ACTA TECNOLOGÍA

electronic journal
ISSN 2453-675X
Volume 1
Issue 2
2015

International Scientific Journal about Technologies

CONTENTS
(DECEMBER 2015)

Acta Tecnología - International Scientific Journal about Technologies
Volume: 1 2015 Issue: 2 Pages: 1-4 ISSN 2453-675X

PEDESTRIAN SAFETY AT CROSSINGS

Pavol Kajánek
Výskumný ústav dopravný, a.s., Veľký Diel 3323, kajanek@vud.sk
Roman Ondrejka
Výskumný ústav dopravný, a.s., Veľký Diel 3323, ondrejka@vud.sk

Keywords: crossings, pedestrian's safety, road marking

Abstract: The article deals with the evaluation of selected pedestrian crossings in terms of their functional parameters. Road safety is still a highly debated issue in all countries with a developed automobile transportation. Risk are the group of participants, with a team that drivers and passengers in motor vehicles are more or less protected by the vehicle itself, cyclists and motorcyclists are partially protected for example, helmet. But pedestrians are not protected at all. Thus pedestrian is the most vulnerable road users. In Slovakia, die each year from an average of 200 pedestrians. The most frequent causes of pedestrian accidents are the entrance to the roadway approaching the motor vehicle from the sidewalk and miscalculation when passing communication.

1 Introduction

Road safety is still a highly debated issue in all countries with a developed automobile transportation. Risk are the group of participants, with a team that drivers and passengers in motor vehicles are more or less protected by the vehicle itself, cyclists and motorcyclists are partially protected for example, helmet. But pedestrians are not protected at all. Thus pedestrian is the most vulnerable road users.

On the road in Europe die each year more than 8,000 pedestrians, of which every fourth accident happens at a pedestrian crossing over a road [1].

In Slovakia, die each year from an average of 200 pedestrians. The most frequent causes of pedestrian accidents are the entrance to the roadway approaching the motor vehicle from the sidewalk and miscalculation when passing communication.

Recently in the media withstand criticism on the quality of horizontal road signs (VDZ) on pedestrian crossings. Especially in winter they are very slippery, possibly they are so worn that they are almost not visible on the road [2].

2 Requirements for road markings

Materials for road marking are in accordance with the Act no. 133/2013 Z.z. construction products. On the Slovak market may be mentioned only product that meets the requirements of this Act and the relevant standards, namely:

- STN EN 1436 + A1: Materials for road marking of roads,
- STN 01 8020: Traffic signs on the road.

Before placing a product on the market, the manufacturer must ensure that the assessment of functional parameters. The evaluation and verification features VDZ and the materials used in their manufacture is carried out in test laboratories and test section according to EN 1824: Materials for road marking of roads [3], [4].

Road signs produced on the highway by the test material is measured and evaluated local color, VDZ reflection in daylight and / or the path and retroreflectivity. These parameters are measured the new road marking and road marking after test on the test section according to EN 1824 [3], [4].

Samples of various types of material are applied to the test section in the dosage indicated by the manufacturer or importer. The dosage was given for materials for the production of road marking materials and for the additional gritting. The test section in accordance with DIN EN 1436 + A1 and EN 1824, the following functional parameters measured by the CGI made from the material:

- Coefficient of retro-reflection R_L dry or wet;
- Luminance factor in diffuse light Qd;
- Color: β coefficient luminance and the chromaticity coordinates *x, y*;
- Slip resistant - the value of SRT;
- Removability (only removable - ready-made materials);
- Index wear.

Materials intended for road markings have all the time trials (one year) meet the requirements of the standard STN EN 1436 + A1 and STN 01 8020 / Z2.

Currently, the production of longitudinal road signs most commonly used include the following materials:

- Material which is applied in liquid form, such as the color or the color of synthetic water-soluble;
- Thermoplastic materials, i. j. material blocks, granules or powder which are heated up to melt the hot-melt and be surface travel;
- Cold setting materials (cold plastic), that is Two-component materials in liquid, pasty or solid form,

which are applied to the road surface after mixing the components in the prescribed ratio;
- Ready-made material applied to the road surface by means of heat, pressure, adhesive, or other means.

For road signs additional scattering is used glass beads, antiskid aggregates or a mixture of glass beads and anti-slip additives. Initial type testing of glass beads and anti-skid additives used the production of road marking are in terms of technical specification STN EN 1423 [1], [4].

Granularity (particle) glass beads and anti-skid additive is reported as the rest of the detainee% test sieves of metal wire cloth ISO 2591-1 [1].

This test assesses the specal categories glass beads applied to improving the properties thereof. The resistance to water is assessed in accordance with Annex E, flotation coating of Annex F in EN 1423. Bonding and any other coatings for glass beads are tested by test method agreed between contractors and building authority [1], [4].

