Experimental investigation of motorcycle safety

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1.Preface

The riders of motorcycles travel at the same high speeds as another motor vehicles on the same roads, existing in approximately the same traffic environment, but at the same time the level of protection for such riders is the same as that of pedestrians, almost total exposure. For these reasons, it is very simple for major injuries to occur in the event of an accident. Furthermore, since motorcycles are, like motor vehicles, capable of high speeds, even the slight impetus provided by a light contact with some object can upset the motorcycle in some cases, so that strong outside influences are not required for there to be major injuries.

During 1973, approximately 130,000 motorcycle-related accidents occured in Japan, 24 percent of all traffic accidents in the country during that one-year period. The number of persons dying as the result of such accidents was 2,330, accounting for 16 percent of all traffic deaths.

In spite of the fact that, as mentioned above, the level of danger to motorcycle riders is much higher than that for motor vehicle passengers, research on protecting the safety of motorcycle riders is not viewed as a socially highly significant problem and is lagging behind due to variety of factors. Some such factors would be that the actions of motorcycle riders and their vehicles on the accidents are complex and it is difficult to understand their current state; the total number of accidents and fatalities is a little small; and that there are some antisocial elements among motorcycle riders, as typified by motorcycle gangs. Moreover, since it is difficult to reconcile safety measures for motorcycles with their lightness and mobility(motorcycles having a greater range of potential riders and locations of operation than the automobiles), such safety measures at presnt are limited to helmets, protective clothing, and similar protective wearing devices. In addition, the motorcycle safety research that is being carried on has produced tank-like vehicles that sacrifice the characteristic performance of the motorcycle or has resulted in safety measures that ignore the motorcycle's steering and handling and simple usage, so that it is difficult for the results of such research to have practical applications.

This paper is a report on experiments conducted on the premise of collisions between passenger car and motorcycles, which are involved in a high proportion of traffic accidents in Japan. Through these experiments, a prototype side protection device was produced as a practical device for providing protection to motorcycle riders, particularly in cases of collision from the side, and studies were made of the efficacy and influences of such a side protection device.

2. The present situation concerning motorcycle accidents

The application of accident analysis to the present state of motorcycle collision accidents reveals that 90 percent of the motorcycles involved in accidents are traveling straight ahead at the time of the accident. Fig.1 indicates the directios of collisions, showing that collisions from the side, including diagonal collisions, represent 77 percent of the total. Fig.2 presents at 40km/h or less account for about 80 percent of all accidents. However, in the case of motorcycle 1 with large engine capacity(250cc and above), accidents occur at an average speed 20km/h higher than that for other models. Table 1 gives the nuber of cases and number of accidents by class of motorcycle the greater the rate of accidents, with motorcycle 1 having an accident rate some seven times as great as that for other motorcycles.

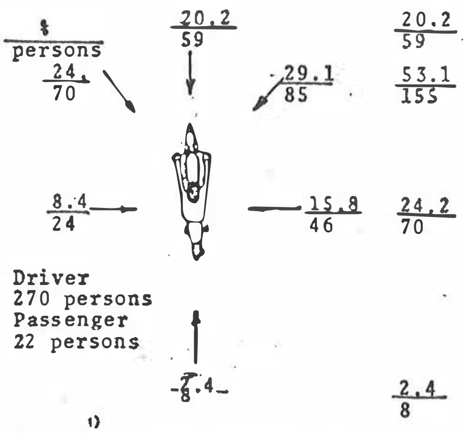


Fig 1[1] Distribution of motorcyclist injury by collision directions

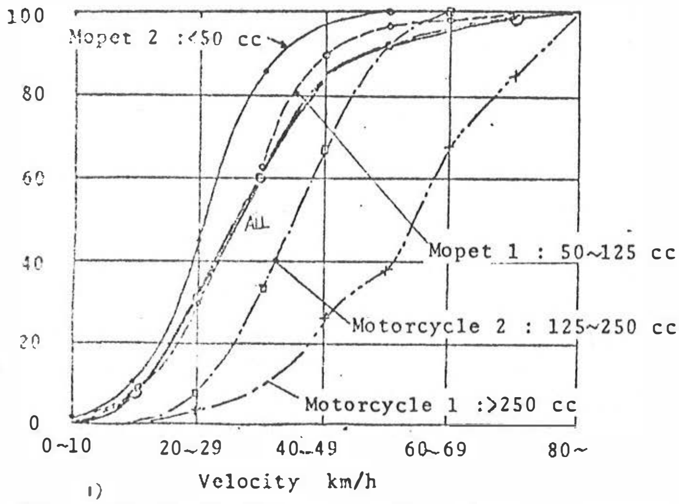


Fig 2[1] Distribution of collision velocity

Table 1[2] Number of accident and owned by each class of motorcycles 1973.

Class engine capacity	Motorcycle 1 > 250 cc	Motorcycle 2 250~125 cc	Mopet 1 125~50 cc	Mopet 2 < 50 cc
A :No of accidents	22705	8217	44702	55101
B :No of owned	264612	511107	3311487	4517252
A/B 10000	858	161	135	123

The relationship between the location of injury inflicting parts in motorcycle accidents and the location of injuries sustained is presented in Fig.3 and Table 2. Injuries sustained concentrate on the head and the legs. There are many cases of injuries to the head inflicted by contact with the roadway, and these can easily become fatal injuries. On the other hand, injuries to the legs are not necessarily fatal injuries,but they are in many cases caused directly by contact with the front-fenders, bumpers, or other parts of the colliding vehicle,and an overwhelming proportion of injuries sustained is to the legs. Fig.4 displays the death and injury rate classified by type of accident, indicating that the death and injury rate for motorcycle riders is numerically close to that of the rate for pedestrians and that the degree of danger involved is great. A look at the figures by class of motorcycles that the injury rate for large-displacement motorcycles is lower than that for other types of vehicles but that the death rate is higher.

