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Zagadnienia wybrane

Praca zbiorowa pod redakcją

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MECHATRONIC STAND FOR VEHICLE HEADLIGHTS GEOMETRY CORRECTNESS MEASUREMENT

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ABSTRACT

The aim of this paper is to present the existing solution for mechatronic stand for vehicle headlights geometry correctness measurement. The paper includes the information about the mechanical solution of the stand as well as the description of the image processing part. In the beginning of the paper the theory of vehicle headlights geometry is described. The paper also contains the review of already patented solutions of stands where the geometry correctness measurements are possible. The End Line Project measurement stand is described in details as the individual solution. The results of laboratory work and the real stand working solution are also presented in this paper.

1. Introduction

Proper behavior of the vehicle light and signaling installation are important for road safety [1]. Effectiveness of light performance depends on their normal installation, the proper use and handling. In the process of installation usage, maintenance is particularly important apart of the diagnostic tool research. Requirements of the state law regards only the new devices. The regulations describe technical conditions of registration including: the type, amount of lights, color and visibility [1]. All of the lights installation of each vehicle compose on of the elements of the electric installation of vehicle. Main task for vehicle lights are:

- Ensure the road traffic safety;
- Control of the mechanisms action;
- Ensure the ride convenience.

1.1. Polish and European Homologation Law

The measurements of the vehicle headlights geometry is a crucial way of fulfilling the Polish and the European standards regarding the homologation law of vehicle headlights [2]. The standards constitute fully described restrictions on the vehicle headlight geometry. The homologation of new headlight pattern can be given, if new element obey all of the statements of European or Polish Homologation Law. None of the new vehicle headlights will be able to pass the homologation procedure, while the safety terms and conditions are not applied. Further on we will show the proper geometry for different bulb type in vehicle headlight.

1.2. Existing solutions for headlights geometry measurements

Patent and literature researches showed that the subject is widely developed in the industry. Authors selected most significant patented solutions which shows different approach to build automatic control stand. All of the stands are stationary benches and the only difference between the is the kind of vehicles they can perform measurements on.

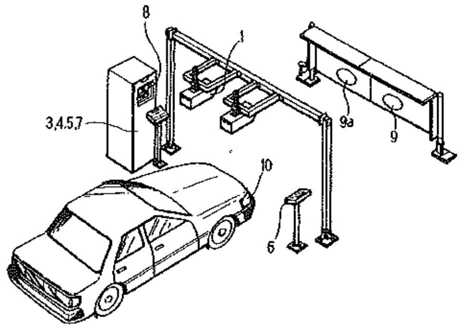

Fig. 1. US5379104 Method of, and apparatuses for, detecting optical axis of headlamp

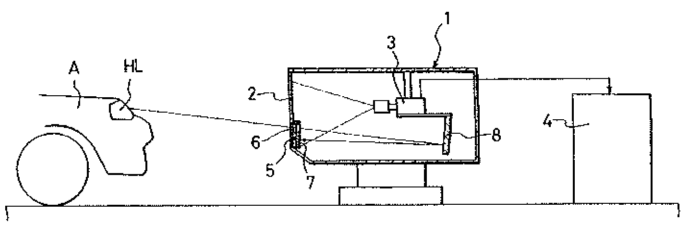

Fig. 2. US5504574 Measuring apparatus for adjusting optical axis of headlights and method of adjusting of optical axis

Patents US5379104 (Fig. 1) and JP61017933 (Fig. 3) describe measurements stands equipped with measurement screens and camera system for acquiring images of projected headlights geometry [7, 8].

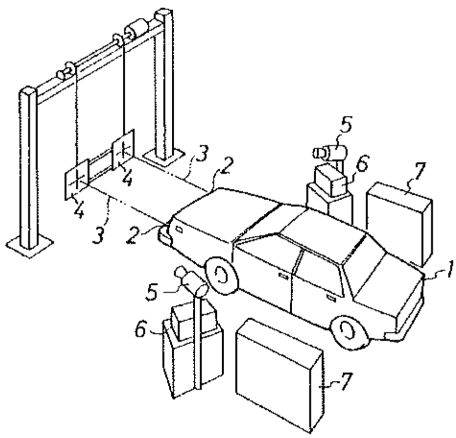

Fig. 3. JP61017933 Adjusting device of fitting position of headlight

Computer systems are used for image processing and analysis of acquired in the process of measurement images. Measurement results are presented on the computer monitor. US5504574 (Fig. 2) patent describes system equipped with classical projector used in actual passenger car service station and camera, which observe the projection of the vehicle headlights [9]. Measurements are processed and analyzed with the computer system.

