LIGHT BEAM CONTROL SYSTEM OF TRAM'S HEAD LIGHTS

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Abstract

Researches in the field of technology of modern sources of light have called for the introduction and application of a few basic hardware solutions of automatic correction systems of light beam position in the vertical and horizontal axes of a vehicle.

Application of Adaptive Frontlighting Systems in motor vehicles has made it possible to adapt light parameters of head lights and fog lights to the actual situation on the road. The system ensures optimal observation conditions of a vehicle's foreground. These systems have contributed to the improvement of driving safety and comfort in the conditions of restricted visibility during fogs and precipitation.

The authors of the present publication substantiate the need of introducing the solution of the foreground lighting of a vehicle, which has already proved effective for motor vehicles, taking into account the specificity of movement of a tram which is one of the main means of transport within the framework of urban public transport system.

The article presents the current standardization requirements concerning head lights for the abovementioned means of transport. The results of laboratory photometric measurements for currently used optical light systems, as well as the results of simulation researches of the foreground lighting of a tram in street traffic have been demonstrated. Moreover, the article presents the analysis of potential solutions for the foreground lighting of a traction vehicle with the application of automatic system of light beam control. The proposal of a method of light beam choice taking into consideration specific movement conditions of a tram has been presented. Attention has been paid to the expected exploitation and economic effect of the application of the system for a company promoted to be used in a tram, as well as to the improvement of working conditions of a tram driver and the influence on other public transport users connected with travel safety and comfort.

The publication emphasizes the merits of the proper use of already existing lighting solutions and their introduction into street traffic system of a tram.

The improvement of the quality of the foreground lighting of a tram significantly increases the safety and comfort of all urban street traffic users.

Keywords: *transport, tram, simulation, lighting distribution, tram lighting, front lighting*

1. Introduction

The growth of public transport usage in urban areas is connected with maintaining a high and unchanging level of safety. A factor directly conditioning safe movement of a tram is the state and quality of main lighting of a vehicle. A proper lighting distribution plays a decisive role in the perception of luminous sensations from the vehicle's foreground. It ensures a proper assessment of behaviour of other road traffic users and conditions proper visibility from a tram driver's seat. Neither the emphasis on the quality of projectors in automotive business, nor their constant development and application of advanced systems of automatic light beam direction translate into application of such solutions in traction vehicles. Literature in this field limits itself only to a small number of papers devoted to improvement of observation conditions through influencing position and shape of a vehicle's beam. Moreover, there is no literature in the filed of lighting from the perspective of application in traction vehicles. Legislation in this field is not adapted either. The current requirements concerning technical parameters of lighting solutions being in use are included in the Directives of the Minister of Infrastructure [1, 2]. These requirements fail to take into account the possibility of applying additional sources of light, applying projectors with the sources of light in the form of discharge lamps and installation of control system of position and direction of light beam. Therefore, an attempt at application of modern solutions in tram's lighting seems justifiable.

The subject matter of considerations shall be projectors and reflectors currently used in traction vehicles, as well as theoretical proposals of light beams possible to be applied in tram traffic. The outline of a light beam control system specifying useful signals that can be used in the process of selection and direction of light beam of tram's front lights shall be presented. In view of the specificity of public transport and a relatively small number or tram vehicles in relation to a general number of vehicles participating in urban traffic, it should be acknowledged that the subject of improvement of lighting quality for this means of transport can be realized and applied in newly produced and implemented constructions.

2. Legal regulations concerning tram's lighting

Tram's lights can be divided into two fundamental groups:
- external lights,
- internal lights.

Whereas external lights are:
- vehicle's head lights (front low beam, main and fog lights),
- signal lights.

Since the subject matter of the present paper is lighting control in the foreground of a traction vehicle with the use of external lighting installed on a tram, only the characteristics of this group of lights shall be considered.

External lights are intended for lighting the road in front of a vehicle or its neighbourhood and they serve as transmitters of information about the state of a given vehicle to other road traffic users. Division of external lighting used in a tram [1, 2]:
- main,
- low beam position,
- indicators: front, rear, side,
- brake "stop",
- position front and rear,
- rear reflectors other than triangular, front, side,
- hazard,
- fog front and rear,
- reverse,
- daylight running lights.

