

Prototype Motorcycle for Lower Limb Physically Disabled “Super EARA”

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ABSTRACT

A prototype motorcycle called the “Super EARA” has been developed that wheelchair users can get on and off, drive and stop by themselves. The functions that the motorcycle should be equipped with were considered in development. The functions are starting, driving and stopping without the using of lower limbs. A vehicle height adjustment system for getting on and off, and an outrigger and a gas pressure type emergency stand to help prevent stack are also equipped. Operation of the newly designed equipment was confirmed by actual driving tests at the Suzuka and Motegi circuits.

1. Introduction

A contest for one’s own dreams was started in the year 2000 at the Asaka R&D Center in order to spark the imagination of the employees. This contest is held by the in-house personnel development committee to promote imaginative ideas. The ideas chosen would be developed into a project and their realization would be pursued by the company. This is also a method for passing on a part of Honda’s culture “pursue development of all types.” The dream of “2-wheeled vehicle touring for people in wheelchairs” was chosen in the 2001 dream contest and the development of the “Super EARA” began.

In order to realize this dream, Honda Sun Co., Ltd. employees who require the use of a wheelchair (who had ridden a motorcycle prior to becoming physically disabled) were consulted. Their desire was to be able to ride a motorcycle that is as close as possible to those ridden by physically unimpaired people. They had a deep desire to control the motorcycle themselves without assistance. In order to respect these desires, the development needed to produce a system that has the handling sense of a motorcycle and that looks like a motorcycle. Therefore, the special wheel designs and gyro based self-supported traveling device considered during preliminary investigation were abandoned.

Instead, the characteristics focused on were its handling, handling sense and external view.

2. Development Details of the Super EARA

Figure 1 shows an external view of the Super EARA and its main specifications are given in Table 1.



Fig. 1 Super EARA

* Asaka R&D Center

Table 1 Specifications

Items	Specification
Overall length (m)	2.265
Overall width (m)	0.880
Overall height (m)	1.080
Ground clearance (m)	Upper 0.120
	Lower 0.075
Seat height (m)	0.630
Vehicle mass (kg)	220
Engine type	Liquid-cooled V-type two-cylinder
Displacement (cm ³)	249
Fuel tank capacity (l)	7.0
Starting system	Electric starter
Clutch type	Wet-type multiple disk clutch, coil spring
Transmission type	Motor-driven shifting, constant-mesh
Caster angle (degree)	31.5
Trail (mm)	130

2.1. Development Concept

The development of the Super EARA had the goals of allowing a person who cannot use his lower limbs to get on and off, run, and stop the motorcycle and to provide them the characteristic feeling of riding a motorcycle. It also has the goal of giving riders the enjoyment of being able to ride their motorcycle at their own will and pleasure. The targeted audience for the development was people who required the use of a wheelchair because they could not use their lower limbs, yet had previous experience riding a motorcycle. The following conditions were also placed on the development:

- (1) Ability to move to and from a wheelchair to the motorcycle without assistance.
- (2) Ability to start, control, and stop without requiring any use of the legs.
- (3) Ability to store a wheelchair on the motorcycle without assistance from others.

2.2. Investigation of the Completed Vehicle Image

Three image sketch ideas were developed to embody the above stated conditions.

Figure 2 shows a rear entry American type. It has equipment that allows the rider to move alongside the rail on top of the rear fender while still in a specialized wheelchair and then to move to the motorcycle seat. Getting off the motorcycle is done using these steps in reverse. The

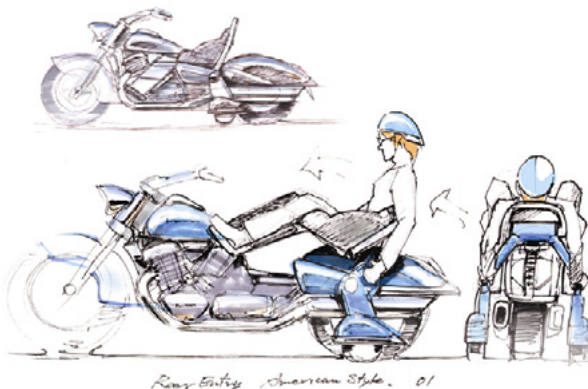


Fig. 2 Rear entry American type

exclusive wheelchair is equipped with small wheels and moves by electric drive. Figure 3 shows an idea that is primarily the same as the one shown in Fig. 2; it is just a design that allows the rider to better become one with the motorcycle. Figure 4 shows a swing type tricycle that allows the rider to bank the entire bike besides the rear two wheels when running, giving a feeling of riding on a motorcycle. This has a swing mechanism below the springs and allows for use of a large displacement engine. The construction is a step through type with a flat floor for the feet making it easy to get on and off. This is an advantage of this type of motorcycle.