2. Theory of measurements

The light geometry correctness measurements can be simple described by following sentence: 'The boundary between light and shadow should be clear enough to distinguish illuminated part of measurement screen from not illuminated part'. Light properties assessment is based on a particular measurable quantities. Those are distance between vehicle headlights and the measurement screens and the geometry given in distances and angles such as:

- Height of the light base line;
- Angle of inclination of the second line.

We can distinguish two different vehicle headlights geometry:

- Case 1: H1, H2, H3 halogen bulb;
- Case 2: H4 halogen bulb.

Above cases should not be mixed.

For reflectors with halogen bulb of H1, H2 or H3 boundary line on the left-hand side of the *v-v* axis on the screen should be horizontal. On the right-hand side of the v-v axis the boundary line should not cross the line 0-$h3$ inclined by 15° to h-h axis (Fig. 4).

For reflectors with halogen bulb H4 boundary line on the left-hand side of the v-v axis on the screen should be also horizontal. On the right-hand side of the v-v axis the boundary line should not cross the broken line consisting of 0-$h1$ inclined by 45° to h-h axis and the $h1$–$h4$ line parallel to the v-v axis (Fig. 4). In none of cases the boundary line should be junction of two cases listed above.

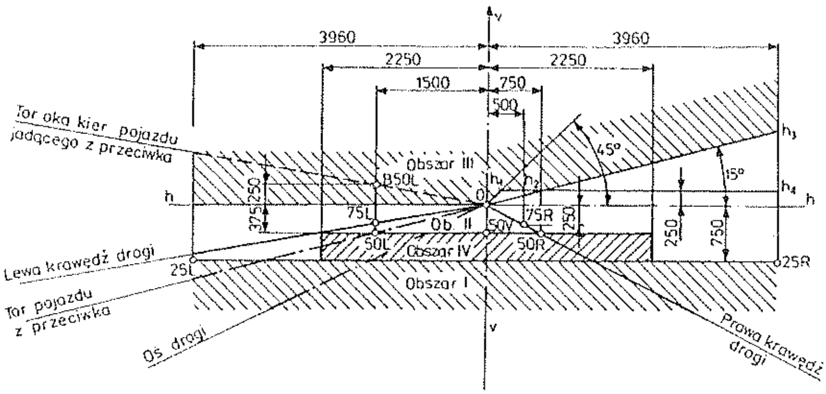

Fig. 4. Headlights geometry cases

3. Method and vision system concept for End line headlights geometry measurements

The concept of the stand is a mixture of sensors, digital cameras, and the automatics device which combined give us working and self-analyzing mechatronic stand.

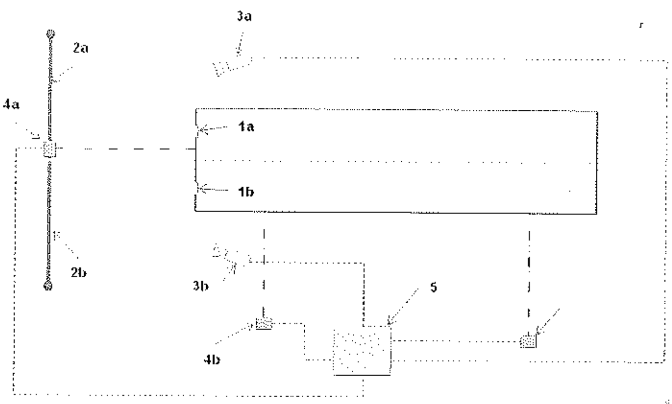

Fig. 5. Concept of the End Line stand [10]

There is five main components of the stand, apart from the vehicle, which are crucial in the stand. All of them are shown in the Fig. 5 and below we can see the descriptions of all of them:

1. Vehicle headlights – necessary for the measurement;
2. Measurement screens – the light form vehicle headlights is projected on the screens. They enable us to the digital image of the lights geometry;
3. CCD digital cameras – they are responsible for making the vehicle headlights geometry photos;
4. Ultrasonic distance sensors – measure the distances between some of the points of the stand and the measured vehicle. They give us the information about the position of the vehicle regarding the measurement screens. Some other parameters for the image processing can be chosen correctly than;
5. PC – the calculating unit enables us to do the image processing of the conciliated photos.