Installation of lighting projectors and reflectors should be conducted in such a way as to make it possible to regulate luminous flux easily. At the same time, the axis of reference of projectors should be parallel to the road and simultaneously to the axis of reference of the vehicle, but perpendicular to warning lights. Lights of the same kind (with the exception of informative and outline lighting) should be placed symmetrically in relation to the vehicle's longitudinal axis of symmetry. They should also have comparable photometric characteristics and fulfil the same requirements as for the colour.

Selected requirements included in the Directives of the Minister of Infrastructure [1, 2] directly related to photometric requirements concerning tram's front lighting are presented below:

Main lights:
- number of lights - 2 (1 allowed),
- colour - white or selective yellow,
- arrangement on a vehicle – lengthwise - on the front, in such a way so that transmitted light does not blind the driver directly, nor through reflection from different elements of a vehicle,
- they should illuminate the road adequately at least 100 m in front of a vehicle with good air transparency,
- luminous intensity of all main lights may not be lower than 30.000 cd and may not exceed 225.000 cd.

Low beam lights:
- number of lights - 2 (1 allowed),
- colour - white or selective yellow,
- they should illuminate the road adequately at least 40 m in front of a vehicle with good air transparency,
- can be produced as symmetrical (allowed since 2003, previously asymmetrical workmanship forbidden).

Requirements for all kinds of lights used in trams are included in the directive. The authors of the present paper have not quoted requirements which are not included in the scope of the paper. Lights of vehicles admitted to road traffic must fulfil a series of photometric requirements (taking into consideration international guidelines within the framework of Economic Commission for Europe ECE), particularly the following parameters [4]:
- range of chromaticity,
- angles of geometrical visibility of lighting devices,
- level of luminous intensity in a particular photometric direction,
- level of luminous flux density on measurement screen.

There are no separate or additional regulations neither Polish nor international, regulating the range of requirements that lighting installed on a tram should fulfil.

Having analyzed the requirements included in the abovementioned directive, it can be stated that there exists a clear reference to photometric requirements concerning motor vehicles. Particularly concerning the levels of directional luminous intensity of main lights, asymmetry of light beam and a light-shade boundary of low beam lights. Another requirement is range of chromaticity - white colour or selective yellow. Nevertheless, the specificity of tram traffic, track neighbourhood and infrastructure should be taken into account when determining photometric requirements. Transferring the value of luminous intensity or lighting distribution directly from motor vehicle's applications may have negative consequences on the functioning of front lighting and maintaining the comfort of visual work performed by a tram driver.

3. Laboratory measurements of tram lighting

Three types of trams have been analyzed (105N, 112N, 120N), as well as lighting installed on them. In Fig. 1-3 particular kinds of tram lighting installed on a tram have been presented.

Tests on tram's head lights have been conducted in laboratory conditions where measurements of directional luminous intensity distribution of particular opto-lighting systems have been conducted.

Fig. 1. Tram 13N with a single reflector 0215.8.10.8.0 produced by Zelmot (with a H4 light bulb)

Fig. 2. Tram 105N with two reflectors 0245.2008.1 produced by Zelmot (with a R2light bulb)

Fig. 3. Tram 120N with two low beam light projectors 1BL 008 193-01 (with a H7 light bulb) and two main light reflectors 1KO 008 191-02 (with a H7 Hella light bulb)

The following kinds of lamps have been tested:

- reflector 0215.8.10.8.0 produced by Zelmot with a H4 light bulb (Fig. 4.),
- reflector 0245.2008.1 produced by Zelmot with a R2 light bulb (Fig. 5.),
- ellipsoidal projector of low beam lights 1BL 008 193-01 produced by Hella with a H7 light bulb (Fig. 10),
- reflector FF of main lights 1KO 008 191-02 produced by Hella with a H7 light bulb (Fig. 11.).

As a result of measurements performed, iso-candela plots have been obtained on the measurement screen presented separately for low beam lights Fig. 6, 7, 12 and for main lights Fig. 8, 9 and 13.

