

New Electric Counter-balanced Forklift Truck Equipped with 360° Steering



Rocla Oy

Rocla Oy (hereafter Rocla), one of the European arms of Mitsubishi Logisnext Co., Ltd., was established as a heating apparatus manufacturer in 1942 in Finland. The company started the manufacture of indoor equipment for lifting and moving materials in the 1950s. In 1992, the company started supplying products under the MHI brand. In the field of electric counterbalanced forklift trucks, the company had manufactured Japanese-designed products, but launched the EDiA EX, the first Rocla-designed product, in November 2014. The product has been well-received by many customers for its beautiful and functional design unique to Scandinavian products. (Refer to “Winning Red Dot Design Award for Forklift Trucks,” Mitsubishi Heavy Industries Technical Review Vol. 54 No. 1.) This paper presents the new EDiA EM electric forklift truck released in August 2018 as a product of the same series as the EDiA EX, and explains its 360° steering function, a first in the product segment.

1. Concept of EDiA series

The concept of the EDiA series focuses most importantly on user experience. Based on this concept, we communicate with various customers to embody products that are rooted in each customer's experiences and work culture. Customer usage environments vary widely (**Figure 1**), and it is very important to understand their needs. As shown in **Figure 2**, we focus on features that allow users to feel the beauty of the product during use, such as “work efficiency” for facilitating work and reducing working time including the 360° steering function and the automatic tilt centering function presented in the upper row in the figure, “safety” including the high visibility, hill holding function, and automatic cornering speed control noted in the middle row in the figure, and “comfort” based on ergonomics including the ease of getting on and off and adjusting the functionality of various control equipment depicted in the lower row in the figure. The EDiA series aims to be a product line that harmonizes these features with sophisticated design.

