Development of an Accelerating Walkway

Katsumi Ikizawa*, Hiroyuki Nagai**, Shin-ichiro Aoe***, Tomoaki Sato****, Ryuichi Okuno***** and Takeshi Yanagisawa*****

The accelerating walkway, which was developed by NKK, travels as slowly at the entrance as a conventional moving walkway (30–40 m/min), but then moves at its highest speed (54–72 m/min) in the middle of the walkway after acceleration. The walkway is decelerated to the same low speed for the exit as used at the entrance. The accelerating walkway is designed to ensure safety and convenience of the users because the handgrips at both sides are synchronized with the adjacent walkway pallets.

1. Introduction

Moving walkways are widely used for transporting passengers in facilities such as railway stations and airports. The speed of these walkways is determined by the need for safety upon entry and exit, which generally limits it to approximately half normal walking speed, or 30–40m/min. The slow speed of the walkway causes impatience, and passengers often walk on the walkway itself or on the adjacent floor rather use the slower walkway.

Recent trends towards the increased scale of railway stations, airports and similar facilities result in increased distances that need methods of transport over walking distances of a few hundred meters. This requires improvements that cannot be expected from moving walkways due to their slow speed, making the installation of moving walkways unpopular.

Accelerating walkways are a new method of transport developed to overcome these disadvantages. For safety reasons, the speed at the entry and exit is the same as that of conventional walkways, but the speed between the entry and exit is increased to walking speed. Some experimental accelerating walkways have been developed and installed in the past, but none have reached the stage of full operation¹⁾⁻⁴. Safety concerns are the primary reason for these walkways not being widely accepted.

Within this context, NKK developed a variablespeed walkway that has the same level of safety as a conventional constant-speed walkway, while providing greater speed and thus resolving the problem of impatience.

2. Features of accelerating walkways

The increasing proportion of elderly citizens in society places the focus on safety as the prime consideration in the development and acceptance of accelerating walkways. These considerations have significantly affected the design, manufacture, and improvement of such walkways⁵).

The features of NKK's accelerating walkway are as follows.

^{*} Group Manager, Diesel Plant Engineering Group, Heavy Industries Manufacturing Dept.

^{**} Group Manager, Industrial Machinery Engineering Group, Heavy Industries Manufacturing Dept.

^{***} Research Engineer, Control Engineering Research Dept., Applied Technology Research Center

^{****} NK Technos Corporation

^{*****} NKK Plant Engineering Corporation

(1) Linear transport is the same as conventional moving walkways.

(2) The entry and exit speed is the same as conventional moving walkways.

(3) The central region moves approximately 1.8 times faster than the entry and exit, and the speed transitions are smooth.

(4) Changing speed seems like expansion and contraction of the walkway surface, while slots in the walkway surface remained meshed for safety.

(5) Individual handgrips are used instead of conventional handrails to ensure safe entry and exit.

(6) The economics of the walkway design was verified.

3. Basic structure of prototype

3.1 Pallet unit

The entry and exit are the same as that of a conventional constant-speed walkway, while the intermediate section incorporates a system of pallets to convey passengers at higher speed. The use of a smooth transition between the low-speed zones at entry and exit to the intermediate high-speed zone ensures passenger safety and comfort. The walkway surface uses the same linear pallet unit arrangement as a conventional walkway, but incorporates a continuous surface that can vary between low and high speeds.

As shown in **Fig. 1**, the pallets are in close proximity at low speed and become separated at high-speed. Auxiliary pallets are used to ensure continuity of the walkway. The auxiliary pallets comb with the slotted sections of the main pallets so that they are within the main pallets at low speed and gradually become separated as speed increases. The apparent contraction and expansion of the surface is due to the slots of the auxiliary pallets moving in and out relative to the main pallets. The main and auxiliary pallets are constantly meshed, eliminating any danger of being caught between them when they expand or contract.

As shown in **Fig. 2**, the structure that allows the distance between pallets to vary consists of diamond-shaped links in the horizontal plane between the pallets. Rollers are fitted to the left and right apexes of each link, and each roller runs in a C-shaped guide rail to restrict movement of the entire structure between the two rails. The spacing between the pallets can therefore be reduced (at low speed) or increased (at high speed) by varying the distance between the guide rails. The guide rails taper together in the variable speed zone between the low and high-speed zones to provide the speed change.