Fig. 4. Lamp 0215.8.10.8.0 produced by Zelmot with a H4 light bulb

Fig. 5. Lamp 0245.2008.1 produced by Zelmot with a R2 light bulb

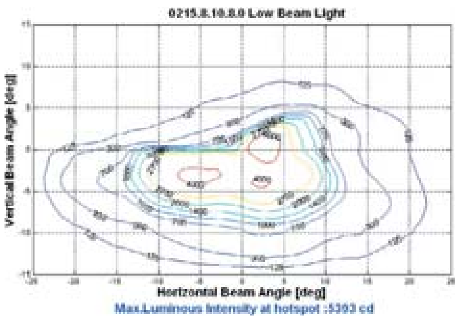

Fig. 6. Iso-candela plot of low beam light lamp 0215.8.10.8.0 (H4) on measurement screen ISO

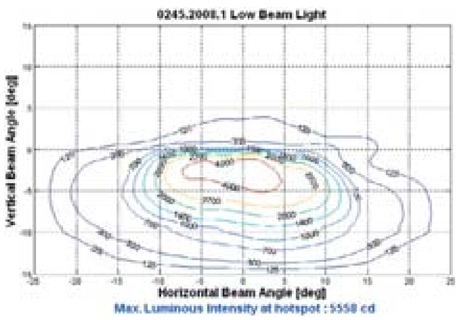

Fig. 7. Iso-candela plot of low beam light lamp 0245.2008.1 (R2) on measurement screen ISO

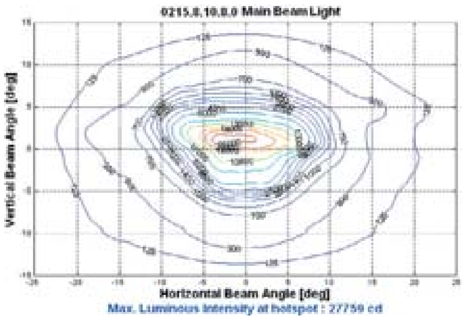

Fig. 8. Iso-candela plot of main light lamp 0215.8.10.8.0 (H4) on measurement screen ISO

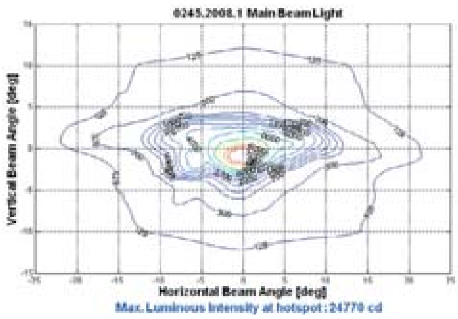

Fig. 9. Iso-candela plot of main light lamp 0245.2008.1 (R2) on measurement screen ISO

Fig. 10. Low beam light projector 1BL 008 193-01 produced by Hella with a H7 light bulb

Fig. 11. Reflector FF of main lights 1KO 008 191-02 produced by Hella with a H7 light bulb

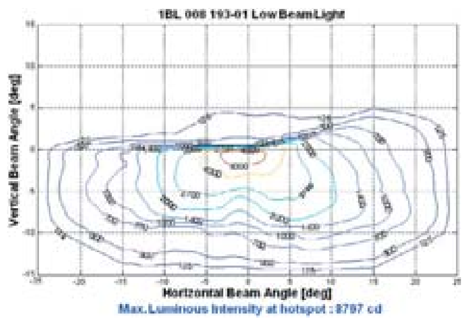

Fig. 12. Iso-candela plot of low beam light projector 1BL 008 193-01 with a H7light bulb produced by Hella on measurement screen ISO

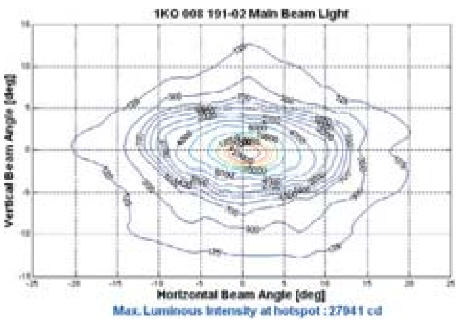

Fig. 13. Iso-candela plot of main light reflector 1KO 008 191-02 with a H7 light bulb produced by Hella on measurement screen ISO

Distribution of luminous flux density on the track surface has been estimated on the basis of laboratory measurements. Track arrangement, where a tram moves in the direction opposite to the movement of a motor vehicle is an extreme case of lighting conditions where there exists high probability of illumination of the driver of a vehicle coming from the opposite direction as a result of maladjustment of lighting distribution to traffic conditions.

