

Development of a 4-wheel Electric Wheelchair, MonPal ML100

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ABSTRACT

The MonPal ML100 is a 4-wheel electric motor-driven wheelchair developed with an aim toward achieving personal mobility while at the same time providing fun, freedom from care and comfort for those with restricted walking capabilities. It is characterized by a rearward tapering design intended to prevent the rear wheels from scraping and snagging.

The power train, which is an integrated transmission and motor type, and the control system were specially developed to provide improved slope-climbing capabilities.

Various features are incorporated in the operating system. These include an emergency stop function whereby if a driver grips the drive lever firmly, the vehicle will automatically come to stop; a sudden start prevention function that is employed to prevent mis-operation related incidents; and, a buzzer notification function.

1. Introduction

The number of elderly people continues to grow in Japan. It is predicted that in the year 2000, one of every six persons in Japan will be 65 years of age or older, and by the year 2010, this ratio will have increased to one in every five persons.

Communication with society is necessary for leading a vibrant life, even after we reach an old age and are no longer able to walk freely. Providing a means to move freely is important for achieving this communication.

Handle-type electric wheelchairs have begun to be used in recent years as vehicles for the elderly. According to the Road Traffic Law, electric wheelchairs are included in the category of wheelchairs for physically challenged persons. Since the driver is treated as a pedestrian, a driver's license is not required. In addition, according to the Japan Industrial Standards definitions, electric wheelchairs are classified into standard types and handle types primarily according to their appearance and application. Handle types are further classified into three wheel types and four wheel types. Since their appearance on the market in 1985, the number of these handle-type wheelchairs has increased each year. Despite this increase, however, the rate of their proliferation is still low in comparison with latent needs.

As a possible reason for this, apart from the present state of the transportation infrastructure, there are many cases in which persons decide not to purchase an electric wheelchair because they feel embarrassed, even though they would like to have one.

The "MonPal ML100" four-wheel handle-type electric wheelchair was developed to eliminate this feeling of

embarrassment and to provide support for persons with restricted mobility thereby encouraging them to go out into society.

2. Aim of the Development

During the course of development of the MonPal ML100, emphasis was placed on the following points in order to realize enjoyable personal mobility and to provide peace of mind, comfort and simplicity:

- (1) A design that offers both fun and peace of mind
- (2) A power train that provides reliable power even on slopes
- (3) A smooth and comfortable travel control system

3. Overview

The appearance of the MonPal ML100 is shown in Fig.1, while the design concept is shown in Fig.2 and the major specifications are in Table 1.

The key styling concept of "enjoyable personal mobility" is aimed at proposing a new style that is able to bring out the enjoyment and fun of the vehicle, while also enabling anyone to use it with peace of mind. The essential features of the design are as listed below.

- A shape that provides a wide step and minimizes the height of the front end of the body.
- A hood design that reliably makes the driver aware of the front of the vehicle, while providing a sense of stability for the legs and feet.
- Emphasis on driving enjoyment by employing a seat with three-dimensional curvature for better holding and large rear tires.

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Fig.1 External view of MonPal ML100



Fig.2 Design concept

Table 1 Major specifications

Items		Specifications
Overall length	(mm)	1190
Overall width	(mm)	680
Overall height	(mm)	1080
Tread	(mm)	Front: 590/Rear: 530
Curb weight	(kg)	94
Motor		DC brush type
Batteries (rated at 5 hours between recharges)		12V 35AH × 2 (sealed)
Tire sizes		Front: 3.00-4 Rear: 70/100-8
Drive systems		Direct 2-rear-wheel drive system (with differential)
Brake systems		Regenerative brake Electromagnetic brake Mechanical brake
Maximum speed	(km/h)	6
Maximum continuous Running distance (6km/h, flat road)	(km)	25

The overall layout of the MonPal ML100 is shown in Fig.3. The chassis dimensions comply with the Japan Industrial Standards classification for “electric wheelchairs” and are compatible with the National Public Safety Commission model type certification. Driver space has been ensured by arranging the control unit at the front of the vehicle, and the battery, charger and power train at the rear of the vehicle. The floor is low (150 mm above the ground) and flat for easy accessibility and ample driver space. A rearward tapering design is employed in which the rear tread is narrower than the front tread to reduce the occurrence of scraping and snagging of the rear wheels when traveling in confined spaces.

