

Rearward Visibility Simulation System of Motorcycle Rearview Mirrors

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ABSTRACT

Visibility provided by the rearview mirrors of motorcycles is regulated by law, and should be measured. Thus far, compliance with legal standards has been checked first by investigation using 2-dimensional CAD, and then manufacturing a prototype motorcycle. However, an issue unique to motorcycles is displacement of the rearview mirror when the rider rides the motorcycle, which affects rearward visibility. This factor hindered sufficient investigation in two dimensions, which delayed determination of the design specifications. Therefore, a simulation system has been developed that uses 3-dimensional CAD, which incorporates a function that automatically sets the legal prerequisites using a combination of the Newton-Raphson method and bisection method. This enabled assessment in the design layout stage, and contributed to early layout maturation.

1. Introduction

Countries around the world have prescribed standards governing the reflection of the rider and the rearward visibility of rearview mirrors in order to enhance motorcycle safety. Thus far, compliance with legal standards has been judged first by checking with 2-dimensional CAD, and then manufacturing a prototype motorcycle, which has delayed assessment of legal compliance. It is challenging to investigate factors such as displacement of the rearview mirror when the rider rides the motorcycle by using 2-dimensional CAD. Therefore, a system has been developed to conduct more realistic simulations by using 3-dimensional CAD data. This system enables accurate assessment of compliance with legal standards in a short time based on the specifications data of the rearview mirror and the rider.

This paper presents an overview of the rearward visibility simulation system for motorcycle rearview mirrors, and reports on rearview mirror surface control.

2. Laws and Regulations for Motorcycle Rearview Mirror

Table 1 lists typical examples of laws and regulations governing rearward visibility for motorcycles. To assess legal compliance, it is necessary to actualize the given setting conditions. Therefore, a function that sets these conditions in 3-dimensional CAD is important to realize a simulation system.

3. Features of Rearward Visibility of Motorcycle Rearview Mirrors

Unlike cars, displacement of the rearview mirrors resulting from tire deformation when the rider rides the motorcycle has a large effect on rearward visibility. In addition, more realistic simulations can be performed by adjusting the rearview mirror position. Therefore, when conducting simulations it is necessary to first obtain the relative positions of the rearview mirrors and the rider when the rider rides the motorcycle (Fig. 1).

4. System Overview

4.1. Flowchart

Figure 2 shows the simulation system flowchart. First, the rider position, rearview mirror position and other data are input. Next, the rider position when riding the motorcycle is obtained from the 3-dimensional layout data and specifications data, and after that the simulation starts. Note that the “JASO T009-94⁽¹⁾ Measurement Method of Field of Rear-view Mirror for Motorcycles” is used as the method for measuring the actual motorcycle. The simulation adjusts the rearview mirror position by positioning the mirror surface in accordance with this measurement method.

4.2. Geometrical Background

The system obtains the point (Reflection Point) on the mirror surface at which the object (Object Point) appears

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Table 1 Laws and regulations for motorcycle rearview mirror

Regulations	Setup	Points to be checked
Rearward visibility of rearview mirror in Japan	Align center point of mirror surface with point, reflecting on mirror surface, 50 m behind.	Non-visible range equal to or less than 25%
Verification of regulation conformity in Belgium / Netherlands	Align corner point of maximum rectangle which is inscribed around edge of mirror surface, with point on ground line, reflecting on mirror surface, 10 m behind reference eye point.	Reflection on 10 m line equal to or more than 2.5 m.
Verification of regulation conformity in Germany	Align lower corner point (vehicle side) of maximum rectangle which is inscribed around edge of mirror surface, with point on ground line, reflecting on mirror surface, 20 m behind reference rear view mirror point.	Reflection on 20 m line equal to or more than 2.5 m.
Verification of regulation conformity in EEC	Align lower corner point (vehicle side) of maximum rectangle which is inscribed around edge of mirror surface, with point on ground line, reflecting on mirror surface, 10 m behind reference rear view mirror point.	Reflection on 10 m line equal to or more than 2.5 m.

as viewed from the position of the motorcycle rider's eye (Eye Point). The reflection point to the mirror surface is calculated geometrically by varying the center point of the sphere (Center Point) while fixing the connection position (Joint Point) of the rearview mirror. Figure 3 shows an image of the mirror surface. The reflection point can be obtained using the following three conditions.