Additional gritting VDZ must be tested together with the material to which they will be in the production of road marking apply [1], [4].

Road signs produced on the highway by the test material is measured dimensions and geometric accuracy, which must meet the requirements of Art. 5.2, 5.3 and normative Annex C; STN 01 8020 [1].

The visual appearance is evaluated VDZ a distance of 1.5 mA determine if they are exactly VDZ enclosed and has a monolithic surface without bubbles and cracks and seamlessly peeling. In the production of the VDZ It establishes the thickness of wet and dry deposition under Art. 6.2.6 in STN 01 8020 [1].

It should be stressed that SK - certificate of conformity is only material and not made horizontal traffic sign. The quality of the material for road markings and the manufacturer is responsible for the quality produced horizontal road signs contractor responsible brand [1], [4].

Figure 1 street Tvrdého

Figure 2 street Orolská

Figure 3 street Veľká okružná

Factory production control is permanent internal control of production by the manufacturers, which ensures that the production of materials for the production of CGI was in compliance with the Act. 133/2013 Z.z. and technical specifications. Monitoring compliance and effectiveness of factory production control system applicable producer performed by an authorized person as initial inspection and continuous surveillance. requirements the FPC system is in § 12 of Act no. 133/2013 Z.z. [1], [4].

The purpose of the initial inspection is to establish whether the manufacturer is creating an effective internal control and they are created by organizational and technical preconditions for sustainable maintenance of quality of production material for the production of road marking. Within the framework of assessing is the initial inspection and factory production control, relating to the production of material for the production of road marking. Result initial inspection and assessment of the effectiveness of factory production control shall include in a written report, which it shall also indicate whether the application of internal control is trustworthy and whether it is consistent with the Act. 133/2013 Z.z. and the technical specifications. Initial inspection is generally performed at the start of manufacture of construction products [2], [3].

For ongoing inspections is to monitor whether the application of internal control of the manufacturer, during production of material for the production of road marking in accordance with the Act. 133/2013 Z.z. and the technical specifications and that the manufacturer has complied with the measures imposed by the authorized person during the initial inspection or during previous interim inspections. Running inspections are carried out on the basis of a written report of the initial inspection deadlines as planned continuous surveillance by an approved person. Between two continuous surveillance shall not be more than 12 months. Running inspections are performed outside the plan: - Upon notification of a change in the manufacturer's production, - Based on the shortcomings identified in the activities of continuous surveillance of factory production control or control by market surveillance authorities in the quality of the material for the production of road marking [2], [3].

The contents of each interim inspection shall be stated in a written report. If during the interim inspection that uses a system of factory production control is not consistent with the Act. 133/2013 Z.z. and the technical specifications and deficiencies can not be removed on place the authorized person shall request the producer to them within the specified time limit. After a specified period conduct further continuous surveillance, primarily aimed at controlling removal shortcomings. If during the interim inspection that the manufacturer fails to correct irregularities, authorized person initiates proceedings for revocation of the certificate of conformity and notified body of state control of the internal market, the declaration of conformity by the manufacturer is in breach of a designated technical specification. The manufacturer is obliged to immediately inform the authorized person of any changes in production technology material used for the production of road marking or in the raw materials and intermediate products, which may affect the properties or quality of the material for the production of road marking [2], [3].

3 The quality of markings depends on many factors:

Type of paint. The most commonly used synthetic and water based paints. The disadvantage of these materials is their short lifetime, ie period in which to meet the required performance parameters according to EN 1436 + A1 and STN 01 8020 / Z2. The passages are subject to the double wear. One is the wear that occurs the passing vehicles and the wear caused by the pedestrians themselves.

The roughness is ensured in the first place to the additional scattering material (glass beads, glass beads, and the mixture additives), although higher roughness of the marking are obtained by using materials with a certain extra scattering portion roughen ingredients. Another factor influencing this parameter is the roughness of the substrate - the road.

This fact is especially important in restoring signs of color when the horizontal road sign applied to existing data center marking layer that reaches the surface roughness of communication. Especially at road crossings cover a relatively wide area VDZ, where especially in bad weather (rain, snow and frost) is created for pedestrian's risk of slipping and injury.

Most synthetic substances used for CGI has a low slip properties. On SK - certificates indicated that they cannot use the materials themselves, but only with additional sanding - glass beads or anti-skid aggregates. In practice, this figure is not respected and in order to save the cost of marking is used without an additional coating material spreading.

Application of climatic conditions (air temperature, substrate temperature, relative humidity, etc.). Producers in their data sheets report the optimum application conditions to be met. The surface must be dry, clean and free of oil. Track temperature must be above the dew point.

Method of application. Machinery systems have different application materials to the additional scattering. Both in terms of kinetic energy and the adjustment of dosing of consumables. Simple machinery to adjust the amount of material per unit area of only approx. The amount depends on the working speed of the machine, the additional scattering material is added is integrated and free-of paint only to the force of gravity.