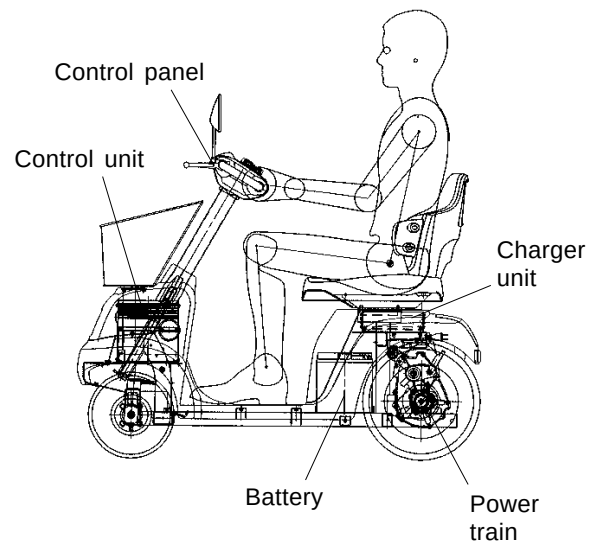


Fig.3 Layout of MonPal ML100

The power train was specially developed to be housed within the rear tread, and is an integrated single unit comprised of a flat motor and transmission.

The seat is specially shaped to support the lumbar region from both sides to provide secure holding against centrifugal force generated during turning and for the easy access required by persons with a weak lower back and legs. All controls are centrally located on the handle, and are arranged for convenient operation within easy reach of the driver's hands. The drive control in particular employs a system that allows traveling and stopping to be performed with a single lever preventing fatigue even when the lever is held for long periods during travel. In addition, a function is also provided to stop the vehicle when the drive lever is gripped firmly by the driver. Full consideration has been given to ensure peace of mind while driving the vehicle by providing a function against operation error that prevents the vehicle from suddenly starting and informs the driver when an error has been made, and one that slows the vehicle down automatically during turning.

4. Component Technology

4.1. Power Train

The appearance of the power train is shown in Fig.4, while its construction is shown in Fig.5.

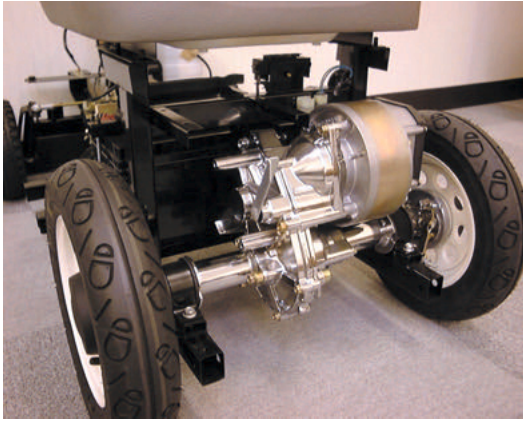


Fig.4 Power train

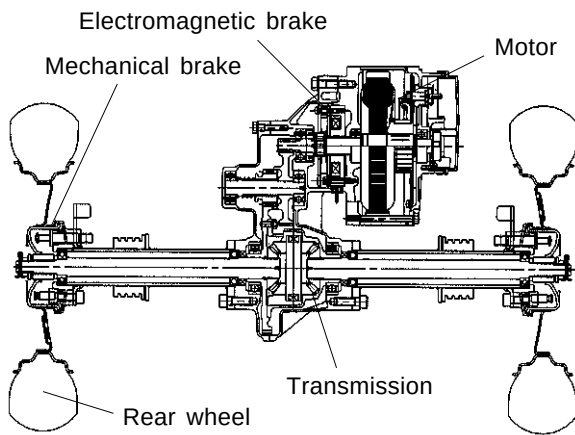


Fig.5 Layout of power train

The power train is a three parallel shaft type which integrates a flat motor into a single unit with the transmission and accommodates the primary reduction gear on the motor shaft. The braking system incorporated in the power train consists of an electromagnetic brake in the primary reduction gear unit that is activated automatically when the vehicle is stopped, a mechanical brake on each end of the rear axle that is operated manually, and a regenerative brake in the form of the motor itself that maintains a constant braking effect when descending a slope.

