LINEAR MOTORS
IN PARALLEL SYSTEMS
Who we are

Dynetics, founded in 1994, with offices in Germany and the Netherlands assist engineers in selecting the best suitable motor for their mechatronical assignment.

Dynetics represents leading manufacturers such as Nidec Servo, Tsukasa, Shinano Kenshi, NPM, Mellor Electrics and offers a wide range of small motors up to 150 Watt with various technologies.

Dynetics helps economizing your design by offering solutions with optimum price-performance ratio.

For stepping motors we offer driver units from Nidec Servo, SHS; from NPM we offer the Motion controller IC’s.

For equipment cooling we offer a variety of axial instrument ventilators and radial blowers from leading manufacturers such as Nidec Servo, and Royal electric.

Many of our motors can be „customized“ with double or modified shafts, encoders, different windings, etc.

All fans and motors can be fitted with connectors per customer request.
Dynetics is located near the High Tech Campus Eindhoven and has a perfect location at the heart of Europe’s leading R&D region. The Eindhoven, Louvain, Aachen triangle (ELAt) is an area that has acquired a strong European position in micro-electronics/nano-electronics and life sciences.

In an area of just one square kilometre, more than 8,000 researchers, developers and entrepreneurs work closely together developing the technologies and products of tomorrow.
Dynetics can devide the product specialism in 6 groups:

1. Stepping motors
2. Linear motors
3. Brushless DC- motors (with or without gear head)
4. Brush motors (with or without gear head)
5. Fans & blowers
6. Customized solutions
Nippon Pulse's family of Linear Shaft Motors are the next generation linear brushless motor. When reliability, zero maintenance, zero cogging, and precision are paramount, the Linear Shaft Motors from Nippon Pulse are an ideal component choice, offering the user uncompromised performance, ease of use, compact package size, and high value.
LINEAR MOTORS IN PARALLEL SYSTEMS

The Next Generation Linear Motor

From Nippon Pulse
Parallel Motor Example
Linear Motion Applications

**Linear Motor Parallel Applications**

Cartesian/gantry robots

- Pick and place
- Glass cutters
- Laser engraving
- Sealant applicators

http://www.greller.com/

http://www.fisnar.com/robots_f9800n

Linear Motion Applications

Linear Motor Parallel Applications

High Force

- Material testing
- Punches

http://www.ecv.com/product/513821.html
Linear Motor Parallel Applications

High Precision/Accuracy

- Microscopes
- Optics
- Semiconductor

http://www.illumina.com/index.ilmn

http://huron-technologies.com/products/tissuescope.html
How Do We Do It Today?

Motion Options

- Ball Screws
- Belt Drives
- Linear Motors
Overview

• Issues with parallel drive systems
  – Orthoganality/squaring issues
  – Flatness
  – Sine errors

• Linear Shaft Motor overview

• Why the Linear Shaft Motor excels in parallel systems
Traditional Linear Motors

Alignment Issues in Parallel Linear Systems

- Perfectly parallel
- Partially skewed (alignment error)

Issue:
- Keeping orthogonality/square alignment between parallel drive systems.
- Impacts ball screws (binding), electric linear motor, belt drive
Traditional Linear Motors

Alignment Issues in Parallel Linear Systems

Perfectly parallel

Partially skewed (alignment error)

Issue:
- Binding
- Straightness Error
- Yaw error

• Impacts ball screws (binding), electric linear motor, belt drive
Traditional Linear Motors

Alignment Errors in Parallel Linear Systems

Issue:

• Sine error, force difference caused by misalignment of coils/magnetic tracks

• The parallel drives are not properly tracking together

• Appear in electric motors

Sine Error Equation

\[ F_{dif} = F_{gen} \times \sin(2\pi \times \frac{D_{dif}}{MP_{n-n}}) \]

- \( F_{dif} \) - Force difference between the two coils
- \( F_{gen} \) - Force generated
- \( D_{dif} \) - Length of misalignment
- \( MP_{n-n} \) - North to North Magnetic pitch
Traditional Linear Motors

Alignment Errors in Parallel Linear Systems

Issue:

• Mechanical linkage; errors in chain drives are the mechanical equivalent of sine error

• Occurs in non-electric motors

http://cfnewsads.thomasnet.com/images/large/007/7281.jpg
Traditional Linear Motors

Flatness Issues in Parallel Linear Systems

Issue:
• Ensuring the flatness, on each side and relative to each other, of the parallel drive systems
• Impacts electric linear motors, ball-screws

Image courtesy of IBEX Engineering
Traditional Linear Motors

**Flatness Issues in Parallel Linear Systems**

**Issue:**
- Lack of flatness results in variation in magnet/coil gap
- Large gap results in lower force
- Small gap results in high force but increases binding potential
Traditional Linear Motors

Solution to Alignment/Flatness Issues

Solution:
- Drive/control each motor independently while electronically synched; expensive option considering cost of multiple sets of electronics
Simple

