Airport baggage handling system using U asynchronous linear motors

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Abstract

Linear induction motor are designed for low speed and automatic luggage transportation system. This paper presents the technical details of an innovative application of small linear induction motors "LIM" based on U shape reaction rail designed by INRETS. The system produced by FABRICOM is the "TELEBAG", it is a Destination Coded Vehicle (DCV) for baggage handling system in airport.

Keywords

Asynchronous linear motor, propulsion, baggage handling system, destination coded vehicle (DCV), transports systems

1. Introduction

Linear Induction Motors (LIM) were topics of research of many universities and research institutes around the world 30 years ago. The main objectives were the propulsion of sustained high speed vehicles without contact with the ground by using different technologies [1]. The high speed German and Japanese projects, which use linear synchronous motor, are the most famous respectively known as "Transrapid" and"MAGLEV". The first commercial line will be in Shanghaï, the German system will operate between the airport and the city at the maximum speed of 430km/h. The Japanese project is still running in experimental way on the Yamanashi test line at over 500km/h.

In France the research on such new transportation technologies were officially fully stopped in 1975. However some important research works were realised on the LIM with success. From 1974 to 1979 a national project allowed to test a LIM with" U" reaction rail design at 180km/h. From 1980 to 1986, in the frame works of research collaboration between Germany and France, a higher speed linear induction motor with " U" reaction rail design, was tested at 300km/h on the INRETS test laboratory at Grenoble, in 1984.

The benefits issued from these research results, were to design experimental and simulation tools, which were used for the design of a lower speed and a smaller linear motors which equip the "TELEBAG" carts. The advantages of a no track contact propulsion chain allow a fully automatic system with accuracy stop location even in go down and go up conditions.

2. Destination Coded Vehicles concept

Due to increase of passengers, airports are asking for new technologies for baggage handling systems. They are looking for high-speed systems and long distance handling between terminals. If bags are traditionally moved on belt conveyors, the new way is to carry them in carts, running on dedicated tracks. These carts are called D.C.V. (Destination Coded Vehicles). Such systems are used to link terminals but are less flexible as belt conveyors inside a terminal.

Generally the track includes flat linear motors, giving thrust to free running carts. These systems are fast, but loading and unloading of bags is not so easy.

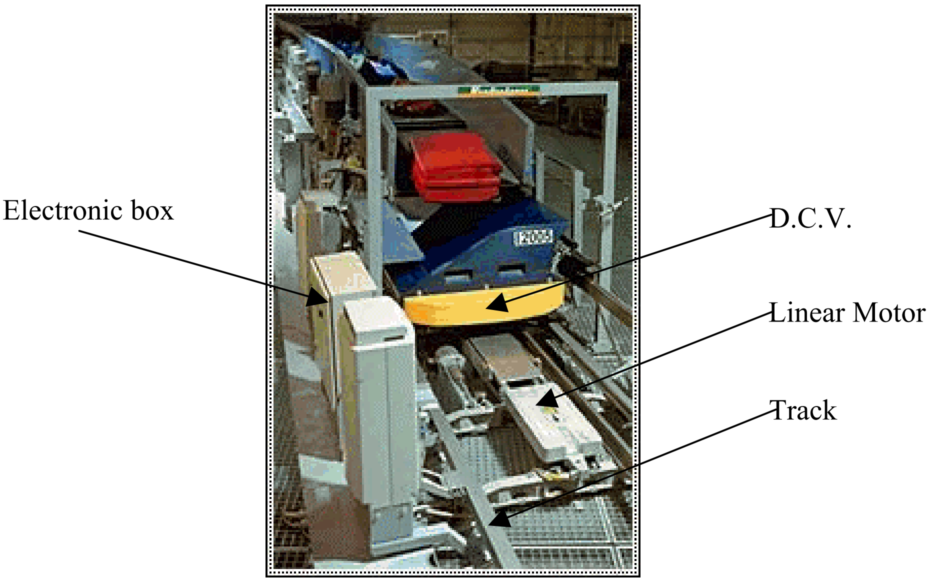


Fig. 1: Photography of a D.C.V. at loading station

3. TELEBAG concept

TELEBAG carts are D.C.V. with onboard motors and intelligence (PLC). This solution gives them more possibilities for managing their own speed, distance between each other, self-accumulation, and performing special functions like loading and unloading on traditional belt conveyors or check-in desks.