- (1) The reflection point is located on the plane that passes through the position of the eye (Eye Point), the position of the object (Object Point), and the center point of the mirror surface point.
- (2) The reflection point is located on the sphere with radius r , centering on the mirror surface central point.

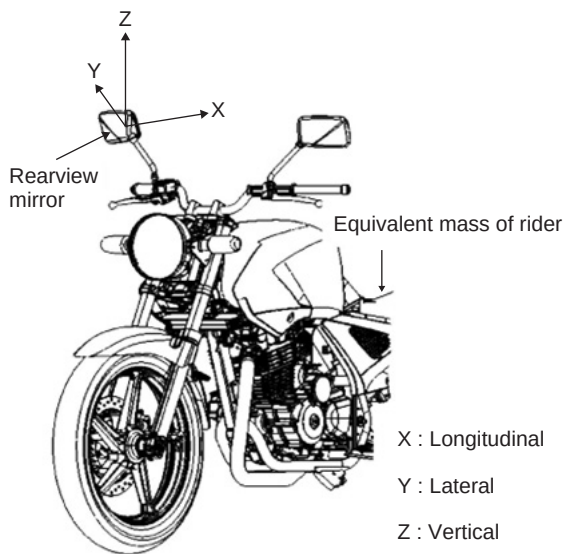


Fig. 1 Positional relationship of rearview mirror and rider when rider rides

- (3) The angle formed by the vector from the reflection point to the eye point and the vector from the reflection point to the object point is bisected equally by the vector from the mirror surface central point to the reflection point.

4.3. Default Value Settings

The parameters were set as follows.

$R(x, y, z)$: The reflection point (Reflection Point)

$E(E_x, E_y, E_z)$: The position of the eye point (Eye Point)

$O(O_x, O_y, O_z)$: The position of the object (Object Point)

$C(C_x, C_y, C_z)$: The center point of the sphere (Center Point)

$M(M_x, M_y, M_z)$: The mirror surface center point (Mirror Point)

$J(J_x, J_y, J_z)$: The connection position with the mirror (Joint Point)

$G(G_x, G_y, G_z)$: The default estimated value (Guess Point)

r : The mirror radius (Mirror Radius)

α, β : Reference points for obtaining the guess point

$f(x, y, z)$: Discriminant for judging presence on the plane CEO

a, b, c, d : Coefficients of $f(x, y, z)$

$g(x, y, z)$: Discriminant for judging presence on a plane

A : Amount of Guess point movement

Figure 4 shows the coordinate illustration of the default value. When the default value is inappropriate, for example when an inflection point is present in the interval to be searched for a solution, either the calculation does not converge on a nearby solution or the calculation