4.1.1. Transmission

A new low-noise, lightweight transmission was developed that is ideally suited for use in electric wheelchairs. The reduction gearbox incorporates a three-shaft secondary speed reducer to ensure that drive power is efficiently transferred to the large-diameter tires. The drive gear is formed on the input shaft itself as shown in Fig.6 with 10 helically shaped gear teeth. The transmission specifications are listed in Table 2.

The gearbox noise level and wear have been minimized by optimizing the tooth shape and gear trace of each gear. In particular, rather than being formed by a normal grinding process, the motor input shaft gears are subjected to two processes: induction hardening and cutting by and ultra-hard cutter (skiving).

The gear case is produced by “waved rib forming” to



Fig.6 Input shaft and gear

Table 2 Specification of transmission

Type	3 parallel shaft reduction gear
Input revolution (rpm)	Forward: 0~2 832 Reverse: 0~983
Reduction ratio	29.3
Clutch type	Constant mesh and manual separation
Dry weight (kg)	7.8

minimize the weight and provide high rigidity with the superior stress flow that results. The standard wall thickness of the case is only 2 mm, resulting in a 20% reduction in weight compared with previous types. This waved rib shape is shown in Fig.7.

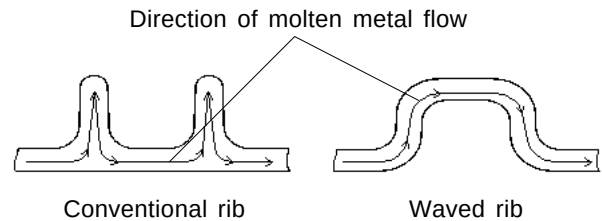


Fig.7 Rib shape

The clutch mechanism incorporates an inverse taper formed by a special rolling process on the clutch engagement portion to ensure reliable transfer of motive power during normal travel. The clutch release mechanism employs a cam and detent, which provides a feeling of shifting continuity operating on a common axis to minimize operating friction. The construction of the clutch is shown in Fig.8.

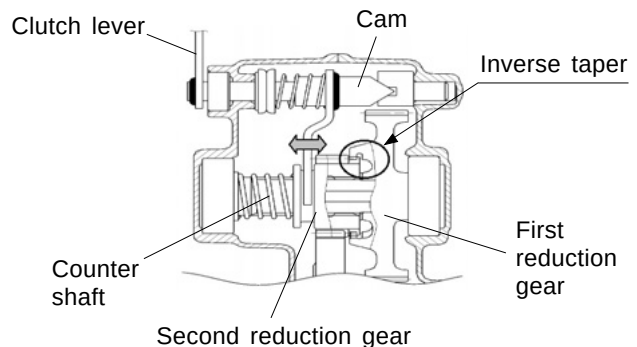


Fig.8 Clutch

In terms of production technology, various methods were employed as processing reduction mechanism. These include: the integration of three components in one model through the use of an optimum die construction and flow simulation; the adoption of a “differential automatic alignment mechanism” that utilizes the meshing alignment force of the pinion gear; and directly inserting the shaft into the die cast skin. The structure of the differential is shown in Fig.9.

