Motion Control Solutions

LinX S-Series Linear Motor - User Guide

D-000168 Rev 03

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LinX S-Series Linear Motor - User Guide

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Chapter Summaries

Table of Contents

1 Safety

WARNING: Cylindrical motor shafts contain powerful permanent magnets. People with pacemakers, AICD or similar medical devices should maintain a minimum distance of 50cm from the shaft.

DANGER HIGH VOLTAGE: Ensure power has been completely disconnected before touching electrical connections. Electrical shock can cause serious or fatal injury.

DANGER HIGH VOLTAGE: The system must be properly earthed before applying power. Ensure the system has been earthed according to *6.3 Electrical***.** National and local electrical codes must be followed. Electrical shock can cause serious or fatal injury.

WARNING: The motor shaft emits a very strong magnetic field. To avoid injury keep fingers and other body parts clear and do not have any ferrous or magnetised material on your person (eg. watches, keys and electronic devices) that could be attracted to the shaft.

This manual and the warnings attached to the LinX cylindrical linear motor only highlight hazards that can be predicted by ANCA Motion. Be aware they do not cover all possible hazards.

ANCA Motion shall not be responsible for any accidents caused by the misuse or abuse of the device by the operator.

Safe operation of these devices is your own responsibility. By taking note of the safety precautions, tips and warnings in this manual you can help to ensure your own safety and the safety of those around you.

1.1 General Safety

The following points must be understood and adhered to at all times:

- Equipment operators must read the User Guide carefully and make sure of the correct procedure before operating the LinX linear motor.
- Memorize the locations of the power and drive isolator switches so that you can activate them immediately at any time if required.
- If two or more persons are working together, establish signals so that they can communicate to confirm safety before proceeding to another step.
- Be aware of the closest First Aid station.
- Always make sure there are no obstacles or people near the devices during installation and or operation. Be aware of your environment and what is around you.
- Keep the vicinity of the LinX linear motor clean and tidy.
- Take precautions to ensure that your clothing, hair or personal effects (such as jewellery) cannot become entangled in the equipment.
- Do not turn on any of the equipment without all safety features in place and known to be functioning correctly. Never remove any covers or guards unless instructed by the procedures described in this manual.
- The magnetic and non-load bearing nature of the shaft means that operator interaction around the shaft must be carefully considered. Ensure appropriate warnings and/or guards are installed to prevent damage to the machine or operator.
- Never touch any exposed wiring, connections or fittings while the equipment is in operation.
- Visually check all switches on the operator panel before operating them.
- Do not apply any mechanical force to the LinX linear motor which may cause malfunction or failure.
- Never attempt cleaning or inspection during machine operation.

- Clean or inspect the equipment only after isolating all power sources.
- Only suitably qualified personnel should install, operate, repair and/or replace this equipment.
- Ensure all external wiring is clearly labelled. This will assist you and your colleagues in identifying possible electrical safety hazards.
- Use cables with the recommended cross sectional area as specified in Section 5.3.3.
- Install cables according to local legislation and regulations as applicable.
- Ensure the forcer will not move relative to the shaft while in contact with the motor electrical connections. Movement can induce a voltage that could cause an electrical shock.

2 Introduction

2.1 About this User Guide

This user guide provides the required information for planning to install, installation and servicing of the LinX cylindrical linear motor. It has been written specifically to meet the needs of qualified engineers, tradespersons, technicians and operators.

2.2 Terms and Abbreviations

GND	Ground
rms	root mean square
V / mV	Volt / millivolt
A / mA	Ampere / milliampere
Ω	ohms
AC / DC	Alternating Current / Direct Current
Hz	Hertz
ms	millisecond
AICD	Automatic Implantable Cardioverter-Defibrillator
EMC	Electromagnetic Compatibility

2.3 Trademarks

LinX® is a registered trademark of ANCA Motion Pty Ltd.