Two Parts
1. Forcer ~ Coils
2. Shaft ~ Magnets
- **Large Air Gap**
  0.5mm to 5.0mm nominal annular air gap
  (1 to 10mm total)

- **Non-critical**
  No variation in force as gap varies over stroke of device
(a) Flat type
Ineffective use of flux

(b) Cylindrical type
Effective use of flux
• First linear motor designed for Ultra-High Precision market
Coreless Linear Motor

- Linear Shaft Motor is shaft type (cylindricality) coreless linear motor.
Linear Shaft Motor in Parallel

Reducing Impact of Alignment Issues

Issue:
• Keeping orthogonality/square alignment between parallel motors

Perfectly parallel

Partially skewed (alignment error)

Solution: Non-critical air gap
Linear Shaft Motor in Parallel

Reducing Impact of Alignment Issues

Issue:
- Costly electronics duplicated for parallel system

Solution:
- One encoder, one servo drive
  - 1° freedom of motion when mechanically tied together
  - When given same signal, act as one motor
Linear Shaft Motor in Parallel

Reducing Impact of Sine Error

Issue:
- Sine error, force difference caused by misalignment of coils/magnetic tracks

Sine Error

\[ F_{\text{dif}} = F_{\text{gen}} \cdot \sin(2\pi \cdot \frac{D_{\text{dif}}}{M P_{n-n}}) \]

Linear Shaft Motor
- 90mm N-N pole pitch
- 1mm misalignment = 7% loss of power

Traditional Linear Motor
- 30mm N-N pole pitch
- 1mm misalignment = 21% loss of power
Traditional Linear Motors

Flatness Issues in Parallel Linear Systems

Flatness in Linear Shaft Motor parallel systems:
- Non-critical air gap reduces impact of flatness issues
- Allows for greater variance in machining
- Reduces machining costs
Solution:

- Linear Shaft Motor allows feedback and force generation to be at the center of mass for accurate positioning.
- Impossible in other linear systems to achieve this, require two encoders and two servo drives.
- Forces can be greatly increased.
Solution:
• Because the Linear Shaft Motor needs just one encoder and one servo drive, number of motors is unlimited
• Force is multiplied by number of Linear Shaft Motors in the system
• System must maintain adequate stiffness
Linear Shaft Motor in Parallel

- A high precision motor, multiple Linear Shaft Motors can be set up in parallel with relative ease.

- Multiple Linear Shaft Motors set up parallel can be run using only one encoder and one drive.

- Using multiple Linear Shaft Motors in a Gantry system will greatly improve force.
G8 TABLE
S500Q 3.3METER STROKE PARALLEL DRIVE

Motor Test Report

G8 TABLE
SHAFT MOTOR S500Q
3200ST
PARALLEL DRIVE
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity &amp; Acceleration</td>
<td>Up to 1,600 mm/s - Up to 0.5G</td>
</tr>
<tr>
<td>Velocity Stability</td>
<td>Velocity = 100mm/s</td>
</tr>
<tr>
<td>Settling time</td>
<td>Condition Velocity : 400mm/s 0.15G ±5um</td>
</tr>
<tr>
<td>Jitter</td>
<td>20 Seconds</td>
</tr>
<tr>
<td>Position Difference</td>
<td>Velocity : 100 mm/s</td>
</tr>
<tr>
<td></td>
<td>Acceleration : 0.1G</td>
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<tr>
<td></td>
<td>Travel : 1000mm</td>
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Test Stage : Robostar 8GEN Demo Stage
<table>
<thead>
<tr>
<th>Item</th>
<th>Yaskawa</th>
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<tbody>
<tr>
<td>Velocity</td>
<td>1,600mm/s</td>
</tr>
<tr>
<td>Maximum Acceleration</td>
<td>0.5G</td>
</tr>
<tr>
<td>Velocity Stability</td>
<td>±0.21%</td>
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<tr>
<td>PTP Move &amp; Settling</td>
<td>400ms</td>
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<tr>
<td>Position Difference</td>
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<tr>
<td>Jitter at Stop</td>
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<tr>
<td>Item</td>
<td>Trilogy</td>
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<tr>
<td>-------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Velocity</td>
<td>1,600mm/s</td>
</tr>
<tr>
<td>Maximum Acceleration</td>
<td>0.5G</td>
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<tr>
<td>Velocity Stability</td>
<td>±0.08%</td>
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<td>PTP Move &amp; Settling</td>
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<td>Position Difference</td>
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<td>Jitter at Stop</td>
<td>n/a</td>
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<tr>
<td>Item</td>
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</tr>
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<tr>
<td>Maximum Acceleration</td>
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<tr>
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<tr>
<td>PTP Move &amp; Settling</td>
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<tr>
<td>Item</td>
<td>Linear Shaft Motor</td>
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<td>--------------------------</td>
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<td>Velocity</td>
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<tr>
<td>Maximum Acceleration</td>
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<tr>
<td>Velocity Stability</td>
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<tr>
<td>PTP Move &amp; Settling</td>
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<td>Position Difference</td>
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