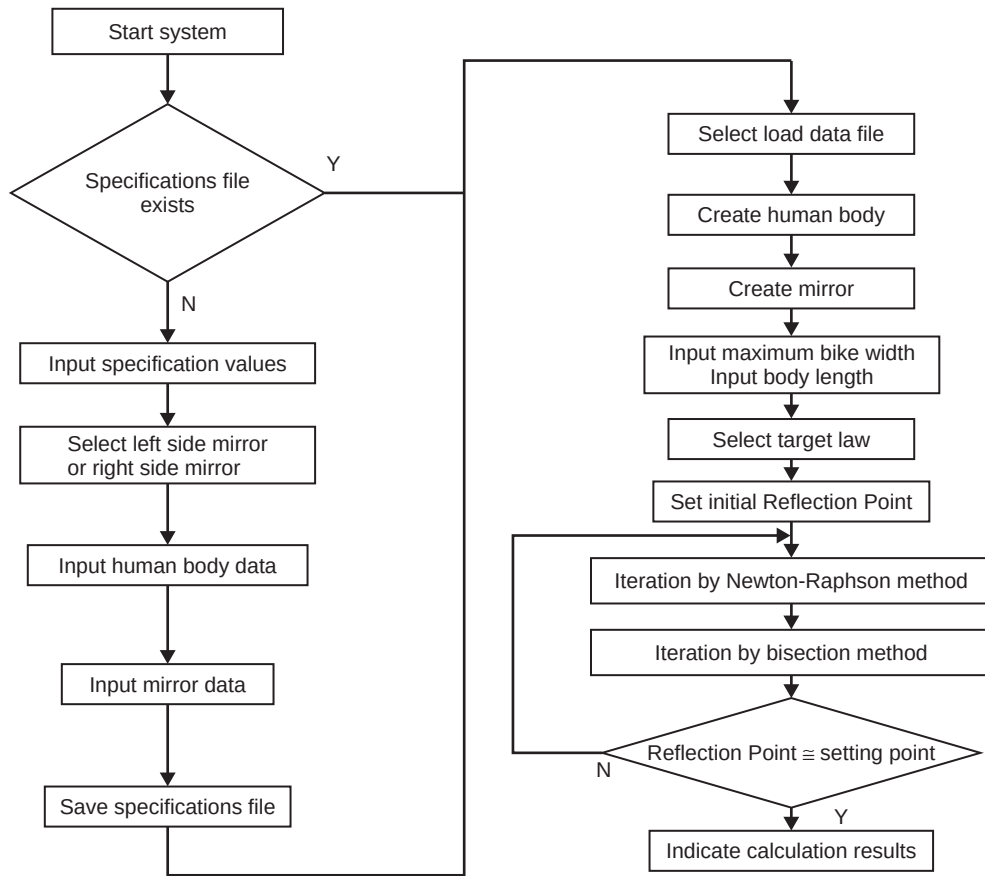


Fig. 2 Simulation flowchart

converges but the convergence speed is slow. Therefore, the default value should be a value thought to be close to the solution. Here, the midpoint between the two points α and β on the mirror surface shown in Fig. 4 is set as the default value.

Therefore, the vector of the default value from the mirror surface central point is as follows.

$$\vec{G} - \vec{C} = \frac{\vec{\alpha} + \vec{\beta}}{2} \quad (1)$$

The four vectors $\vec{G}$, $\vec{C}$, $\vec{\alpha}$ and $\vec{\beta}$ represent the vectors from the origin to the respective points.

That is to say, the guess point of the default value can be expressed as follows.

$$G(Gx, Gy, Gz) = \frac{1}{2} \left\{ \left(\frac{\vec{CE}}{|\vec{CE}|} + \frac{\vec{CO}}{|\vec{CO}|} \right) \cdot r + 2\vec{C} \right\} \quad (2)$$

4.4. Calculation Algorithms

The calculation is performed by the following procedure.

- (1) The reflection point on the mirror surface is obtained by iterative calculations starting from the default value.

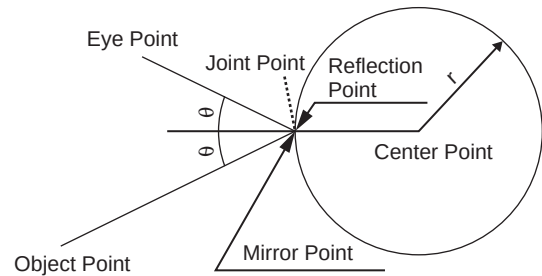


Fig. 3 Mirror surface image

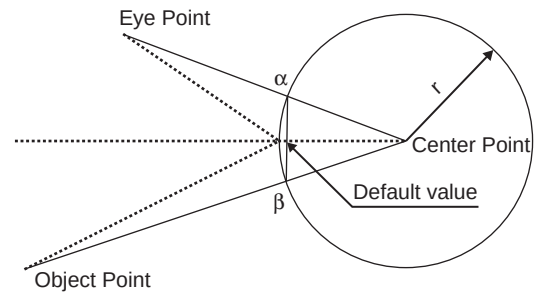


Fig. 4 Image of default coordinate value

- (2) The rearview mirror is positioned so that the obtained reflection point matches the legally stipulated position. At this time, as “Center Point” also moves, some deviations appear in the reflection point.
 - (3) A new default value is given.
- Steps (1) to (3) above are repeated until the values converge.