For use, the currently used devices that meet the highest requirements - automatically adjusting the amount of paint, the amount of glass beads, and the pressure adjustment in which the glass beads applied to the label. The type of glass beads. The level of retroreflectivity is substantially affected by the incorporation of sufficient material to glass beads.

Effect of a type used glass beads, material properties and technology applications. When applying glass beads it can be built into the material either only through its gravitational energy or kinetic energy for interaction.

It has a great influence and size of individual beads of glass beads. Smaller balls are in a 'sunk', while larger diameter balls will be mounted only a small part of its surface, which will result in their crumbling and subsequent loss of retroreflective road marking and roughness.

The quality of the road surface and its maintenance. The quality of markings affects road roughness, depth textures, potholes, cracks, a sign of old balances. Maintenance of way - the type and quantity of spreading material, maintenance roads snow plows, conditions of application, etc.

Traffic volume. The traffic is intense, the more wear occurs VDZ. It has a great influence traffic intensity especially trucks [2], [3].

Acta Tecnología - International Scientific Journal about Technologies
Volume: 1 2015 Issue: 2 Pages: 1-4 ISSN 2453-675X

Figure 4 street Milcová

Figure 5 street Tvrdého

4 Conclusions

Functional requirements of pedestrian crossings shortly after application conform to STN 01 8020. Their quality with time is rapidly declining in case of paints. Already after a month and a half since applications road markings do not meet parameters - slip resistance and retroreflectivity.

When deciding what kind of material on road markings used for the application of pedestrian crossings principals have several options. The purchase price is in most cases a decisive parameter, but it is important to take into consideration other parameters such as material quality, durability, price maintenance, usability and disposal. These parameters may be incurred in the future to reduce costs.

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Acknowledgement
The article was elaborated during the implementation of project Research Centre of the University of Žilina - ITMS 26220220183, funded within the Operational Programme Research and Development.

Review process
Single-blind peer reviewed process by two reviewers.

MATHEMATICAL MODELLING WITHIN THE ROAD SAFETY MANAGEMENT

Roman Ondrejka
Veký Diel 3323, Výskumný ústav dopravný, a.s., ondrejka@vud.sk
Lenka Moravčíková
Veký Diel 3323, Výskumný ústav dopravný, a.s., lenka.moravcikova@vud.sk

Keywords: modelling, road, safety, management
Abstract: The precondition for effective management of road safety on the part of the road administrators is a thorough and correct identification of sites with increased frequency of accidents on individual sections of the road network. The adequacy of identification results from the application of such specific methodologies, which will allow to reveal sites with a high rate of local risk factors with the potential to cause collisions in road traffic and thus appropriately allocate adequate funds to remove them. Besides the empirical statistical records, one of reliable methods for the identification of potential black spots is also the mathematical modelling of adverse events on individual road entities and their subsequent estimation in terms of probability of occurrence in the future. The application of the method described in the article allows, following the discovery of a causal link between the frequency of accidents and their consequences and possible risk factors concerning the nature of traffic, to identify potential black spots without the necessity of reporting high accident rate in the past.

1 Identification of sites within increased accident rate

Identification, analysis and evaluation of the black spots on the road network and the intervention through the adoption of appropriate measures are one of the key tasks of road managers in relation to the road safety improvement. On one hand, it is the responsibility of the manager to create conditions for reduction of the number of potentially negative events in the form of road accidents through the elimination local risk factors and on the other hand to create conditions locally in the form of adopting effective measures preventing the occurrence of these events with consequences for the life and health of road users [1,2].

Currently, there are several approaches in the area of determination of sites with increased frequency of accidents that vary in data, time and computational complexity as well as in the identification reliability. In general, these approaches can be divided into those, whose identification is based on empirical data on accidents from the past and those, whose identification on the site under consideration is based on the expected number of traffic accidents or their consequences at the given site in the future [2].

From a theoretical perspective, for the assessment of the suitability of the applied approach it is necessary to consider, whether the used method eliminates the influence of random fluctuations in the recorded number of road accidents or their consequences on the overall assessment of the section as a site with an increased occurrence of accidents or consequences in terms of fatalities or health damage. Elimination of this systematic error within the determination of black spots is possible only through targeted inquiries and demonstration of causal relationships between traffic accidents and local conditions. They are represented through a wide range of factors related both with the traffic itself and with the construction and technical conditions of considered road entity [3].

In case that the causal relationship of accidents with some indicators is identified on a specific road segment, resulting in higher expected number of accidents or their consequences as is the case at similar sites in the future, it is necessary in the next step of the management of the identified black spots to quantify these local risk factors and to take measures to improve the safety at the given site to an acceptable level expressed by a reasonable level of accidents or their consequences [2,3].