The above images and ideas were discussed with people who use wheelchairs. This brought up the fact that they needed to be able to use their regular wheelchairs, not a special wheelchair discussed in Fig. 2 and 3. It was also found that they do not like large-scale devices. Concerning Fig. 4, it was found that though it has the appearance of a motorcycle, the fact that it has 3 wheels lead to the opinion that it would not sufficiently satisfy their dream of riding a motorcycle.

Next, American Scooters, Super Sports, and Touring motorcycles were brought to Honda Sun Co., Ltd. to provide people with disabled lower limbs the opportunity to feel how it felt to sit on a motorcycle. Of course, they did not actually drive any, but instead they just sat on the motorcycle. The severity of those with lower limb disability varied; one person who had a spinal injury did not have any feeling below a few centimeters under his armpits and had very few abdominal muscles as well. Generally, motorcycles require control by a rider's lumbar region. Determining the ability of a person with handicapped legs for maintaining balance of his body and the bike, as well as controlling the motorcycle during banking with just arm strength was something that we were concerned with and needed to be addressed carefully.

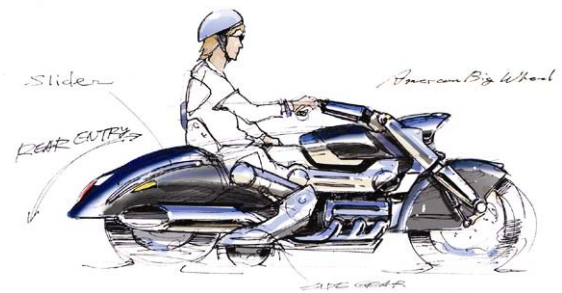


Fig. 3 New American type

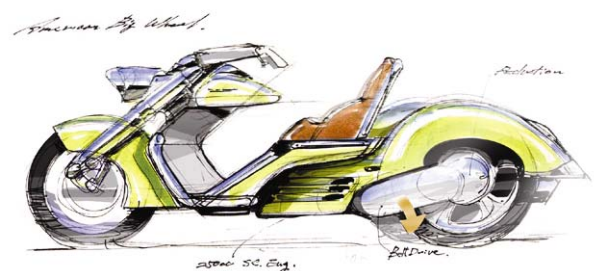


Fig. 4 Swing-type tricycle

2.3. Issue Discovery using Precedential Experimental Vehicle

A precedential experimental vehicle was prepared so that a person who uses a wheelchair could (according to our hypothesis) control it in a limited manner. This was used to discover and confirm issues. The base motorcycle chosen was the Honda Magna 250 as it has a low seat and the following changes were made:

- (1) The rear suspension was fully bottomed out.
- (2) A fixed type outrigger where the width and height could be adjusted was added to keep the motorcycle upright and set at a slight distance above the ground so that the motorcycle could be driven at a low speed.
- (3) The motorcycle was changed so that the lever on the right handle controlled both the front and rear brakes (the rear brakes were converted to disk brakes).
- (4) A high back rest that came to the subscapular, side supports for the lower back and a special soft seat were added.

At Honda Sun Co., Ltd. two experienced riders were asked to try and ride this precedential experimental vehicle. One of the persons asked to perform this test drive did not have any feeling in his body lower than a few centimeters below his armpits; therefore the backrest was strengthened near the shoulder blade so that he could sense the movements of the motorcycle there. The outrigger was set just above the ground on the right and left side to hold the motorcycle in an upright position. The motorcycle was also set so that it could be driven at low speeds (it was set so that it could not come out of low gear). We supported the motorcycle on both sides to keep it straight when taking off. However, after just a few meters, the motorcycle leaned to one side when the outrigger came into contact with the ground, and it stopped. The second person to test the motorcycle was a person that had raced motorcycles previously. He was successful at balancing the motorcycle and riding it on his first try.