The whole process of stand performance can be visualized in following algorithm:

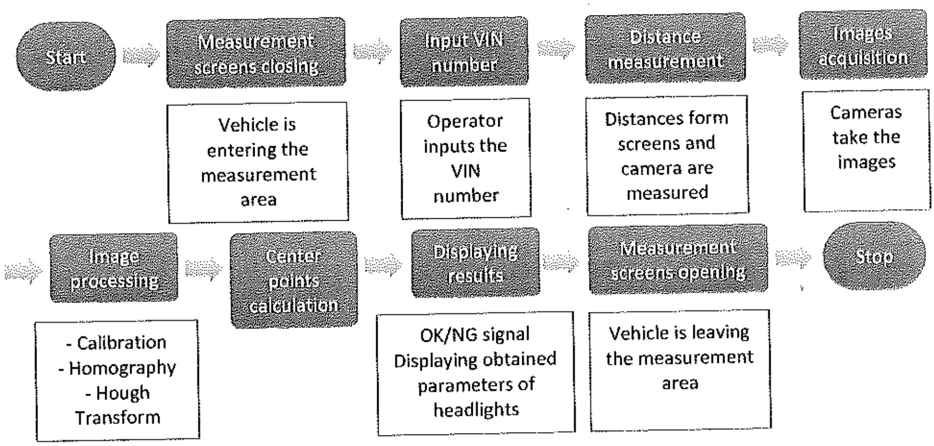

Fig. 6. Algorithm of measurement process for real end line testing of headlight geometry correctness

4. Image processing for the stand requirements

The image processing applied in the measurement stand can be divided in four parts and is shown as follows.

4.1. Calibration and distortion removal

Camera calibration is a process of determining a 3x4 matrix, called the projection matrix P, which is a mapping from 3D coordinates X to 2D image coordinates x such that:

$$x_i = PX_i \tag{1}$$

for all i, assuming a pinhole camera model [multiple-view] [6]. The matrix $\mathbb{P}$ captures intrinsic parameters (scale factors, aspect ratio, focal length and the center of projection) and extrinsic parameters (rotation and translation of the camera coordinate system w.r.t. the global one). After such a treatment we can get rid of barrel and pincushion distortion which are not tolerable in line detection and angle calculation for our purposes.

4.2. Marker detection and image filtration

For our stand requirements, used markers are points (circles) of black color, distinctive and well contrasted with the white surface of the screen, on which headlights geometry is projected. In addition, knowing the left screen positions regarding the left camera and right screen with right camera, we are able to choose the region of interest, which will be used for further processing. In the detection phase, we used a simple binarization of image (region of interest), finding the exact center points of already placed markers on the screens. After the regions of interest are know we can skip to the filtration of the image, which results in removal of the noises in the image.

4.3. Homography – rectification

Formally a planar homography is an invertible linear mapping in 2D projective space that maps lines to lines [multiple-view] [3, 4]:

$$x' = Hx \tag{2}$$

where **H** is a *3x3* homography matrix, x and x' are homogenous vectors. Homography can alter an image to create an impression that it was captured with a camera of different position and orientation than the original one.

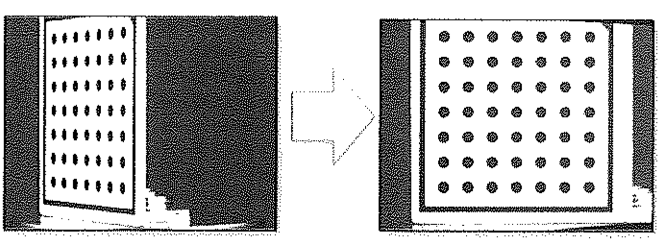

Fig. 7. Rectification process input and output images

The kind of homography we used in our processing is called rectification [5]. It means that we rectify the image to the form of image which would be taken form the camera placed perpendicular to the scene. Type of transformation used is model transformation of the image. We know the position of the markers on the measurement screen so we can create matrix with markers positions and calculate the transformation (homography) matrix which describes differences of model image and the real one.