2 Application of mathematical modellingi n the identification process

Within the evaluation of the current safety level of individual road entities, i.e. road sections, intersections and level railway crossings, it is necessary to not only consider the recorded number of accidents, thus not only what happened on the entity in the past, but also of what will happen, i.e. the expected number of accidents or their consequences in the future. It is necessary to build upon this basic premise when deciding, what methods to apply in order to reliably identify sites with increased frequency of accidents.

Safety defined in this manner should be explicitly modelled mathematically, allowing the application of theoretical knowledge about the so-called Bayesian methods. These represent advanced mathematical - statistical evaluation methods, which are based on the basic premise that empirical data in the form of e.g. total number of accidents at a particular road section, or a number of accidents with certain consequences, or the number of persons with specific consequences for life and health are a discrete random variable with a value of an unknown parameter expressed by means of a probability distribution.

The value of an unknown parameter, a random variable, is actually based on the statistics of traffic accidents managed by the Presidium of the Police Force of the Slovak republic - Department of Traffic Police, presently through the Road Accidents Information System (ISDN). The main difference with the simple procedure of determining the critical value based on the cumulative probability of a certain level of significance, utilized presently for the identification of black spots by the Slovak Road Administration, is that the mentioned variable is acting as a dependent variable in a certain mathematical formulation of a set of independent variables.

The principle of modelling of safety on road entities, i.e. road sections with length of 0.5 or 1 km, or three-way or multi-way intersections, or level crossings of the road with the railways, should be based on two basic input assumptions. The first one is the frequency of accidents expected on the entities with the same characteristics, i.e. attributes that act as exogenous in developed models, i.e. explanatory variables. In case of road sections it is concerning for example the daily traffic volume, type of area (rural area, urban area), percentage of heavy vehicles, the vertical alignment slope, radius of horizontal curves, etc.

In the case of intersections it as also concerning the daily traffic volume, type of area, the number and hierarchy of gateways, share of vehicle types, type of traffic control (traffic rules, traffic signal system) and other. For railway crossings, such attributes include mainly the intensity of train traffic, traffic volume on intersecting road, security level, i.e. installed level crossing protection system (mechanical, lighting), number of tracks, etc.

The second, equally important prerequisite for modelling is the frequency of accidents on the assessed road section or intersection for a period of one, two or three years. The Decree of the Ministry of Transport, Construction and Regional Development No. 251 of 2011 also suggests considering all traffic accidents occurring on the relevant entity for the last three years. It also indicates the method of classification of identified black spots by:

- ✓ quantified social costs associated with accidents,
- ✓ severity of accidents,
- ✓ functional class and category of road,
- ✓ capacity of road and traffic volume,
- ✓ conclusions of Cost-Benefit Analysis of the countermeasure implementation.

The resulting estimate of safety is subsequently determined by the quality of the estimated mathematical model of independent variables in the form of a safety function, which is then used for calculation of the share of the modelled safety component in the total amount of the safety on a section, intersection or level railway crossing in the future, usually for the next three years.

3 Calibration of safety regression models

The starting point for determination of the current level of safety is the calibration of safety functions in a form of mathematical formulations of behavioural patterns of the dependent variable, in this case, the number of accidents on individual entities, the frequency distribution of which we assume has the character of a negative binomial distribution. This assumption can be verified by the calculation of a so-called empirical distribution compliance testing with estimated theoretical distribution at the selected level of statistical error. Since this variable will be modelled using regression, the validity of this assumption will be verified by the significance of the developed model, which requires the random variable represented by the number of traffic accidents to be distributed by the negative binomial distribution.

The general form of prediction models of accident rate can be expressed as a function of:

$$E(Y_i) = f\{x_i, \beta_j\} \tag{1}$$

In our case, we consider the function in a form of a correlation of relative change in the number of road accidents from absolute change in explanatory risk factors. The form of the negative binomial regression model can then be written in the following matrix form:

$$\vec{y} = X\vec{\beta} + \vec{\varepsilon} \tag{2}$$

where $\vec{\mathbf{y}}$ is a n-dimensional column vector of observations of endogenous variable, i.e. number of road accidents in the form of a logarithm on the entities i = 1,2,3, .. n, $\mathbf{X}$ is the matrix of observations of explanatory variables, i.e. individual characteristics of entities, the vector $\vec{\boldsymbol{\beta}}$ is a column vector of unknown parameters of the model and $\vec{\boldsymbol{\varepsilon}}$ is the n-dimensional vector of random disturbances that meet the assumption of distribution normality. Then the Log-linear model for the mean value η_i is as follows:

$$\ln(\eta_i) = x_i^T \beta + \varepsilon_i \tag{3}$$

Random failure ε_i has an expected value of zero, constant variance and each is generated independently, which means that the residual variations are not mutually autocorrelated.