For these reason, the TELEBAG system is an homogeneous baggage handling solution, from the check-in desk to the chutes, including security check of bags through X-Rays machines, sorting, etc…

Fig. 2: TELEBAG cart loading a bag from a belt conveyor

Traditional flat linear motors would have been too large and heavy to be fixed onboard this kind of cart. Another difficulty is that track includes horizontal and vertical curves, 15° slopes, merges and switches. For this reasons, U-shape linear motors have been used.

Fig. 3: Photographies of the TELEBAG carts and track

Each cart is equipped of a special control system which is able to determine the distance from the front cart. Taking account of this information and of the speed information, it is possible to keep automatically a distance of 5 meters between cart at full speed, which is reduced at 0,6 meter for the low speed section. By this concept driving, the carts create themselves a flexible convoy which is auto-adapted to the baggage traffic requirements.

4. Propulsion by U asynchronous linear motor

The linear induction motor (LIM) designs were probably issued from the rotating machines, the first design was proposed a long time ago by J.B.Entz and A.Zehden for the traction of small train [2, 3, 4]. The concept way of the different linear induction motors is presented on figure 4. The initial electromagnetic structure (1) is the rotating induction motor, this machine is developed from the cylindrical shape to a flat shape (2), then we got the basic flat linear induction motor.

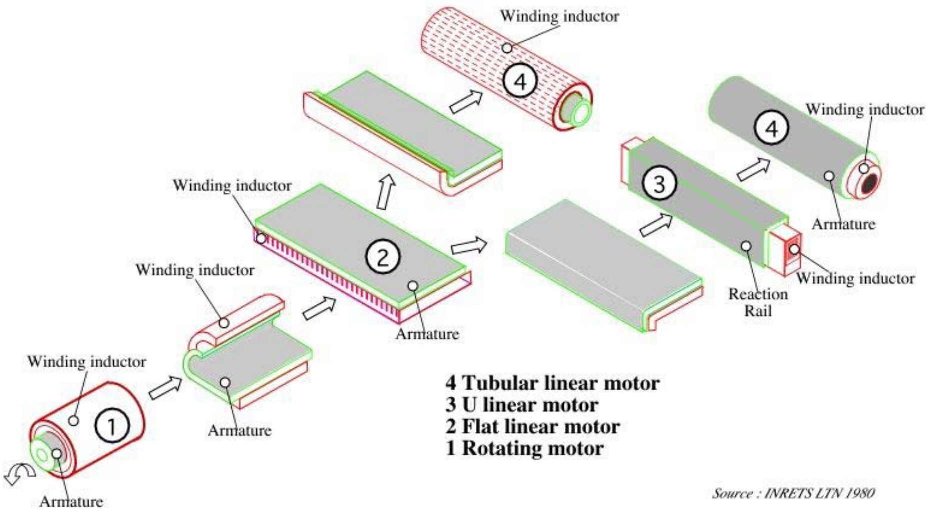


Fig. 4: Ways for different LIM structures

An other way of transformation is to fold the magnetic core in order to get a rectangular cross section (3), then the winding coil structure move to become around this core, it is the typical “Gramme“ winding, the reaction rail (or armature) is a U shape which can be fixed to the ground or to the mobile [5, 6]. The last step is to close the opened side of the U to get a tubular linear motor (4), which are used today for actuators as “electrical jack“, the motor can be synchronous using permanent magnet in the mobile part. Many researches and applications were proposed with different LIM structures [13, 14, 15].

