HEADLIGHTS TYPE APPROVAL REQUIREMENTS AND ON FIELD REQUIREMENTS - TECHNICAL IMPACT ON SAFETY

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Abstract

On field requirements for headlights are significantly dependent on type approval requirements. But the type approval requirements are described differently than exploitation requirements. They assume that basic photometrical requirements tested during type approval are met. But this assumption is not described and checked. Finally on field real headlamp photometric values could be significantly different than expected because depends on factors as light source geometry tolerance, headlamp design sensitivity for filament geometry, possible precision of aiming/levelling method. Moreover drivers and services awareness of this situation is not meaningful. As result safety during night-time traffic is significantly deteriorated. In paper are described important factors concerned way of defining present type approval requirements. It concern the way of defining of photometric criteria for vertical measuring screen in fixed distance, choice of points and zones for assessment, limits and their restrictions. Also differentiation of requirement in dependence on light source used is analysed as well as some other important factors. The important issue is glare caused by headlights and their restriction in type approval requirements. It is also analysed influence on headlights performance on field conditions as result of lack of reference to imperfect but defined type approval photometric requirements. The visual aiming on the base of cut-off line and subjective judgement is the only way to allow use of vehicle. Moreover as well service as drivers believes that this is sufficient for safety driving at night with speeds allowed by common road traffic law.

Keywords: *headlighting, type approval requirements, traffic safety*

1. Introduction

The most important for night-time driving traffic safety is good road illumination by vehicle headlamps. Formal legal requirements for headlamps were described in UN ECE Regulations coming into force, more than 50 years ago [9]. They are based on technical possibilities for headlamps design and photometrical measurements of time were created. Headlamp design were based on single-paraboloidal reflector with multi-trapezoidal front glass lens. Luminous flux of low voltage filament lamp was significantly limited. Designers had not much freedom in beam pattern creation what result in similar performance of most headlamps.

For measurements were used photo-detectors of relatively big size, around 60 mm, because it was need to obtain appropriate sensitivity and spectral characteristics. They allow only for limited number of points measurements in reasonable time. Those days so defined criteria were sufficient and they were appropriate for the capabilities of existing measurement instruments. Moreover there was neither imagination nor possibility to check performance of beam pattern during exploitation especially in photometric domain. It was in use assumption that headlamps checked during type approval tests should maintain sufficient performance on field conditions. This assumption was never strictly expressed. But it started the idea that aiming is enough to guarantee minimum road visibility and protect oncoming drivers against excessive glare. In fact the matter is more complicated. Final headlamps light beam performance depends on design of headlamp, performance of mass production light source and aiming on the vehicle. Especially for modern advanced headlamp design and light sources. It is also significant influence of ageing and of dirt outside and inside of headlamp.

When halogen bulbs appeared on the market, new, additional regulations were created, in the same way than previous but different by higher number of measuring points and required values [10, 11]. Introduction of xenon light sources resulted in a similar situation [13]. This changes did not lead to introducing any on field photometric requirements. Introducing of adaptive lights (AFS, ADB) went very similar way. As a result presently there are variety of type approval requirements with respect to lighting equipment having the same illumination function. It means that any vehicle can use any allowed headlighting system without any restriction for speed or other driver's behaviour. Present technology offers many advanced diverse designs of headlamps. The market participation of single-paraboloidal reflector headlamps has significantly decreased, while the lighting model adopted for the purpose of defining the regulations and their simplifications became obsolete. Significant differences of the quality of road illumination, and the degree of glare in road conditions are observed. This is confirmed by many experiments [2, 3] as well as the author's research results [5, 6].

2. Structure of type approval requirements

Type approval requirements for headlamps which finally influence the road visibility and glare are dived into groups depending on light source used. Moreover there are separate requirements groups: for light sources [14, 15], for headlamps as optical device [7, 8, 12] and, for headlamp location on the vehicle including aiming [16]. All these groups are separately regulated. In addition for test are required standard conditions. Etalon light source are used during testing photometrical characteristics of headlamps. They have significantly decreased geometrical tolerances comparing mass production light sources. According requirement mounting height is assumed to have nominal value (750 mm) and nominal cut-off inclination (1% down).

Photometric requirements (illuminances or equivalent luminous intensities) are specified for screen surface located at constant distance (25 m) from tested headlamp (Fig. 1).

