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Bolesław KARWAT
Dariusz GŁOWIŃSKI
Emil STAŃCZYK

ANALYSIS OF THE INFLUENCE OF FACTORS ON THE PHOTOMETRY OF THE OPTICAL LIGHT SYSTEM OF CHMSL CAR LAMPS

ANALIZA CZYNNIKÓW WPŁYWAJĄCYCH NA FOTOMETRIĘ SYSTEMU OPTYCZNO-ŚWIETLNEGO LAMPY SAMOCHODOWEJ TYPU CHMSL*

The article presents an analysis of the construction of CHMSL (Centre High-Mounted Stop Lamp) car lamps and a study of the influence of individual components on the photometric parameters (light intensity). The authors have conducted a detailed study of the various design elements and the impact of their settings on each photometric parameter of the tested lamp. There is also a presentation of research results on the impact of plastic injection technologies used to manufacture the lamp, such as holding pressure, holding time and injection speed, on the photometric parameters of the CHMSL lamp's optical system.

Keywords*: photometry, optical system, car lamp, plastics.*

Artykuł zawiera analizę budowy lampy samochodowej typu CHMSL, (ang. Centre High-Mounted Stop Lamp) oraz badania wpływu poszczególnych jej elementów konstrukcyjnych na parametry fotometryczne (natężenie światła). Autorzy przeprowadzili szczegółowe badania w zakresie wpływu konstrukcji poszczególnych elementów i ich ustawienia względem siebie na parametry fotometryczne badanej lampy. Przedstawiono również wyniki badań w zakresie wpływu wykonania elementów lampy w technologii wtrysku tworzyw sztucznych takich jak: ciśnienie docisku, czas docisku i prędkość wtrysku na parametry fotometryczne całego systemu optyczno-świetlnego lampy typu CHMSL.

Słowa kluczowe*: fotometria, systemy optyczne, lampy samochodowe, tworzywa sztuczne.*

1. Introduction

The automotive industry is associated with continuous development and with innovative solutions in design and technology being implemented in motor vehicles. The most spectacular solutions are those involving propulsion systems, where such changes cause motor vehicle power to surge while fuel consumption is reduced. However, the most rapid development and the greatest evolution are taking place in motor vehicle exterior lighting systems. At present, these are intricate and technologically advanced systems, the primary functions of which have expanded significantly. Only a few years ago the role of motor vehicle lighting systems was to improve the driver's visibility in adverse atmospheric conditions, signal his presence on the road and to inform others of his manoeuvres [8]. While fulfilling these fundamental requirements, the automotive industry has also come up with new lamp designs and some new ideas for lighting system solutions [17]. One of these solutions is extra lights for daytime driving, *Daytime Running Lights*, which, since 2011, in accordance with EU directive 2008/89/EC, have been required for all new motor vehicles, passenger cars, trucks, and buses.

A particularly rapidly developing trend in this sector is the application of *Light-Emitting Diodes* [4, 13] as a source of light on an ever-greater scale. LED diodes, due to their substantially lower consumption of electric energy, reduce fuel consumption and thus lower CO_2 emissions into the atmosphere [7, 13]. Due to smaller dimensions, lower heat emission and enhanced longevity, they increasingly tend to replace traditional halogen bulbs on the market [7, 12].

Among the new ideas and solutions, attention should be paid to the technological development of lighting not only with LED diodes, but also using laser diodes [15] as a light source, which not long ago was a futuristic vision of lighting but right now is being implemented by a number of automotive companies in their models of the cars of the future. There is also work in progress on selective lighting, whose function of adapting to road conditions will allow drivers to selectively choose areas to be lit so as to limit negative impact on other road users [8, 9]. *Adaptive Front-Lighting System* constitutes a breakthrough in lighting technology [9]. It enables automatic adaptation to changing traffic conditions such as the speed of the vehicle, atmospheric conditions, curves in the road, etc. All these changes pose an ever-greater challenge to lamp designers and control-and-feed system designers, but most of all to the provisions of laws concerning safety and compliance of specific parameters with technical requirements.

