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A Study on Motorcycle AFS Visibility and Glare

In recent years, the Adaptive Front Lighting System (AFS) has been increasingly used in headlamps for four-wheeled vehicles. The AFS is a system that improves the visibility in accordance with the driving conditions by controlling the light axis of headlamps in response to the steering angle or by adding light sources to existing headlamps.

With regard to the motorcycle AFS, Japanese motorcycle manufacturers have presented AFS-mounted prototype vehicles as part of the Advanced Safety Vehicle (ASV) Project, which is being implemented by Japan's Ministry of Land, Infrastructure, Transport and Tourism. However, the motorcycle AFS has not yet been introduced to the market.

In the case of motorcycle headlamps, the range of road illumination in the direction of travel tends to be narrow because the headlamp leans with the vehicle body in curves. Therefore, the visibility is expected to improve if we can compensate the headlamp tilt ("bank angle") and keep the cut-off line horizontal.

With this background, this study gathered discussion materials necessary for specifying standards for the motorcycle AFS and discusses the effect of correcting the motorcycle headlamp bank angle on the improvement of visibility as well as on the glare to oncoming vehicle drivers (uncomfortable glare or "glare").

1. Measurement of the bank angle and the aiming direction of a motorcycle headlamp in a curve

1.1 Purpose

The purpose is to measure the bank angle and the aiming direction of a motorcycle headlamp in a curve to determine the input values that are needed for Section 2 "Simulation Evaluation of Motorcycle AFS Visibility" and Section 3 "Simulation Evaluation of Motorcycle AFS Glare".

1.2 Method

On a steady-state circular turning track (with white lines marked on circles having different turning radii), the bank angle and the aiming direction of a motorcycle headlamp in a left curve were measured.

As the test vehicle, a 400cc motorcycle was used. The images produced by the CCD camera mounted on the motorcycle at the height of the headlamp (850 mm; Figure 1) and the images produced by the CCD camera fixed on the ground were analyzed to determine the bank angle and the aiming direction of the motorcycle headlamp.

The test riders were four males who regularly ride motorcycles for test work.

The measurements were taken 20 times under each measurement condition (4 riders x 5 rounds).

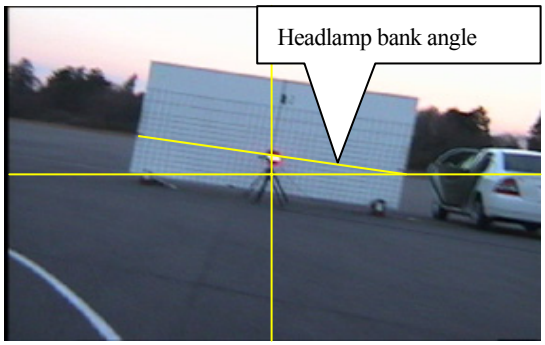


Fig. 1 Image by motorcycle mounted CCD camera

1.3 Results

Based on the analysis results of the 20 rounds for each measurement condition, the bank angle of the motorcycle headlamp was determined, and the aiming direction for that bank angle was determined (Table 1).

Table 1 Results of headlamp bank angle measurement and aiming direction measurement

Condition		Headlamp		
Radius (m)	Speed (km/h)	Bank angle (Degree)	Direction (Degree)	
			Y	Z
20	20	11.1	0.3	0.6
30	30	12.9	1.7	0.3
50	40	13.3	3.6	0.2
70	50	15.2	0.5	0.2
140	60	13.4	1.3	0.4

Y : + Indicates rightward. Z : + Indicates upward.

2. Simulation Evaluation of Motorcycle AFS Visibility

2.1 Purpose

The purpose is to compare, by simulation, the visibility performance among a bank angle-compensated headlamp, a headlamp whose cut-off line is adjusted so that it remains parallel to the ground at all times (AFS headlamp), and a conventional headlamp.

2.2 Method

Simulation was conducted on the headlamp passing beam presenting a symmetrical lighting pattern with a horizontal cut-off line. The headlamp aiming direction was set with a cut-off line 1% (0.57 degrees) downward of the horizontal line.

The visibility distance was determined based on the criterion that the visual target is considered visible when it is located in the range below the cut-off line of the motorcycle headlamp passing beam (that is, when the relatively strong light of the headlamp reaches the target).

The simulation was conducted for the condition where the motorcycle headlamp bank angle is not compensated and for the conditions where the bank angle is compensated. As the conditions for the bank angle compensation, a total of four conditions were set: three conditions with the fixed bank angle compensations (7.5 degrees, 15 degrees, and 22.5 degrees) and one condition with the cut-off line adjusted to remain parallel to the ground (AFS headlamp).