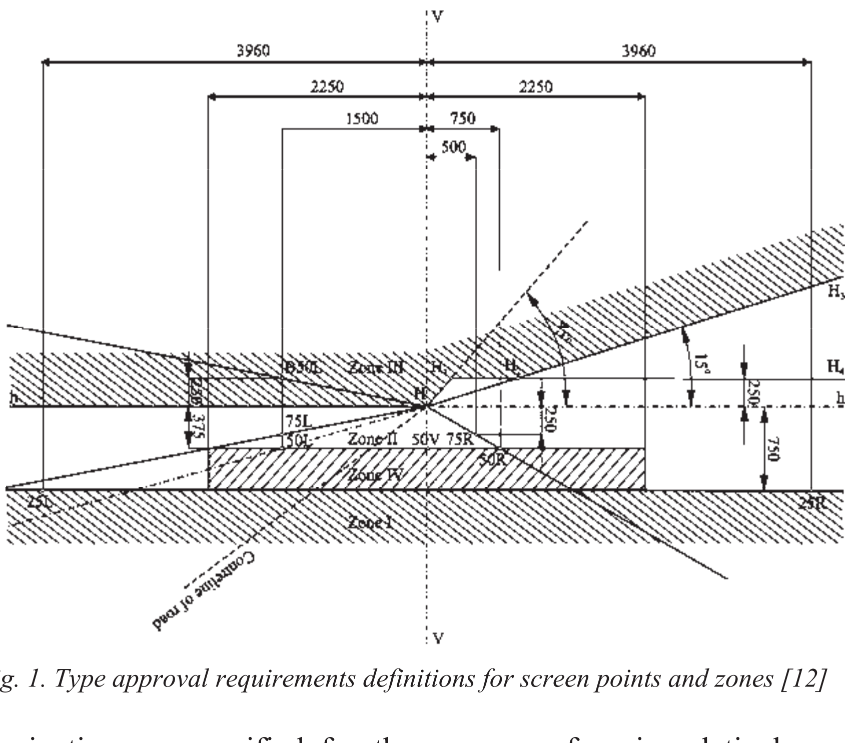

Fig. 1. Type approval requirements definitions for screen points and zones [12]

Values of illumination are specified for the screen surface in relatively small number of selected points corresponding to characteristic areas of straight road segment and few relatively large areas or segments. Perception and measurement of the projected beam pattern on this kind of screen differs significantly from illuminance values at objects at the road surface and the surface of oncoming driver eyes. (Fig. 2, Fig. 3).

Fig. 2. Visualization of illuminance distribution of real headlamp beam pattern on vertical measuring screen corresponding type approval assessment

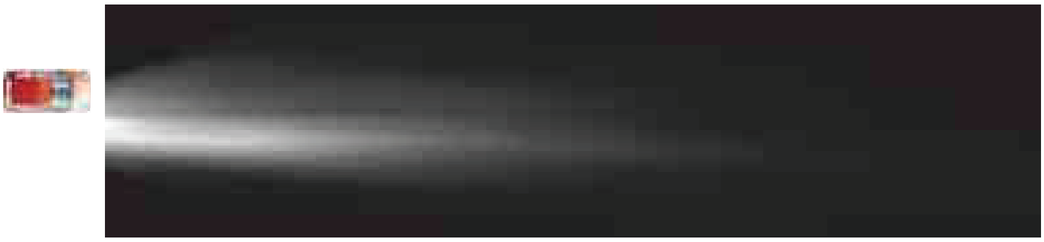

Fig. 3. Bird-eye view visualisation of vertical illumination at the road surface corresponding to object illumination on the road and their visibility

Such way of requirements specification allows for simplified assessment only when illumination distribution is uniform and varies monotonically between selected points. Requirements of constant value limits for rectangular areas allow for good road illumination but do not guarantee it. Headlamp designer can decide how are changes inside beam pattern. For old constructions it was more or less predictable by design restriction. Using contemporary methods of forming beam pattern, e.g. FF or LED matrix projection technique, it is possible to create high (required) illumination in close neighbourhood of the test points. In somewhat farther vicinity it is possible to create distribution contradictory to the presumed character of changes, e.g. in case of limitations of light source luminous flux, or other production difficulties. It becomes rather matter of designer and manufacturers responsibility than regulatory controlled performance requirements.

