

The Magazine of the International Building Transportation Industry

ELEVATOR WORLD

November 2008

www.elevator-world.com



Cover: Eco Issues
in Vertical Transportation

Going Green
in Elevator & Escalator Design



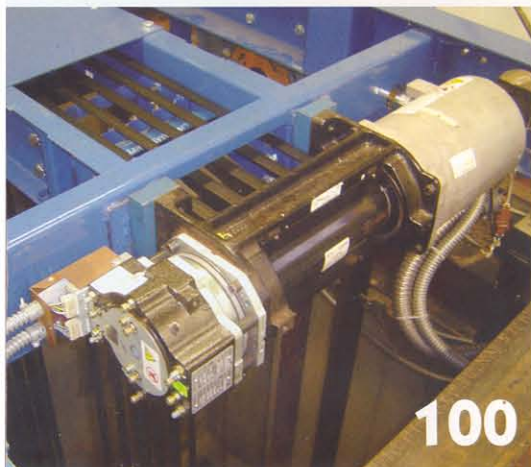
Improving Elevator
Performance by Monitoring
Elevator Cab Volume



Inside pages now
on recycled paper



160



100



53

COVER: Eco issues in vertical transportation:

Ecological trends in the elevator industry and “going green” in elevator and escalator design

FEATURES:

53 Eco Issues: Technology: Going Green in Elevator & Escalator Design

by Robyn Nothstein

How LEED® certification works for elevators and escalators

78 Events: ExpoElevador 2008: The Brazilian Elevator Show

by Carmen Maldacena

São Paulo hosts two-day event focused on Brazil’s elevator market.

100 Eco Issues: Technology: Ecological Trends and the Elevator Industry

by Louis Bialy

Responsible action toward the environment is necessary for the entire industry.

114 Earthquake Special Report: From the Wenchuan Seism: Statistics & Analysis of Elevator Damages in Xi’an

by Pinghu Du

An analysis of elevator damages from the May 12 earthquake

129 Events: NAESA International 2008 Workshop

by Robert S. Caporale

NAESA International met in Calgary, Canada, to discuss the elevator industry.

IN EVERY ISSUE:

- 11 Calendar
- 240 Comments
- 171 Classified
- 175 Advertisers Index
- 176 Last Glance

ECO ISSUES:

Company Spotlight

124 Mobile Service: The New Generation of Field Service

by Anita Seymour

Total Service software provides a paperless solution.

Continuing Education

73 Technology: Improving Elevator Performance by Monitoring Elevator Cab Volume

by James O'Laughlin

Camera technology helps minimize unnecessary hall calls.



149 Assessment Examination Questions

Earn one hour of continuing-education credit by following the directions and passing this exam.

Manufacturer Spotlight

44 Wittur Goes Green

by Wolfgang Adldinger, Ercüment Hizal, Volker Thoss and Martin Zellhofer

The Wittur Group works toward energy efficiency.

70 Peelle Contributes to Green Movement

The Peelle Co. makes changes to become environmentally friendly.

86 Being Green Is Part of the Service

Schindler's destination control cuts energy use.

110 Mitsubishi Electric Advances toward a New Era in the Field of Green Elevators

by Yutaka Otagiri

Mitsubishi Electric offers advanced technology to China.

144 ThyssenKrupp Develops Green Business Model

by Stuart Prior

ThyssenKrupp develops long-term goal of sustainability.

158 Energy Efficiency Technologies for Escalators Qualify for Utility Cash Rebates

by Christine Toledo

Power Efficiency's Motor Efficiency Controller saves escalator energy.

Marketing

60 Globalizing Green, Verde, Vert, Vihreä, Grün, Grön, Groen

A shift in focus toward sustainable design

Technology

48 Bridging the Gap between Urbanization and Eco-Efficiency

by Simon Barrette

KONE offers solutions for reducing environmental impact of elevators and escalators.

90 As Green as It Gets for a Hydro

by Sylvain Mongrain and Jean Larcher

Leistritz Corp.'s hydraulic elevator Emarolle™

120 Qualifying and Applying for Utility Energy Savings Rebates

by Don Vollrath and Ross Smith

Energy-savings rebates as they apply to elevators

152 German Lift Technology: Greener than Green

by Undine Stricker-Berghoff

The VFA-Academy works toward creating new guidelines for energy efficiency.

COLUMNS:

History

66 Elevator Controllers: Schureman Types

by Dr. Lee Gray

Early 20th-century catalog launches elevator controllers.

Legal Issues

94 Clearing My Desk

by Marvin A. Jacobs, JD

Lawsuits are more than just arguing the facts.

Special Topic: Escalators

136 Advanced Dynamic Models for Escalator Simulation

by Jose Maria Cabanellas Becerra, Juan D. Cano Moreno, Berta Suárez, J.A. Chover and Jesús Félez

Computer-generated models are used to determine escalator behavior.

142 Product Announcements

Escalator maintenance panels and deflector brushes

DEPARTMENTS:

6 Editor's Overview

Green, Greener, Greenest

8 Re-Call-Backs

The Green Core

26 Corporate Reports

* Toshiba revises business forecast

* Kleemann six-month financial statement

28 U.S. Industry News

* New water ride includes elevator

* And much more . . .