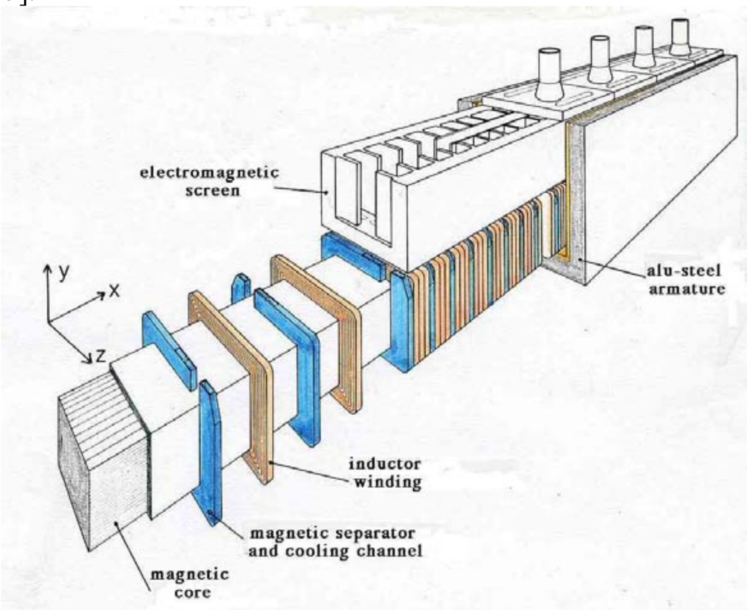
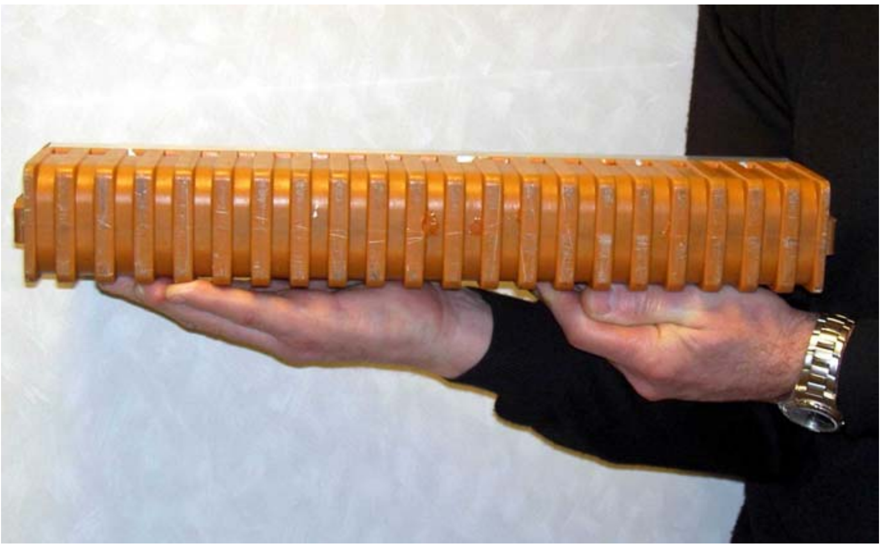


Fig. 5: U shape reaction rail LIM (Celduc source)

The figure 5 shows the design of the “ U” LIM designed by INRETS which reached 300 km/h at a peak power of about 1MW, tested in 1984 on the wheel reaction rail of the Grenoble laboratory. The next picture (figure 6) shows the “ U” LIM designed to drive the TELEBAG cart. The size is compact and the power is in the range of few kilowatts.



Basic characteristics

Pole pitch	60 mm
Pole number	6
Air gap	2,5 mm
Frequency	50 Hz
Thrust (max.)	480N
Speed	5 to 6 m/s

Fig. 6: Photography of the U LIM TELEBAG

The electromechanical characteristics are calculated by using a dedicated INRETS code, it is a program based on the usual analytical equations of the linear induction motors, the major parameters were fitted thanks to experimental plans by means of scaled machines tested following a test protocol issued from the electromagnetic similarity laws or “Reynolds“ electromagnetic laws [7, 8, 9, 10, 11, 12],