Limits of required illumination (luminous intensity) are mostly one-sided. This enables for multiple times higher illumination of given points by one headlamp than by another also type approved. It is common tendency to compare headlamp as a classes depending on light sources used. It is result of absence other agreed more objective criterions. But talking about e.g. H4 headlamp and comparing it with H7 or gas discharge (xenon) headlamp is unreliable. It works only when beam pattern is optimized on the same base. But it is possible to realise a reflector (e.g. FF) with a H4 bulb which in selected points will have higher values than another headlamp with a H7 bulb, because the minimum regulatory requirements are identical. Of course optimal utilising of luminous flux in a headlamp with a H7 bulb (1500 lm at 13.2 V single filament) will lead to better performance than an H4 one (1000lm at 13.2 V), because H4 has double filament, diaphragm cutting luminous flux and possibility to use only top part of reflector. The same luminous flux may be directed in different places where requirements are not established, e.g. to road shoulders or bends, very close to the vehicle or simply lost. Finally comparisons based on category of light source is not reliable.

2. Light source, cut-off line, etalon bulbs

The next problem of present type approval requirements is dependence on the used light source. Inappropriateness of such condition looks to be obvious - the allowed vehicle speed is not limited in relation to the applied headlamps. Let imagine that a xenon headlamp meet the requirements of the Regulation No. 112 [12] (incandescent, halogen), and do not meet the requirements of the Regulation No. 98 [8] (gas discharge). Why there shouldn't be a possibility to use it on field in such situation? In fact it can happen when luminous flux of gas discharge light source will decrease after some years of use, and the requirements of the Regulation No. 98 will not be met, while the requirements of the regulation No. 8 will still be met. But on field conditions there is no requirements referenced to measurements of photometry.

The most important for headlamps aiming is cut-off line. It is the subject for separate contribution. Here is needed only to say that the phenomenon of cut-off line is not clear-cut defined. Allowable tolerances of its properties are not determined. Aiming of headlamps is made basing on subjective visual impressions as well during type approval as well on field vehicles exploitation, what is more important. Requirements for distinct cut-off line of precisely determined shape results from the need of aiming the headlamps. The designers efforts concentrated on getting a cut-off line of (presumed) proper quality resulted in many unfavourable effects like change of light colour, or discomfort glare caused by high headlamp surface luminance. On the other hand it is possible to find headlamps with excellent performance but very difficult to properly aiming. Finally arise question how to aim such headlamp on field conditions to obtain it optimum performance when visual aiming could be not effective.

During type approval tests of headlamps are used standard light sources (etalon). The regulations even allow for use etalon light source delivered by the headlamp maker if the laboratory light source does not ensure that the requirements are met. Segregation of light sources into mass production and standard ones is doubtful because in vehicles those mass production light sources are used, so they are responsible for actual road illumination and glare but it is not possible to predict how sensitive is headlamp for these inaccuracies. Anyway it is not tested. For old constructions of single-paraboloidal reflector of relatively big size, inaccuracies were essentially compensable by aiming, although results depend on reflector focal length and shape of headlamp lens. In case of "free form" clear lens (FF) and also ellipsoidal design, the effects of size and light source location inaccuracies are difficult to evaluate because they depend on overall size and sensitivity to those inaccuracies in case of each concrete design.

Quite often is observed effect of deformation of cut-off line, and change of location of the maximum luminous intensity with respect to the centre of the co-ordinate system. The quality of road illumination and the degree of glare may in such cases be significantly deteriorated in an uncontrollable manner with comparison to test results with a selected etalon light source, and will not be correctable by headlamp aiming.

In Fig. 4 and Fig. 5. are shown examples of distributions of illumination of the same headlamp but equipped with different random mass production filament lamps. There is possible to observe significant differences in position of maximum of illumination by the same position of cut-off line. In fact such influence is typical for on field conditions but cannot be predicted and controlled under present regulatory system. But it can have significant influence for quality of road illumination and glare.