The article contains an analysis of factors influencing the photometry of CHMSL lamps. In Poland such lamps are described as 'third brake lights' or else as 'central brake lights'. This lamp was introduced in 1986 in USA and Canada as part of the obligatory equipment for passenger cars. In Europe this type of lamp was not introduced until 1998. The function of the lamp is to provide an extra warning of a braking manoeuvre, especially in a situation when the main brake lights are not visible [17]. The implementation of CHMSL lamps has reduced by a few percentage points the number of road accidents characterised by rear-end collisions with a vehicle directly ahead in standard road traffic conditions and, in particular, in city traffic [16].

Within the study programme established to test the process of CHMSL lamp production, several tests and observations have been carried out. Their objective was to confirm the current knowledge on the process of design and manufacture of the tested lamp. The expected result was the identification of boundary parameters for the

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl*** manufacturing process which would enable assured improvements in the process's stability and maintenance of the required quality parameters for the end product.

2. Construction of the CHMSL car lamp

The tests were performed using a typical serially-produced CHMSL lamp, in which LED diodes were applied as a source of light and the exterior construction joined with ultrasonic welding. The tested lamp consisted of four major functional elements featured in figure 1, marked as follows: 1 – an external lens manufactured with the PMMA thermoplastic injection process, 2 – a Fresnel lens, also manufactured with the polycarbonate plastic (PC) injection process, 3 – a PCB (printed circuit board) with LED diodes, 4 – housing produced with the PC-ABS injection process, which, due to its properties, makes the lamp as a whole sturdier and resistant to breakage.

The performed study omitted structural elements of the CHMSL lamp with no influence on the photometric parameters (intensity of light), such as seals, rear wipers and mounting elements.

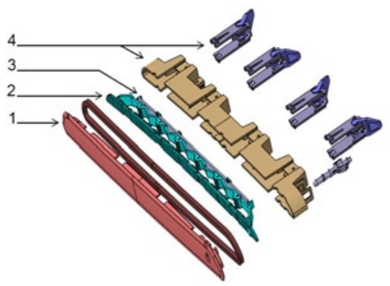

Fig.1. Construction of CHMSL lamp

The external lens is manufactured through the PMMA thermoplastic injection process using a screw injection moulding machine (by Demag) with a holding force of 200 Mg. The use of PMMA thermoplastic derives from its properties, i.e. high transparency at a 92% level; as well, it is an amorphic polymer, shiny, with a sparkling surface, characterised by good mechanical strength, resistance to chemicals, and very high resistance to atmospheric conditions.

In the sequence of thermoplastic injection into a mould socket, the holding process consists of three stages, for each of which the value of holding pressure is different. For amorphic polymers such as PMMA, the values in the individual stages should decrease in order to reduce the frozen-in residual stress.

The tested lamp used LED diodes, Lx E6SF series, made by Osram. These diodes are characterised by amber light, high effectiveness, and a 120° light emission angle. This diode has no convex external lens, so the emitted light does not undergo refraction when the boundary between two sources is crossed, as is the case with the traditional diodes, and it is reflected only from the concave reflector, which contains a connector emitting optical radiation.

The reduced angle of emission to 120°, as compared to 180° and greater in traditional diodes, reduces losses connected with light energy dispersion, and hence enhances the diode's efficiency. Apart from the above-mentioned properties for brake lights, one essential parameter is the lamp's reaction time, i.e. the inertia of the light source. For the sake of comparison, an LED diode reaches full luminous intensity within 30 μs, a traditional car bulb within 75 μs [3].

Thanks to its shape, the Fresnel lens applied in the tested lamp enables a substantial reduction in dimensions compared with a traditional lens with the same optical parameters. This is due to the structure of the lens, which consists of two dispersive collimator areas and a focusing collector. It is this very feature, i.e. small dimensions, and hence low production costs, that allow this lens to be widely used for devices requiring small dimensions, high efficiency and low cost. Lenses of this type are characterised by a certain distortion on the edges; however, for industrial use this imperfection is not critical.