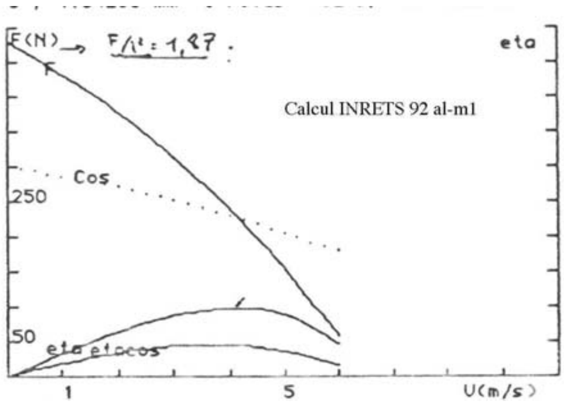


Fig. 7: Mechanical thrust, power factor and efficiency

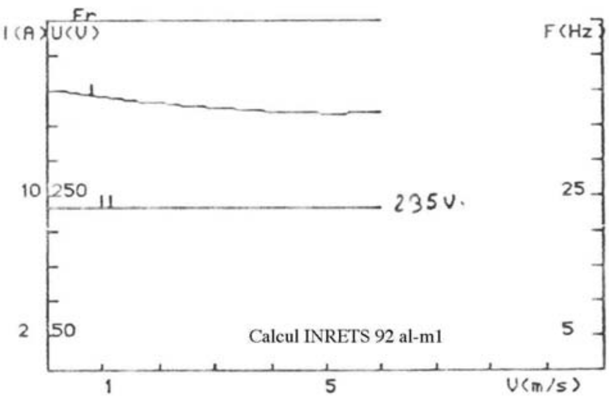


Fig. 8: Electrical power supply, current and voltage

At the fixed frequency of 50Hz, the simulation results show a starting force over 450N, which is reduced until 150N at 5m/s. The two critical parameters are the extremity effects and the magnetic leakage field. Due to the guidance constraints of the cart running in the track, taking account of the radius of the track (left-right and up-down) the length of the inductor is limited at about 42 cm, and the mechanical airgap between the track and the mobile part can be no smaller than 2,5 mm.

Looking about the cross section of the motor, the advantages of the “ U” shape are that this type of LIM offers three active electromagnetic sides with a very compact assembly. The fourth side of the motor is necessary for the electrical connection and the mechanical assembly. However, this last side is also use as an electromagnetic screen allowed by using a conducting matter (copper or aluminium), at least this side must be also used for the thermal exchange to cool the winding.

The track technology, shown on figure 9, is based on aluminium U shape obtained directly by using a U matrix form with a fast industrial process, which assume the electrical conducting part for the asynchronous currents generated in the secondary part (fixed part) of the LIM. A steel sheet fixed on each side of this “ U” aluminium shape assumes the feedback of the magnetic field. Each cart is moved by two LIM installed on each side of the cart, then the track presents 2 “ U” symmetrically.

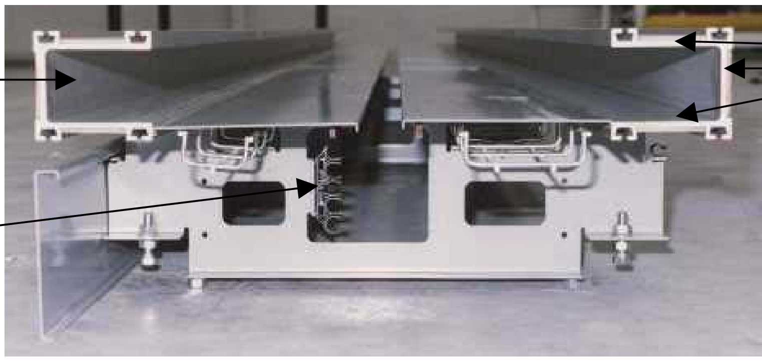


Fig. 9: Photography of the TELEBAG track section

Taking account of these different assembly constraints on the design of the LIM: on mobile part (winding part) and on fixed part (track on the ground), these low speed motors don't allow to get high performances on power factor and efficiency. The technological choice results of a balance between the electromechanical performances and a low cost assembly design, in order to get an industrial competitive solution for airport application.

5. Power supply and speed control

The TELEBAG system requires a distributed power supply along the track. The more easy technical solution is to provide a three phases and earth busbars distribution, installed in the track assembly (figure 9) and sets of brushes, fixed on the carts, to connect them to the power supply network.

In order to keep a low cost objective, forces and speed were controlled only from voltage level applied at the fixed frequency of the grid (50 or 60 Hz), the voltage level is also standard (400Vrms), then it is possible to use any industrial electrical components. The electrical power factors of the LIMs are corrected by using capacitors on board.

The critical points are the speed control in different conditions (radius, go up and go down) without crash with any other carts, and the stop at accuracy location for the luggage transfer for loading and unloading on the cart. A very fast loop control is required in order to get the highest baggage flow of the airport.

The electrical power of each cart is controlled by using a power circuitry based on thyristors integrated modules (2 thyristors in opposite connection) driven by a microcontroller system which use mainly 3 information: the speed of the cart, the distance from the front cart, the speed allowed in the track section. Cart speed is measured on board, distance from the front cart is issued from a special sensor system dedicated to TELEBAG, and speed allowed is collected from a busbar dedicated to exchange information with the carts.