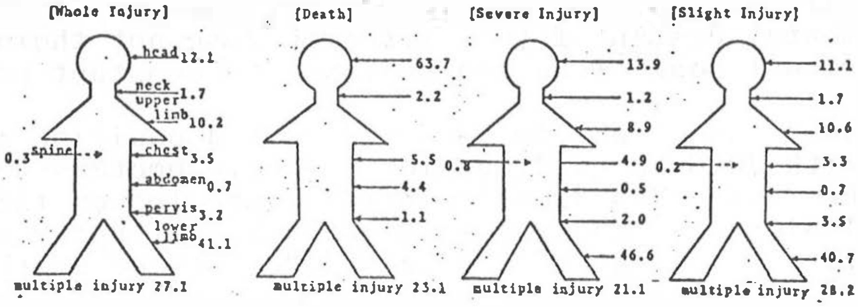


Fig 3[3)] Injury location and percentage of motorcyclists

Table 2[4)] Motorcyclists injury (location of greatest injury),with or without helmet,versus inflicted parts

Helmet		With					Without				
Inflicted \ Sustained		1	2	3	4	5	1	2	3	4	5
Road	Road	6	0	2	2	35	6	0	8	7	36
	Road equipment and what not	0	1	1	1	3	2	0	0	0	0
Vehicle	Front bumper	0	1	3	0	13	0	0	3	1	7
	Bonnet	0	0	0	0	2	0	1	1	0	2
	Front windshield	0	0	0	0	1	1	0	1	0	2
	Front fender	1	0	3	1	7	0	0	0	0	1
	Body side	0	0	0	0	1	0	0	1	0	1
	Rear cab	0	0	0	0	3	1	0	3	0	0
	Tyre	0	0	0	0	0	1	0	1	1	0
	Others	1	1	0	0	2	0	0	0	0	3
Motor cycle	Handlebar	1	0	1	0	1	0	1	0	0	0
	Fronttyre	0	0	0	0	1	0	0	1	0	1
	Others	0	0	0	0	4	0	0	1	0	3
	Unknown	0	0	0	1	3	0	0	1	0	1
Total		9	3	11	5	76	11	3	17	13	60

Persons

Sustained
1:Death 2:Severe(> 3month)
3:Severe(1~3month)
4:Slight(3~4weeks) 5:Slight(< 3weeks)

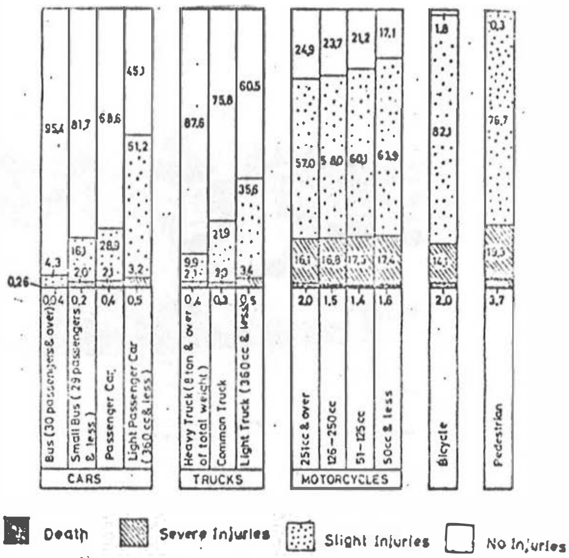


Fig 4[4)] Injury percentage vehicles, motorcycles,bicycles and pedestrians

3. Experimental method

Based on the results of the accident analysis described in section two above, we conducted experiments on the premise of collisions by a passenger car into the side of the highly accident-prone motorcycle 1. The motorcycle is equipped with a human dummy and measuring devices and is placed in the center of the road perpendicular to the direction of travel of the collision vehicle.

The collision vehicle is a light -weight 2,000cc class passenger car, and a moving barrier (placed flat atop an SAEJ972 M.B.) is also used as the collision car to reduce variation in the experimental conditions and ease the evaluation of the experimental results. This collision car is accelerated to the specified speed, the brake is applied immediately before impact, and with the brake being applied the car collides with the motorcycle and draws to a halt. Since in normal traffic accidents, a motorcycle's speed at time of collision usually is not zero but some positive value, the experimental design of this research dose not thoroughly replicate actual conditions can be fixed to constant parameters.

The dummy is an ITO AM 50-70 seated position and is installed with 200G three-dimensional accelerometers on the head and the chest. The dummy's left leg, the leg on the side of the collision, is constructed of a "bone" of epoxy with a maximum bending load of 200 kg and "crust" of urethane with a 4 kg/cm^2 compression load, making it possible to evaluate from the degree of the leg's destruction contusions, cuts and other injuries that normally cannot be evaluated because of the acceleration involved.