4 Estimation of model parameters by means of log-likelihood function

In the following interpretation we are going to omit the stochastic errors and work only with the deterministic form of the model in the following form:

$$E(Y_i \mid x_i) = \eta_i = \exp(\beta_0 + \sum_{j=1}^{n} x_{ij}\beta_j) \quad (4)$$

where $E(Y_i \mid x_i)$ is modelled mean value of the number of accidents expected on the entity i (concerning road sections per unit length) over a time period of model calibration, x_{ij} in a form $x_{i1}\ldots x_{in}$ are the values of characteristics, independent variables of individual entities within the same time period, β_j is the intercept or else a level constant, which may not be explicitly estimated in each model coefficients and coefficients $\beta_1\ldots\beta_n$ are parameters of explanatory variables estimated by the model.

For the negative binomial distribution with a mean value η_i and the dispersion parameter ϕ is the vector of unknown parameters β, mean values η_i, also known as $\hat{y}_i$, i.e. estimated values of the number of road accidents to the actual number of accidents y_i, together with dispersion parameter $\hat{\theta}$ obtained by maximizing the so-called log-likelihood function $\ell(\boldsymbol{\beta},\theta)$ in the form:

$$\ell(\boldsymbol{\beta},\theta) = \sum_i \left\{ \sum_{r=1}^{y_i-1} \log(1+\theta r) \right\} - y_i \log(a) - \log(y_i!) +$$
$$y_i \log(\theta\eta_i) - (y_i + \theta^{-1}) \log(1+\theta\eta_i) \quad (5)$$

Maximum likelihood estimation $(\hat{\boldsymbol{\beta}},\hat{\theta})$ can be achieved by maximizing the function $\ell(\boldsymbol{\beta},\theta)$ with regard to β and θ. Then the associated relations are:

$$\frac{\partial \ell(\boldsymbol{\beta},\theta)}{\partial \beta_j} = \sum_i \frac{(y_i - \eta_i)x_{ij}}{1+\theta\eta_i} = 0 \quad (6)$$

for $j = 1,2,\ldots n$ and

$$\frac{\partial \ell(\boldsymbol{\beta},\theta)}{\partial \theta} = \sum_i \left\{ \sum_{r=1}^{y_i-1} \left(\frac{r}{1+\theta r} \right) \right\}$$
$$+\theta^{-2} \log(1+\theta\eta_i) - \frac{(y_i + \theta^{-1})\eta_i}{1+\theta\eta_i} = 0 \quad (7)$$

By means of the maximum likelihood method the estimates $(\hat{\boldsymbol{\beta}},\hat{\theta})$ can be obtained simultaneously, whereby the mentioned computationally demanding process includes sequential iterations. In the first sequence at the initiation value θ i.e. $\theta_{(0)}$ through maximizing $\ell(\boldsymbol{\beta},\theta)$ with regard to β we get the estimate of β_1 In the second sequence at β fixed at value of β_1 the maximization of $\ell(\boldsymbol{\beta},\theta)$ with regard to θ we obtain the value $\theta_{(1)}$. Through the iterative procedure and cycling between the used fixed value θ and the used fixed value β we get by maximum likelihood estimates $(\hat{\boldsymbol{\beta}},\hat{\theta})$. Currently, this calculation is facilitated by computer equipment using appropriate mathematical software.

Obtained estimates of the parameter θ and of the parameter vector β need to be tested for the statistical significance at the respective selected level of significance. It is also necessary to verify the significance of the model as a whole through the Pearson χ^2 test at respective degrees of freedom for the selected statistical error. In case of compilation of multiple models, it is possible to assess obtained maximized values of credibility functions as well as auxiliary assessment criteria such as Akaike or Bayesian information criterion. We are not specifying the principle of the test of significance of variable parameters or the model as a whole, as it is often a part of the output sets of computer software products. The estimated equation, as a function of characteristic variables and some regression parameters then indicates the average frequency of accidents on entities of given type per calibration period.

The resulting safety function can be applied for the calculation of safety for a given set of entities with the same or similar characteristics. The calculated value in the form of the number of road accidents per one year is the mean value of the frequency on a given road section, intersection or railway crossing at individual values of input variables for each entity.

In this way we obtain deviation of the actual number of accidents from the modelled mean values, i.e. from the expected level of safety for entities with the same or similar characteristics. In the Bayesian estimation by the function of the frequency of accidents, the obtained difference represents the proportion of the local risk factors on the accident in the locality. By means of relevant mathematical and statistical formulas it is possible from the estimated frequency of accidents to express the expected proportion of accidents with consequences, and based on the estimated number of fatal, serious and minor injuries to express the amount of the expected social losses resulting from road accidents on individual road entities. After subsequent implementation of adequate measures from the side of the manager of the respective road aimed at the reduction of accidents, it is possible, after calculation of implementation costs, to express the effectiveness of invested public funds through the cost-benefit analysis.