34 International Industry News

* EESF at NAESA workshop

* Dubai World gets green building consultant

* And much more . . .

106 Codes & Standards

* The International Code Council's new committee supports green efforts.

* TÜV Reinland offers a "Test & Measurement" guide.

* EEE and IEC expand agreement for standards

160 Product Spotlight

* Green elevator cabs

* Covered stairlift

* And much more . . .

168 Patents

* Fire control system for elevator

* Emergency elevator system

* And much more . . .



www.elevator-world.com

Visit EW Online for this month's extras, available only on the web:

- * More useful eco-friendly information for the elevator industry
- * Additional coverage of the annual NAESA International Workshop
- * A video of an amusement park water ride that uses elevators
- * A look ahead to some of the articles coming in the December issue of EW and beyond

Always available on www.elevator-world.com:

- | | |
|-----------------------|---------------------|
| * Daily News | * Industry Links |
| * Magazine Features | * Calendar |
| * Classifieds | * Bookstore |
| * Message Board | * Find-A-Part |
| * Research Center | * Museum |
| * Safety | * Find-A-Contractor |
| * Project of the Year | |

EW SERVICES

How to Contact ELEVATOR WORLD

- Mail: P.O. Box 6507; Mobile, Alabama 36660
- Shipping: 356 Morgan Avenue; Mobile, Alabama 36606
- Phone: (251) 479-4514 or toll-free: 1-800-730-5093
- Fax: (251) 479-7043
- E-mail: editorial@elevator-world.com or sales@elevator-world.com
- Website: www.elevator-world.com

Subscriber Services & Back Issues

- ELEVATOR WORLD is available in both print and digital versions. Questions regarding new print or digital subscriptions, renewals, bulk subscriptions, subscription payments, change of address, back issues or billing may call (251) 479-4514 or 1-800-730-5093, ext. 42 or 23.

News, Press Releases and Article Submissions

- Submissions to be considered for publication should be sent to editorial@elevator-world.com. Editorial space is non-paid; material is accepted based on newsworthiness or educational value and may be edited.

Reprints/Permission

- To order editorial or advertising reprints, call Patricia Cartee, ext. 23.
- To obtain permission to use any part of ELEVATOR WORLD, call Ricia Hendrick, ext. 25.

Advertising

- For display, classified or online advertising information, contact Assistant Advertising Manager Lesley K. Hicks, ext. 29.

The Bookstore

- For educational books, posters, CDs, DVDs and videos, contact Robin Lawley at ext. 19; online at www.elevatorbooks.com; or see our supplemental booklet in this issue.

Online

- www.elevator-world.com: News, links, calendar, classifieds, bookstore, feature articles, people and products of the industry. Site updated daily.
- www.TheElevatorMuseum.org: Take a tour of the history of the elevator industry.
- safety.elevator-world.com: Complete Safety Handbook PDF plus current revisions, quizzes, safety products, toolbox meetings and links.
- <http://www.liveboards.com/mb/server/board.cgi?b=107638>: Express your opinion, ask for help, join a forum or get technical and business tips.
- research.elevator-world.com: A free comprehensive database covering information and features published in ELEVATOR WORLD from January 1953 until December 2001 is included. Each monthly issue has been indexed, so you can search for any word or combination of words that have appeared in the magazine during this time period. The most recent articles and information (2002-current) are only available by contacting our Research Department. Personalized research pricing information is also available. Contact Monica Tapper at phone: (251) 479-4514, ext. 40 or e-mail: research@elevator-world.com.

Mailing Lists

- ELEVATOR WORLD does not release its subscriber list.
- The Elevator World Source© published yearly in January provides a comprehensive list of elevator industry suppliers, contractors, consultants and associations. Call Michelle Hanks, ext.42, for more information.

ELEVATOR WORLD

Founder: William C. Sturgeon

1953

President and Publisher Executive Vice President

Ricia S. Hendrick, ext. 25
T. Bruce MacKinnon, ext. 20

EDITORIAL

Editor Editorial Manager Senior News Editor Associate Editor Editorial Administrative Associate Research and Project Development Copy Editor

Robert S. Caporale, ext. 26
Terri Wagner, ext. 30
David M. Clothier, ext. 13
Lee Freeland, ext. 41
Deloris D. Browder, ext. 34
Monica Tapper, ext. 40
Lindsay Crandall, ext. 36

PRODUCTION

Production Manager Graphic Design Associates

Lillie K. McWilliams, ext. 15
Ginger Harrell, ext. 28
Bambi Springer, ext. 24
Jessica Trippe, ext. 16

COMMERCIAL

Director of Commercial Operations Vice President of Marketing Advertising Manager Advertising Account Executive Advertising Assistant Subscriptions/Customer Service Specialist Educational Sales Service Associate

Patricia B. Cartee, ext. 23
Brad O'Guynn, ext. 38
Lesley K. Hicks, ext. 29
Scott O. Brown, ext. 31
Cleo Brazile, ext. 12
Michelle Hanks, ext. 42
Robin P. Lawley, ext. 19