4.4.1. Obtaining the mirror surface reflection point

The Newton-Raphson method, which has a fast convergence speed, was expanded to three dimensions and used to obtain the reflection point⁽²⁾. Figure 5 shows the algorithm flow for obtaining the reflection point. The algorithm exits the loop when each component of A in this flow infinitely approaches zero, or after 100 loops in consideration of cases when the solution does not converge.

When the function Eq.(3) obtained from each component and intercept of each vector has zero, the “Reflection Point” is considered to be on the plane that passes through C, E and O.

$$f(x, y, z) = ax + by + cz + d \quad (3)$$

When the function Eq.(4) obtained from the equation of sphere has zero, the reflection point passes through C and is considered to be on the sphere with radius r .

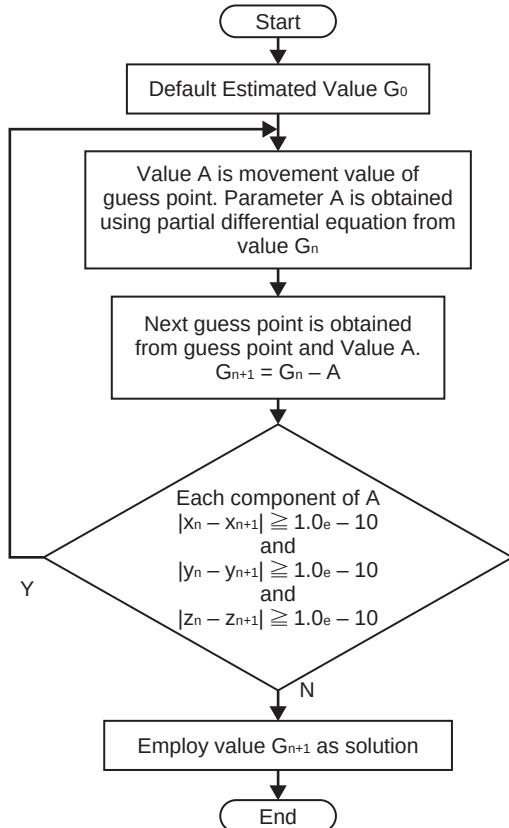


Fig. 5 Newton-Raphson method algorithm flow

$$g(x, y, z) = (x - Cx)^2 - (y - Cy)^2 - (z - Cz)^2 - r^2 \quad (4)$$

According to the conditions of angle bisection described in 4.2. (3) above, when the angle formed by $\overline{CR}$ and $\overline{RE}$ and the angle formed by $\overline{CR}$ and $\overline{RO}$ are equal, the light coming from O is reflected by R and reaches E.

The following equation uses Eq. (3) with not just one variable, but expanded into a three-dimensional simultaneous nonlinear equation.

$$\begin{bmatrix} x_n - x_{n+1} \\ y_n - y_{n+1} \\ z_n - z_{n+1} \end{bmatrix} = \begin{bmatrix} f(x_n, y_n, z_n) \\ g(x_n, y_n, z_n) \\ q(x_n, y_n, z_n) \end{bmatrix} \begin{bmatrix} \frac{\partial f}{\partial x_n} & \frac{\partial f}{\partial y_n} & \frac{\partial f}{\partial z_n} \\ \frac{\partial g}{\partial x_n} & \frac{\partial g}{\partial y_n} & \frac{\partial g}{\partial z_n} \\ \frac{\partial q}{\partial x_n} & \frac{\partial q}{\partial y_n} & \frac{\partial q}{\partial z_n} \end{bmatrix}^{-1} \quad (5)$$

Here, when the values of $|x_n - x_{n+1}|$, $|y_n - y_{n+1}|$ and $|z_n - z_{n+1}|$ each infinitely approach zero, the solution to the simultaneous equation is considered to have converged.