As already mentioned, the TELEBAG is fully automatic, each cart keeps automatically a distance of 5 meters from the front cart at full speed, which is reduced at 0,6 meter for the low speed section. By this driving concept, the carts create themselves a flexible convoy which is auto-adapted to the baggage traffic requirements.

6. Application of TELEBAG systems

The automatic luggage transportation system using carts with LIM becomes a competitive solution witch is chosen by several airport in Europe. The example of the LUTTON Airport is today the highest complex network of carts, 102 carts can be operated in the same time. The drawing on figure 10 presents an overview of the complexity of the LUTTON baggage transportation network.

LUTTON airport is now 8 000 000 passengers per day. The number of bags through the TELEBAG system reaches 11 000 bags per day during the peak period.

The system is operational 24 hours a day, 7 days a week. The availability of the system is very good better than 99%. As all the complexity of the system is quite only on board the carts, and as the carts can be moved rapidly from the tracks, the system never stops.

For the same reasons, maintenance can be done during the day. Linear motors drive don't generates any maintenance.

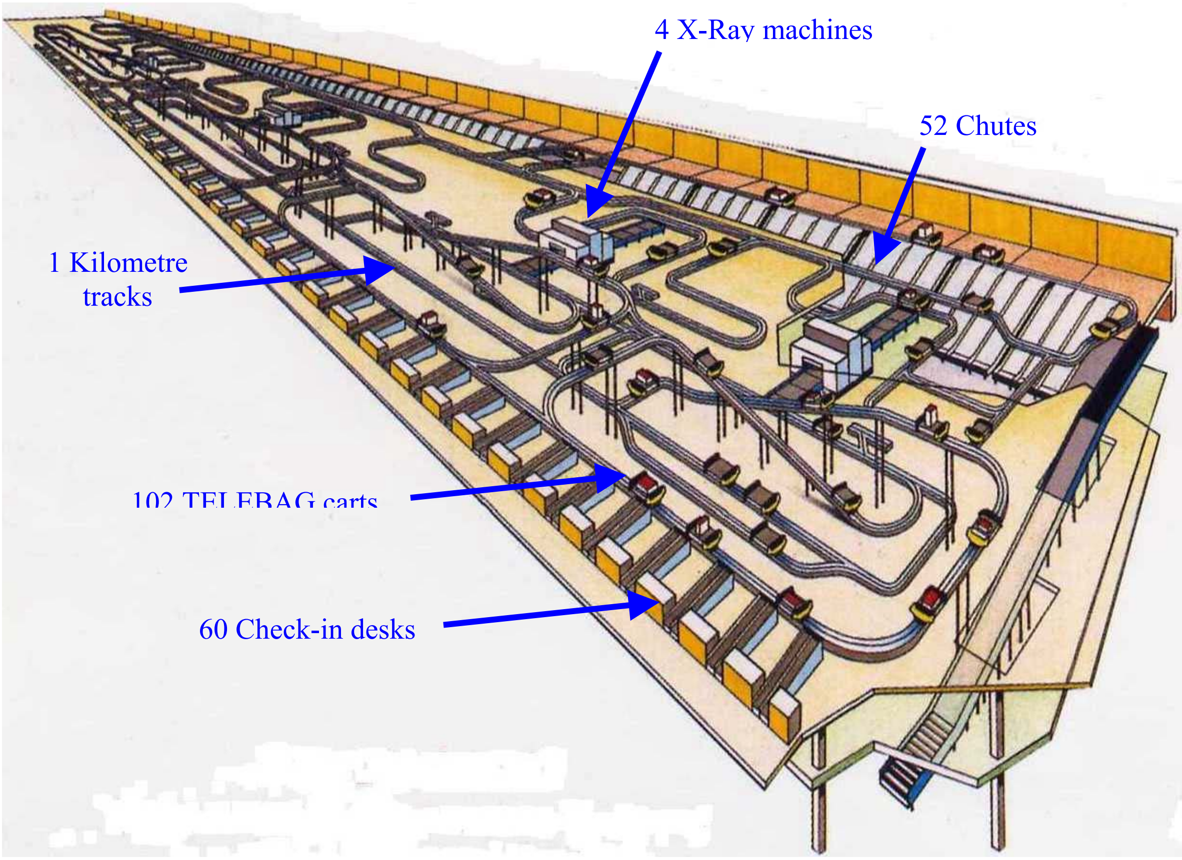


Fig. 10: Baggage transportation network of the LUTTON Airport with the TELEBAG system

The next table gives the list of the applications of the TELEBAG system, today about 540 small LIM are realised to drive the carts.