ADMINISTRATION

Director of Administration Information Technology/Web Manager Financial/Human Resource Associate

Linda A. Williams, ext. 33
Torri Dixon, ext. 10
Jeanna Kenny, ext. 11

TECHNICAL/LEGAL RESOURCE GROUP

Edward A. Donoghue; Dr. Lee Gray; Marvin A. Jacobs, JD; Jim Marcuskay; Zack McCain; Al Saxer; George Strakosch; and Dee Swerrie

INTERNATIONAL CORRESPONDENTS AND CONTRIBUTORS

Argentina: Carmen Maldacena; **Australia:** John Inglis; **Brazil:** Edilberto C. Almeida; **Canada:** John Murphy; **Czech Republic:** Jan Dvůrák, Lubomír Janovský; **Germany:** Andreas Wirths; **Hungary:** Marius Makovsky; **India:** TAK Mathews; **Iran:** Amir Reza Hashemi; **Israel:** Ami Lustig; **Japan:** Yutaka Otagiri, Youichi Saji; **Kuwait:** S. Hemanth Kumar; **Mexico:** Raul Gonzales Mora; **New Zealand:** Bob Johnston; **People's Republic of China:** Peng Jie, Zhang Lexiang, Zong Qun, Dr. Albert So; **Philippines:** Clodoveo Soriano; **Russia:** Viktor Khristich, Yury Kireev; **Saudi Arabia:** Mubarak Ali; **Singapore:** Kenneth Chan Man Wong; **Taiwan:** Shigeharu Kitamura; **Turkey:** Ersan Barlas; **United Arab Emirates:** M.J. Mohamed Iqbal; **United Kingdom:** John Gale, Roger Howkins, Dr. Lutfi Al-Sharif, David Cooper; **United States:** John Brannon, Jim Coaker, Galen Dutch, Lawrence Fabian, Richard Gregory, Ronald Schloss

ELEVATOR WORLD, INC. BOARD OF DIRECTORS AND OFFICERS

Richard Baxter, Don Charest, Jo Chateau, Bob Denniston (Chairman), George Gibson, Ricia Hendrick (President, Vice Chair), Paul Horney, Martha Hulgán, Achim Hütter, T. Bruce MacKinnon (Executive V.P.), Davis Turner, Linda Williams (V.P. Administration, Secretary/Treasurer), Tricia Cartee (V.P. Commercial Operations), Robert S. Caporale (Senior V.P. Editorial Operations), Brad O'Guynn (V.P. Marketing)

CORRESPONDING PUBLICATIONS

Argentina: Revista del Ascensor, Subir y Bajar; **Brazil:** Elevador Brasil; **Chile:** Elevator Chile; **Germany:** Lift Report; **Greece:** Anelkistiras - Greek Elevation Magazine; **Iran:** Donya-ye Asansor; **Italy:** Elevatori; **Japan:** Elevator Kai; **Korea:** Lift Industry, The Monthly Elevator; **The Netherlands:** Liftinstituut Mededeling; **People's Republic of China:** China Elevator; **Russia:** Lift Russia; **Spain:** Ascensores y Montacargas, Vertical Report; **Turkey:** Asansör Dünyası; **United Kingdom:** Elevation

ELEVATOR WORLD is a registered trademark and all rights reserved. Copyright © 2008. For permission to reprint any portion of this magazine, please write ELEVATOR WORLD at P.O. Box 6507; Mobile, AL 36660. ELEVATOR WORLD is published in the interest of the members of the elevator industry, to improve communication within the industry and to further the continuing education of members of the industry. ELEVATOR WORLD publishes articles by contributing authors as a stimulation to thinking and not as directives. ELEVATOR WORLD publishes this material without accepting responsibility for its absolute accuracy, but with hopes that the vast majority of it will have validity for the field. The ideas expressed therein should be tempered by recognized elevator engineering practices, guidelines, codes and standards. Publication of any article or advertisement should not be deemed as an endorsement by ELEVATOR WORLD. Printed by Cummings Printing, Inc., 4 Peters Brook Drive, Hooksett, NH 03106-6495.

Periodicals postage paid at Mobile, Alabama and at additional mailing office. Post Office Publication Number 172-680 (ISSN 0013-6158), under the act of March 3rd. U.S. Pat. Office. POSTMASTER: address all correspondence to Elevator World, Inc., P.O. Box 6507, Mobile, AL 36660; Fax: (251) 479-7043. Published on the 1st of the month. Subscription rates (print): U.S. and possessions: \$75/one year, \$125/two years, \$175/three years. International, including Canada: \$125/one year, \$225/two years, \$325/three years; Digital format: \$25; Single copies (print or digital): \$15; THE ELEVATOR WORLD SOURCE© (print or digital): \$46. (All subscribers receive THE ELEVATOR WORLD SOURCE© free.)