2.4. Concept Definition

Through this type of investigation, the type of motorcycle that needed to be realized became more apparent. The type of motorcycle that will fulfill the dream of people who require a wheelchair is simply not a specialized vehicle that is operated by electricity or has a unique appearance. It is important that mechanisms used for support be kept to a minimum, allowing the rider to enjoy controlling the motorcycle on his/her own. And, while being a motorcycle built for people who require a wheel chair, it should have an appealing look to all who behold it. In order to realize the dream of being able to use the motorcycle for touring, it is necessary that the rider be able to completely get on and off, and handle it by himself/herself.

2.5. Choice of Engine

In order to preserve the feeling of riding a motorcycle (such as turning while banking) and for the enjoyment of acceleration as well as deceleration, a sufficiently large engine displacement is needed. It was considered that a 250 cc level of power was desirable to meet these needs. The following were also considered in this choice.

In order to preserve the ability of the rider to get on and off the motorcycle, it is important to make the area where the gasoline tank is normally situated on a regular motorcycle as

low as possible, making it easy to ride. Therefore the VT250 engine, which has intake valves in front and is short was chosen for the application (as use of a commercial engine was a primary condition). Using a V-style 2 cylinder engine also proved effective in reducing the overall width and weight of the motorcycle.

2.6. Discovery of Technical Issues

In order for a rider without the use of his lower limb to drive the motorcycle by himself/herself, the following additional functions were required:

- (1) In order to be able to move from the wheelchair to the motorcycle without assistance, the motorcycle needs to stand up on its own while the rider is getting on and off, when first starting to move, and while stopped.
- (2) Equipment needs to be added so that the hands can perform all of the functions performed by the feet.
- (3) After riding, the vehicle needs to support the rider from the forward and reverse directions.
- (4) Structural elements that are in the way of the rider getting on and off the motorcycle need to be removed to the extent possible.
- (5) A wheelchair provides the same function as a physically unimpaired person's legs. Therefore, the wheelchair and wheelchair cushion need to be able to be loaded on the motorcycle.

The original layout is shown in Fig. 5 while the illustration of the final specification is shown in Fig. 6.

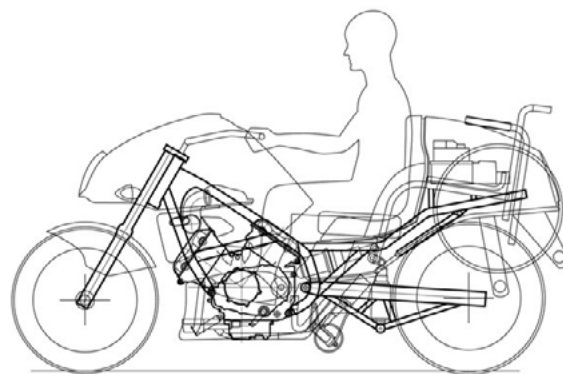


Fig. 5 Layout of Super EARA



Fig. 6 Illustration of Super EARA

3. Technologies Implemented on the Super EARA

3.1. Vehicle Self-supported System

In order for a rider with physically disabled lower limbs to ride a motorcycle, it is necessary that the motorcycle stand up with stability when the rider is getting on and off and while it is stopped. For example, a retractable outrigger has been considered as a mechanism to support the vehicle when stopping. However, in order for the outrigger to provide sufficient stability the outrigger needs to have sufficient span when lowered and significant strength. It was therefore believed that it would become fairly big and heavy. On the other hand, in order to preserve the image of the motorcycle and maneuverability, the outrigger needs to be stowed quickly and be as compact as feasible when traveling. To resolve these conflicting issues, a self-supported system developed by Honda with the combination of a mechanism for lowering the height of the motorcycle and a compact outrigger is used for when the Super EARA is stopped. In order to ensure operation and preserve safety, ideas for various mechanisms were generated. The details of these are described below.

3.1.1. Vehicle height adjustment mechanism

In order to make it easier for the rider to get on and off when it is stopped, a height adjustment mechanism was attached to the motorcycle's rear wheel suspension. The motorcycle's height adjustment mechanism is shown in

Fig. 7. When a switch on the right handle is lowered, two actuators begin to operate and through a link turn the upper suspension pivot lowering the motorcycle height by about 50 mm. When the same switch is raised the opposite actions occur and the motorcycle height is returned to the correct height for traveling.