The input data necessary for the calculation (the bank angle and the aiming direction of the motorcycle headlamp) as shown in Table 1 were used.

The motorcycle driving course and the visual targets are shown in Figure 2. The lane width is 3.5 m, and the motorcycle was driven along the center of the left lane on a left curve. The distance was indicated based on the circular distance along the lane center.

Four turning radii of curves were set: 30 m, 50 m, 70 m and 140 m.

Three visual targets were set: inner line, lane center, and center line in the left curve.

The range of calculation was determined to be that where the distance between the motorcycle headlamp location and the eyepoint reaches 1/4 of the circle or 100 m. That is, the calculation was performed using the 47 m range for the turning radius of 30 m, the 78 m range for the turning radius of 50 m, and the 100 m range for the turning radii of 70 m and 100 m.

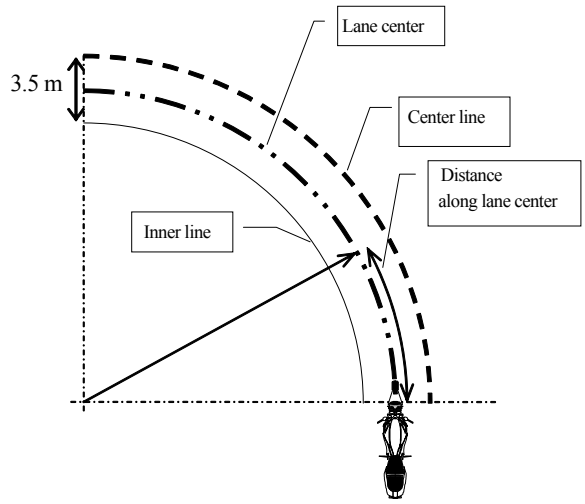


Fig. 2 Driving course and visual targets

2.3 Results

The results of simulation of motorcycle AFS visibility are given in Table 2.

The ground angle is indicated as negative when the bank angle compensation of the motorcycle headlamp was below the bank angle of the vehicle body, as zero when the bank angle compensation was the same as the bank angle of the vehicle body, and as positive when the bank angle compensation exceeded the bank angle of the vehicle body (the same applies hereafter).

Compared with the case in which the bank angle of the motorcycle headlamp is not compensated (with the bank angle

compensation of 0), the cut-off line reaching distance becomes longer when the bank angle is compensated. All the visual targets are located below the cut-off line when the bank angle compensation is 22.5 degrees (with the positive ground angle) and at the AFS condition (with the zero ground angle).

Assuming that 40 m or longer is the permissible distance in terms of visibility, that is, the distance at which the visual target can be visually recognized, all the visual targets are within the permissible distance when the bank angle compensation is 15 degrees, 22.5 degrees and at the AFS condition.

It is therefore found that the headlamp visibility is improved by compensating the headlamp bank angle when driving in a curve. In particular, when the headlamp bank angle is compensated to the same level as the bank angle of the vehicle body (with the zero ground angle) or to a level higher than the bank angle of the vehicle body (with the positive ground angle), the visibility is greatly improved.

Table 2 Results of visibility simulation for headlamp bank angle compensation

(Distance between headlamp and cut-off line: m)

Radius	Speed	Bank Angle Compensation	Ground Angle (Degree)	Inner Line	Lane Center	Center Line
30m	30km/h	0°	−12.9	9	13	16
		7.5°	−5.4	19	21	23
		15°	2.1	○	○	○
		22.5°	9.6	○	○	○
		AFS	0	○	○	○
50m	40km/h	0°	−13.3	9	15	18
		7.5°	−5.8	20	23	26
		15°	1.7	○	○	○
		22.5°	9.2	○	○	○
		AFS	0	○	○	○
70m	50km/h	0°	−15.2	11	18	23
		7.5°	−7.7	21	25	29
		15°	−0.2	95	95	94
		22.5°	7.3	○	○	○
		AFS	0	○	○	○
140m	60km/h	0°	−13.4	18	26	33
		7.5°	−5.9	36	41	46
		15°	1.6	○	○	○
		22.5°	9.1	○	○	○
		AFS	0	○	○	○

○ : Indicates all visual targets are below the cut-off line.

: Indicates the cut-off line is over 40m ahead from the headlamp.