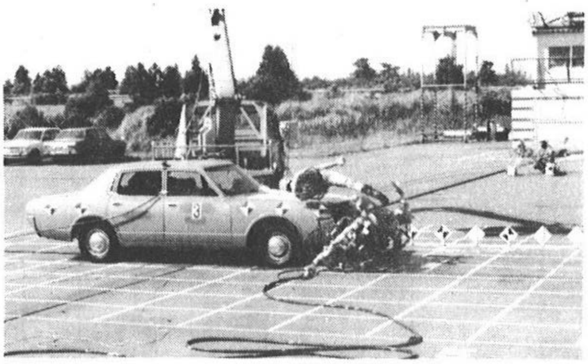
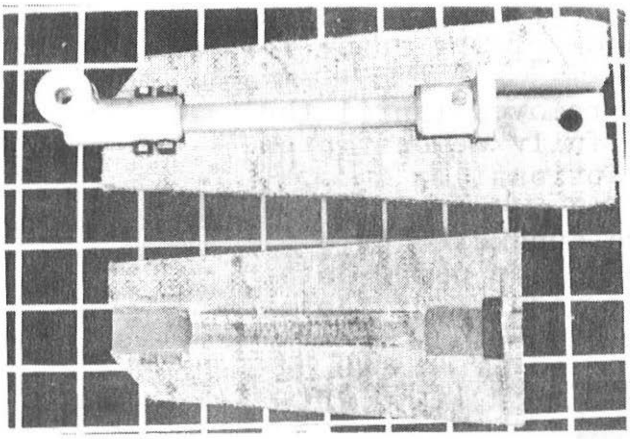
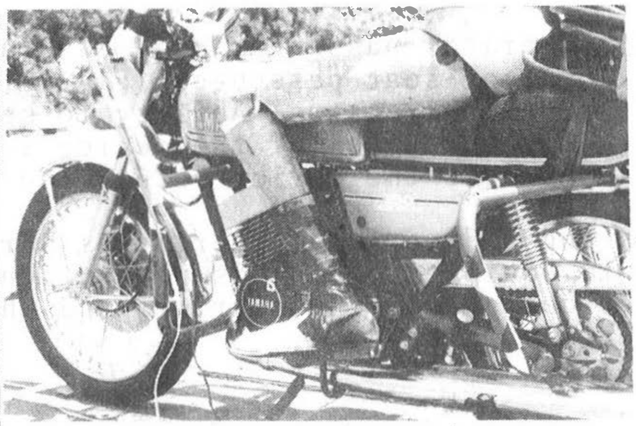


Fig. 5 Test scene



Bone : Epoxy
Crust : Hard urethane cavered with nylon cloth

Fig.6 Crushable foot of the dummy



Set up to dummy

4. Side protection device

Injuries to the head and leg are common in motorcycle accidents. Because injuries to the head can be fatal, protection of the head is an important problem, but at present, it has been impossible to discover appropriate protective measures other than the use of helmets. Injuries to the leg are fatal only in a few cases, but they occur frequently, so that protection of the leg is also a matter of importance. The purpose of a side protection device is protection of the legs, the location of 40 percent of all injuries to motorcycle riders. Here, we divided the production of side protecters into 1st and 2nd periods in conducting out experiments. During the 1st period, four types of device were constructed, tested using a moving barrier, and compared for protective effectiveness.

Fig.7 presents one of these devices which was constructed on one motorcycle as a Strength Level 1 protector, using 50mm pipes for front and rear guards which are joined together. This device is similar to the one used at AMF. In the 2nd period, the range of side protection devices was narrowed down to one type based on the results of the 1st period,and improvements were added. This side protection device is shown in Fig.8, and in its protection, consideration was given to the following points so that it would relate closely to the actual conditions involving motorcycles.

(1) Style--Styling appropriate to motorcycles.
(2) Steering and Handling--Design that fulfills the potential of present-day motorcycles.
(3) Usage--Design so that the protector does not impede getting on or off the motorcycle and permits pushing of the motorcycle while the rider is dismounted.

(4) Operator-passenger use--Assurance of leg space for a rear-seat passenger (Fig.9).
(5) Optional status--Ability to be removed (until the effectiveness of the device is fully demonstrated, used of the device being made optional).

During 2nd period, experiments were conducted on a motorcycle equipped with this protection device using both passenger car and moving barrier, and the results of these experiments were studied.