Advanced Dynamic Models for Escalator Simulation

by Jose Maria Cabanellas Becerra, Juan D. Cano Moreno, Berta Suárez, J.A. Chover and Jesús Félez

In this paper, the dynamic models developed for the analysis of solutions for new escalator designs are described. The current escalator design is an evolution of an ancient design that has added improvements over time. However, new solutions for a cheaper, safer and more reliable escalator design are being pursued. For this task, the models described here constitute a tool to test a series of new design ideas. With the dynamic models, it is easy to obtain values of tension, reaction, velocities, etc., to deduce the best solution before physically building the escalator. For more efficient results, an analysis of a statistical procedure has been developed that guides the improving trajectory.

Introduction

In previous papers,^[1,2] the current situation of escalator design has been described as well as some of the improving lines that could be tested. Patent history shows that escalator mechanical-design evolution, from its appearance at mid-19th century to now, has maintained the same basic characteristics. Centro de Investigación en Tecnologías Ferroviarias (CITEF) has developed models and guidelines to analyze the static, kinematic and dynamic behavior of the escalator system.

Some of these guidelines are meant to lengthen the chainlink pitch, use pulse-free guides instead circular ones and replace rotational engines with linear traction systems. In addition, statistical models have been used to compact simulation results and explain some parameter variations.

An escalator is a closed-chain multibody system with several joints, loops and contact forces. These characteristics constitute great difficulties from the mathematical point of view that have been solved in the following ways:

- ◆ *Static* analysis programmed in MATLAB
- ◆ *Kinematic* models implemented in a computer-aided 3D interactive application
- ◆ *Dynamic* studies developed in SIMPACK
- ◆ *Statistical* analysis using the program STATGRAPHICS

This paper is focused on making statistical conclusions about dynamic models.

Dynamic Model Description

Several models have been developed in order to characterize the dynamic behavior of this multibody system. The methodology behind these models will be described using one of them. Overall parameters of the model are displayed in Table 1.

This model simulates a guide for an escalator with 4.5 meters between the upper and lower landings, powered by a linear motor that is located at the top of the upper inclined zone of the guide, as shown in Figure 1.

Continue +

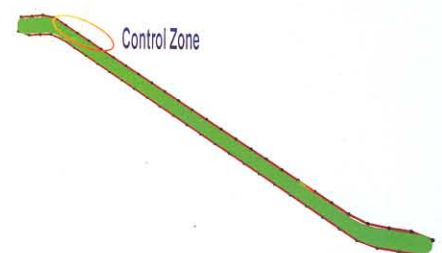


Figure 1: One guide model 3D representation

José María Cabanellas Becerra is associate professor in the Mechanical and Manufacturing Engineering Department of the Universidad Politécnica de Madrid. His Ph.D. thesis was on system modeling and simulation, similar to the major projects that he manages for Centro de Investigación en Tecnologías Ferroviarias (CITEF).

Juan David Cano Moreno works as research engineer for CITEF. He specializes in escalator simulation and design. He received his master's degree in mechanical engineering from the Universidad Politécnica de Madrid. At present, he is preparing his Ph.D. thesis.

Berta Suárez is head of Railway Dynamics for CITEF. She received her master's degree in mechanical engineering from the Universidad Politécnica de Madrid. At present, she is preparing her Ph.D. thesis.

J.A. Chover works as research engineer for CITEF. He specializes in railway mechanical systems simulation and design. He received his master's degree in mechanical engineering from the Universidad Politécnica de Madrid. At present, he is preparing his Ph.D. thesis.

Jesús Félez is full professor at the Universidad Politécnica de Madrid. He is also currently the director of CITEF. He has wide experience in system modeling and simulation and has published a large number of technical papers on the subject.

Parameters	Measures
Number of links and rollers	58
Chain link pitch (m)	0.405
Guide-roller contact stiffness (N/m)	3,520,000
Guide-roller contact damping (Ns/m)	15,000
Linear velocity (m/s)	0.5
Guide diameter in reversing zones (m)	0.39265
Transitions diameter (m)	2.1
Roller diameter (m)	0.075
Pre-load in the tensioner (N)	3,000

Table 1: Parameters of the One Guide Dynamic Model

The concepts and basic guidelines of how to design and simulate the model are herewith explained.

Geometries

There are four different kinds of bodies: roller, chain-link, guide and tensioner (Figure 2). Roller and chainlink include a combination of basic geometries. Guide and tensioner curves are defined by points programmed in MATLAB, a program in which any kind of curve can be simulated and analyzed.



Figure 2: Geometries of the model

Joints and Loops

Dynamic and kinematic relation among the different bodies is shown in Figure 3, which represents a topological diagram of the model reduced to four chain links. These joints, loops and forces define the multibody system equations and behavior.

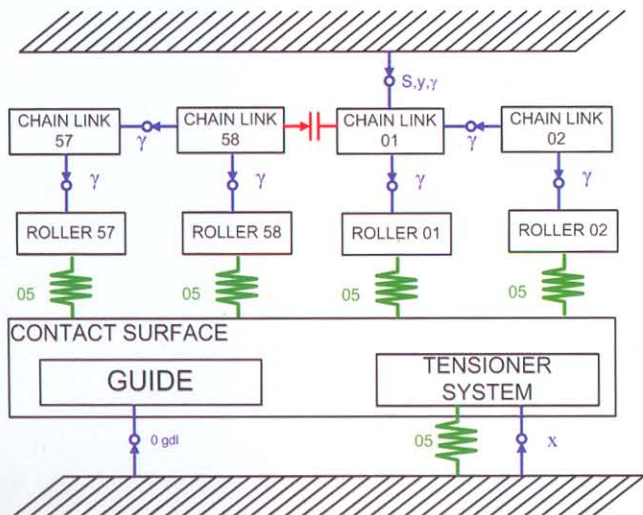


Figure 3: Topological diagram

Contact Forces

To define contact forces between two bodies in SIMPACK, a force from one marker to another has to be defined. Each marker must belong to a different body.