4.4.2. Positioning the rearview mirror

Once the mirror surface reflection point has been obtained, the rearview mirror is positioned so that the point is at the set position prescribed by law. When positioning the rearview mirror, the Newton-Raphson method obtains the solution at relatively high speed, but the solution may diverge. Therefore, the bisection method was used from the standpoint that the solution always converges as long as the calculation interval is determined. The outline of the bisection method and the application of this method to calculate the reflection on the mirror surface are described below.

(1) Bisection method

The bisection method theorem (calculation method)⁽²⁾ used to position the rearview mirror is described below.

The actual numerical calculation starts with the two points a and b ($a < b$) such that $f(a)f(b) < 0$ as default values, and the calculation $f(c)$ is performed on the point $c = (a + b)/2$ that bisects the interval $[a, b]$. When $f(c)f(a) < 0$, b is replaced with c . When $f(c)f(a) > 0$, a is replaced with c . This operation is repeated so that the solution is always within the interval $[a, b]$, and the calculation ends when the interval width $|b - a|$ becomes less than the determination value ε that controls the solution accuracy. Figure 6 shows the bisection method algorithm flow.

(2) Application of the bisection method to calculation of mirror surface reflection

Figure 7 shows an image of applying the bisection method to mirror surface reflection. The vector that joins “Center Point” and “Reflection Point 1” is labeled $\overline{CR_1}$, the vector that joins “Center Point” and “Reflection Point

2" is labeled $\overrightarrow{CR_2}$, and the vector that joins "Center Point" and "Target Point" is labeled $\overrightarrow{CT}$. The angle formed by $\overrightarrow{CT}$ and $\overrightarrow{CR_1}$ is labeled θ_1 (- direction), and the angle formed by $\overrightarrow{CT}$ and $\overrightarrow{CR_2}$ is labeled θ_2 (+ direction). These θ_1 and θ_2 are substituted to a and b in the bisection method described in 4.4.2. (1) above.

(3) Adjusting the reflection standard position on the mirror surface and the line of sight by rearview mirror automatic adjustment

Figure 8 shows the algorithm flow to actually obtain the line of sight and rearview mirror adjustment angle using the bisection method. As shown in Fig. 8, there are