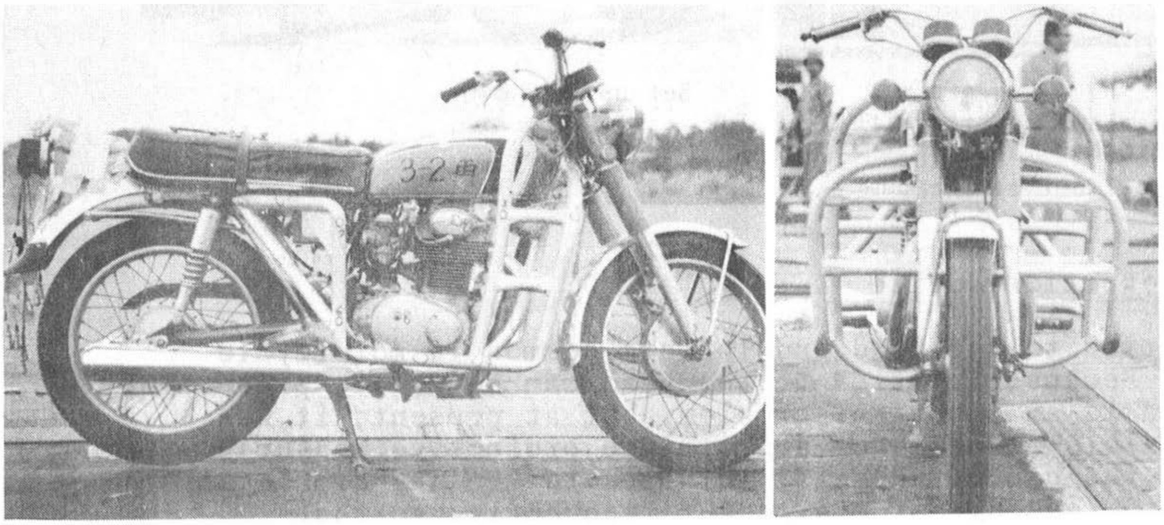


Fig.7 Side protection device modelled after AMF type
(Side protection device of strength level 1)

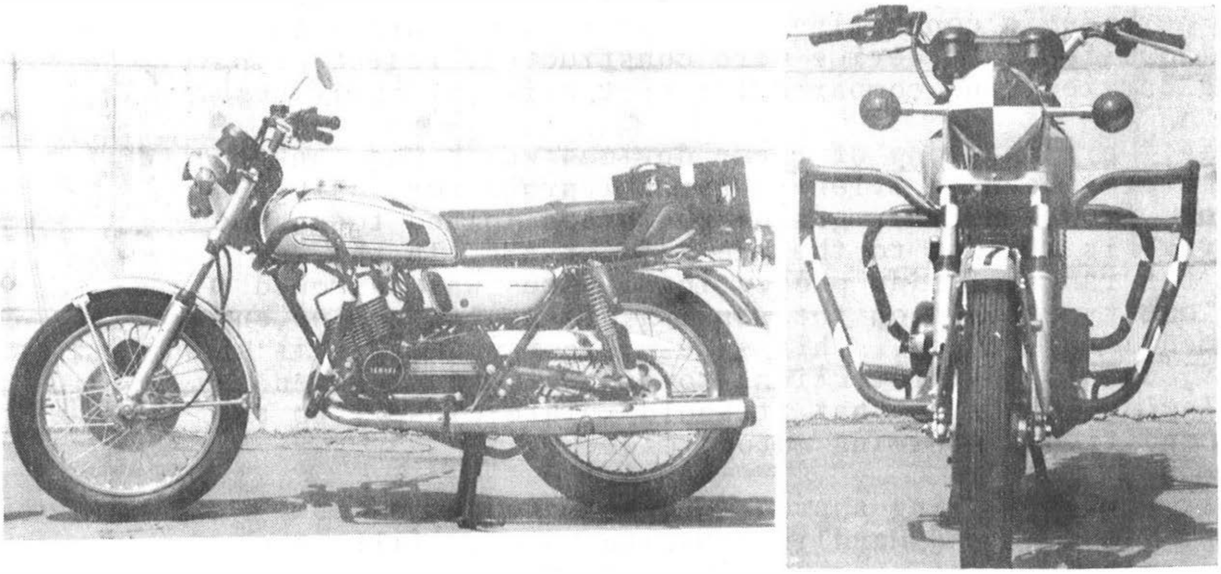


Fig.8 Improved-model protection device (Protection device design to closely reflect existing conditions)

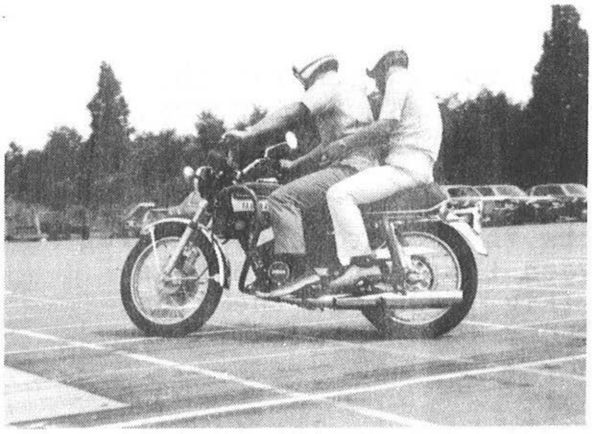


Fig.9 Use by two persons

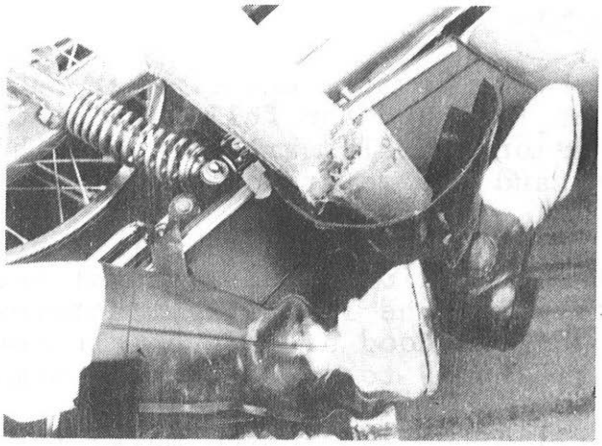


Fig.10 Mode of foot crushing

5. Experimental results and consideration

Table 3 presents a summary of the experimental results.