To simulate the roller-guide contact, *parent/child* mobile markers have been used. These markers can move around a curve defined for each, maintaining a minimum distance from a corresponding marker. There are 116 mobile markers: 58 follow the roller circumference (*children*), and the rest follow the guide curve (*parents*).

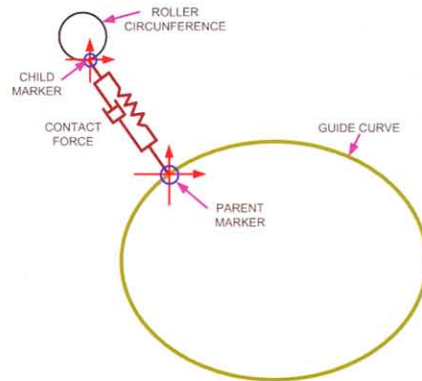


Figure 4: Contact force definition with parent/child markers

Tensioning System Design

Tensioning system design is not a trivial task. Contact force between each roller and guide is defined with *parent/child* markers, which have to follow a closed curve. If the tensioner is added (like the guide geometry) as a closed curve defined by points, there are two different curves that the roller markers have to follow. In addition, the tensioner curve is mobile, and the guide curve is fixed. Therefore, some markers can lose their correct positions, as shown in Figure 5. Unreal forces could appear, and the model analysis would be wrong.

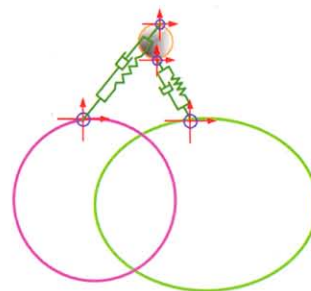


Figure 5: Contact forces between a roller and guide with tensioner geometries and markers out of order

The solution to resolve this problem has the following characteristics:

- ◆ Tensioner and guide geometries have to be the same. Thereby, markers will never be out of order due to tensioner displacements.
- ◆ Two different contact forces are defined using expressions to detect if the roller must take contact with the guide or with the tensioner. Thus, when one roller is in the tensioner zone, the expression for the contact

force between this roller and the guide has to be null, and the opposite.

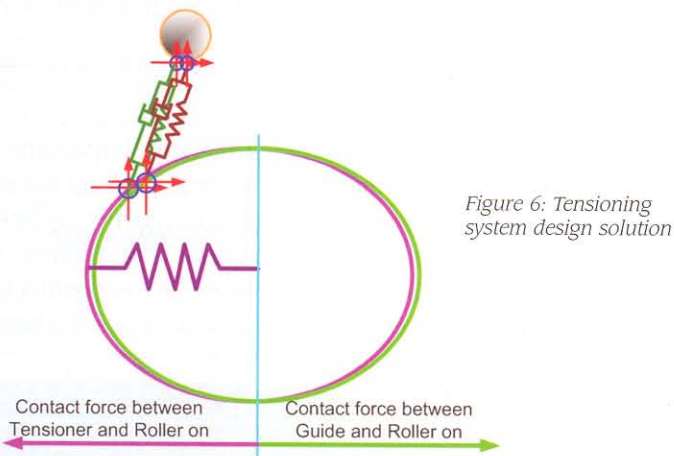


Figure 6: Tensioning system design solution

By way of illustration, the following figure shows details of a tensioning system design solution for the model.

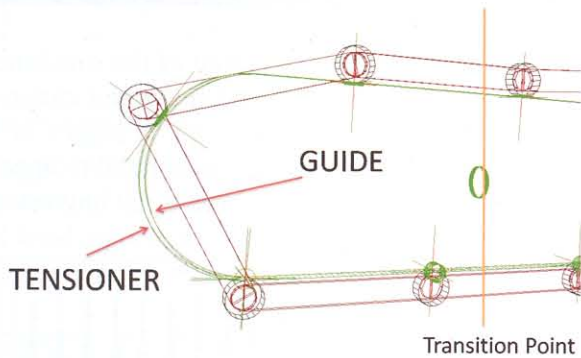


Figure 7: Detail of the tensioner and guide of the model

Linear Motor Simulation

Several aspects have been taken into account to simulate a linear traction system:

- ◆ *Velocity control system's* overall scheme is shown in Figure 8. This system is the key to simulate the linear traction system designed in SIMPACK. Proportional control has been used in this model. Nevertheless, a proportional integral derivative control system could be used in future models. The force output expression for this control type is:

$$Force\ Output = K_p \cdot (V_{measured} - V_{reference})$$

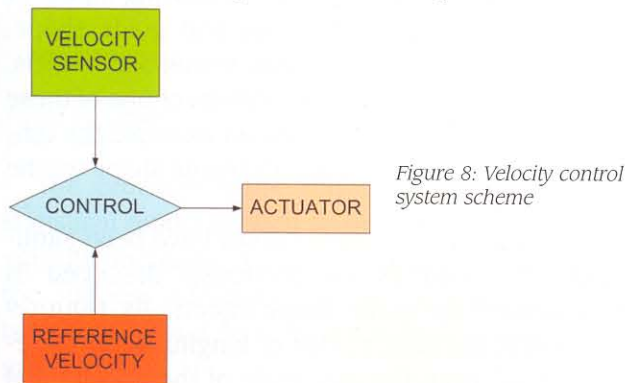


Figure 8: Velocity control system scheme

- ◆ An *expression* wherein the value coincides with the output force value of the velocity control system when the corresponding roller is inside the control zone. This value shall be null for the rest of time.
- ◆ An applied *longitudinal force* in the direction of the displacement of each chain link (axis X), as shown in Figure. Thus, this force value is defined by the expression explained in the previous point.

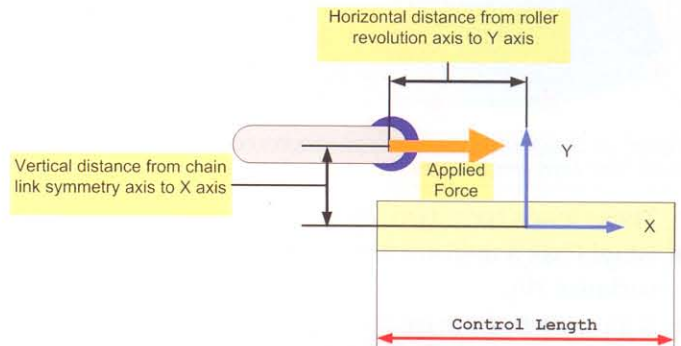


Figure 9: Velocity control system of SIMPACK model

Statistical Models

Managing the results of the previous points could easily become unaffordable when the number of tests and inputs increases. Thus, statistical models have to be developed by using small models in such a way that computational cost decreases. Statistical models are required to reach these objectives:

- ◆ *Compacting results.* Statistical parameters will characterize each model output.
- ◆ *Explaining some dependent variables* (outputs) as a function of the changed parameters (inputs)
- ◆ *Robust design.* Signal to noise ratios can be obtained by introducing random noise signals, such as variable loads or geometrical parameters, in the experiment designs.
- ◆ *Model validation.* This is a better way to compare real and simulated results of a model and to quantify the resemblance of the dynamic model with the prototype. Simulations to develop statistical models can be performed from SIMPACK, MATLAB or by a combination of both.

A small chain of passenger conveyors has been implemented in SIMPACK. This chain has the same characteristics as the guide of 4.5-meter-high escalator: contact and tensioner parameters, bodies, traction system, etc. Figure 8 schematizes the design of this experiment. Random passenger loads have been programmed in MATLAB, and input functions that can be read by SIMPACK have been created.

Continued

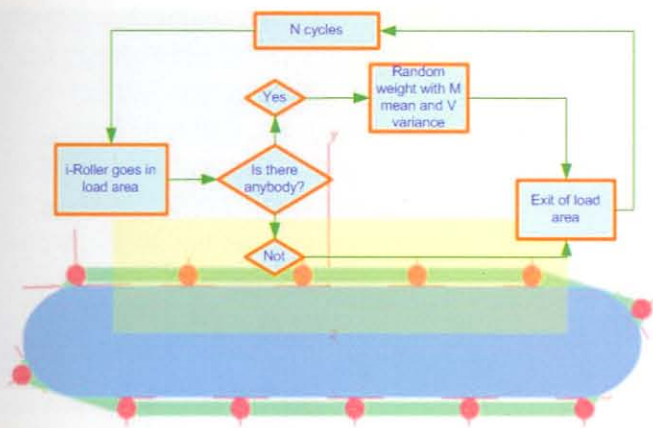


Figure 10. Design of experiment of passenger conveyor: how random loads have been programmed

These loads have two variables (Figure 10):

- ◆ *Weight* has a uniform distribution with a mean (M) and variance (V).
- ◆ *Is there anybody?* In each step, a person may be accounted for, with a probability of 0.5.

The figure below show the input functions of each roller for 10 cycles (approximately 100 seconds). These functions are the noise signal of the experiment.

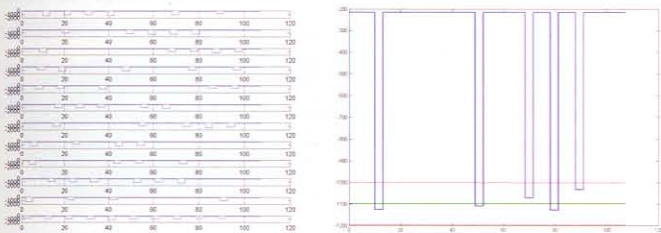


Figure 11: (l-r) Random load functions of the 12 rollers and the function of one roller

The experiment has three factors, or control parameters, and three levels per factor, as shown in Table 2.

