

PROPOSAL TO INCLUDE FREE FORM MIRRORS IN REG. ECE 46.06

Summary

- The purpose of the following analysis is to offer an update of quality in optical vision in rear view mirrors by adopting innovative surface designs and manufacturing processes. The intention is to let the current spherical product continue to be offered on the market and at the same time to let the new generation of free form mirrors to be offered to improve the quality of the reflected images and optimize the mirror size for a given field of vision.
- The vehicles manufacturers (style, function, quality), together with the car components industry supply chain, will determine whether to use this optical innovation to improve comfort and safety (same surface dimension with improved field of view) or to achieve energy savings, reduce pollutant emissions and noise and, in case of BEVs, to increase the range (same field of view with reduced surface dimensions).

Reg. ECE 46.06: current state of the art (1/2)

This section refers to the part of the **Regulation related to exterior rear view mirrors**. The Regulation states that:

- **"Spherical surface"** means a surface, which has a constant and equal radius in all directions (§ 2.1.1.7.).
- **"Aspherical surface"** means a surface, which has only in one plane a constant radius (§ 2.1.1.8.).
- **The reflecting surface** of a mirror shall be either flat or spherically convex. Exterior mirrors may be equipped with an additional aspherical part provided that the main mirror fulfils the requirements of the indirect field of vision (§ 6.1.2.2.1).

Reg. ECE 46.06: current state of the art (2/2)

➤ The **value of "r"** for spherical mirrors shall not be less than:

- **1200 mm for rear-view mirrors (Class I)** (§ 6.1.2.2.4.1.);
- 1200 mm for Class II and III main rear-view mirrors (§ 6.1.2.2.4.2.);
- 300 mm for "wide-angle" mirrors (Class IV) and "close-proximity" mirrors (Class V) (§ 6.1.2.2.4.3.);
- 200 mm for front mirrors (Class VI) (§ 6.1.2.2.4.4.).
- 1000 mm or more than 1500 mm for Class VII main rear-view mirrors (§ 6.1.2.2.4.5.).
- **where "r" means the average of the radii of curvature measured over the reflecting surface, in accordance with the method described in Annex 7** (§ 2.1.1.4.).
- The radius of curvature r_i of the aspherical part shall not be less than 150 mm (§ 6. 1.2.2.3 .2.).
- The difference between r_i or r'_i , and r_p at each reference point shall not exceed 0.15 r (§ 6.1.2.2.2.1.).
- The difference between any of the radii of curvature (r_{p1} , r_{p2} , and r_{p3}) and r shall not exceed 0 .15 r.

Annex 7 describes the procedure to measure with a spherometer the radii of curvature in three points according to two orientations of the spherometer. In this way the measurements are six and, from the experimental data, the mean value "r" has to be computed, together with a set of differences among the measured radii that have to be less than 0.15 r.

Analysis of the spherical mirrors compliant with Reg. ECE 46.06 (1/2)

- The Regulation states that the reflecting surface of the mirror shall be spherically convex, with allowance of mean radius deviations due to the production tolerances
- The Regulation establishes an experimental procedure to measure the deviation of the real surface of a mirror with respect to the ideal one, and sets the relevant limits
- Cars should ideally be equipped with perfectly spherical mirrors. In reality, because of the production process, all of the mirrors are provided with surfaces in which each point is randomly deviated with respect to the position on the ideal sphere
- In the past, the need to extend the field of vision for safety purposes suggested to adopt the spherical surface as it was the easiest surface to design and to produce. The radius was reduced step by step till the actual limit of 1200 mm as a good compromise among different requirements: field of view, mirror size, reflected objects dimensions and image distortion

Analysis of the spherical mirrors compliant with Reg. ECE 46.06 (2/2)

- The current regulation is responding to the need of geometrical verification of the mirror surface, indicating limits related to the surface geometry - spherically convex - and minimum mean radius of 1200 mm - as a result of measurements taken at given positions on the convex surface and valid for all exterior rear view mirrors to define a minimum size of reflected objects at a given distance
- The quality requirements - optical distortion and ratio between vertical and horizontal sizes of reflected objects - are not indicated in the Regulation and they are left to the quality assurance protocols and negotiations between car makers and mirror suppliers
- The distortion and dimensions ratios requirements define the quality of the reflected images in addition to ECE 46 mean radius measurements

From spherical mirror surface to free form mirrors (1/2)

- A *free form* surface can't be described by an equation because each point has been defined through a mathematical procedure that allows to achieve specific optical design targets. Taking into account the production tolerances, real spherical mirrors installed on the cars, even those better produced, actually have ***random free form surfaces*** because the deviation of each point inside the limit established by the Regulation, even if small, is due only to the random result of the production.
- In the last ten years many studies have been done on the optical behaviour of non-spherical surfaces, and all of these studies show that the usage of non-spherical surfaces allows to get improvements of the optical performances. Moreover, it's a matter of fact that the optical axis of a spherical mirror installed on a car is rotated and decentred with respect to the axis of the driver's eyes; this condition leads to images squeezed in the horizontal direction. The adoption of a free form surface can compensate the asymmetrical position of the mirrors, reflecting images with the right proportions.

From spherical mirror surface to free form mirrors (2/2)

- Design software and manufacturing processes of moulds - CNC multi axes and optical polishing - have created the concrete conditions to reproduce complex surfaces with very affordable quality and reproducibility. Current manufacturing processes of mirrors can be adopted for free form surfaces.
- Complying with the requirements of Reg. ECE 46.06 and utilizing the allowed tolerance – $0.15 r$ – as a potential freedom allowance to design free form surfaces will bring the opportunity to optimize the optical performances of the mirror through the appropriate optical software tools. The Average Radius of the free form surface, measured according to the procedure given in Annex 7, will still comply with the regulation.

Experience of process design and manufacturing on mirrors for vehicles (1/2)

A spherical mirror was replaced by a *free form mirror* for the purpose to allow a significant size reduction of the mirror (-20% area):

- the *free form mirror* complied with ECE R46
- the *free form mirror* contributed to reduce the volume of the mirror body, as well as noise at wind gallery test and CX index of the vehicle
- the results have been validated by a car maker

Experience of process design and manufacturing on mirrors for vehicles (2/2)

An *aspherical mirror* was replaced with a *free form mirror with extended area*. Aim of the project was to reduce the mirror size (-20%) and to improve the image quality of the binocular vision in the transition zone between spherical and aspherical part of the original aspherical mirror:

- the *free form mirror with extended area* complied ECE 46R
- the *free form mirror with extended area* has been designed with a slight change between low and high curvature part. In this way the binocular vision through the transition zone between low and high curvature zone, that is marked with a line, has been significantly improved and the mirror guarantees a clear and relaxed vision through the full mirror. Therefore, higher safety in rear view vision has been achieved and the driver has a clear view in the external part of the mirror as well, and not just a perception of objects, distance and speed