The basic structure of the drive unit is shown in **Fig. 3**. A drive chain is installed in the (constant speed) high-speed zone that drives the main pallets. Auxiliary drive chains are installed in the (constant speed) entry and exit low-speed zones to ensure smooth speed transitions.





Fig. 3 Accelerating walkway drive chain system

3.2 Handgrips

A new handrail system was needed for the variablespeed pallet unit. Conventional handrails eliminate the potential safety problems associated with loss of synchronization between the rubber belt and the surface of the conventional constant-speed walkway. A rubber belt-based system consisting of multiple rubber belts along the longitudinal axis of the walkway has already been developed, but it has safety problems due to an inability to synchronize with the walkway in the variable-speed zone and to the need for joints in the handrail that force users to change their grip frequently.

These deficiencies led to the development of a system of individual handgrips that are synchronized with the speed of the pallet unit. This system consists of individual left and right pairs of handgrips for each pallet, with all three components moving as a unit. This arrangement ensures that the positional relationship between the pallet and handgrips remains constant even in the variable-speed zone, thus allowing safe entry and exit from the walkway.

The arrangement of the handgrips is shown in **Fig. 4**. The longitudinal axis of the handgrips is aligned with the direction of movement of the walkway, with a pair located on either side. The space between handgrips is covered by a flexible accordion cover that allows expansion and contraction as required by the changing grip spacing. Each accordion cover is contained within the balustrade cover.



Fig. 4 Accelerating handgrip system

The structure that permits variation in the distance between the handgrips is shown in **Fig. 5**. The handgrips are linked by a V-shaped link mechanism, with a roller fitted to the apex of each link. The left and right rollers move within the left and right guide rails. There are two types of guide rails: straight reference guide rails that are parallel to the walkway surface, and variable guide rails the width of which varies to obtain the required spacing to match the reference rails. The position of the variable guides change as required to allow expansion and contraction of the V- shaped ring. The structure of the ring used therefore differs; however, the principle of expansion and contraction is the same as for the pallets.

In the variable guide, the distance between the guide grooves is varied as necessary to expand and contract the V-shaped links.

While the link structure used differs, the basic principles of expansion and contraction are the same as for the pallet unit.

The basic structure of the drive unit is the same as for the pallet unit (see **Fig. 3**). The drive for each hand grip and pallet unit is mechanically linked so that the main pallets and handgrips are completely synchronized for transporting passengers.



Fig. 5 Link mechanism of accelerating moving handgrips

3.3 Prototype specifications

Basic specifications for the prototype unit are shown in **Table 1**. The unit itself is shown in **Photo 1**.

Table 1 Accelerating walkway test specifications

Item	Specification
Туре	1200
Distance between supports	25 m
Width exposed treadway	1000 mm
Speed at entrance and exit	30-40 m/min
Speed in high-speed zone	54–72 m/min
Ratio of high speed and low speed	1.8
Type of treadway	Pallet type treadway
Type of handrail	Moving handgrips
	(same speed as walkway)
Driving machine	Link coupling and drive chain
Transport ability	12000 passengers / h



Photo 1 Accelerating walkway under test

4. Evaluation of safety

The various safety problems associated with the different functions and shapes of the accelerating walkway compared to a conventional constant-speed walkway were investigated experimentally on the basis of ergonomic criteria. These evaluations are outlined below⁶. See **Photo 2**.



Photo 2 Experimental verification of ergonomic factors

4.1 Speed patterns

The speed at entry and exit is similar to that of a conventional walkway and therefore presented no particular problems. The speed in the high-speed zone is 54–72 m/min, which is approximately 1.8 times that at the entrance and exit (30–40 m/min). This approximates a normal walking speed and, as such, does not seem unfamiliar to the user. However, some problems remain that are associated with the acceleration from the low-speed zone to the high-speed zone to the low-speed zone.