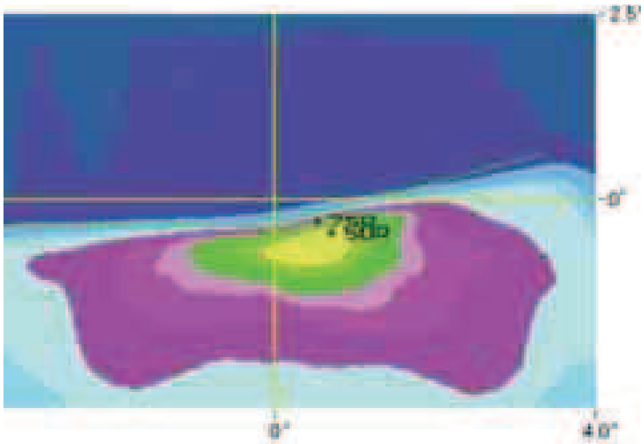

Fig. 4. Illumination distribution for headlamp with random mass production bulb. Correct position of maximum of illumination, close to the 50R and 75R points

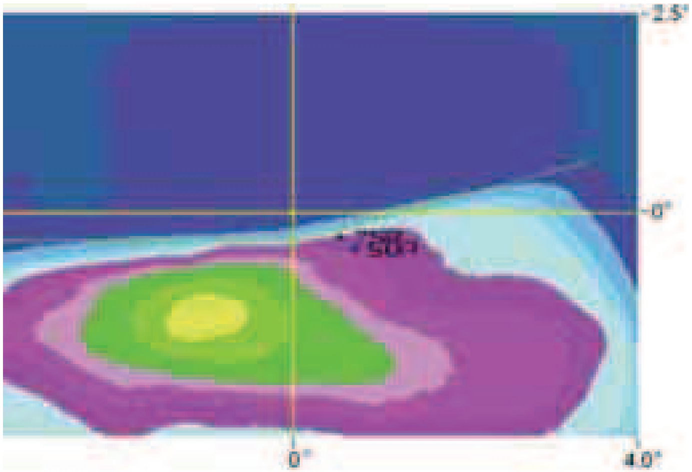

Fig. 5. Illumination distribution for headlamp with random mass production bulb different than for fig. 4. Maximum of illuminance moved far from the 50R and 75R points

Requirements take into account perspective view of a road straight segment on the surface of test screen (compare Fig.1.). Characteristical elements of road and its vicinity usually are not sufficiently reproduced with a static model of straight road geometry [14]. Because of statistical distribution of objects in the driver's field of view, each of them corresponds not to points and lines but to areas described by probability density. Hence at least areas should be defined which take into account real shapes of roads and locations of objects, corresponding to presently defined points like B50L, 75R, 50R.

4. Mounting conditions and glare

Real mounting heights of headlamp above the road surface has not been taken into account by type approval tests. The mounting height can change from 500 mm to 1500mm for passing beam [16]. Road illumination is a superposition of light beams from both headlamps and depends both from their mounting height, spacing and actual aiming. It should be added initial aiming tolerances and leveling tolerances. The position of cut-off at the rod surface for nominal conditions of type approval requirements can vary from 20m to 200m [6]. For on field conditions in fact could be much more and in fact unpredictable.

Glare assessment in type approval conditions is performed at constant distance of the test point (screen) from the headlamp. It is reduced to the measurement of illumination above the cut-off line (zone III) where for the whole area one limit value is valid when in real road condition is significant change of illumination with distance and angle. Identical illumination value in constant distance from the screen means very strong illumination variability on the eyes of the oncoming driver. Real locations of eyes of oncoming drivers for the constant distance occupy significant area [1], resulting in small correlation between real values of illumination and those measured in tests. The requirement of light asymmetry and presence of an oblique segment when additional requirement concerning the right side are not defined (right turn, rear view mirrors) allows to direct significant amount of light there, what results in high diversification of glare which is not adequately controlled. Moreover, using illumination as criterion for glare assessment in case of headlamps with small lens area results in their very high luminance which in reality increases the glare feelings. Because ellipsoidal headlamps design are more and more popular it becomes significant on field problem.

5. On field requirements influence for safety

As was shown above the differences between type approval requirements and possible headlamps performance in on field traffic situation could be significant. And it regards only new type approved headlamps when other problems decreasing performance occurs like incorrect aiming, aging, dirt.