3. Simulation Evaluation of the Motorcycle AFS Glare

3.1 Purpose

The purpose is to compare, by simulation, the glare to the oncoming vehicle driver among the bank angle-compensated headlamp, the AFS headlamp, and the conventional headlamp.

3.2 Method

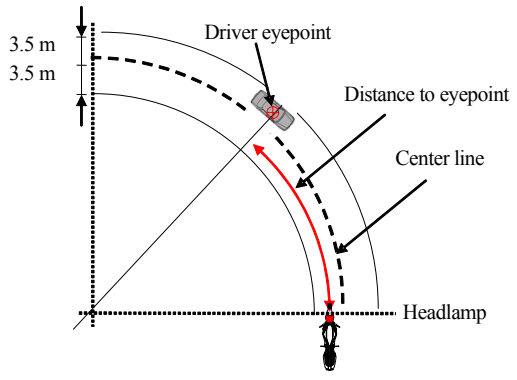
The range of the motorcycle headlamp glare to the oncoming vehicle driver was determined based on the criterion that the glare is considered present when the eye location (“eyepoint”) of the oncoming vehicle driver is below the cut-off line of the motorcycle headlamp (that is, when the relatively strong light of the headlamp reaches the eyepoint).

The headlamps, aiming direction, and bank angle compensation conditions used in the simulation are the same as those listed in Section 2.

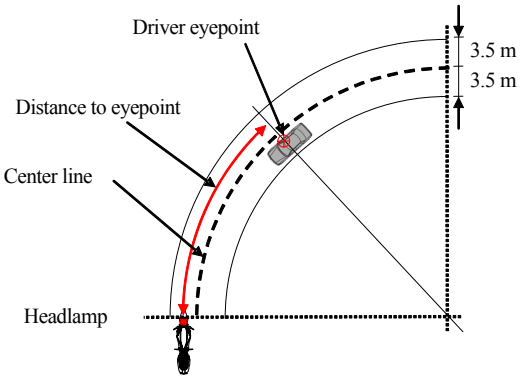
The input data necessary for the calculation (the bank angle and the aiming direction of the motorcycle headlamp) as shown in Table 1 were used.

The motorcycle driving course and the oncoming vehicle driver’s eyepoint location are shown in Figure 3. The lane width is 3.5 m, and the motorcycle was driven along the center of the left lane on a left curve or right curve. The oncoming vehicle driver’s eyepoint location was set at the standard eyepoint location of the drivers of passenger cars driving along the center of the oncoming lane (1.35 m outward from the center line and 1.1 m above ground). The indication of distance and the conditions of turning radii of curves are the same as those described in Section 2.

The range of calculation was determined to be the range where the distance between the motorcycle headlamp location and the eyepoint reaches from 30 m to 1/4 of the circle or from 30 m to 100 m. That is, the calculation was performed using the 30–47 m range for the turning radius of 30 m, the 30–78 m range for the turning radius of 50 m, and the 30–100 m range for the turning radii of 70 m and 100 m.



(Left curve)



(Right curve)

Fig. 3 Driving course and driver eyepoint location

3.3 Results

The results of simulation of motorcycle AFS glare are given in Table 3. Here, the ranges where the oncoming vehicle driver's eyepoints are below the motorcycle headlamp cut-off line are considered.

The oncoming vehicle driver's eyepoints are located above the motorcycle headlamp cut-off line without exception when the headlamp bank angle compensation is 0 degrees (with the negative ground angle), 7.5 degrees (with the negative ground angle), and at the AFS condition (with the zero ground angle). Therefore, the oncoming vehicle driver receives no glare under all these conditions.

For the headlamp bank angle compensation of 15 degrees, the oncoming vehicle driver's eyepoints are located above the motorcycle headlamp cut-off line when the headlamp bank angle is compensated to the same level as the bank angle of the vehicle body (with the negative ground angle). Therefore, the oncoming vehicle driver does not receive glare under this condition. However, when the headlamp bank angle is compensated to the level higher than the motorcycle bank angle (with the positive ground angle), there are ranges where the oncoming vehicle driver's eyepoints are below the motorcycle headlamp cut-off line, and so the driver may receive glare.

For the headlamp bank angle of 22.5 degrees (with the positive ground angle), the oncoming vehicle driver's eyepoints are below the motorcycle headlamp cut-off line without exception, and so the driver receives glare.

Hence, we can say that the oncoming vehicle driver receives no glare when the motorcycle headlamp bank angle is compensated to the same level as the vehicle body bank angle, but does receive glare when it is compensated to the level higher than the vehicle body bank angle.