5 Conclusions

The proposition of sophisticated methods and procedures applied in the area of road safety management increases the demands on the work procedures of road managers in the process of credible identification of sites with an increased occurrence of traffic accidents. The need for systemic change in performance of this process is highlighted not only in the mentioned Decree of the Ministry of Transport, Construction and Regional Development of the Slovak Republic No. 251/2011 on details concerning safety management on roads, but also in the EU Directive 2008/96/EC on road infrastructure safety management, regulating procedures within the implementation of safety inspections, where it recommends to take into account the attributes of roads as well. Currently, Výskumný ústav dopravný (Transport Research Institute, Inc.) develops a software solution for decision support for road managers in the process of identification of black spots, as well as in the process of implementation of the safety countermeasures. The purpose of the software tool is not only an address but mainly an effective use of funds allocated for the improvement of safety on road infrastructure in Slovakia.

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Acknowledgement

The article was elaborated during the implementation of projects University science park ITMS 26220220184, funded within the Operational Programme Research and Development.

Review process

Single-blind peer reviewed process by two reviewers.

OPTIMIZATION OF THE PRODUCTION PROCESS OF THE PLASTIC INJECTION MOLDING ENGINEERING WITH THE TECHNOLOGY OF REVERSE ENGINEERING APPLICATION

Michal Balog
Faculty of Manufacturing Technologies with a seat in Prešov, Technical University of Košice, Bayerová 1, 080 01 Prešov, Slovakia, michal.balog@tuke.sk
Miroslav Maľcovský
Faculty of Manufacturing Technologies with a seat in Prešov, Technical University of Košice, Bayerová 1, 080 01 Prešov, Slovakia, miroslav.malcovsky@tuke.sk

Keywords: reverse engineering, plastic injection molding, scan, NURBS
Abstract: The publication focuses on the issue from the field of reverse engineering. The theoretical introduction contains basic information from the reverse engineering and describes the process of reversing as such. It consists of the procedure of component production, its calibration and setting the device used for reversing, scanning of the given object, scanned data connection, creation of 3D model of scanned data and evaluation of divergence of the modelled sizes in comparison with the real sizes of the component. The basic anticipated benefit from the implementation of reverse engineering application is obtaining 3D data from real components and their further using in creating the molds for plastic injection.

1 Introduction

Today, the reverse engineering in the field of engineering industry offers many ways of use. The main reason for this is the fact that reverse engineering functions as an intermediate step towards obtaining models and missing 3D data for further processing and use in production process where it can be optimized. Obtained 3D data can be used in the creation of construction and technological documentations; it speeds up the production process and actual finalization of the construction of molds for plastic injection.

The time needed for making the construction of the product is a significant indicator of a successful production company. From the given 3D model, shape particles are created to make the form and reach the accurate dimensions in tolerance of a pressed part which has a particular function. The companies offering construction molds for plastic injection also offer service and reparation of the molds. If a customer requires a repair of some shape particle consisting of different 3D shapes which are hard to measure just with the optical gauge without using the 3D coordinate measuring devices, the reverse engineering is applied to obtain a particular shape used for subsequent scanning and getting the 3D model.

2 Characteristics of reverse engineering

The reverse engineering (RE) has its origins in the analysis of hardware for commercial or military purposes. The aim is to deduce the procedure of the original production from the final design of the product based on a small amount of information or no information at all. The same techniques are examined and used in software to replace inaccurate, incomplete or otherwise unavailable documents.

It is necessary to obtain NURBS (Non-uniform rational basis spline) surface from the given model that can be further processed in CAD/CAM/CAE software. Physical object is measured by 3D scanning technology like CMM, laser scanners, digitizers or industrial CT scanning devices. The obtained data is represented usually as clouds of points, triangular nets, NURBS surfaces or CAD model.

3 Characteristics of reverse engineering

Many factors affect the quality of scanned objects. They are:

- Scanner and scanning technology used in RE
- Projector, its settings and calibration
- Camera, its settings and calibration
- Surface of the scanned object
- Size of the scanned object

OPTIMIZATION OF THE PRODUCTION PROCESS OF THE PLASTIC INJECTION MOLDING ENGINEERING WITH THE TECHNOLOGY OF REVERSE ENGINEERING APPLICATION
Michal Balog; Miroslav Mal'covský

Figure 1 The projector and camera calibration with laser scanner DAVID

During the calibration, it is important to pay attention to the appropriately chosen calibration area according to the size of the component and the distance and scanning angle of the scanned object, to get the best scanned data possible (Figure 1). These are later connected and create required output in the OBJ format. Angle between the camera and the projector should be between 15° and 25° (max. 10° - 35°) (Figure 2). The smallest calibration area is used for scanning the component details to obtain a detailed scan.