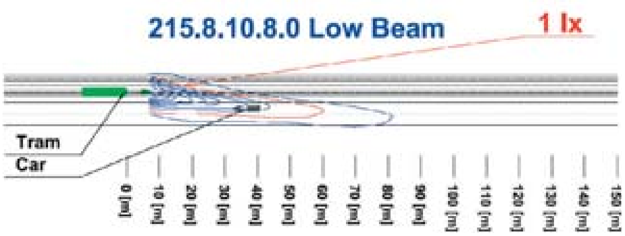

Fig. 14. Distribution of luminous flux density of reflector of lamp 0215.8.10.8.0 (H4), low beam light on road surface

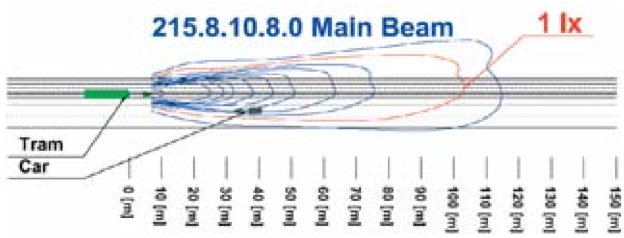

Fig. 15. Distribution of luminous flux density of reflector of lamp 0215.8.10.8.0 (H4),main light on road surface

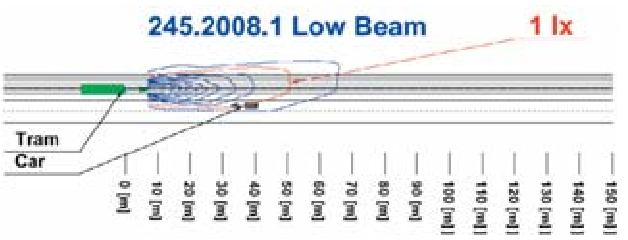

Fig. 16. Distribution of luminous flux density of reflector of lamp 0245.2008.1.(R2), low beam light on road surface

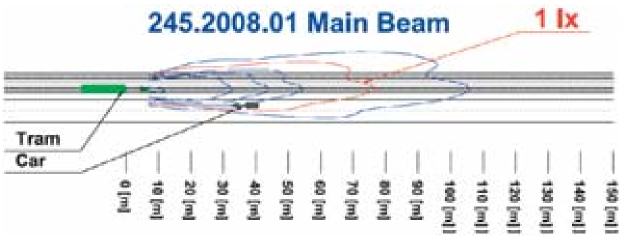

Fig. 17. Distribution of luminous flux density of reflector of lamp 0245.2008.1.(R2), main light on road surface

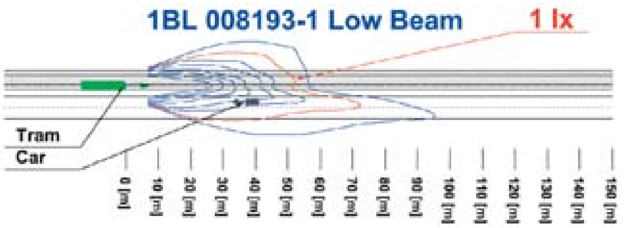

Fig. 18. Distribution of luminous flux density of projector of lamp 1BL 008193-1(H7), low beam light on road surface

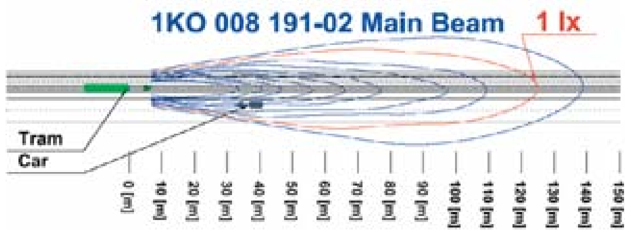

Fig. 19. Distribution of luminous flux density of projector of lamp 1KO008191-2(H7), main light on road surface

Measurements performed of solid luminous intensity of particular kinds of lights and their presentation on measurement screen ISO, as well as calculations of isolux plot on the road plane make it possible to compare and assess light beam in the context of its width on the vertical and horizontal planes and the level of maximum luminous intensity and range. Fig. 14-19 present range of lights in ideal atmospheric conditions – according to automobile light technique of isolux on the road surface of the value of 1lx [4].