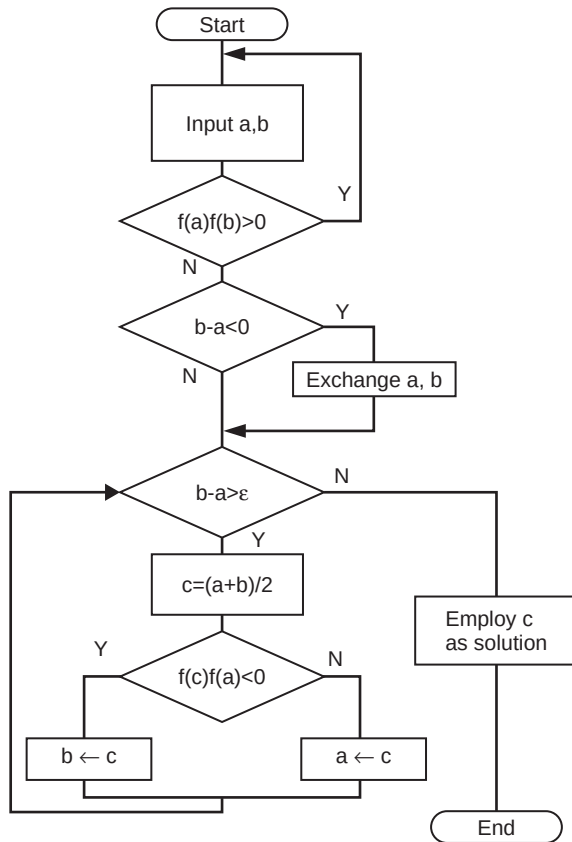


Fig. 6 Bisection method algorithm flow

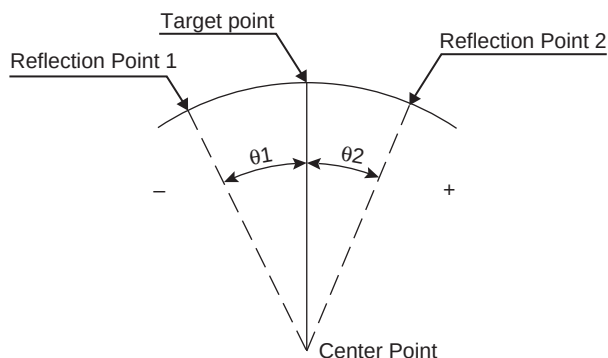


Fig. 7 Image of bisection method in mirror reflection

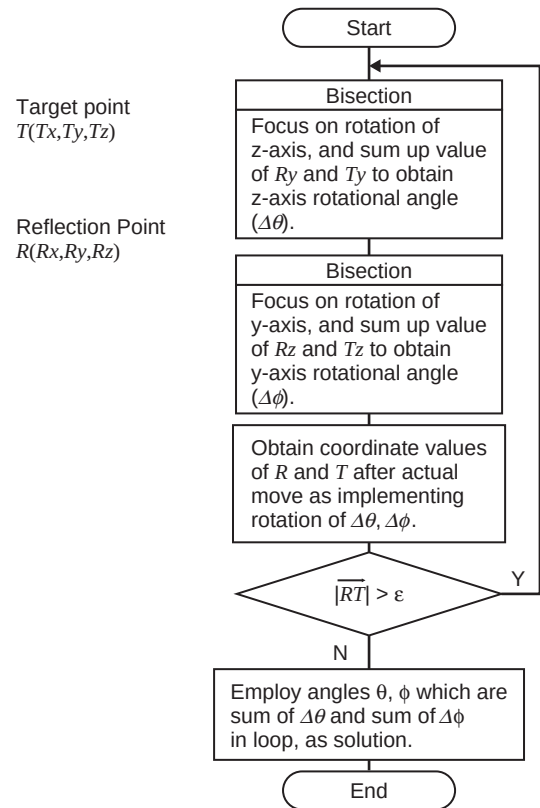


Fig. 8 Mirror automatic adjustment flow

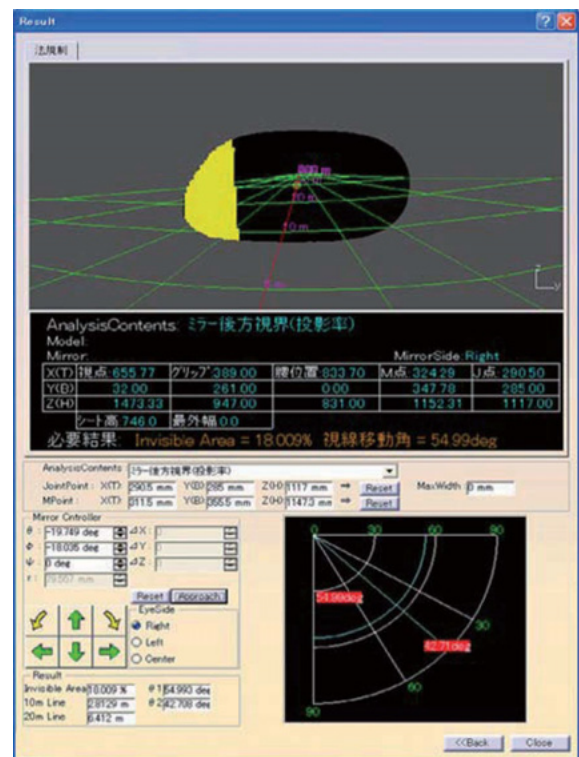


Fig. 9 Graphical user interface (GUI) of simulation system

an infinite number of patterns for aligning the standard position on the mirror surface with the line of sight, so calculation is performed without taking into account the X axis.