For quality and range of road illumination is important actual aiming of headlamps. In garages are used optical/visual aiming devices which are used to aim headlamps on base of cut-off line. The allowed tolerances of on field aiming are quite big but it is assumed that aiming precision is good enough. Legal tolerances of vertical aiming are from 0.3% up to 0.5% down. Aiming inaccuracy for presently used visual devices are in best situation additionally ± 0.3% without taking into account irregularities of cut-off line. Of course it regards the worst conditions but legally allowed by type approval and exploitation requirements. There are three basic aspects of aiming efficiency: quality of shape and sharpness of cut-off line, geometric relation between cut-off line position and maximum of illumination and possible precision of aiming.

The first two are more or less dependent on design of headlamp and of light source used. It is difficult to predict this influence. It is result of proper headlamp design and it is not checked during type approval. For the contemporary headlamp it is not a big problem to optimize it to be not much sensitive for light source geometry. It depends on designer decision. It also exists common dependence between lamp size and bulb geometry sensitivity. Because most popular are small size headlamps the difficulties increases. The cut-off shape and sharpness are more complicated problem. For free form (FF) reflectors the shape of cut off is often unpredictable, regarding common requirements. Creation of cut-off line can be done on many various ways. It could result by different sensitivity for bulb geometry. Finally irregular shape of cut-off line which could be interpreted on many ways depends on personal feeling so that aiming is ambiguous. Good example are “multiply” cut-off lines. On field requirements do not describe rules how are tolerances for shape of cut-off line and it is difficult to question their performance. Finally many ambiguous aimed headlamps are present on the roads.

Geometrical relations between cut-off line and important beam pattern photometric characteristics are not possible to check visually using standard aiming device. In this area vehicle users relay only on manufacturers and service.

There are manufactured significant variety of headlamps with much better performance which are easy to aim and are equipped with high precision automatic leveling device. For typical headlamp, especially aftermarket replacements, situation is unpredictable but drivers are not aware of it. Periodical technical inspection is also not aware of situation following simple exploitation requirements only. Influence for road traffic safety of such complicated situation looks to be obvious. Visibility at night is essential to avoid accident. If quality of beam pattern and road illumination cannot be predicted, checked and assessed it is difficult to say how is it influence for safety. But if it is no measure of problem there is no motivation to do improvements. Statistics shows that risk of accident and fatalities increase at night for 50% to even 3 times.

To achieve new quality in this area it is needed to improve description of technical requirements as well for type approval as for periodical technical inspection. The new level in this area can be achieved by use of headlight analyzer. This device utilize CCD camera and computer image analysis and allow to test detailed characteristics of beam pattern in garage condition. It allows for precise photometrical measurements and precise aiming. It also allows to asses cut-off line shape and quality.

6. Conclusions

The above analysis concerns most important problems of headlamps requirements. Some other requirements imperfections, like permitting changes in headlamp alignment when photometric requirements are not met, ambiguousness of lateral changes disturbing good visibility, are less important but exists.

The purpose of type approval is to ensure quality of products licensed for use. But present requirements can be met by quite simple headlamps design when level of present technology allow for much more. It seems that at contemporary technological capabilities the regulations in force extended by periodical technical inspection requirements allow of large and partially uncontrolled dispersion of properties of headlamps used in vehicles. Meeting of minimum performance do not guarantee safety driving by speeds allowed by common road traffic law (over 40-60 km/h). From the other side quite much contemporary passing beam designs allow for much higher driving speed (from 70-90 km/h and more for adaptive systems).

It leads to conclusions that criteria applied for automotive vehicle headlamp assessment should be independent from the type of light source, emitted flux or headlamp design. Assessments should take into account the set of headlamps mounted to the vehicle including consideration of their mounting point. Illumination of road and its surrounding should be evaluated rather than screen illumination. Significant improvement is possible to obtain by changing type approval co-ordinate system from vertical screen to horizontal road surface. Similarly requirements for glare should take into account the distance from the eyes and their location. To obtain better conformity type approval with on field conditions for tests should be used light sources with luminous flux conforming with that emitted in operational conditions, and with extreme of geometrical dimensions allowable in mass production tolerances. Cut-off line should be much more precisely defined to effective serve the purpose of headlamp aiming. Should be also possible to use other means to aiming instead of cut-off line. One of this is checking of meeting photometrical requirements measured on vehicle.

The best solution in exploitation conditions looks to be photometrical measurements using headlight analyzer. On field requirements should be defined similarly to type approval but simplified. The capabilities of presently applied measurement methods are sufficient for significant improvement as well of ECE regulations as on field.

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