Iso-candela plot of low beam light presented in Fig. 6 is characterized by three areas of high directional luminous intensity of the value of about 4000 cd, causing irregularity of directional distribution. Luminous flux density distribution of this reflector presented in Fig. 14 indicates the existence of narrow light beam on the road surface directed mainly outside the track area.

Iso-candela plot of main light on measurement screen ISO (Fig. 8) of the same reflector is characterized by maintaining regularity. It clearly has maximum luminous intensity placed in the center of measurement screen and having the value of 27759 cd in the maximum point. The area of maximum levels of directional luminous intensity 25000 cd is not symmetrical and is included within the angle of about 5º on the horizontal plane. The range of this reflector is about 100 m (Fig. 15), in addition to which it covers the road area and significantly exceeds the opposite motion path of a tram coming from the opposite direction.

For the reflector presented in Fig. 7, low beam light is characterized by lack of a clear light-shade boundary. It has a regular area of maximum luminous intensity of the value of 4000 cd, including within a wide distribution angle of the value of about 10º on the horizontal. It is revealed in Fig. 16, where a light-shade boundary cannot be observed. This light beam can be considered symmetrical. The range of light equals about 50 m.

Light beam of the same reflector for main light indicates lack of symmetry around vertical axis of the screen. However, it retains a high level of luminous intensity (about 27000 cd) in the central area of the measurement screen. Asymmetry of light beam is indicated in isolux plot on the road plane (Fig. 17). A change of range value can be observed for isolux of the value of 1lx in the area of opposite motion path of a traction vehicle.

Fig. 12 presents iso-candela plot for a low beam light lenticular projector. The existence of a clear light-shade boundary results from using a physical screen, quenching part of luminous flux emitted in the space in the vehicle's foreground. Such a solution ensures obtaining high growths of directional luminous intensity within border area. Ellipsoidal system of reflector ensures regularity of horizontal distribution in areas situated below x-x axis on measurement screen. Maximum luminous intensity is concentrated around central point and has the value of about 6000cd. Light beam emitted in such a way ensures obtaining clearly asymmetrical isolux plot on the road plane maintaining the expected range of the value of about 45 m and guaranteeing lighting of the track and shoulders.

Iso-candela plot of reflector type Free Field presented in Fig. 13 is characterized by retaining a high level of directional luminous intensity in the central area (about 27000 cd). Also revealed are symmetrically distributed in relation to y-y axis areas of equal values of luminous intensity ensuring regular distribution of luminous flux density on the road plane. This light beam has the range of the value of about 125 m and wide distribution on the road plane.

All the tested and presented light beams of lights installed on tram vehicles realize functions included within standardizing stipulations. However, it should be pointed out that lamps used on trams come from motor vehicles. Functionality of light beams presented is unfortunately not sufficient.

4. New proposals of improvement of the current state of tram's head lighting

Two light beams have been initially proposed in order to solve the problem, namely, of low beam lights (Fig. 20) and of main lights (Fig. 21).