Table 3 Summary of the experimental results

Type of collision			SP-PS			MC-PS		SP-MB			MC-MB	SP-MB	
Test No			1	2	3	4	6	6	7	8	9	10	
Collision velocity			29.4	39.8	46.8	19.2	39.1	29.0	38.0	39.4	19.3	42.5	km/h
Dis-placements		Dummy	7.1	6.7	9.2	2.2	10.9	6.7	9.5	11.8	2.7	11.2	m
		Motorcycle	6.9	10.0	10.0	2.9	8.3	8.6	10.4	14.5	3.9	17.4	m
		Vehicle	4.2	4.9	6.3	0.9	8.3	4.6	7.2	8.9	1.5	7.9	m
Head collision	1st	Max G	18	33	72	37	71	35	48	41.	192	193	G
		HIC	55	155	248	12	264	64	136	144	1798	1220	
		Impact part	Hood	Hood	Wind	Hood	Hood	M.B. atop		←	←	←	
	2nd	Max G	48	20	56	16	145	41	26	30	163	60	G
		First touch to road	Foot	Foot	Hip	Foot	Head	Foot	Foot	Foot	Foot	Foot	
No of leg injury	Femur	Bone	S.F 1	C.F1	C.F1 S.F1	S.F1	S.F1		S.F1	S.F1 C.F1	S.F1		C.F:Compound Fracture S.F:Simple Fracture C. :Cut W. :Whittle G. :Graze A. :Amputation
		Crust	W.1 G.1	C.1 W.1 G.1	W.3 G.2	C.1 G.1	W.1 G.1	W.1	W.1	W.1 G.1	W.1 G.1		
	Lower leg	Bone				C.F1	C.F1 S.F1		S.F2	S.F2			
		Crust	G.2	W.2		A.1 G.1	A.1 W.1 G.1	W.1	W.1	W.1 G.1	W.1 G.1		

SP:Motorcycle with side protection device PS:Passenger car
MC:Conventional motorcycle MB:Moving barrier Wind:Windshield

5.1 State of collision

Motion of the dummy and motorcycle after collision varies depending on the collision vehicle, its speed, the side protection device, and similar factors, but in general the motion followed the following process. In these test cases, collision vehicles are set as to hit the left side of the dummy and the motorcycle.

(1) The collision vehicle contacts the motorcycle, the leg on the collision side is caught between the vehicle and the motorcycle, the lower leg fractures (Fig. 10), and the front edge of the hood of the vehicle contacts the hip area. This occurs from 0 to approximately 60msec.

(2) After the 50msec mark, the upper body begins to fall. Since the leg is caught between the vehicle and the motorcycle, the femur twists and fractures. At 70-80msec, the head bends 30-60 degrees to right and then in reaction bends some 40 degrees to the left. (The dummy is equipped with a rubber neck.) At 150-200msec, the head hits the hood of the vehicle. (Depending on the location of the head impact and the speed, the head receives an impact of about 40g from the hood and about 60g from the windshield.)

(3) When the motorcycle is pushed away from the collision vehicle and falls, the leg which had been pinned between the collision vehicle and the motorcycle is released and the dummy slides up on the hood of the vehicle. At high collision speeds, the dummy may even be stood on its head or be lifted up into the air. Thus, when a motorcycle is equipped with a side protection device, the leg is seldom pinned between the two vehicles, so that the leg is pulled out of position quickly and the body rises quickly. The passage of time for this portion varies considerably depending on the conditions of collision.

(4) Because of the braking of the collision vehicle, the dummy begins to slide off of the hood. Following this point, the motions of the dummy are roughly the same as for a collision with a pedestrian.

(5) The dummy falls from the hood and the feet touch the surface of the road. During the dummy's fall from the hood, the head at times strikes a hard surface of the forward potion of the hood and sustains a major impact.

(6) The body's fall and the head and chest's impact on the surface of the road take place between 1,000 and 2,000msec (thought there is considerable variance on this point). Since the head's impact speed is near that for free fall, it takes place at the relatively low speed of 10-20km/h.

Fig. 11 gives an example of experiment No.5, presenting consecutive photographs of motions in a passenger car's collision with a conventional motorcycle at 40km/h.

The leg is pinned and is mutilated from the joint with the femur, and the dummy is thrown high into the air. After the motorcycle has fallen over, its speed drops suddenly because of the resistance of the road surface, and the motorcycle is run over by the collision vehicle.(This was the only example of the motorcycle being run over by the collision vehicle, and normally, it seems that the collision vehicle will not run over the motorcycle if the vehicle's brakes are being applied.)
In Fig. 12 is displayed the acceleration history of the dummy head and the motorcycle in this experiment.

