of bones with cut-marks at East African sites at Olduvai and East Lake Turkana. Cut-marks are distinguishable [51] from other surface marks in terms of metrical characteristics, anatomical location, grouping, and microscopical characteristics, particularly those such as microstriations which may be observed with the scanning electron microscope.

3.3. Tachographs

Considering the practicability and universality, one thing in vehicle was never worthy to be thought highly but of close connection to speed and never to be concerned by researchers or analyzers. This was the speedometer. We have neglected the speedometer in accident analysis from its born to now. We all knew its function of telling travelling speed during the driving, but few of us thought of its function of recording the instant speed value trustily at the moment of collision in the evidence way.
R. F. Lambourn, who had researched the traffic accident speed analysis for decades. He not only researched the tyre skid marks on the road, but also the tachographs.

A tachograph is a device that combines the functions of a clock and a speedometer. Fitted to a motor vehicle, a tachograph records the vehicle's speed and whether it is moving or stationary. The mechanical tachograph writes on a round piece of paper which constantly turns throughout the work day. The marker moves further from the center the faster the vehicle is moving. An entire rotation encompasses 24 hours.

Analogue tachographs record the driver’s periods of duty on a waxed paper disc. However, these are vulnerable to tampering, and so are being replaced by digital tachographs which record data on smart cards.

Tachographs are also used to improve road safety and ensure fair competition. They are also used in the maritime world. Rules for this are made by the Central Commission for Navigation on the Rhine.

Apart from enforcing regulations, tachographs are often used in Germany to investigate and punish speeding. This practice was approved by the German high regional court in the 1990s. Also, after an accident, the discs are often examined with a microscope to discover the events that took place at a collision site.

But the situation is, the tachographs are not commonly in each country. So the methods can provide us a novel idea of traffic accident analysis in speed estimation but of no practical use in real cases.

4. Visualization and collection

For visualization, optical properties are important because they provide a nondestructive means for identifications and are responsible for all the features one immediately observes and admires including color, luster, brilliance, scintillation, and dispersion, as well as special phenomena, plays of colors, labradorescence, and the like. In the last decades, studies focus on the fluorescence techniques such as multi-band light waves, and spectroscopic methodology.

For color, the photography is important to collect the data. And morphological analysis provides tools on this problem to do further studies.

The visualization usually involves in the latent marks, and there is the chemical etching technique. Viewed under an optical microscope, the microscopy technique relevant to SSTND observations [53] has been described: light and dark field illumination, transmitted and reflected light, contrast enhancement techniques, special devices, etc. Starting from this basis a study of each step is undertaken: conception and description of various etching baths, nature of the etchant according to the detector structure, influence of the etching parameters such as concentration, temperature, time, stirring, and influence of interruptions in the process and of the reaction products. Peculiar methods such as TINT [54], TINCLE [55], perforated detectors [56], multilayer detectors [57] and thin foil techniques [58] have been described in the history.

There were others dealing with the so-called decoration techniques, namely, silver chloride crystals [59], fluorescent and/or dyed detectors [60], silver precipitation in glasses [61]. The latter is just mentioned whereas the two former techniques are described in more detail: the working principles are explained from the theoretical point of view,
the technological behavior and properties of those detectors are described together with their possible applications.

With the development of researching, the use of “mixed techniques” forms the conclusion of the part on track revealing, until eventually, the use of the transmission and stereo electron microscopes [62] was considered and the specific fields of application of these techniques are reviewed.

Two important kinds of surface collision marks have been studied for the decades. One is scratches on the tires which have been discussed formerly, while the other is needle marks by mechanical press which will be discussed later.

A collection method is a built-in function or procedure that operates on collections and is called using dot notation. You can use the methods EXISTS, COUNT, LIMIT, FIRST, LAST, PRIOR, NEXT, EXTEND, TRIM, and DELETE to manage collections whose size is unknown or varies.

But the practical methods used in the surface marks collection still focused on the optical ways especially by camera.

5. Discussion

5.1 In mechanical identification methods
(1) In theory, search for the mechanical tools to solve speed calculation problem;
(2) In the actual identification, when there is no skid marks, new methods should be found to solve the problem;
(3) A theory of uncertainty calculation on speed should be developed.

5.2 In the computer simulation
(1) Develop new simulation models based on the original model, to improve their accuracy and computational speed operation;
(2) Develop a practical application of modern automotive simulation software.

5.3 Surface analysis
The multidisciplinary and complicity of cause the difficulties of surface collision marks analysis.

Within the analysis of many frictional contact problems Coulomb's law [63] with a constant friction coefficient $\mu$ is used. This assumption is sufficient for many applications in structural mechanics; however in the special case of rubber friction on rough surfaces the resulting simplification cannot be accepted. The physical interactions between e.g. a tire and a road surface are very complex and still widely unknown. The elastomer undergoes large deformations during contact, such that the frictional properties result for the main part from internal energy dissipation and not just from the combination of surfaces in contact like e.g. adhesion. As it is apparent from experiments, the friction coefficient depends heavily on various parameters like sliding velocity, surface roughness, normal forces and temperature change. In this contribution a multi-scale approach will be used to make an attempt to understand the sources of elastomeric friction in a more rigorous way.

5.4 Speedometer marks
There are two kinds of speedometer. One is mechanical, and the other is electronic. In this research, it studies only about the former one.

For the mechanical speedometer, on the basis of the Locard's Exchange Principle [64], the needle marks have been found to be a kind of physical evidence in some reports [65] and thought of limited use in speed analysis but without experimental studies on the details. In this study, it brought forward two hypotheses.

The first hypothesis is:
The tip of the needle may leave marks on the faceplate surface nearby the scale of the speedometer during the collision;

while the second hypothesis is:
The middle part of the needle may leave marks on the faceplate surface of the speedometer during the collision.

Based on the laboratory impact system and mechanical analysis, the first hypothesis and half of the second hypothesis had been proved. As the needle of the speedometer was resting like a cantilever beam above the speed scale, when collision happened, its tip might hit the faceplate surface, and left marks like the finger print. Analyzers could take use of these marks, as shown in Figure 4, to determine the collision speed directly from the scale.
More can be studied on this subject of collision marks for speed analysis, since it is useful both for collision accident analysis and impact injury treatment.

Figure 4. The middle characteristic (light source: white, incidence angel of 15°) of needle marks (80 km/h) on the gauge plate of the mechanical speedometer from the real case.

6. Conclusions

Speed analysis techniques have been developed into a new period of elaboration. And more can be studied on this subject of collision marks for speed analysis, for it is useful both for collision accident analysis and impact injury treatment. Since the mechanical speedometers have been universal in the traffic system, and the optical and camera techniques have been developed into the microspur, the collision marks on speedometer would be a new direction for the speed analysis. And the electronic speedometers have been gradually spread in the world. This will open a new period of elaboration. And more can be studied on this subject of collision marks for speed analysis, for it is useful both for collision accident analysis and impact injury treatment.

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