3.1.2. Outrigger

The outrigger that is placed low on the motorcycle is operated with the same mechanism as the motorcycle height adjustment. When the switch on the right handle is lowered, the outrigger is lowered through a link and opens a distance of roughly 25 mm between the wheel and the road surface. When the switch is raised, the opposite action occurs and it is retracted inside a cover that is behind the footrest to the side of the swing arm. The outrigger is shown in Fig. 8.

When the rider gets onto the motorcycle, it is parked slightly inclined to either the right or the left. The rider places his hand on the end of the handle bars when getting on the motorcycle. When starting, the motorcycle makes contact with the ground at three points. The rider engages the clutch, begins to travel at his discretion, providing 2-wheel driving, then retracts the outrigger. For the outrigger, there are two possibilities for operation, automatic (speed response type) and manual. At the current time, the best speed for starting to retract the outrigger depends on the conditions. As it was not necessary to satisfactorily provide control in all conditions at this stage of the development of this technology, this prototype used manual control.

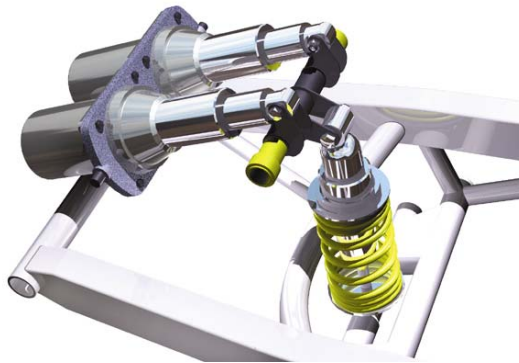


Fig. 7 Vehicle height adjusting system



Fig. 8 Outrigger

3.2. Actuator Control System

The new electrical equipment on the Super EARA are the actuator control unit, outrigger monitor display, and each of the actuators. The actuators are the height adjustment, outrigger drive, and shift pedal operation and each of them are controlled with the actuator control unit. A block diagram of the electrical structure is shown in Fig. 9.

The control unit is mounted in the motorcycles rear seat cowl. The actuators are driven with 24 V electricity.

3.3. Visual Monitor for Outrigger Motion

The visual monitor is shown in Fig. 10. When the motorcycle comes to a stop it is essential that the outrigger be lowered, otherwise, the motorcycle will fall over. Therefore,

an indicator showing the outrigger's position was installed; however, it did not completely reconcile the fears of the rider. In order to resolve this issue, a camera with the ability to capture both the right and left side was mounted at the pivot point of the outrigger and a monitor that continually displays the condition of the outrigger was mounted on top of the tank shelter. When the outrigger is down the wheel is shown in the middle of the monitor allowing for better visibility and abating an element of the rider's anxiety.

3.4. Gas Pressure Emergency Stand

The gas pressure emergency stand is shown in Figs. 11 and 12. The gas pressure emergency stand was developed for dealing with the situation where both the non-operation of the