In the tested lamp, the optical element consists of several constituents: an inverted Fresnel lens, the lens itself, and cushion lenses situated on the external part. A lamp thus constructed is characterised by uniform dispersion of light, due to which the light emitted by point sources is close to a uniform beam of light. This lens is responsible for uniform propagation of light in a vertical plane within the required angular range, i.e. +10°/10° from the lamp's vertical axis.

The lamp housing and the external lens are joined through ultrasonic welding, i.e. a process inducing mechanical vibrations with frequencies of approximately 20 kHz in one of the two elements being connected. During this process the two elements being connected are situated so that the surfaces to be joined can touch one another.

3. Programme of study of the parameters influencing CHMSL lamp photometry

3.1. Formulation of the equation of state

One of the fundamental parameters defining lamp efficiency is intensity of emitted light. In the automotive industry this value is measured on a dozen or so points of a measuring grid, and is defined by standard no. E/ECE/324 of the Economic Commission for Europe [16].

In order to limit study costs, and on the basis of former observations concerning the CHMSL light lamp manufacturing process, an assumption has been made regarding only partial variations in the tested optical system. Likewise, assuming zero external interference, the tested optical system can be described by the equation of state (1)

$$B+C+D+[A(n)] = [E(n)]. \tag{1}$$

using the following notation:

B, C, D – constant values (B – Fresnel lens, C – LED source of light, D – housing),

[E(n)] – output signal, light intensity (18-element matrix corresponding to light intensity at 18 points of measurement, n = (1 ... ∞) – lamp),

[A(n)] – matrix of variables, A – external lens.

$$\left[\mathrm{A}(\mathrm{n})\right]\begin{bmatrix} a(n) \\ b(n) \\ c(n) \\ d(n) \end{bmatrix}. \tag{2}$$

In the equation (1) [A(n)] denotes the matrix describing changes in the parameters of the external lens. It has been assumed that for every one of the *n* tested cases (lamps), an essential influence on the photometric parameters of the lamp appears precisely in that area. This variability ensues the high susceptibility of that element to changes in the parameters of the manufacturing process; the essential role played by the external lens in the lamp's optical system has necessitated certain detailed tests of precisely that element.

In order to define the main factors influencing changes in the constituent values of matrix [A(n)], the following tests have been performed:

a(n) – impact of changes in holding time,

b(n) – impact of changes in holding pressure,

c(n) – impact of changes in injection speed, d(n) – other factors not tested, but influencing the tested system, e.g. the lighting surface of the lens [11], the extent of dirt contamination [10], how precisely the external lens has been joined to the housing, etc.

The output variable [E(n)] is the main parameter defining functionality and photometric efficiency, meaning the intensity of light as emitted by the tested lamp. Intensity of light was measured according to the SI system in Candelas (cd). In compliance with the standard E/ECE/324 for lamps in the S3 group, in which the tested lamp is classified, this parameter is measured at eighteen points of the measuring grid. These points are located on the grid with a scale of 5 angular degrees, in the +/– 10° range for the horizontal coordinate and in the +10°/– 5° range for the vertical coordinate. A recommended value is used to define the grid of intensity distribution through the definition of minimum and maximum values of intensity for each of the points, as a percentage value of nominal intensity at the central point of the grid. These points are set by an appropriate deviation from the central point (the point crossing through lamp axis H-0; V-0) by 5° or 10° in either the horizontal or vertical plane. The light intensity value at points H-0 and V-0 as per the valid standard for the tested lamp should fall within 25 to 110 cd. The standard E/ECE/324 in chapter 5 allows for reduction of that criterion to 95% [1].

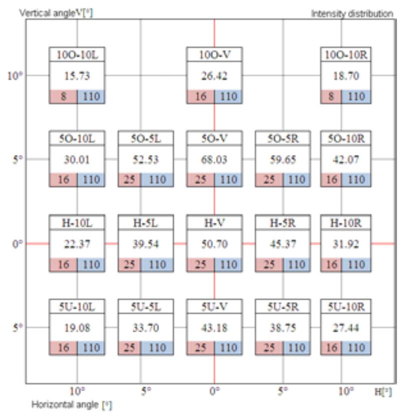

Fig. 2. Exemplary report from performed CHMSL lamp study

Figure 2 presents an exemplary measurement report, generated at the end of the study as a summary and a collection of measurement results. This report presents the grid of points. Individual measurement points are presented in figure 3, using the following notation: 1 – location of measurement point, 2 – measured value of light intensity in cd, 3 – minimum and maximum values of light intensity for that measurement point in cd.