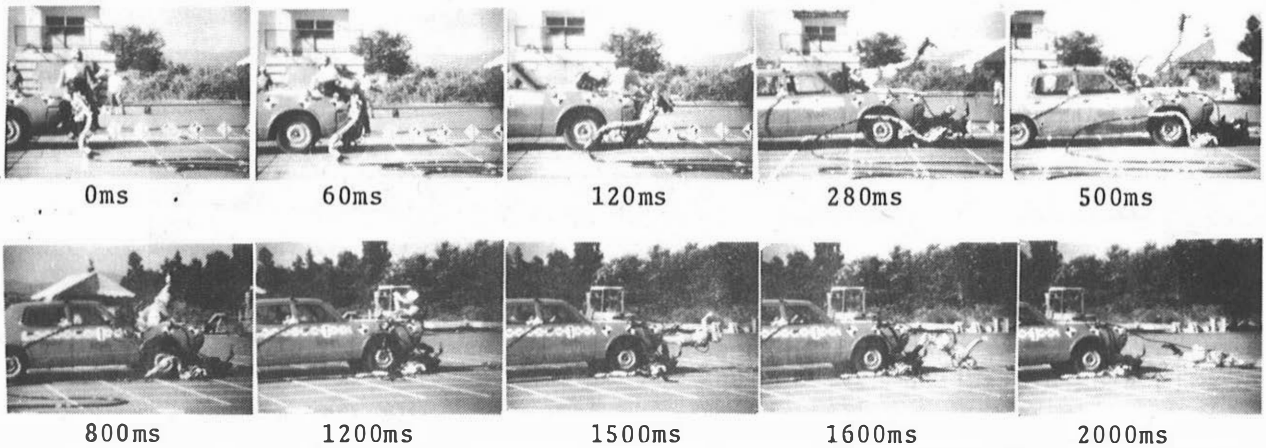


Fig.11 Extracted films showing sequence of collison used the conventional motorcycle Test No.5 Impact velocity : 39.1 km/h

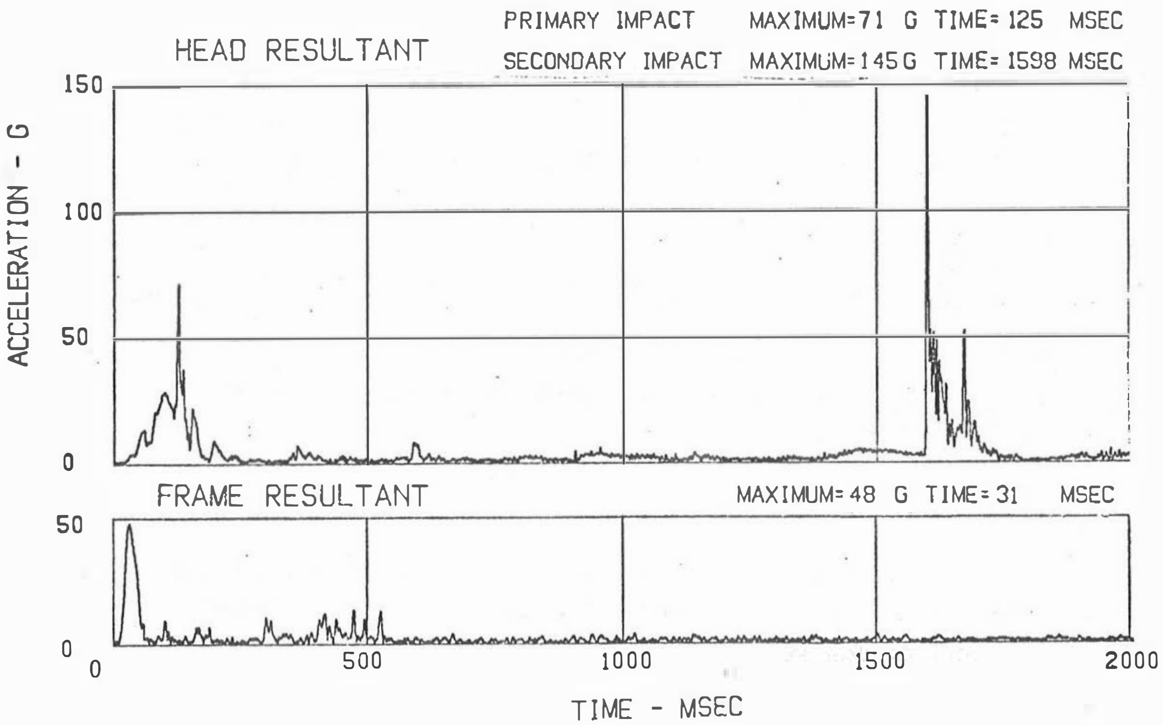


Fig.12 Acceleration history of the dummy and the motorcycle in test No.5

In Fig. 13 is displayed an experimental example of a collision at 40km/h with a motorcycle equipped with a side protection device. Since the leg is not pinned, the body slides smoothly up onto the vehicle hood, and overall injuries are few. Fig.14 is acceleration history of this case.

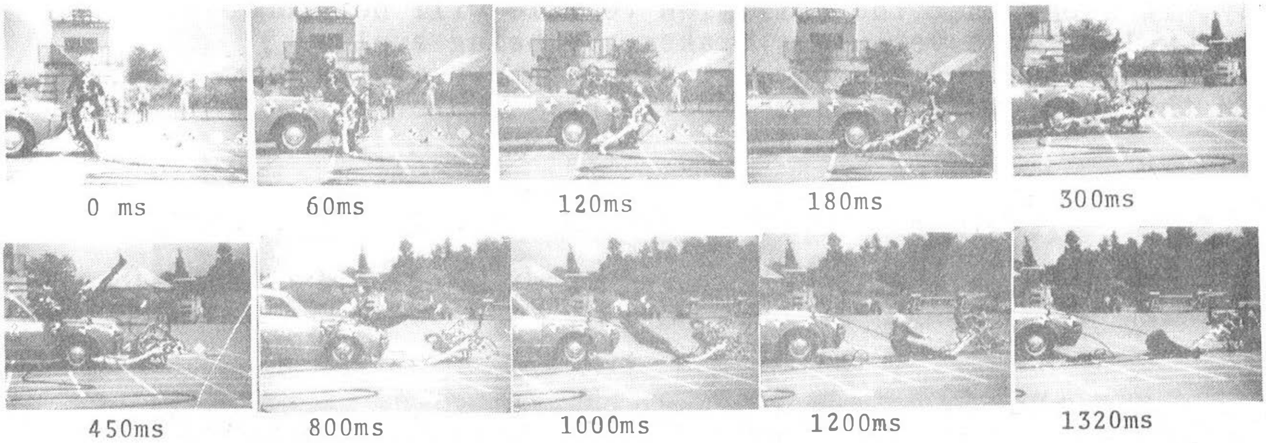


Fig.13 Extracted films showing sequence of collision used motorcycle with side protection device Test No. 2 Impact velocity : 39.8 km/h