As seen in **Fig. 6**, an experimental evaluation of ergonomic factors in terms of the perceived danger and transport speed showed that the most appropriate entry and exit speed range is 30-40 m/min, with an average acceleration of 0.008-0.015 G.



Fig. 6 Questionnaire results

4.2 Safety at exit

The structure of the pallets is such that the space between the main pallets increases in the acceleration zone after entry and decreases between the deceleration zone and the exit. Deceleration at the exit is a possible cause of congestion, and a number of experimental evaluations were therefore conducted from an ergonomic standpoint to provide data for improving the system. An outline of these evaluations is provided below.

4.2.1 Guiding passengers onto the walkway (1) Coloring of pallets

Congestion at the exit can be avoided if passengers are on the main pallets at the beginning of the deceleration zone. A method of coloring the main pallets was investigated to determine whether passengers could be induced to consider auxiliary pallets as temporary pallets, and thus be unconsciously guided towards the main pallets. The main pallets were therefore colored black, while the auxiliary pallets were colored red.

(2) Handgrips

The handgrip pairs are located at either side of the center of each main pallet. The handgrips and main pallet are therefore completely synchronized during movement. When passengers hold the handgrips they are therefore riding on a main pallet (see **Fig. 7**).

When used in combination with warnings, taking hold of a hand grip or moving to the location of a hand grip will naturally result in the passenger riding on a main pallet and avoid congestion at the exit.



Fig. 7 Safe use of accelerating walkway

4.2.2 Evaluation of pallet structure

An analysis of the use of conventional moving walkways and escalators showed that, with pallets 400 mm wide, passengers generally ride on alternate pallets rather than on a continuous strip of the surface. This may be because passengers feel too close to others if riding on a continuous strip of the walkway or escalator. Simulations of congestion in the deceleration zone suggested that passengers tend to alter their position in relation to other passengers, thus eliminating any possibility of danger.

The prototype unit has pallets that are 400 mm wide and auxiliary pallets that are approximately 320 mm wide. Thus, under normal conditions of use, it is very unlikely that passengers will be simultaneously on both a main pallet and an auxiliary pallet, even if congestion occurs.

4.2.3 Warnings to passengers

Methods of conveying warnings to passengers were investigated to ensure greater safety in using the walkway. In particular, warnings are given to passengers prior to entering the deceleration zone to the effect that the exit is approaching, and appropriate action should be taken (e.g., face the direction of travel, be aware of auxiliary pallets, and grasp the handgrips or move to a position where this is possible).

With this in mind, the following types of warnings were selected.

(1) Signs

Signs (e.g., images) placed prior to the deceleration zone and at other locations.

(2) Audio

Messages broadcast at locations prior to the deceleration zone. For example, 'The exit is approaching, please hold the handgrips.'

(3) Flashing lights

Installed prior to the deceleration zone. For example, lights flash from the exit towards walkway and from the walkway towards the exit.

(4) Area lighting

Installed before the deceleration zone to the deceleration zone. For example, the area directly below the auxiliary pallets is illuminated.

4.3 Handgrips

4.3.1 Configuration of handgrips

Evaluations of passenger impressions of independent handgrips fitted at various intervals were conducted in parallel with other experiments. The evaluations showed that passengers readily accepted the grips and that the grips could be used safely over the entire speed range because they are fully synchronized with the pallets.

4.3.2 Shape of handgrips

(1) Width

A handgrip width of approximately 8 cm was found to be most appropriate.

(2) Height

A height of approximately 4 cm was found to be appropriate in terms of ease of use.

(3) Coloring

A light blue color was clearly found to promote use of the grips, while at the same time providing a good contrast with the black accordion covers.

5. Conclusion

This paper introduced the accelerating walkway developed by NKK for passenger transport over short distances.

During the process of development, safety in use was considered the most important criteria, and a number of ergonomic evaluations were conducted on this basis. At the same time, the guidance of a variety of experts in the field of transportation systems was sought to ensure that the equipment was suitable for practical use.

The equipment received general certification from the Japan Construction Center on June 24th 1999 and was certified by the Minister of Construction in accordance with Clause 38 of the Construction Standards Law on February 3rd 2000. It is expected that the equipment will find applications throughout Japan as a new method of convenient passenger transport.

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