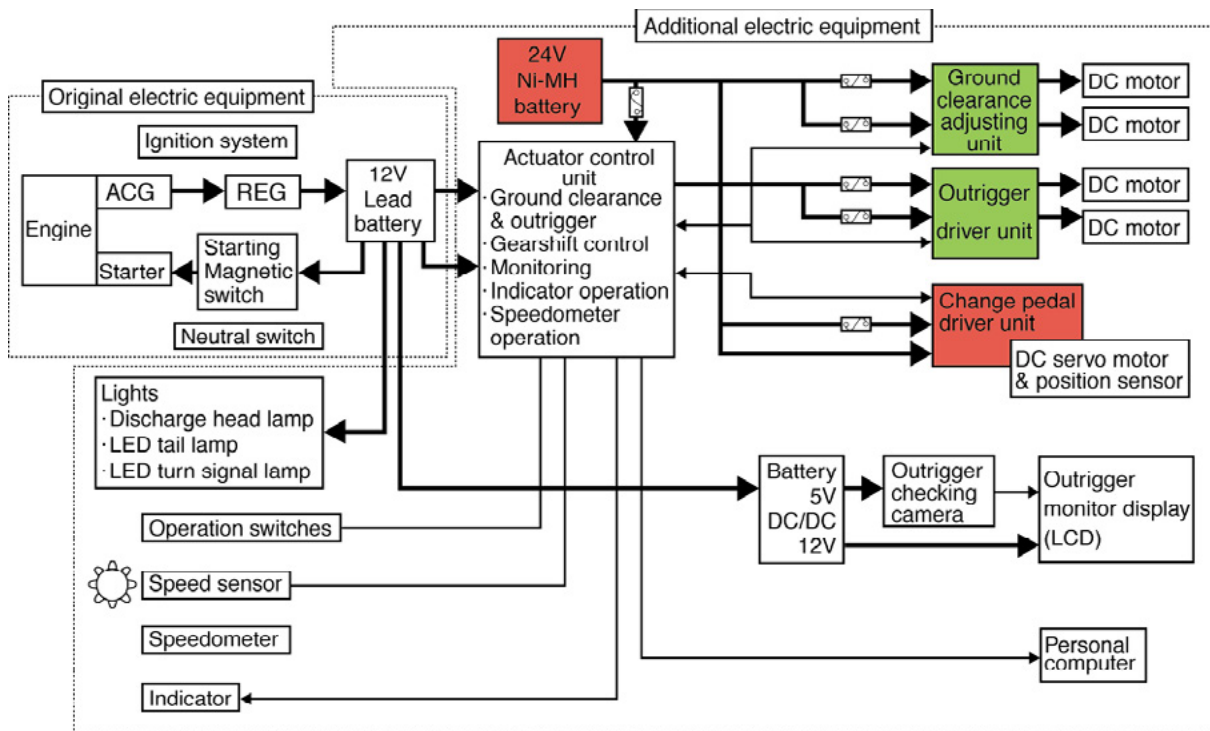


Fig. 9 Illustration of electric circuit



Fig. 10 Monitor of outrigger position

outrigger and stalling of the engine occur simultaneously. In order to make the system as compact as possible, an inflatable mat was used for the system. When it deploys, it is required to hold up the weight of both the motorcycle and the rider, therefore it requires considerable strength. To meet these requirements and to increase the capability to withstand pressure, polyester textile base, which is durable and does not stretch, was used for the mat. In addition, polyester thread and circumferential nylon belts were added to give it more rigidity. It operates instantly through the simple pulling of a rope with the right hand causing a hole to be opened in the system gas cylinder. Through optimizing the hole size, the air tube and flow resistance in the joints, the speed of the emergency stand expansion is sufficient. The mats are mounted under the footrests on the right and left sides (10 liters in total), can be inflated to 100 kPa, and through coming in contact with the ground help prevent the motorcycle from falling over.

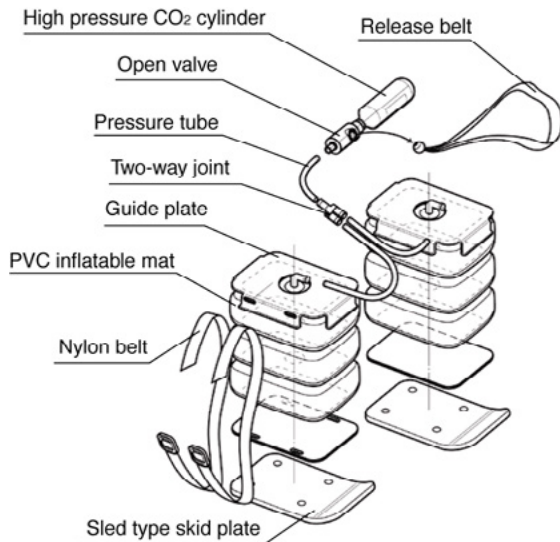


Fig. 11 Structure of gas pressure type emergency stand

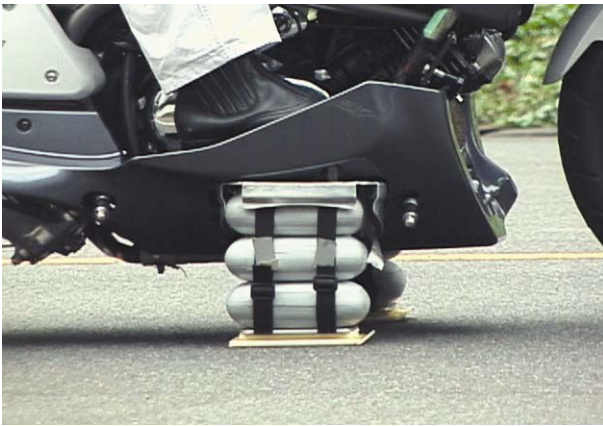


Fig. 12 Side view of gas pressure type emergency stand



Fig. 13 Manual control gearshift system

3.6. Moveable Tank Shelter that also Serves as Support when Getting On and Off

The moveable tank shelter is shown in Figs. 14 and 15. When getting on and off the motorcycle from a wheelchair, a large fuel tank in a high position becomes an obstacle. Therefore, the fuel tank was installed to the bottom of a shelter, providing a “tank shelter”. When getting on and off, it is possible to lift up the entire tank shelter. When the tank