4.5. Graphical User Interface (GUI)

A GUI was created to simplify the applicable legal settings and the results display of object reflection to the rearview mirror (Fig. 9). This made it easy to reselect the applicable laws and regulations, and enabled both visual and data display of the results simply by pressing the automatic adjustment button.

5. Results of Positioning Rearview Mirror in the Simulation System

The results of positioning the rearview mirror in order to check the legal compliance of the rearward visibility provided by a rearview mirror are introduced here as an

example of application. Figure 10 shows the simulated conditions based only on specifications, before making adjustment in order to comply with the regulations. Figure 11 shows the results after automatically adjusting the position to check legal compliance. Note that the yellow portion on the mirror surface represents the reflection of the rider's arm.

The above-mentioned results illustrate that the simulation system enables the rearview mirror positioning to comply with the setting specified in the regulation to align the mirror center point with the point 50 m to the rear. This helps eliminate the need for manual positioning, and the results can be obtained in a short time, enabling simulations to be performed as many times as necessary in order to check legal compliance.

The rearview mirror position can also be adjusted automatically in the same manner to comply with other legal standards.

6. Conclusion

In order to check the legal compliance of motorcycle rearview mirrors, a simulation system that uses 3-dimensional CAD, which has a function that automatically sets the legal prerequisites using the Newton-Raphson method and the bisection method, has been developed.

- (1) The ability to perform simulations using 3-dimensional CAD enables checking of legal compliance without creating a prototype motorcycle.
- (2) Simulations can be performed for various legal standards, enabling designers to perform simulations using the latest information.
- (3) This contributed to early maturation of the 3-dimensional layout in the design stage.

References

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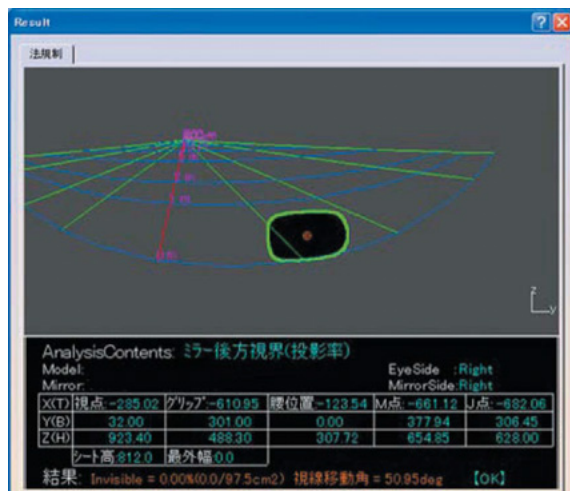


Fig. 10 Before mirror adjustment

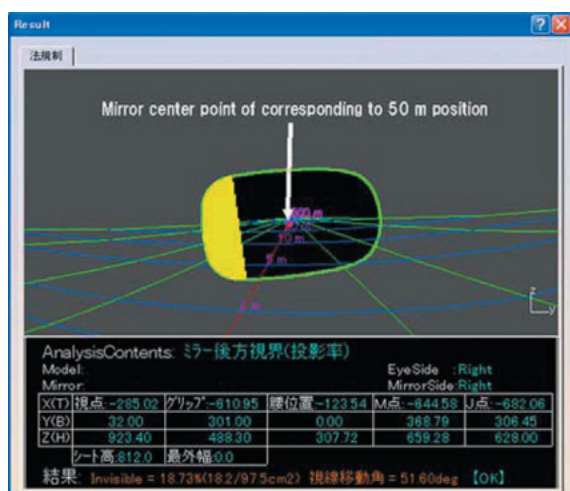


Fig. 11 After mirror automatic adjustment