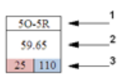

Fig. 3. Description of measurement point

3.2. Description of measurement chain

The measurements of light intensity of the tested lamp were performed with the use of a device known as a goniophotometer. This device consists of a flex arm on which the lamp to be tested is mounted, a fixed sensor, a control-measurement apparatus, and an IT system provided with an application to carry out and edit measurement results. The arm on which the tested lamp is mounted enables changes in position so that during the measurement sequence the axis of the tested lamp is capable of assuming any of the eighteen different positions corresponding to the eighteen measurement points defined by the standard. When the CHMSL lamp is tested, the sensor is placed 25 metres away from the arm on which the lamp is installed. That distance is needed in order to preserve the inverse square law of distance, i.e. the measured intensity of light is directly proportional to the luminous intensity of the source, and inversely proportional to the square of the distance between the source being tested and the location of the measurement device, i.e. of sensor placement. To perform the study, a Goniophotometer GO-H1400, a dedicated device used for measuring light intensity, was applied.

The accuracy of the aforementioned device together with the measuring sensor SP 30 S0T-GO, which had already been used in the study, fulfils the requirements imposed on qualified devices as compliant with the "L" standard described in the standard DIN 5032, part 7 [6]. The discussed measuring device was built in the underground testing tunnel depicted in figure 4, which, thanks to its location and the additional covering of its walls with paint which absorbs reflected radiation, eliminates the influence of external distortion and guarantees suitable measurement conditions.

Fig. 4. Measurement tunnel for photometric study of various type of car lamps

3.3. Scope of the study

3.3.1. Study of the impact of lamp completeness

For the purpose of describing the functional impact of each of the lamp elements on the tested photometric parameters, tests were performed consisting of the measurement of the intensity of light emitted by parts of the complete optical system, i.e.:

- a system consisting of a light source in the form of PCBs installed in the housing with no optical elements,
- a system consisting of a light source and a Fresnel lens as well as a housing.

The last part of the study of the impact of lamp completeness on photometric parameters consisted of measurements of light intensity for an optical system consisting of a light source, Fresnel lens, external lens and housing, i.e. for the entire lamp.

3.3.2. Study of the impact of technological process of making external lens

In accordance with the equation of state (1), in which the elements of the matrix [A(n)] are: a(n), b(n) and c(n), a study was performed in order to define the impact of changes in the parameters of the injection process on the intensity of light emitted by the lamp being tested. In accordance with the primary assumptions, only the external lens manufacturing process was analysed. This does not mean, however, that the remaining lamp elements such as the Fresnel lens or the housing are not essential. Their functional significance in the entire optical system of the lamp is important even though a simplification has been assumed on the basis of the proven high stability and repeatability of the process for these elements. Such an assumption was made in chapter 1 while formulating the equation of state (1), where the thesis regarding the stability of these two components was described in terms of constant values B and C affecting the output value [E(n)].

The study programme on the impact of the parameters of the injection process of the external lens on the intensity of light emitted by the CHMSL lamp covered changes in: holding time, holding pressure, and injection speed [2, 14, 18].

a) Impact of changes in holding time – a(n)

As part of the study, an analysis was made of the impact of change in the holding time parameter value on the quality of manufactured mouldings, and, in effect, on the intensity of light generated by the tested lamp. During the study, a change in parameter was forced by gradually reducing the given value of the set time by 1 s from nominal value, which was initially 7 s, while leaving the temperature of the injection mould for fixed and flexible parts as well as the constant speed of injection unchanged.

b) Impact of changes in holding pressure – b(n)