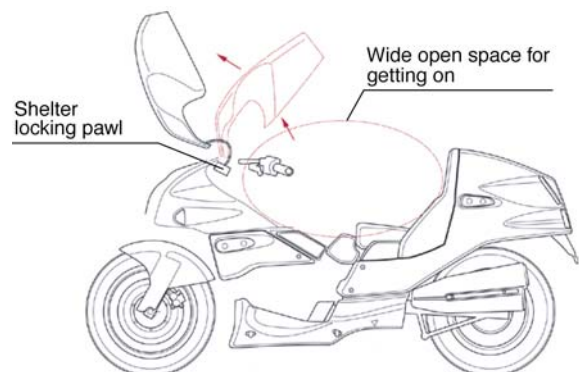


Fig. 14 Layout of movable shelter

3.5. Manual Control Gear Shift Mechanism

The manual control gear shift mechanism is shown in Fig. 13. When the paddle switch on the left handle is lowered, an actuator with a 24 V power supply is activated and through a link the shift spindle is rotated. This causes a gearshift into low gear or down one gear, depending on the original gear (if this paddle switch is pushed up, the opposite of what has been describe occurs and causes a gearshift up one gear). If the button on top of the handlebars is pressed while in low gear, the motorcycle shifts into neutral. The clutch lever is the same one that is used on the base motorcycle, the Magna 250.

In order to help reduce rider errors to the extent possible, the operating systems for the brake (front and rear combined) were placed by the right hand, and for shifting (electric shift) a button was placed by the left hand.

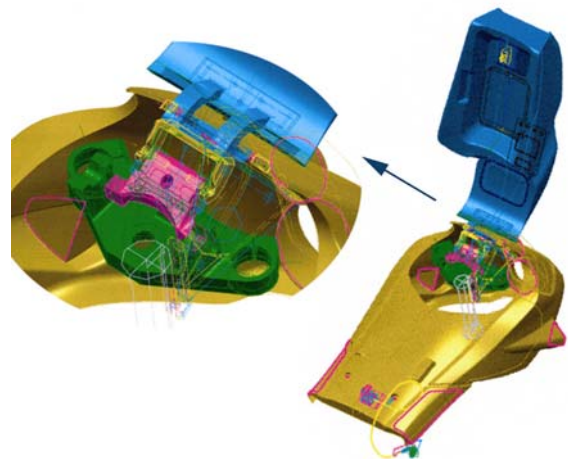


Fig. 15 3D drawing of movable shelter

shelter is raised, the projection of the hinge fits into the handle bars making it so they can not move. As a result, a large open space is generated in front of the seat allowing the rider to easily lift and move his legs and straddle the seat. Also, as the rider moves from the wheelchair to the motorcycle, the fixed handlebars can be used for support. When the fuel tank shelter is then lowered it helps prevent the rider from moving forward or backward on the seat providing a more stable seat position. Also, the step board and the half step on the left side, as well as the form of the specially shaped seat help provide handling support and aid in getting on and off.

3.7. Loading Device of Wheelchair

The equipment used to load the wheelchair is shown in Fig. 16. To the rider, the wheelchair provides the same functions as legs to a person who is not disabled, and is something that can not be parted with in order to move freely. Therefore the wheelchair needs to be with the rider at all times, making the ability to carry the wheelchair an obvious requirement and the rider needs to be able to easily and quickly load and unload the wheelchair. The following instructions show how this is done:

- (1) After getting on the motorcycle, the rider folds up the wheelchair. Next he/she pulls the wheelchair in until the inside wheel comes into contact with guide rail 'A' by his/her right hand.
- (2) Using the rotation of the wheelchair's inside wheel, the rider uses his right hand to lift the wheelchair onto guide rail 'A'.
- (3) When the wheelchair is lifted it comes into contact with guide rail 'B' where its leaning is corrected and rolls up onto guide rail 'C'. The upper surface of guide rail 'C' is smooth and the wheelchair slides to the rear of the motorcycle under its own weight and is locked into place due to contact with the end plate.