3 Product Overview

3.1 About LinX

The ANCA Motion Patent Pending LinX cylindrical linear motor is a 3 phase brushless AC permanent magnet motor which provides improved performance at lower cost when compared to conventional flat linear motors and rotary motors. The cylindrical design and the extremely strong magnetic flux deliver excellent efficiency with continuous force from 335N to 630N and peak force from 2136N to 4272N. The high speed and acceleration, standalone thermal stability and the ability to achieve IP69K protection make LinX an ideal solution for machine tools, food processing and other automation industries.

The LinX linear motor consists of a shaft containing rare-earth magnets and a forcer containing wound copper coils. When combined with a servo drive and linear encoder the coils in the forcer are energized to produce relative force between the shaft and forcer. The zero attractive forces between the forcer and shaft resulted from the symmetric design greatly reduces the loading requirement on support bearings. The ironless design and even force over entire stroke result in very low cogging forces. With the simple construction, non-critical air gap and no physical contact between shaft and forcer, the machine installation is simplified with very low maintenance and extended machine life. The LinX's design allows it to easily replace ball screws in existing machine designs.

The LinX Linear Motor range is available in a variety of different sizes to allow for application specific solutions.

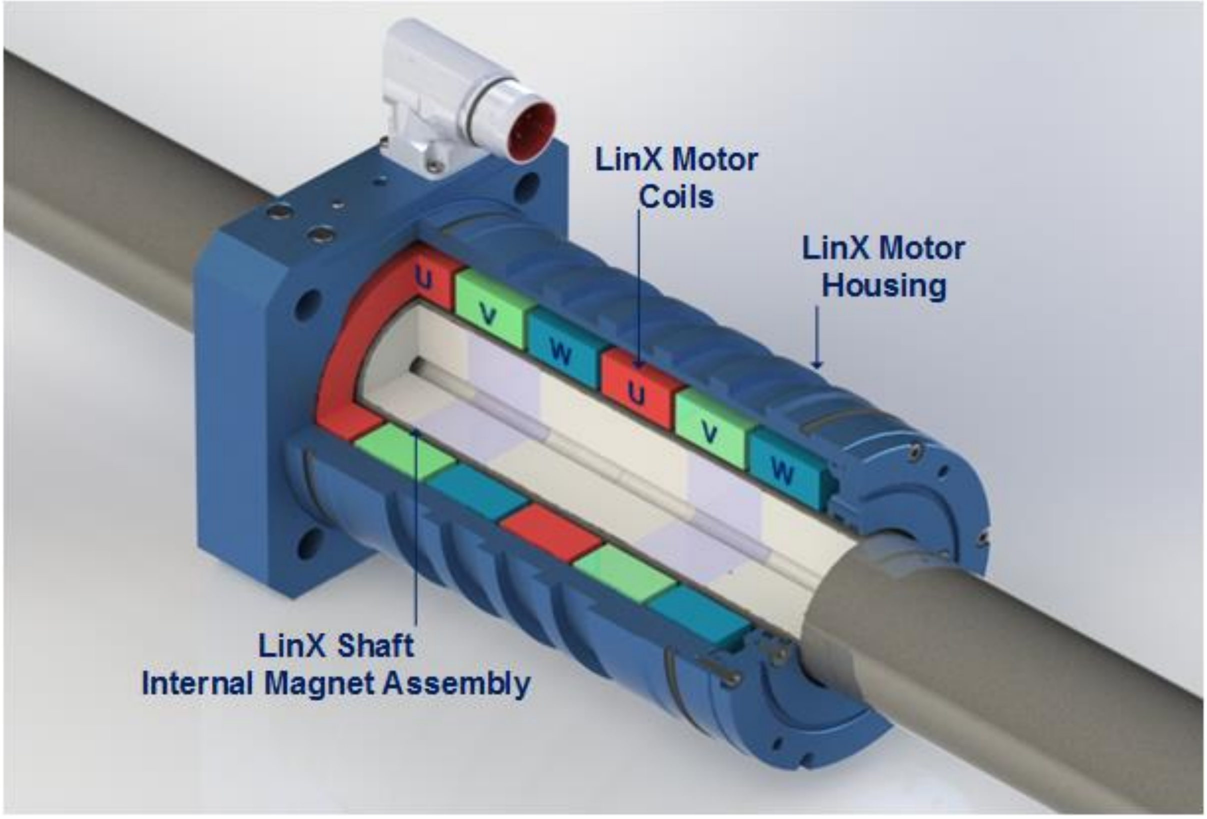


Figure 3-1 - LinX motor construction

3.2 Features

- High speed – Capable of velocities of over 3.5 m/s.
- Zero backlash – No requirement for a ball screw or gearbox eliminates backlash.
- High acceleration forces – Up to 4272N depending on model.
- Low motor cogging – Ironless design results in very low cogging forces.

- Low installation and maintenance costs – Simple construction, non-critical air gap and no physical contact between shaft and forcer results in less time spent in machine construction and downtime.
- Efficient cooling and thermal barrier – Standalone thermal stability (fluid cooling options available for increased performance).
- Fully sealed – IP67 rating as standard, IP69K as optional.
- Designed for machine tools – shaft design results in even force over entire stroke.
- Zero down force – zero net attractive forces improve efficiency with no down force and extended machine life.
- Durable – No physical contact results in no lubrication requirements and no motor wear. Forcer materials' high insulation class results in long motor life.
- Efficient – The extremely strong magnetic flux, cylindrical design and small moving mass provide for very efficient linear motion.

3.3 The LinX System

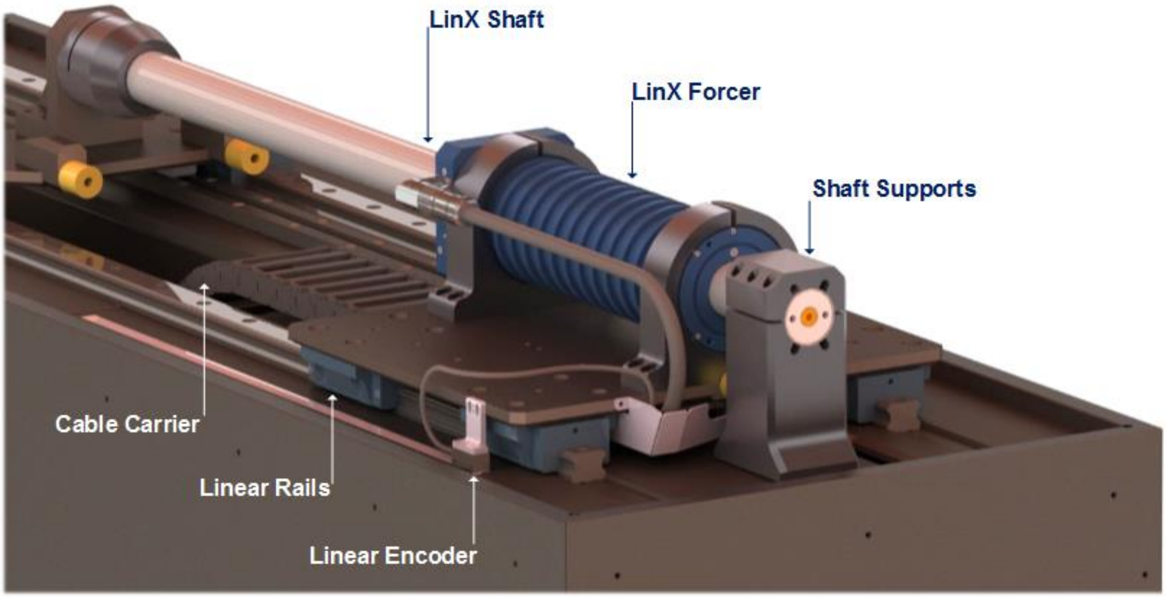
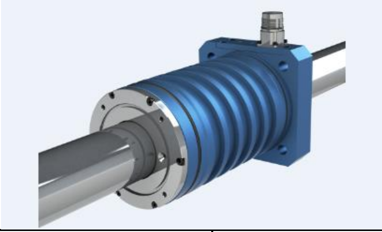