As part of the study on the impact of changes in holding profile, some gradual changes were introduced in each of the three stages, beginning with nominal values of 150 bar – stage 1, 130 bar – stage 2, 110 bar – stage 3; then pressure values were reduced by 2 bar in each of the stages, thus reaching values of 130–110–90 bar.

c) Impact of changes in injection speed – c(n)

During the course of the study there were proportional changes made in the injection speed at each of the 3 stages, similar to those made during injection pressure testing. The study commenced with the values 24–38–26 mm/s (test 1), followed by reductions of 2 mm/s, thus reaching values of 18–32–20 mm/s (test 4). The study was performed for 3 different additional conditions, with the mould temperature as the variable. While testing sample no. 1, when changes in speed were made, the standard temperature was maintained; while testing sample no. 2, the temperature was reduced by 5°C from nominal value; while testing sample no. 3, the temperature was reduced by 10°C.

4. Presentation of study results

4.1. Study of an optical system with a light source in the form of PCBs with LED diodes mounted in the CHMSL lamp housing

The tested light system may be described by the equation of state (3).

$$C+D = [E(n)]. \tag{3}$$

Figure 5 features the study results for the analysed system. It may be concluded that, for the majority of the 18 measurement points, the light intensity has such a low value that it does not fit within the measuring scale, whereas for the remaining points the incidental light intensity falls within the scale or even meets the requirements, as in the case with point 10O-10R. The distribution is dispersed and not uniform, and the majority of the light emitted by each of the LED diodes constituting part of the light source is lost as a result of the dispersion of light rays in planes which are not tested and are functionally insignificant.

A system constructed in this way, despite combining power corresponding to the power emitted by a complete CHMSL lamp meeting the requirements of the standard E/ECE/324, does not fulfil that standard's requirements, as the majority of light energy is dispersed and lost. The functionality of a system thus constructed fails to fulfil the basic requirements.

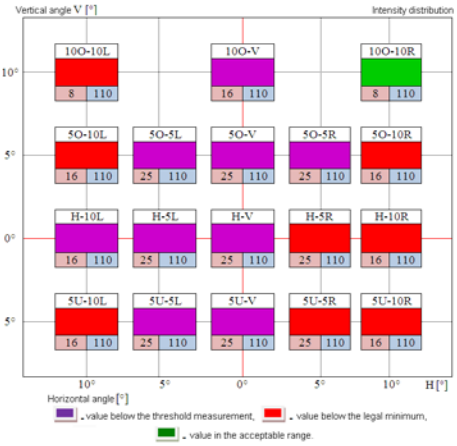

Fig. 5. Distribution of light intensity for the tested light system

4.2. Study of a lighting system with a light source in the form of PCBs with LED diodes mounted in the CHMSL lamp housing with a Fresnel lens

The tested light system may be described by the equation of state (4). In this case the tested light system has been additionally provided with a Fresnel lens.

$$B+C+D = [E(n)]. \tag{4}$$

Figure 6 features a diagram for eighteen tested points of the lamp. By analysing the diagram featuring the results of measurement of the system, one can observe significant improvement in the photometric parameters; however, for the majority of the eighteen points of measurement, the intensity of light is still below the lower boundary of the minimum value required by the standard E/ECE/324.

By analysing the diagram it can be seen that light intensity at points located on the main horizontal axis fulfils the requirements, as the measured value is within the required range; nonetheless one can still observe asymmetrical distribution, especially for extreme points for which the values are beyond the measurement boundaries. The non-linearity of the distribution is also caused by the low rigidity of a light system constructed in this way. In this form the incomplete lamp (no welding to join the housing and the external lens) indicates a high propensity to deformation and distortion.

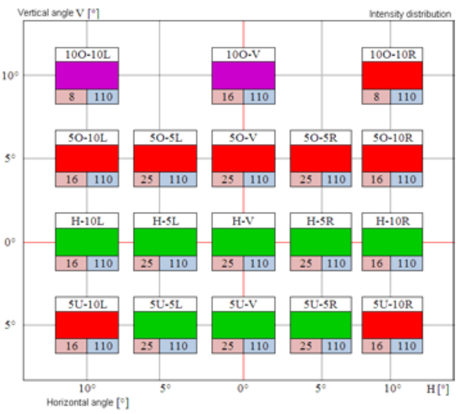

Fig. 6. Distribution of the intensity of light for the tested light system (notations as in fig. 6.)