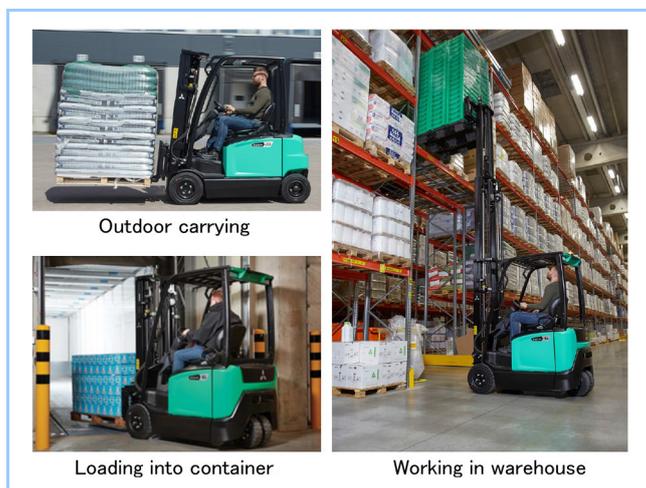


Figure 1 Usage examples of forklift truck

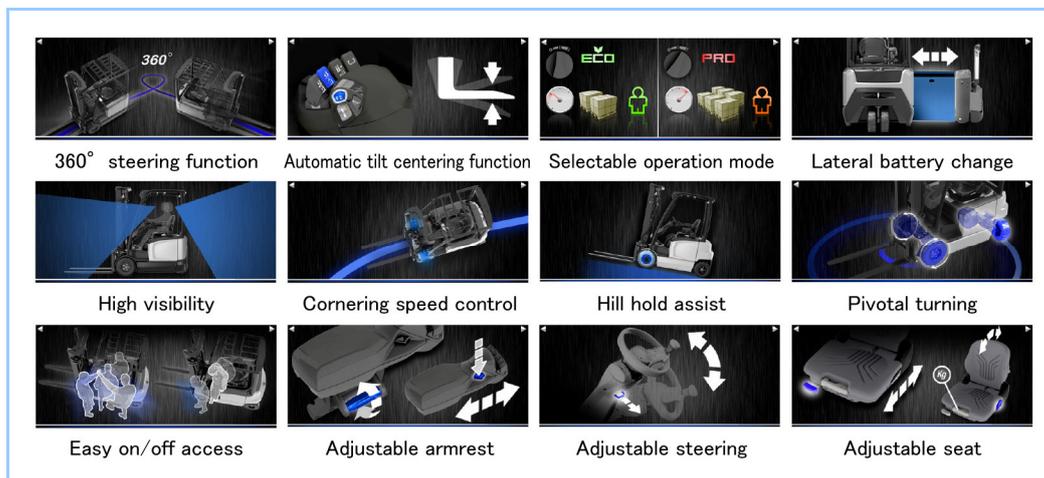


Figure 2 Concepts of EDiA EM

2. Product features of EDiA EM

2.1 Vehicle design

By enlarging the cabin space and the entrance by 25 mm compared to the previous model, a comfortable operating environment even for physically large operators is realized. In addition, by improving the height of the dashboard, the arrangement of the attachment hoses for the mast, etc., the front view is enhanced to improve operability (Figure 3). Figure 4 depicts the interior design. A user interface based on the same series concept as the EDiA EX is adopted. The small-diameter steering wheel, armrest-type cargo handling control lever, accelerator pedal, and brake pedal are optimally positioned based on ergonomics and customer feedback, contributing to the reduction of operator fatigue. The multi-lingual color display has an easy-to-use design using as few characters as possible and a large number of icons, the meaning of which can be understood at a glance. For cabin interior equipment, which is a major feature in Scandinavia, operation switches of the heater, wiper, etc., are located at positions that are easy to see in the operator's field of view, and the vehicle adopts an easy-to-open/close long door handle, a large glass window and a low-position wiper motor that does not interfere with the operator's view. The cabin also features an interior light, radio unit, etc., providing customers with a safe and comfortable environment similar to a passenger vehicle.



Figure 3 Improvement of cabin space and entrance



Figure 4 Interior design

2.2 Assist control function

The operation assist control functions installed on the EDiA EM are inherited from the EDiA EX. The first one adjusts the set speed according to the operating speed for cargo handling or vehicle travel (**Figure 5**). The corresponding vehicle action becomes quicker when the control interface is operated quickly at full stroke, and slower when operated slowly. The second one finely and smoothly changes the travelling speed while turning according to the angle of the tire (**Figure 6**). Both control functions are set to simultaneously realize the safety and workability reflecting customer opinions. The EDiA EX is equipped with many other control functions based on the user experience design. The next chapter explains the 360° steering function newly adopted for the EDiA EM.