Table 1: European airport equipped with the TELEBAG system for the baggage management.

Airport	Country	Year	Number of carts	Number of ULIM
Jersey	U.K	1997	40	80
Tromsöe	Norway	1997	20	40
Luton	U.K	1999	102	204
Nantes	France	2002	25	50
Bordeaux	France	2003	20	40
Montpellier	France	2004	33	66
Bastia	France	2004	27	54

7. Conclusion

The TELEBAG system is working with very high level of services. The major advantage of the Linear Induction Motors is to move the carts without the dependency of the adhesion coefficient between wheel and ground contact thanks to the direct transfer of the traction-braking forces from the mobile to the ground by means of the electromagnetic field, This characteristic allows to stop the cart at very accuracy location for loading and unloading of baggage. The carts can be stopped and started in slope location. Then LIM drive is a very efficient system for automatic transportation system.

The cart presents also the advantage from the security point of view to be dedicated to one bag, The speed can be increased until 10m/s for fast transfer on large airport. The total of LIMs mounted on carts will be about 540 units at the end of 2004, the reliability of the traction chain is very high.

Improvements on TELEBAG system are possible. The latest technology of low cost integrated MLI inverters could be used to develop new power supply systems in order to reduce electrical losses in the linear motors and in the track. The electrical power supply of the carts could be provided by using high frequency energy transmission system.

References

[1] Laithwaite, E. R., Barvel, F. T.: Application of linear induction motors to high-speed transport systems, Proc. I.E.E. 116 n° 5 (1969).

[2] Zehden, A.: New improvements in electric traction apparatus, U. S. Patent n° 88145., 4- 6 (1902).

[4] Autruffe, H.: Le moteur linéaire, Revue Générale des Chemins de Fer., Avril (1968).

[3] Wiart, A.: Bases théoriques et applications des moteurs linéaires, Revue Jeumont-Schneider., n° 8 (1970).

[5] Guimbal, J.: Propulsion électrique à grande vitesse. Le moteur axial et ses applications, Revue Génèrale Electrique., n°2, Fév. (1975).

[6] Pascal, J. P.: Rapport des essais du prototype du moteur linéaire à induit en U, Rapport IRT., octobre (1976).

[7] Giovachini, J. L.: Evaluation par la similitude des systèmes de propulsion et freinage électromagnétiques, Revue Générale des Chemins de fer., Dunod édition, Juin (1977).

[8] Coquery, G.: Contribution à l'étude et à la vérification expérimentale des lois de similitude dans les machines à induction électromagnétique, Rapport de Recherche IRT., n°34, Août (1978).

[9] Ayasse. J. B.: Etude simplificatrice des modèles analytiques du moteur linéaire, Rapport de recheche IRT., n°52, (1981).

[10] Project of cooperation between France and Germany : Transportation System U-LIM-AS., Final report phase 1, Annex E (1984).

[11] Fintescu, N. D., Pascal, J. P. : Test Results of Full-Scale 1 MW Linear Induction Motor (“U-LIM-AS”) with PWM Inverter, IEEE International Conference on Maglev and Linear Drives., Vancouver, pp.165-170, May 14-16, (1986).

[12] Sattler, P. K.: A 3-dimensional calculation method for a LIM having U-shaped secondary compared with measurements. International, Conference on Maglev Transport '85., pp29-36 (1985).

[13] Hayashiya, H., Tokuda, M., Ohsaki, H., Masada, E.: Design of Linear Induction Motor for a Combined Lift and Propulsion System of a Steel Plate, Applied Electromagnetics and Mechanical Systems., Eds.Nagaya and Ioan, JSAEM, pp.296-301 (1999)

[14] Morizane.T, Masada.E, Ohsaki.H, Tamura.M, ``Vertical Motion Direct Drive with Linear Induction Motor'', International Power Electronics Conference, IPEC., Yokohama'95, pp.557-562, (April, 1995).

[15] Coquery.G, Chollet.H, ``From small scaled experiments to full scale prototypes, The french experience in linear motor development“, International Symposium on Speed-up and Service Technology for Railway and Maglev Systems STECH’03, 19-22 August 2003 Tokyo.