4.3. Study of the light system with the source of light in the form of PCBs with LED diodes mounted in the CHMSL lamp housing, a Fresnel lens and an external lens

The tested light system may be described by the equation of state (5).

$$B+C+D+[A(n)] = [E(n)]. \qquad (5)$$

In this case we have a complete lamp consisting of four elements, i.e. housing, source of light, Fresnel lens and external lens. A light system constructed in this way demonstrates the expected properties, i.e. the intensity of light falls in within the required range for each of the measured points. This has been achieved by adding the ultimate element, i.e. the external lens, which, first of all, completes the entire construction, creating a uniform and closed solid (enhancing the rigidity of the system); secondly, it fulfils the role of an optical filter enabling the emission of waves ranging from 630 to approximately 780 nm, i.e. waves visible as red light [19]. The third function, being of key importance, is the optical function connected with 'cleaning up' the radiation emitted by the LED diodes and initially corrected by Fresnel lens, so that the distribution of radiation, in this case in the horizontal plane, is compliant with the requirements, i.e. so that it fits within the range of +10°/–5°. Such intensity of light has been achieved thanks to the specific shape of the external lens's internal surface, on which there are several asymmetrical prisms. It is important, for the calculation of the entire system, to accommodate the coefficient of light refraction at the time of crossing the boundary between two sources, PMMA thermoplastic and the air, which is 1.46 (compared with e.g. 1.6 for optical glass, 1.5 for water; and 1.0 for a vacuum) [5]. By studying the intensity of light emitted by the optical system constructed in this way, the impact of each of the constituting elements on the intensity of light at the defined points of measurement is observed. As can be seen, each of the elements fulfils an important role in the system; nonetheless, the function of the external lens is most complex and essential from the perspective of the functionality of the entire CHMSL lamp. The measurement results are presented in Figure 7.

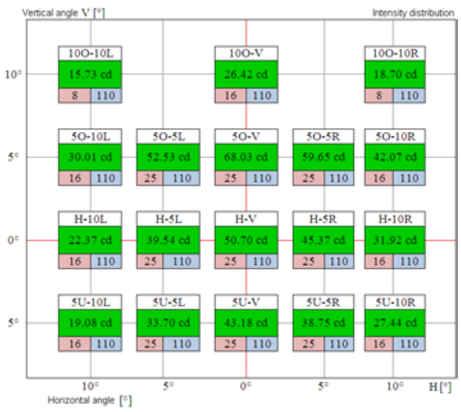

Fig. 7. Distribution of the intensity of light for the tested light system (notations as in fig. 6)

4.4. Impact of changes in the parameters of the injection process

4.4.1. Impact of changes in holding time – a(n)

The results point to relatively small changes in the intensity of light with respect to light intensity values obtained from the measurement of external lenses produced via the process, for which the holding time was 7 s. The study of changes in that value was completed with a holding time of 3 s. Any further reduction of that time caused visible and unacceptable changes as well as geometrical deformations. The study results are featured in Figure 8.

Fig. 8. Impact of changes in mould holding time on the intensity of light emitted by lamp

The analysis of the results indicates that a change in holding time value of 50% causes insignificant changes in light intensities at the measured points of approximately 2% of initial value. Thus it can be assumed that given conditions such as these, the impact of changes in that parameter on our output variable is insignificant. However, it should be remembered that an insufficient holding time may be a cause of deformation in the surface and could cause a deformation resulting from shrinkage of the thermoplastic material in the injection mould chamber.

4.4.2. Impact of changes in holding pressure – b(n)

The list of holding pressure values in the performed tests is presented in Table 1. A reduction in holding pressure to 130–110–90 bar was performed. Setting parameters below that limit causes unacceptable changes in the form of flawed mouldings and deformations resulting from plastic shrinkage. The performed study pointed to an inversely proportional relationship of changes in the intensity of light relative to changes in holding pressure in the central area of the grid of measurement points; reduction increases light intensity values. This rule holds as far as holding pressures of 142–122–102 bars.