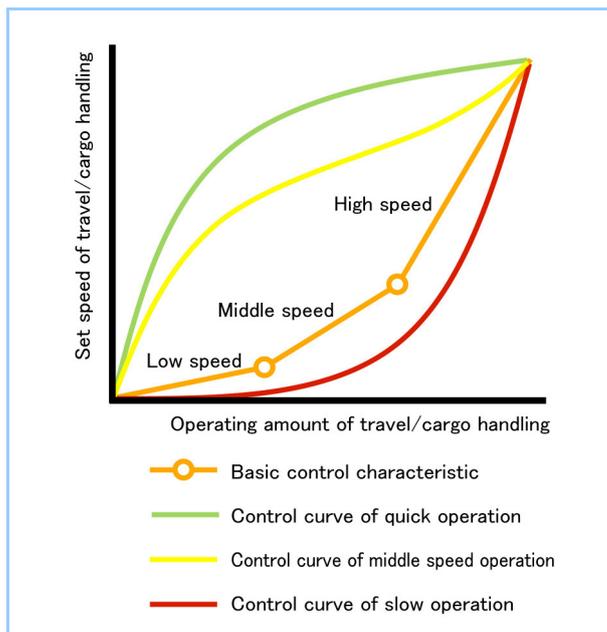


Figure 5 Operating speed-sensitive control curves

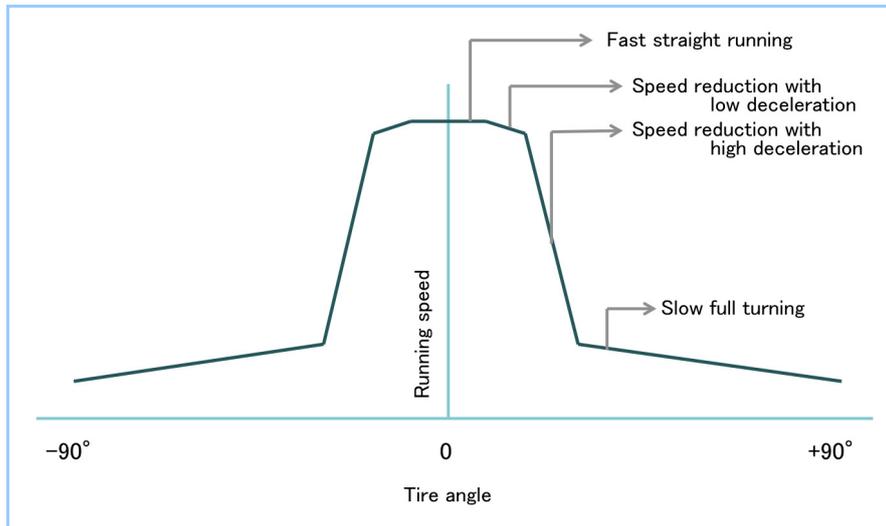


Figure 6 Automatic cornering speed reduction control

3. 360° steering function

3.1 Explanation of 360° steering function

In the past, when switching the running direction of a forklift 180° for unloading or loading, it was necessary to perform turning while running backward, stopping, switching forward/backward, starting, and turning while running forward as can be seen in **Figure 7**. In this switching of direction, the operator is required to turn back the steering wheel left to right. When the tire angle reaches 90° left and right (180° in total), the steering angle reaches the limit, and the steering wheel is not turned any more in the same direction. On the other hand, in the case of switching direction with the 360° steering function, when the tire angle approaches 90°, forward/backward motion is switched automatically simply by continuing to turn the steering wheel in the same direction without turning back. **Figure 8** illustrates the movement of the tire and the rotational speed ratio of the left and right motors while switching direction. The movement of each component from running straight backward to starting turning, continuing to turn the steering wheel, and running straight forward is as follows:

- (1) The tire continues to steer beyond 90° and reaches 180°, which is the straight forward running position.
- (2) The position of the knob on the steering wheel returns to the neutral position when the tire reaches the straight forward running position.
- (3) At the start of turning, the rotation speed of the backward running side of the left and right driving motors starts to decrease, and when the tire angle reaches 90°, the left and right motors rotate in mutually opposite directions at the rotation speed ratio of 1:1, which enables the minimum turning radius. After that, the rotation speed of the forward running side increases, and when the tire reaches the straight forward running position, both the left and right motors rotate fully forward.

To realize these control functions, the forklift truck is required to be equipped with driving motors independently on the left and right wheels, a steering-by-wire system with no mechanical connection between the steering wheel and the tire, a steering wheel that can turn 360°, a forward/backward operation switch that returns automatically to the neutral position, etc. In addition, fine control tuning is performed so that the behavior becomes stable and continuous and smooth direction change is possible even if any unexpected operation is performed. As a result, continuous and smooth automatic switching forward/backward motion in a series of operations become possible.