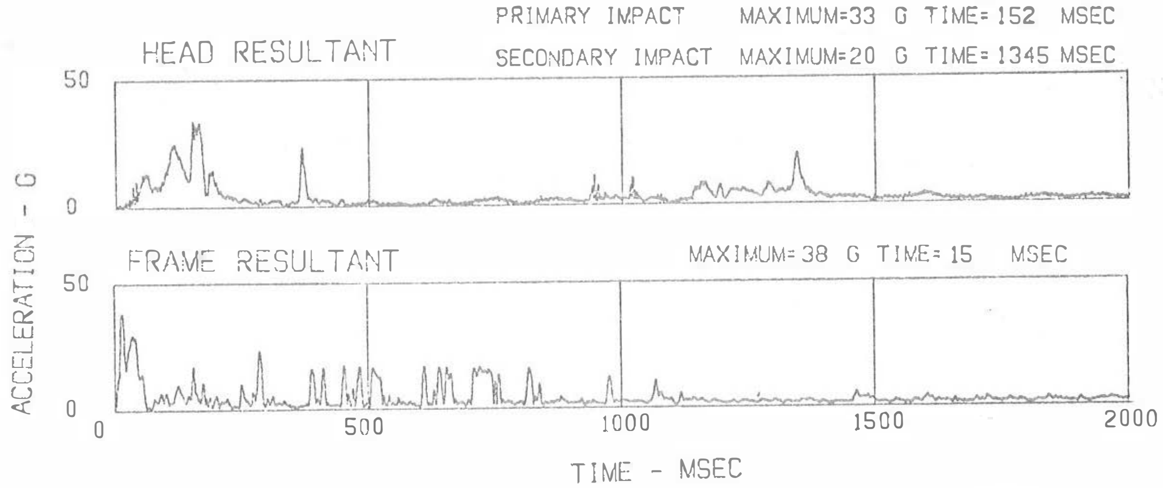


Fig.14 Acceleration history of the dummy and the motorcycle in test No.2

5.2 Location of rider collision

A consideration of the parts of the human body involved in collisions and the locations inflicting injuries produces Table 4. The section of this table labeled " Rate " was compiled using observations from high-speed film and marks left on the paint by the collision to find the rate of collisions of given parts. Since it shows overall injuries, it differs to some degree from the results of accident analysis given in Fig.3 but the two match in that head and leg injuries are prominent.

5.3 Protection of the leg by the side protection device

From the results given in Table 3, it can be seen that normally, there is damage to the leg when the collision vehicle collides with the side of the motorcycle even at a collision speed of 20km/h, with the tibia receiving major damage and fracturing. A motorcycle equipped with the protector test-produced for these experiments was able to protect the tibia in collisions with vehicles even at 30 and 40km/h. The femur is not injured by being pinned between the vehicles, but because there is little protected space, the leg cannot be easily and smoothly removed from between the vehicles when the body falls over, and the resultant twisting leads to injuries of the femur. In moving barrier collision experiments at 30km/h, the leg receives no injuries, because the flat impact surface causes little intrusion.

In the case of the device produced as strength level 1 as shown in Fig.7, the maximum distortion of the protection device in a 40km/h collision with the moving barrier was 20mm, and the leg received practically no injury, so that the device efficiency is fulfilled for leg protection.

5.4 Protection of the upper body

Fig.15 presents the maximum acceleration of a motorcycle at the time of collision. The impact is absorbed by the distortion of the protector, with its impact normally being around 10G less than that of the motorcycle. This reduction of impact not only reduces the injuries sustained by the leg on the opposite side from the collision, it also influences the motion of the upper body.

Table 4 Collision parts in experiments

Dummy parts	Object parts	Rate
Head	Hood,Windshield Road	16%
Abdomen	Hood	15%
Hip	Front of hood Road	14%
Hand	Hood, Motorcycle Road	15%
Leg	Bumper, Grill, Motorcycle,Road	40%