The dependence observed in the first range, i.e. improvement of light parameters, results from, among other things, a reduction in the density of the sample. This change is the result of the reduced weight of the mouldings, which is a consequence of reduced holding pressure, i.e. of the supply, within the same time unit, of a smaller quantity of material. Further reduction in holding pressure would cause the appearance of deformations, as clearly indicated by measurements performed with the use of an optical projector. Poorer results on the edges are caused by greater deformations of optical elements, which appear in proportion to increasing distance from the centre of the lens. The results of the measurements are presented in figure 9.

One conclusion from these tests is the confirmation of the positive influence of a reduction in holding pressure value on the improvement of photometric parameters; however, this is observed only in the central part of the grid of measurement points, i.e. central part of the lens. One side effect is a deformation (flexion) of the element, as

Table 1. List of performed tests.

Test no.	Holding profile [bar]
Test 1	150–130–110
Test 2	148–128–108
Test 3	146–126–106
Test 4	144–124–104
Test 5	142–122–102
Test 6	140–120–100
Test 7	138–118–98
Test 8	136–116–96
Test 9	134–114–94
Test 10	132–112–92
Test 11	130–110–90

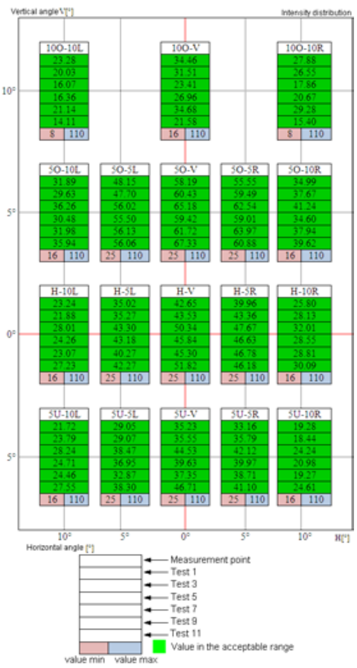

Fig. 9. Impact of changes in mould holding pressure on the intensity of the light emitted by the lamp

well as changes in the imaging of internal cushion lenses, which cause gradual deterioration of the optical parameters in the extreme ranges. These deformations are related to incomplete formation of the moulding due to insufficient pressure. This effect intensifies proportionately to distance from the centre of the moulding, which in this case is also the point of thermoplastic injection.

The tests indicate the feasibility of an improvement in the parameters of light intensity through a change in pressure value; however, such changes would probably be insignificant, a maximum of 5% over the present parameters of injection, and with a risk of deformations, which, within the initial range of parameter reduction, are not easily spotted; nonetheless, with a further reduction in holding parameters, they tend to increase and exert a negative influence on photometric parameters as well as on the geometry of the produced element.

4.4.3. Impact of changes in injection speed – c(n)

A list of injection speed values for various mould temperatures is presented in table 2.

The analysis of the results of tests presented in Figure 10 indicates a change in the photometric parameters of the tested lamp with respect to a change in plastic injection speed. In the first case, in which the injection mould maintained a nominal temperature, a reduction in injection speed caused an improvement in the photometric parameters. However, in a case where temperature was reduced by −5°C and –10°C, this dependence proceeded in the opposite direction, i.e. a reduction in the injection speed caused a reduction in light intensity value. Knowing that injection speed has an impact on the temperature of injected material resulting from flow through a gate channel, it can be concluded that in the first case the reduction in speed caused reduced friction, and thus a reduced impact of injection speed on temperature increase; in addition, reduced speed caused a prolongation of injection time, and hence an improvement in the formation and quality of mouldings. In the following two cases a reduction in speed, and thus a reduction in temperature growth resulting from the process of material injection, coincided with additional forced temperature reduction, which caused deterioration in the moulding parameters.