Control Parameters	Level 1	Level 2	Level 3
Tensioner pre-loan (N)	1,500	3,000	4,500
Stiffness (N/m)	10,000	55,000	100,000
Damping (Ns/m)	5,000	10,000	15,000

Table 2: Control parameters and levels of the experiment

Therefore, 27 combinations of factors are simulated for each noise signal (two means and two variances), with a total of 108 performed simulations.

Linear-velocity standard deviation has been the measured output of each case. Thus, it can be explained as a function of the control parameters using a multiple-regression analysis. The next equation shows this relationship. This analysis explains 95.0682% (R-square) of the linear-velocity standard-deviation variability.

$$STD = A - B * Amortiguamiento + C * Precarga - D * Rigidez$$

$$A = 0.049829700$$

$$B = 5.25323E - 8$$

$$C = 6.90286E - 7$$

$$D = 2.95552E - 9$$

Equation 1: Multiple regression analysis

Variance analysis shows the statistical importance order of the control parameters. Tensioner preload is the most important parameter, followed by damping and stiffness. The sign before each constant in Equation 1 indicates if the *standard deviation* variable grows positively or negatively, in a marginal sense. Table 3 shows the best and the worst parameter combinations.

Control Parameters	Best	Worst
Tensioner pre-load (N)	1,500	4,500
Stiffness (N/m)	100,000	10,000
Damping (Ns/m)	15,000	5,000

Table 3: Best and worst parameter combinations

Figure shows linear-velocity output of the simulations corresponding to both the best and the worst cases. As Equation 1 predicts, velocity variability is bigger in the worst case than in the best one. This variability appears mainly in the return zone, where there is not any velocity control.

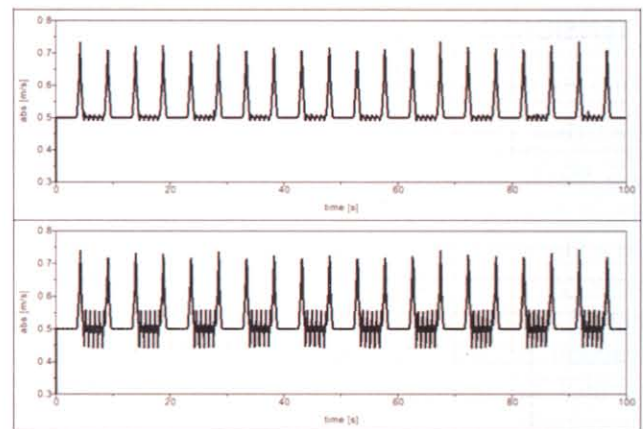


Figure 12: (top to bottom) Linear velocity at worst and best parameter combinations

Simulation Results

For each model, tests exist for the following inputs of the system: load, stiffness, damping and guide shape. CITEF has developed several dynamic simulation models. This paper examines parameter variations of one of these models that has been described. As an example the tensioner parameters, load per roller and guide shape will be changed.

Circular and pulse-free guide curves have been simulated under the assumptions previously described in order to compare the guide-shape effects. As Figure 9 shows, although the peak values of longitudinal and reaction forces are near, the amplitude of the longitudinal

force is more elevated in the circular guide case. This effect can be explained as a consequence of the polygonization that these kinds of curves produce.

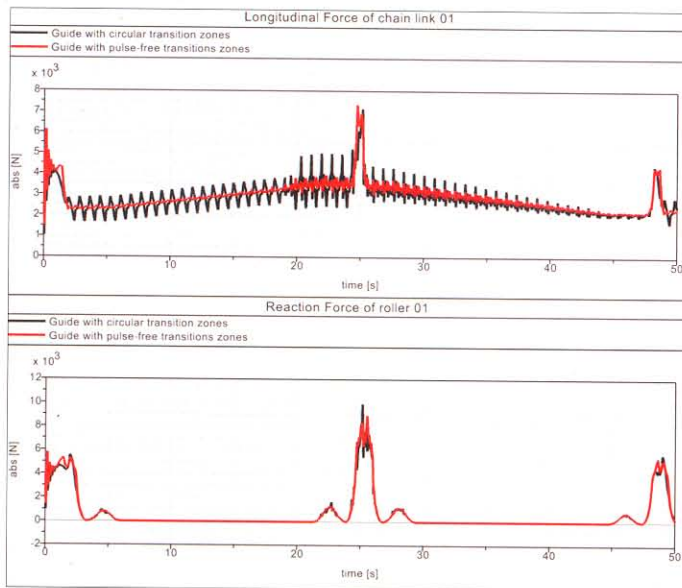


Figure 13: Longitudinal and reaction forces using both circular and pulse-free guide shape models

To infer statistical model results, one guide model of 4.5 meters high has been simulated searching the most and least significant tensioner parameter values. Linear velocity of both cases is shown in Figure 14.