4.4. Hough transform

The Hough transform is a feature extraction technique which allows us to find certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform. Formula for local maxima calculation is following:

$$x \cos(\alpha) + y \sin(\alpha) = \rho \qquad (3)$$

where: ρ – radius vector, α –angle between ρ and OX axis and can be represented in two dimensional coordinate system where the maxima can be found. We use the Hough transform for the boundary lines searching in the image with the headlights geometry projection.

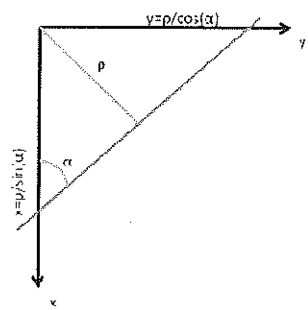

Fig. 8. Hough transform algorithm

5. Experimental results

In this section we would like to present you the results of our work in laboratory for optimizing the image processing algorithm. The latest version of our the program is fulfilling the requirements given by the stand user.

5.1. Experimental results

All experimental results comes from the real stand measurements while testing the vehicle headlights.

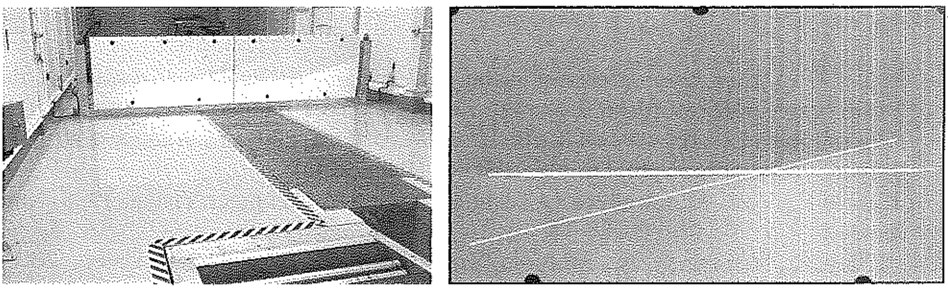

Fig. 9. Real test stand for headlights measurement(left), result of image processing (right)

Also another results of the headlights geometry projection are available. E.g. the light intensity distribution image Fig. 9. In the Fig. 10 left image shows non homogenous distribution of light intensity caused by improper setting of headlight, it can cause blinding to drivers of other road vehicles. In the Fig. *10* right image shows proper distribution of light intensity.

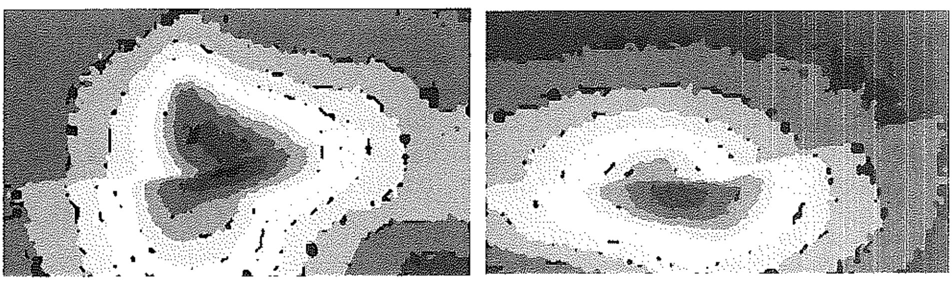

Fig. 10. Light intensity distribution of headlight geometry projection

Conclusions

As a result of End Line project the real test stand for headlight testing was developed. Presented in the article method and algorithms for image processing and analysis were implemented as a part of all end line tests software. Presented in this paper results shows that proposed algorithms allows to measure correctness of settings headlights including its position, rotation and geometry. Test stand was successfully tested on vehicles, what confirms correct selecting and implementation of chosen methods and algorithms.

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