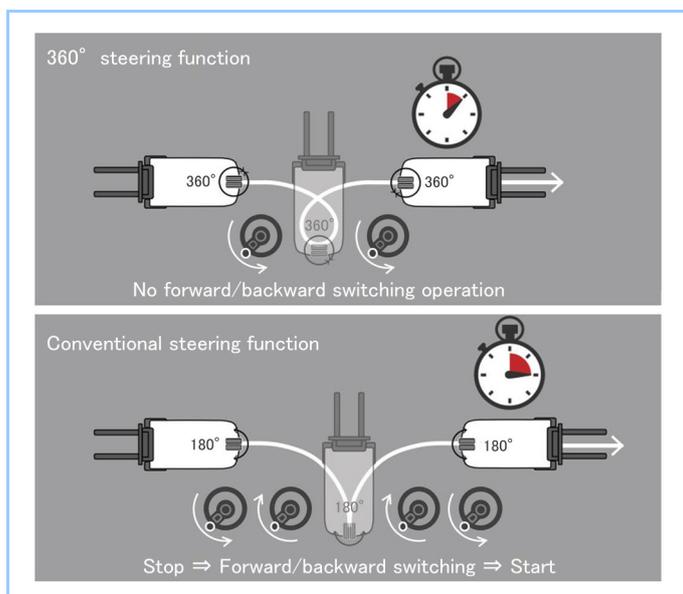


Figure 7 Comparison of 360° steering function and ordinary steering function

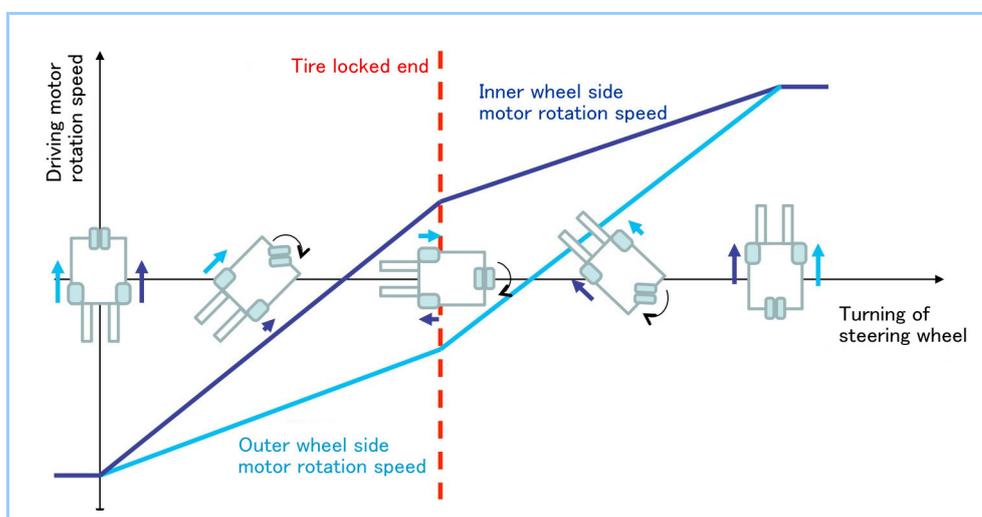


Figure 8 Tire movement and rotational speed ratio of left and right motors

3.2 Advantages of 360° steering function

Using the 360° steering function improves work efficiency by saving time for stopping and starting for switching direction, and also enables easy turning in narrow spaces and reduces the centrifugal force applied to the cargo and the load caused by acceleration and deceleration. In addition, it is expected that the smooth behavior lowers the burden on the operator resulting in fatigue reduction and reduces tire wear. For customers who prefer the conventional steering function, the conventional system can be selected.

3.3 Application example of 360° steering function

Figure 9 presents an application example. When loading factory cargo onto a truck or other carrier vehicle, the forklift truck reciprocates between the truck and the cargo pickup point. This section estimates how much the work time can be reduced by the 360° steering function in such cases.

- Approximately 2 seconds per turn can be saved. (According to a result of a comparison and verification by Rocla. This actually depends on the operator and environment.)
- In this application example, which has 2 turns per work cycle, 4 seconds in total can be saved.
- Assuming that 60 seconds are required per working cycle, the time saving effect results in 6.7%.
- Assuming that the annual total actual operation time (including rest time, etc.) is 1000 hours (4 hours per day, 250 days per year), 16.7 days can be saved.

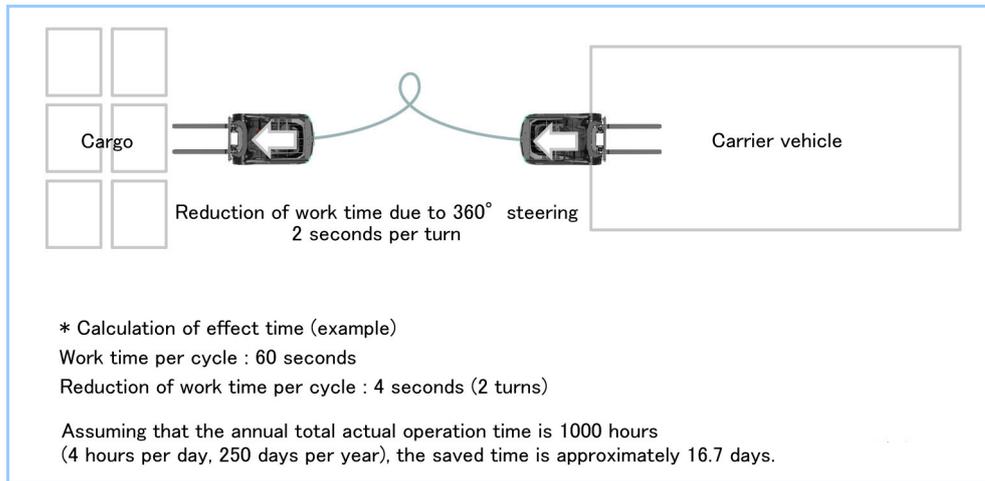


Figure 9 Application example of 360° steering function

In addition to shortening the work time as shown above, the work becomes safer and the burden on the operator is reduced. Moreover, since loads such as centrifugal force applied to the cargo are reduced by the smooth turning, the risk of cargo collapse and product damage is also reduced.

4. Future development

Forklift manufacturers in Europe have developed products and logistics solutions that strive to improve work efficiency, reduce the burden on workers and improve safety ahead of the world in response to user needs. Under these circumstances, we will actively propose solutions for customer problems and the smarter use of forklifts, and continue to communicate with customers to provide value based on the user experience design.