The process of loading the wheelchair can be performed in a matter of seconds.

4. Running Test

The running tests were performed at the Suzuka and Motegi circuits where the maximum speed reached was 130 km/h.

It was possible for a person without the use of his legs,

whom requires the use of a wheelchair, to get on and off and to control this motorcycle by him/herself without assistance. The goal of having the feel of a motorcycle and allowing its riders to fully enjoy controlling it without assistance was considered fulfilled.

Figure 17 shows the driving condition of the test and Fig. 18 shows a standstill condition.



Fig. 17 Running view of Super EARA

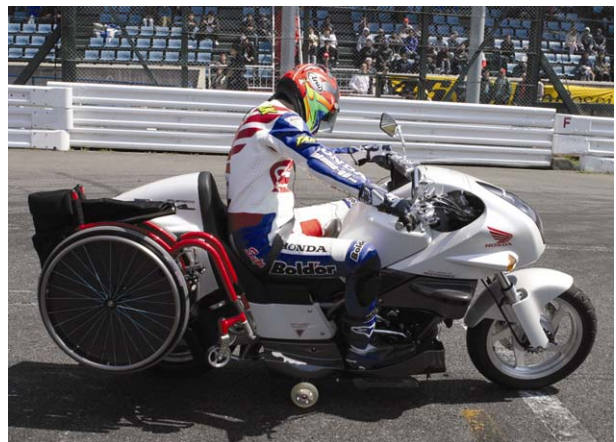


Fig. 18 Stopping view of Super EARA

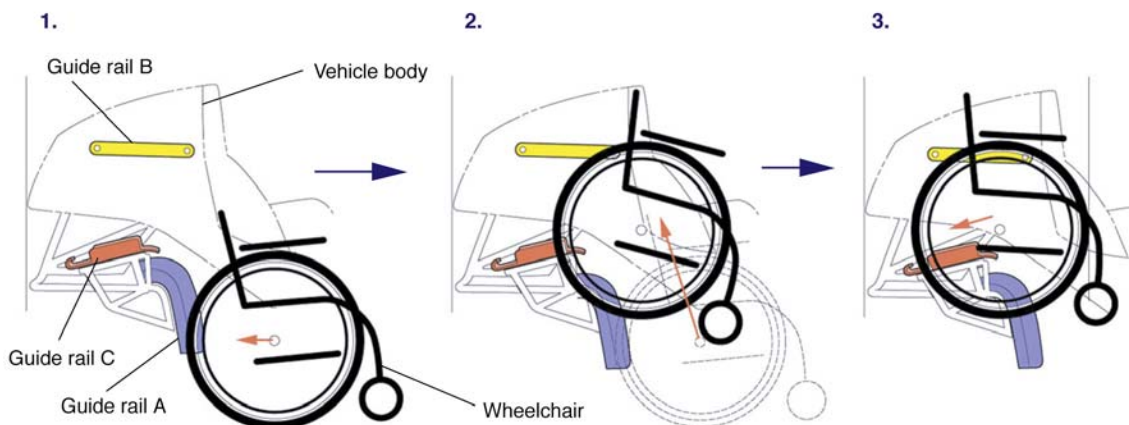


Fig. 16 Wheelchair carrying equipment

It was also possible to test the motorcycles ability for self-support, though on a limited course; however, the expected operation of the system was confirmed. As the riders gained experience they became better at retracting and lowering the outrigger when starting and coming to a stop. They also became faster at adjusting the height of the motorcycle and became very good at driving it smoothly. They were also able to easily use the visual monitor to confirm operation of the outrigger.

5. Conclusion

The technology achieved at this time is such that it can only be used for driving on a circuit track or other limited courses. The motorcycle was demonstrated at some major events such as Moto-GP (Suzuka, Motegi) and the Suzuka eight-hours endurance race. This provided a good opportunity to display the technology and numerous motorcycle fans as well as people who live with wheelchairs have given their warm approval.

6. Afterword

It is possible for disabled persons to drive a car on public roads. In the future we hope that through the development of this technology that this will also be realized for motorcycles.

■ Authors ■



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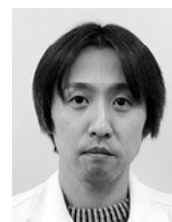
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