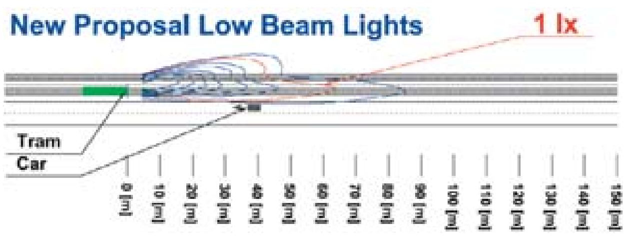

Fig. 20. Distribution of luminous flux density of low beam light on road surface - new proposal

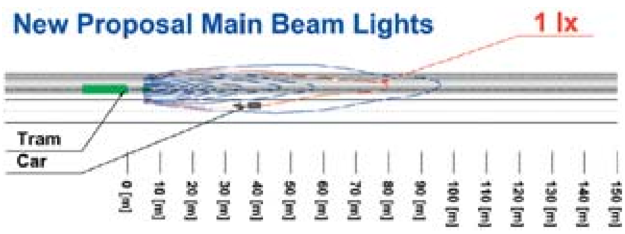

Fig. 21. Distribution of luminous flux density of main light on road surface - new proposal

The two proposals of light beams are characterized by limiting the width of distribution on the horizontal plane in relation to existing solutions. Directing light beam of low beam lights towards tram's motion path ensures limiting of negative emission in the direction of a motor vehicle coming from the opposite direction. This can influence the limiting of illuminating the driver of a motor vehicle coming from the opposite direction. Limiting the range of main light (Fig. 21), still ensures indispensable safe distance for a tram driver to stop the vehicle simultaneously limiting of illuminating other road traffic users in urban conditions.

There is also a possibility of using other kinds of light beams, for example, to light road bends, crossroads, or particularly dangerous spots. In automobile technique solutions are implemented enabling automatic change of a kind of light beam, as well as its directing [3]. There are no contraindications against this type of systems being used in traction vehicles. Fig. 22 presents a sample proposal of a system together with possible applications of information sources indispensable for lighting control in a tram. Decision of light beam direction is taken within ECU system on the basis of signals from detectors installed on a vehicle (vehicle speed, distance, location on the route on the basis of a digital map), as well as external signals (GPS, tram traffic supervision system). Tests on possible sources of useful signals are in the initial stage. Researches on fully autonomic control system are currently in progress.

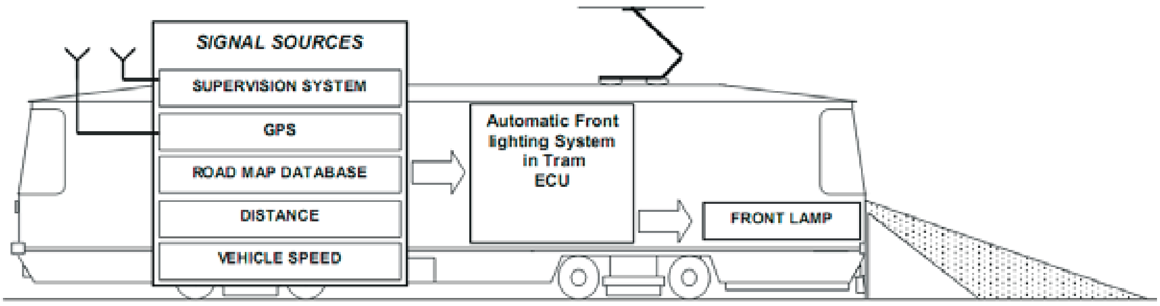

Fig. 22. New proposal of automatic light beam control system of a tram

5. Summary

Realization of fundamental and minimal photometric criteria regarding lights installed on trams results from lack of research and precise guidelines for this kind of vehicles. The specificity of tram traffic in urban environment requires detailed analyses and determining optimal directions of emission of light beams and the value of directional luminous intensity. Such conduct will allow for selection of the most advantageous kinds of light beams from the point of view of realization of lighting functions. The final effect of such researches should be ensuring a tram driver optimal observation conditions of the vehicle's foreground.

Introduction of standardized construction solutions in all types and models of trams together with application of automatic system of light beam control would contribute to improving the quality of lighting. These systems could also find application in older types of vehicles.

The advantages of introducing a standardized construction solution are:

- maintaining comparable observation conditions of a vehicle's foreground by a tram driver in different tram models (which is significant in shift – system of driving different vehicles),
- identical lighting control system by a tram driver,
- maintaining a discriminant in the form of identical shape of output opening of a lamp, which is favorable in differentiating a tram from other vehicles in road traffic,
- fully replaceable system of spare parts and lamp components, including the use of the same sources of light,
- standardized system of service, regulation and conservation of front lighting.

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