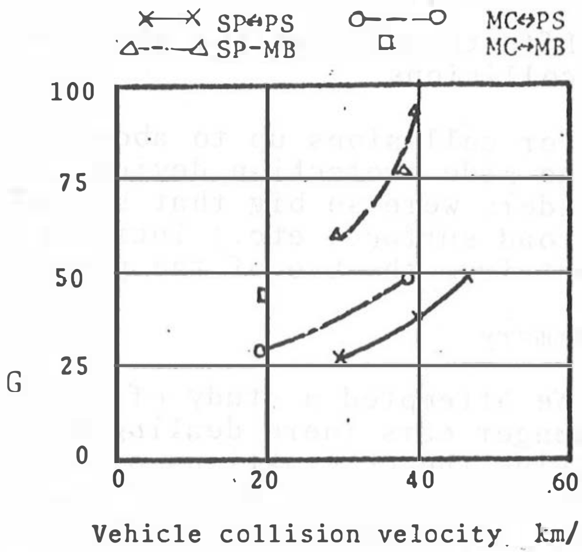


Fig.15 Maximum acceleration of motorcycle at the time of collision

Fig.16 gives the speed of the head's collision with the hood, and Fig.17 presents the maximum values for head acceleration. Reductions can be seen in each of these. The mark of ▼ in Fig.16 is the experimental result from Fig.7 for collision between the moving barrier and motorcycle equipped with rigid protector. Because there is almost no absorption by the protecter, the head impact is roughly the same as for a conventional motorcycle. In such a case, there is the possibility that the result will be, as expressed by Bartol of AMF,"there is effect as far as the leg is concerned, but the injury to the head becomes even greater." In other words, it is possible to reduce injuries to the upper body through appropriate deformation of the protection device.

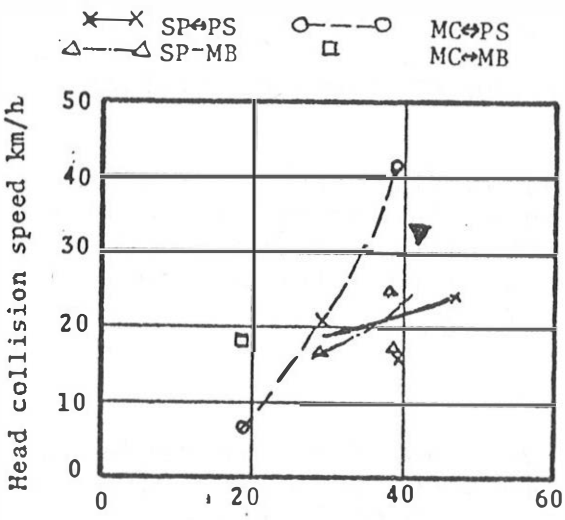


Fig.16 Speed of the head's collision with the hood

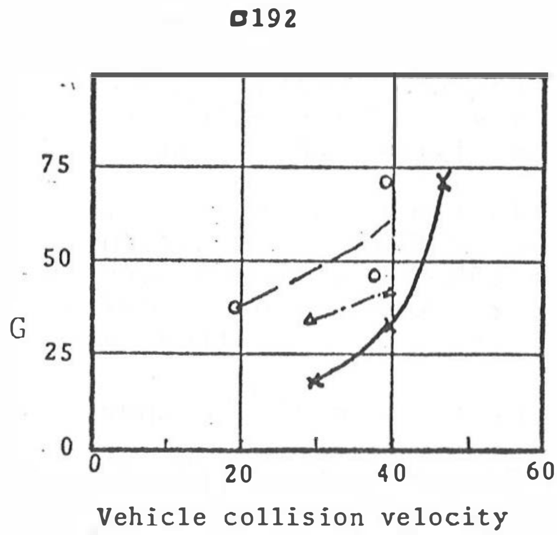


Fig.17 Maximum values of the acceleration on the time of collision with hood

5.4 Effectiveness of the protector as seen from overall collisions

For collisions up to about 35km/h, there are obvious effects of the side protection device, but beyond that point the motion of riders were so big that secondary injuries (from falling on the road surface, etc.) increase and significant differences in effect from the use of the protector disappear.

6.Summary

We attempted a study of the safety of motorcycle and passenger cars (here dealing only with 90 degree side collision), studying the observations of the riders' motions and the coditions of their injuries, countermeasures, and experimental method. The results regarding the side protection device may be generally summarized as follows.

(1) It is possible to protect the leg in collisions of 30-40km/h without impinging on current levels of motorcycle steering and handling,etc.

(2) By providing the protection device with absorption, it is possible to reduce injuries to the upper body.

(3) The side protection device is effective measure for the overturn accidents and the prevention of getting under the collision vehicle.

(4) When collision speeds pass 40km/h, even though the protection device is strengthened, other injuries become frequent and the overall effect is not very great.

(5) In order to make the suitable device, it is importance that protection device structure are considered with the basic frame of the motorcycle.

(6) The riders injuries are highly affected by the absorption and the shapes of bumpers, hood,and other collision parts.

As stated in the preface to this paper, the protection of motorcycle riders is a difficult problem that can easily be in negative proportion to the lightness of the motorcycle, and it must be approached comprehensively through helmets, protective clothing, etc. Here, as one protective measure, we have studied side protection devices, but we have not studied such matters as the problem of overturning or that of urban traffic accidents involving small sized motorcycle which are owned in large numbers and which, in items of total accidents, have three times as many accidents as motorcycles. These are problems which we would difinitely like to study in the future.

Japan produces six-tenths of all the motorcycles in the world and is greatly interested in the safety of those motorcycles. At the same time, however, the conditions concerning motorcycle traffic, ownership structure, road environment, and outlook on safety all differ from country to country. In the future, each country's exchange of pertinent information and their cooperation will be the most important elements in the reduction of motorcycle accidents and the promotion of research on protecting the safety of motorcycle riders.

REFERENCE
1) The Japanease Council of Traffic Science ; Property of motorcycle accidents 1971.
2) National Police Agency Japan ; Statistics of traffic in Japan 1973.
3) The Metropolitan Police Board Japan ;Statistics of traffic in Tokyo 1973.
4) The Japanease Council of Traffic Science ; Motorcycle accidents and effectiveness of helmet; 1975