Table 3 Results of glare simulation for headlamp bank angle compensation
(Range where driver eyepoints are below cut-off line)

Radius	Speed	Bank Angle Compensation	Ground Angle (Degree)	Left Curve	Right Curve
30m	30km/h	0°	−12.9	○	○
		7.5°	−5.4	○	○
		15°	2.1	35～47	30～47
		22.5°	9.6	30～47	30～47
		AFS	0	○	○
50m	40km/h	0°	−13.3	○	○
		7.5°	−5.8	○	○
		15°	1.7	56～78	50～78
		22.5°	9.2	30～78	30～78
		AFS	0	○	○
70m	50km/h	0°	−15.2	○	○
		7.5°	−7.7	○	○
		15°	−0.2	○	○
		22.5°	7.3	33～100	30～100
		AFS	0	○	○
140m	60km/h	0°	−13.4	○	○
		7.5°	−5.9	○	○
		15°	1.6	○	○
		22.5°	9.1	47～100	30～100
		AFS	0	○	○

○ : Indicates the driver eyepoints are always above the cut-off line.

x～y : Indicates the range (m) where the eyepoints are below the cut-off line.

4. Conclusions

The results obtained in the "Simulation Evaluation of the Motorcycle AFS Visibility" and "Simulation Evaluation of the Motorcycle AFS Glare" are summarized in Table 4.

In the evaluation of visibility, it was considered within the permissible range when the headlamp cut-off line reaches 40 m or longer forward at the inner line of the lane. In the evaluation of glare, it was considered that oncoming vehicle drivers receive no glare when their eyepoints are located above the headlamp cut-off line. In the synthetic evaluation, it was considered within the permissible range when the visibility in a curve is within the permissible range and the oncoming vehicle driver receives no glare.

The results of the study on the motorcycle AFS visibility and glare are summarized as follows:

(1) It was found that the headlamp visibility is improved by compensating the headlamp bank angle in curves. The motorcycle headlamp visibility in curves was found to be within the permissible range when the headlamp bank angle is compensated to the same level as the vehicle body bank angle (with the zero ground angle) or to the level higher than the

vehicle body bank angle (with the positive ground angle).

(2) It was found that, in curves, the oncoming vehicle driver receives no glare when the headlamp bank angle is compensated to the same level as the vehicle body bank angle (with the negative or zero ground angle), but does receive glare when it is compensated to the level higher than the vehicle body bank angle (with the positive ground angle).

(3) As a result of the synthetic evaluation of motorcycle AFS visibility and glare, it was found that, if the motorcycle headlamp bank angle is compensated in curves, it will be appropriate to use the compensation angle that is close to the vehicle body bank angle but does not exceed it.

Table 4 Summary of visibility evaluation, glare evaluation and synthetic evaluation for Motorcycle AFS

Radius	Speed	Bank Angle Compensation	Ground Angle (Degree)	Visibility	Glare	Synthetic Evaluation
30m	30km/h	0°	−12.9		○	
		7.5°	−5.4		○	
		15°	2.1	○		
		22.5°	9.6	○		
		AFS	0	○	○	○
50m	40km/h	0°	−13.3		○	
		7.5°	−5.8		○	
		15°	1.7	○		
		22.5°	9.2	○		
		AFS	0	○	○	○
70m	50km/h	0°	−15.2		○	
		7.5°	−7.7		○	
		15°	−0.2	○	○	○
		22.5°	7.3	○		
		AFS	0	○	○	○
140m	60km/h	0°	−13.4		○	
		7.5°	−5.9		○	
		15°	1.6	○	○	○
		22.5°	9.1	○		
		AFS	0	○	○	○

○ : Indicates the evaluation value is equal to or above the just acceptable level.

Indicates the evaluation value is below the just acceptable level.

Furthermore, the validity of the results of the “Simulation Evaluation of the Motorcycle AFS Visibility” and “Simulation Evaluation of the Motorcycle AFS Glare” was also confirmed in the actual driving test using a motorcycle equipped with the conventional headlamp, a motorcycle with the bank-angle compensated headlamp, and a motorcycle with the prototype AFS headlamp.

5. Requirement for the motorcycle AFS

Based on the results obtained in this study, we propose the following requirement for the motorcycle AFS:

“When the motorcycle headlamp bank angle compensation is performed in curves, the compensation angle shall be close to, but shall not exceed, the bank angle of the vehicle body.”

References

(1) Interpretation and Implementation of the Road Construction Ordinance, Japan Road Association, pp. 309-320 (2004)