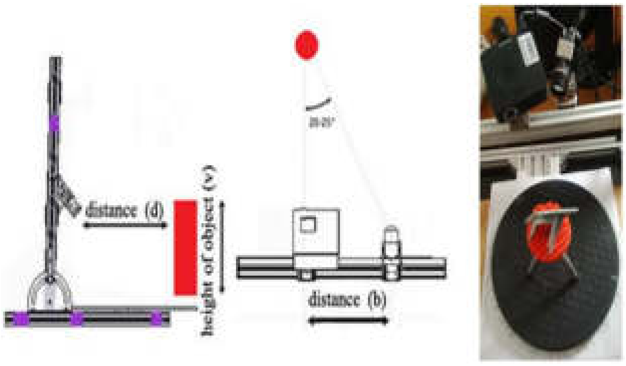

Figure 2 Process of scanning model [4]

Orientation settings of the scanned object are shown in the following table (Table 1).

Table 1 Orientation settings of the scanned object

Height of object (v)	**Calibration area**	**Distance between lenses of camera and projector (b)**	**Distance between object and scanner (d)**	**Possible achievable accuracy (approximately 0.1% of object size)**
<30 mm	30 mm	cca. 60 mm	cca. 90 mm	< 0.05 mm
50 mm	60 mm	cca. 60 mm	cca.120 mm	cca. 0.05 mm
70 mm	60 mm	cca. 65 mm	cca. 180 mm	cca. 0.08 mm
90 mm	120 mm	cca. 80 mm	cca. 220 mm	cca. 0.01 mm
120 mm	120 mm	cca.110 mm	cca. 300 mm	cca. 0.013 mm
150 mm	120 mm	cca. 125 mm	cca. 350 mm	cca. 0.15 mm
200 mm	240 mm	cca. 160 mm	cca. 450 mm	cca. 0.2 mm
300 mm	240 mm	cca. 250 mm	cca. 700 mm	cca. 0.3 mm
500 mm	240 mm	cca. 400 mm	cca. 1200 mm	cca. 0.5 mm
Normal values	**About the objects**	**Angle between them 15°-25°**	**Object should fill the camera screen**	**about 0,1% of scanning object**

It is necessary to adjust the surface of the object while scanning by spraying a layer of light and matte colour, so that the scanned area is transferred to the software in the best way possible. The ray can reflect from dark and shiny surfaces and scan the object imprecisely. The individual scanned areas are one by one cleaned from redundantly scanned parts in the object surroundings that are used for its attachment and are afterwards connected either by automatic rotation functions and individual edges recognition or by manual turning of the models to required position and creating a tie by using the texture of details alignment and they create the whole object represented by NURBS surface (see Figure 3 and Figure 4).

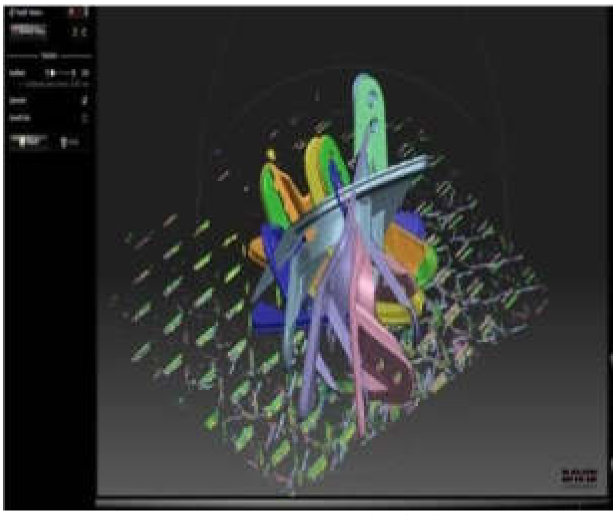

Figure 3 Sequential connection of individual NURBS surfaces

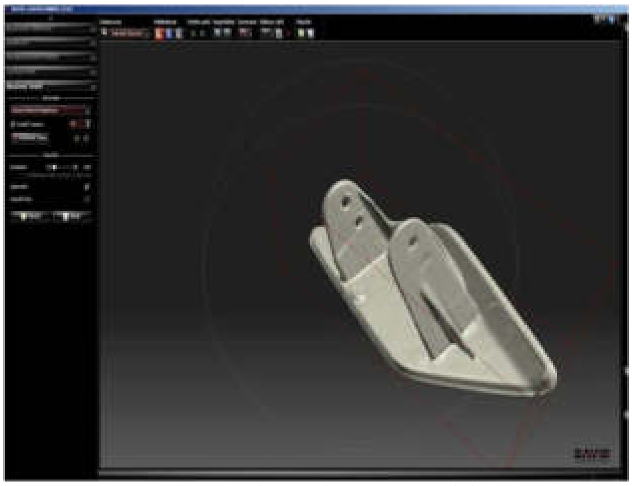

Figure 4 The final NURBS model

NUBS surface is then saved in .OBJ or .STL format and imported to CAD software where it is used as a base for constructing a specific 3D model. Construction is executed by the functions which the software offers through domains creation, cuts through surfaces, sketches of individual levels of the object and smoothing of the surfaces. A model created in this way can be used for further drawings or technological operations for CNC machining.