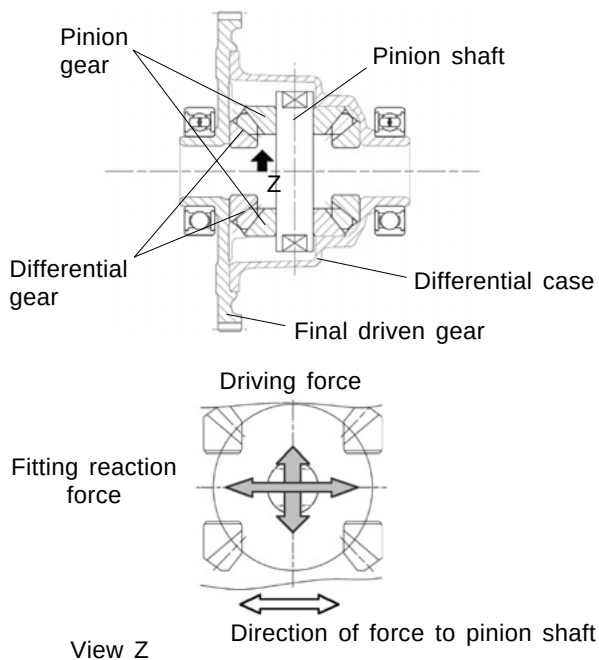


Fig.9 Differential

4.1.2. Motor

The flat disc motor has a flatness ratio of 1:8.75 in contrast to the ratio of cumulative thickness to armature outer diameter of 1:1 in typical motors. The motor specifications are shown in Table 3.

Table 3 Specifications of motor

Motor	Rated power (V/W)	24/360
	Armature (mm)	Ø140×16 (31 slots)
	Winding	Wave class B
Sensor	Revolution	2-phase magnetic pickup
	Temperature	Thermistor

The relatively large diameter of the motor makes it possible to incorporate 31 poles, enabling the voltage between segments to be maintained at a low level.

In addition, the use of a large-diameter armature provides good heat dissipation and high overload characteristics to ensure adequate power even when climbing slopes.

4.2. Control System

A 16-bit micro-controller is integrated into a single unit with the motor driver. The control unit is composed of the core “travel control unit,” the “indicator unit” that provides the interface with the driver, and the “power control unit” that is linked with the charger and is responsible for overall system management. The system diagram is shown in Fig.10, while the inside of the control unit is shown in Fig.11.

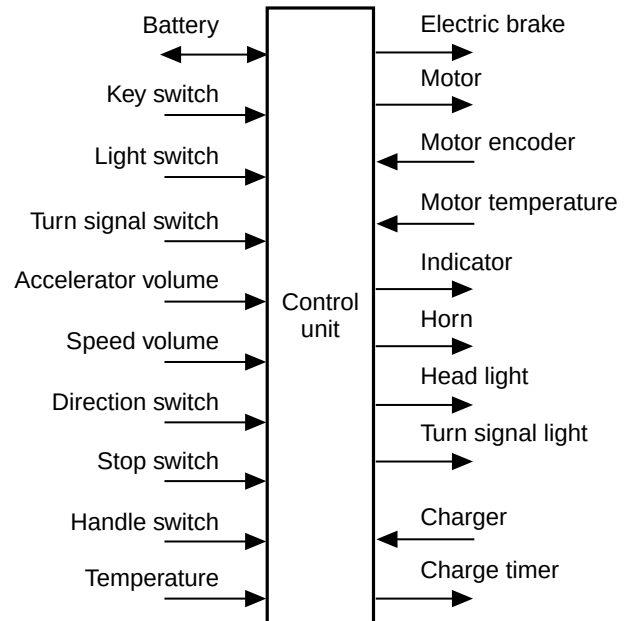


Fig.10 System diagram

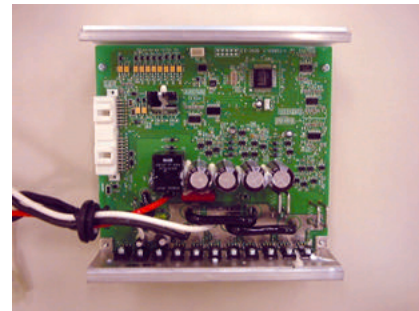


Fig.11 Control unit

4.2.1. Motor Driver

The motor driver employs a full-bridge configuration consisting of two parallel FETs to control forward and reverse rotation of the motor.

A finned heat sink is incorporated into the extruded aluminum case to provide high cooling efficiency and thereby gain maximum motor output.

4.2.2. Control Unit

(1) Travel Control

1. Constant Speed Control

Digital PI control is used in which the rotational speed and rotation direction are fed back from a Hall IC rotation sensor contained in the motor.