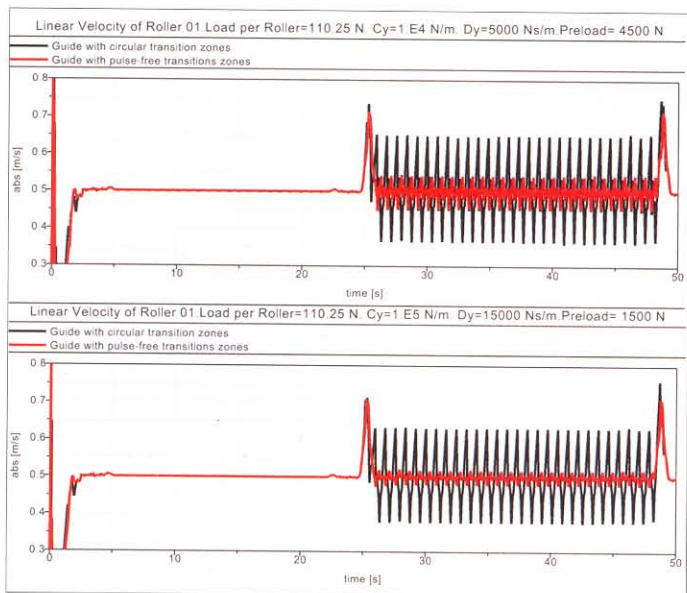


Figure 14: Linear velocity for two different guide shapes in the best and worst values of tensioner parameters obtained from one statistical model

The previous figure shows the coherence with the statistical model in such a way that the variability of the velocity increases when the preload is enlarged and the stiffness and damping are reduced. This tendency is also followed by the guide with circular transition guide shapes.

Two different load states are shown in Figure 15, reflecting the logical increase in reaction and longitudinal forces.

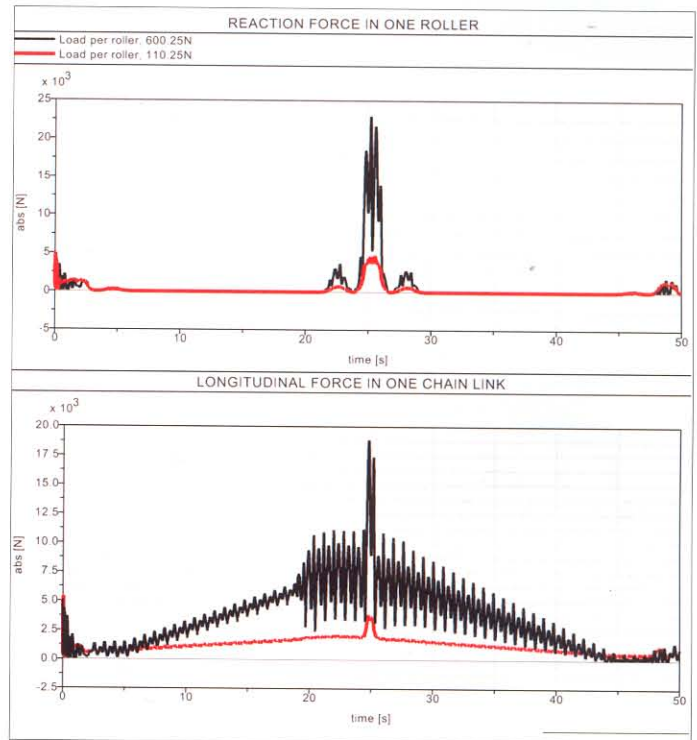


Figure 15: Longitudinal and reaction forces in varying the load per roller

As in the statistical point was described the tensioner preload forces has an important influence in the variability of velocity in the return zone. The result is slightly different from what the intuition says and it has to be tested in the real prototype.

Conclusions

The developed models are useful tools for the design of new solutions for escalators. The results obtained from these models show the influence of design changes on escalator behavior. The escalator prototype described has been designed following the conclusions obtained from its model. This prototype will be finished in brief and the results tested. The experimental results will help to improve the model. The improved model will be able to better predict the escalator behavior and obtain a better design.

References

[1] J.M^a. Cabanellas, J.D. Cano, B. Suárez, J.A. Chover, J. Félez (2008). Mejora de un Diseño de Más de 100 Años. Nuevos Conceptos en Escaleras Mecánicas. Anales de Ingeniería Mecánica, Revista de la Asociación Española de Ingeniería Mecánica, Vol. 1, pp. 233-239.
 [2] J.M^a. Cabanellas, J.D. Cano, B. Suárez, J.A. Chover, J. Félez (2008). Methods for Improving Escalators. Elevator Technology 17, Proceedings of ELEVCON 2008 (The International Association of Elevator Engineers), pp. 22-33.
 [3] Y.S. Kwon. (1998). Dynamic Analysis Step-by-Step. Mechanical Engineering-CIME.
 [4] Y.S. Kwon, G. Scott, N. Park (2005). A Multibody Dynamic Model for Escalator Handrail Systems and its Application to Dynamic Characteristics. Springer, Multibody System Dynamics, Vol. 13, No. 2, pp. 253-266.
 [5] A. Miravete, E. Larrodé (2007). Elevadores: Principios e Innovaciones, Reverté (Ed.), pp.285-389.