While creating a model via the technology of reverse engineering, 100% accuracy is never guaranteed and also in this case, at final comparison of the 3D model and the model from scanner, divergences of 0,1% of the components size occurred as guaranteed by the manufacturer (Figure 5, Figure 6).

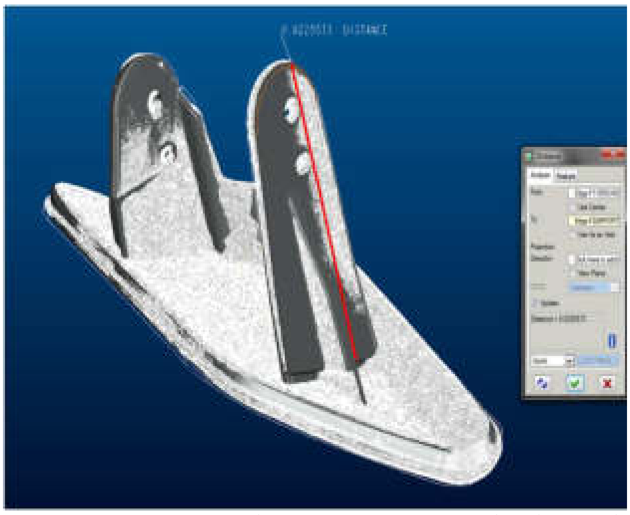

Figure 5 Comparison of divergences from scanned and created 3D model

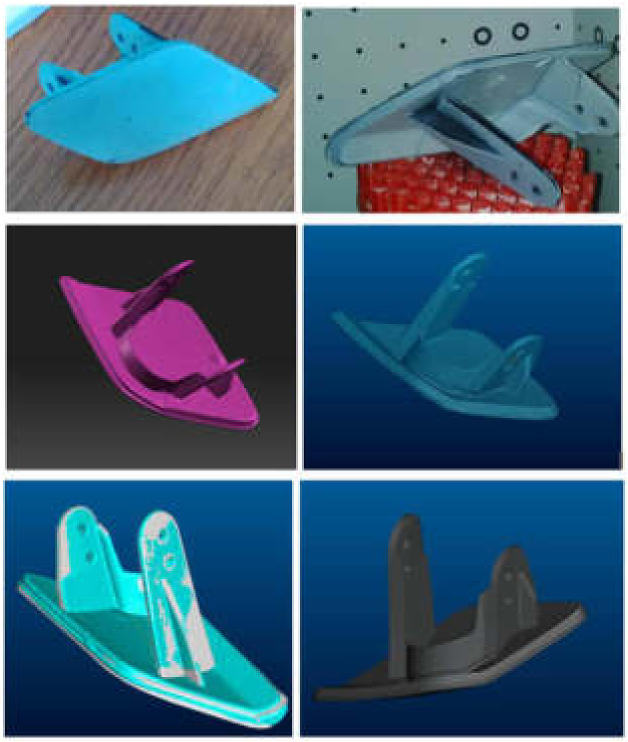

Figure 6 Progress of reverse engineering from real object to created 3D model

Conclusion

Many manufactures want to use modern, innovative technologies and resources for development and rejuvenation of their manufacturing process from the initial idea to the final product given to the customer. One of the methods of speeding up the 3D model creation and drawing the manufacturing process for its improvement is the technology of reverse engineering

Considering the price/performance ratio, laser scanner DAVID, is one of the best options of how to to introduce the department of reverse engineering into the factory and use it to improve the manufacturing process for those components which lack the 3D documentation. With the right settings and calibration of camera and projector and quality scanned real model, obtained 3D data with the divergence of 0,1% of the components size are used as a foundation for further construction and technological processing.

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Review process

Single-blind peer reviewed process by two reviewers.

JOURNAL STATEMENT

Journal name:	**Acta Tecnología**
Abbreviated key title:	Acta Tecnol
Journal title initials:	AT
Journal doi:	10.22306/atec
ISSN:	2453-675X
Start year:	2015
The first publishing:	October 2015
Issue publishing:	Quarterly
Publishing form:	On-line electronic publishing
Availability of articles:	Open Access Journal
Journal license:	CC BY-NC
Publication ethics:	COPE, ELSEVIER Publishing Ethics
Plagiarism check:	Worldwide originality control system
Peer review process:	Single-blind review at least two reviewers
Language:	English
Journal e-mail:	**info@actatecnologia.eu**

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Publisher:	**4S go, s.r.o.**
Address:	Semsa 24, 044 21 Semsa, Slovak Republic, EU
Phone:	+421 948 366 110
Publisher e-mail:	**info@4sgo.eu**

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