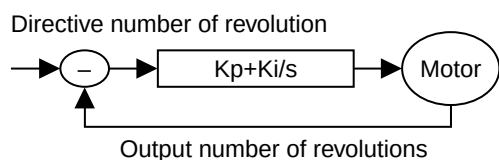


Fig.12 Speed control system

2. Optimization of the Acceleration and Deceleration Patterns

The profiles of the acceleration pattern to the target speed as set with the speed setting knob, and the deceleration pattern when the drive lever is opened, are set to 5 and 10 steps, respectively, for smooth starting and gentle deceleration.

3. Feel-Easy Functions

The travel control system incorporates the feel-easy functions required for use primarily by the elderly.

- The automatic stop function is activated by tightly gripping the drive lever. This quickly stops the vehicle whenever the driver wants to stop suddenly.
- The sudden start prevention function prevents the vehicle from moving forward suddenly when the power is turned on while gripping the drive lever.
- The automatic deceleration when turning function automatically slows the vehicle down to 4 km/h when the steering handle is turned.

4. Alarm and Protective Functions

Various alarm and protective functions are provided, including “overload detection” and “motor overheating detection” that can occur when climbing steep slopes, “motor lock detection” if the motor becomes locked such as when traveling over a bump, and “low battery detection” that prevents excessive discharging of the battery.

(2) Control Indicators

Various types of information are conveyed to the driver by 5 LEDs installed on the control panel.

1. Battery Power Level Indicator

This calculates the residual battery capacity from the battery voltage and current and displays the information in six levels. This indicator returns to the fully charged display when charging complete.

2. Charging Indicator

This indicates the progress of charging in terms of the battery voltage and elapsed time.

3. Error Mode Indicator

This indicates fifteen types of errors that can occur, including a defective rotation sensor and defective charger.

4. Maintenance History Indicator

This provides a history of the five most recent malfunctions that occurred to facilitate dealer inspections.

The travel distance, number of times charged and charging time are also indicated by LEDs.

5. Headlight Indicator

The left LED flashes to indicate that the headlight is on. This prevents the battery from being discharged

due to inadvertently leaving the headlight on.

Examples of these indications are shown in Table 4, while the appearance of the control panel is shown in Fig.13.

(3) Power Control

Table 4 Indication

Condition	Indication	Comment
Battery power	●●●●●●	
Charging	●●●○●○	
Error mode	●○●○●●	Motor lock
Maintenance history	●○●○●○	Charge cycle: under 50
Headlight	○●●●○●	Lighting on

● Lighting on ○ Lighting off ◎ Flashing



Fig.13 Control panel

1. Charger

The charger is a constant voltage, constant current type. The charging voltage range is 29.6-32.3 V, and the current is 5 A. The output voltage is set according to the outside air temperature to enable reliable charging under all temperature conditions. The charger has been certified by the Electrical Appliance and Material Control Law.

2. Charger Management

A system is employed that allows the selection of three charging modes corresponding to the battery status to prevent battery deterioration caused by overcharging from a low level of discharge. These charging modes are shown next.

*Normal charging mode

Charging is performed for 5 hours under timer control after the set voltage has been reached.

*Quick timing mode

Charging is performed for 2.5 hours under timer control in case the set voltage is reached within 2 hours.

*Overcharging prevention mode

Charging is quickly terminated the charging current falls to 1 A or lower within 1 minute. The set voltage that operates the charging timer is corrected for temperature based on an outside air temperature sensor.

Additional power saving features have been adopted such as an alarm function that operates when the power switch is on and a function that automatically turns off the headlight or turn signals when either has been inadvertently left on.

3. Travel prevention when charging

A function is provided that activates a buzzer alarm and prevents the vehicle from being moved forward by operating the drive lever while the power plug is inserted into an AC power supply and the power switch is turned on.

4. Battery

A lead-acid battery is used that is ideally suited for recharging. The battery is sealed, making it maintenance-free.

5. Conclusion

The MonPal ML100 is an electric wheelchair possessing functions that make it well-suited to areas having many slopes. It supports the leading of an enjoyable life by users with otherwise-impaired mobility. Future products will evolve in response to the changing needs of society.

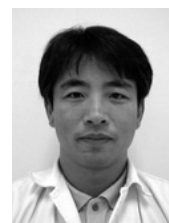
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