Table 2. List of performed tests

	Sample no. 1 Nominal temp. of mould	Sample no. 2 Temp. reduced by 5°C	Sample no. 3 Temp. reduced by10°C
Test 1 [mm/s]	24 – 38 – 26	24 – 38 – 26	24 – 38 – 26
Test 2 [mm/s]	22 – 36 – 24	22 – 36 – 24	22 – 36 – 24
Test 3 [mm/s]	20 – 34 – 22	20 – 34 – 22	20 – 34 – 22
Test 4 [mm/s]	18 – 32 – 20	18 – 32 – 20	18 – 32 – 20

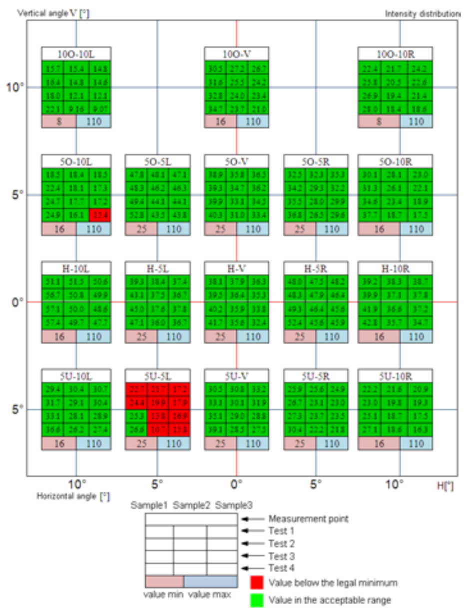

Fig. 10. Study of changes in the photometric parameters of the lamp at changing injection speeds

The performed tests showed that injection speed can be reduced at a given mould temperature; however, this extends cycle time, and hence increases costs. The conclusion regarding the impact of changes in mould temperature is also significant, as this should force better and more accurate monitoring of the systems responsible for the maintenance of temperatures at an appropriate level.

5. Summary

The article presents the results of the study of the impact of individual design elements and of the technological process of external lens manufacture on the photometric parameters of a third lamp, type CHMSL, that signals that a car is braking, applied in passenger cars, trucks and buses. The solutions currently in use in the automotive industry such as LED diodes as a source of light, or newly-developed laser diodes, pose utterly new challenges for designers and producers, and require greater accuracy, repeatability and stability from the manufacturing process.

The objective of the performed tests was to describe the variability of the manufacturing process and the impact of these changes on output value, i.e. the intensity of light emitted by the CHMSL lamp. The presented tests and observations are part of the optimisation of the manufacturing process which can be conducted using various methods, starting with theoretical analysis, to digital simulations or the performance of tests consisting of simulations of process variability in order to define acceptable tolerance ranges for process input variables such as geometrical parameters of lamp elements, parameters of the injection process, etc.

The performed analyses indicated the proportional influence of input variables on output signal, which until now was merely an estimated value. The impact of changes in the parameters of injection process, apart from pointing to certain anomalies, particularly in connection with the temperature of the injection process, has caused a change in the system of injection moulding machine inspections, since the demonstrated instability of the process (frequently related in reality to technical condition), especially in the case of tested external lenses, has a critical effect on the parameters of the entire lighting system.

Based on this study, the fundamental parameters influencing the quality of the manufactured design elements of CHMSL lamps can be defined. Taken as a whole, the presented tests and experiments, which frequently consisted of forcing certain extreme conditions upon the technological process, have contributed to better familiarisation with the process and to its further optimisation. The results of the study will be successively implemented in the technological process of manufacturing CHMSL lamps and other lamps of similar construction.

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Bolesław KARWAT, Ph.D., D.Sc. (Eng.), Assoc. Prof.
Dariusz GŁOWIŃSKI, M.Sc. (Eng.)
Emil STAŃCZYK, M.Sc. (Eng.)
Faculty of Mechanical Engineering and Robotics
AGH University of Science and Technology
Al. A. Mickiewicza 30, 30-059 Kraków, Poland
E-mails: karwat@agh.edu.pl, dariusz.glowinski@interia.pl, stanczykemil@gmail.com