Figure 3-2 - The LinX system

The LinX linear motor system can be broken up into the following discrete components:

LinX forcer	Available in various forcer models. The appropriate model needs to be chosen for the application.
LinX Shaft	Available in a wide range of shaft lengths.
Shaft supports	Two supports – one at each end – are required to affix the shaft to the rest of the system.
Linear rail or aligning rods	Components to ensure the forcer moves parallel to the shaft and to take any lateral load.
Servo drive	AC servo drive controls motor in conjunction with the encoder according to a control input.
Encoder	Provides position feedback to the servo drive.
Cable carrier	Guides and protects cables that are connected to the forcer and must therefore move with the forcer.

3.4 Product Range

TLMS-18P0-SA00		TLMS-27P0-SA00		TLMS-36P0-RA00	
					
Peak Force	2136 N	Peak Force	3204 N	Peak Force	4272 N
Cont. Force Fluid	335 N	Cont. Force Fluid	510 N	Cont. Force Fluid	630 N
Cont. Force Air	207 N	Cont. Force Air	290 N	Cont. Force Air	360 N

Refer to *5 Specifications* for more detailed model information.

3.5 Catalogue Number Interpretation

LinX cylindrical linear motor models are marked with an identification label. The identification label contains important information about the motor including the catalogue number. The catalogue number is defined as shown below.

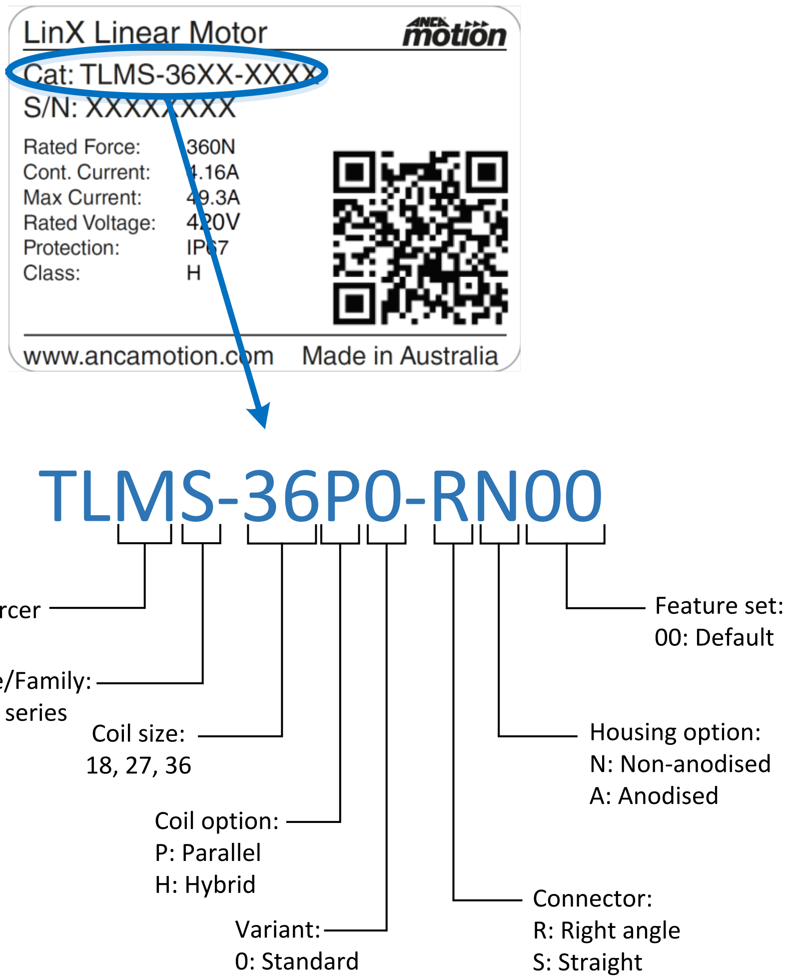


Figure 3-3 – Forcer Catalogue Number

The forcer is available with hard anodised surface finish option for use in harsh environments. Contact ANCA motion for further information.

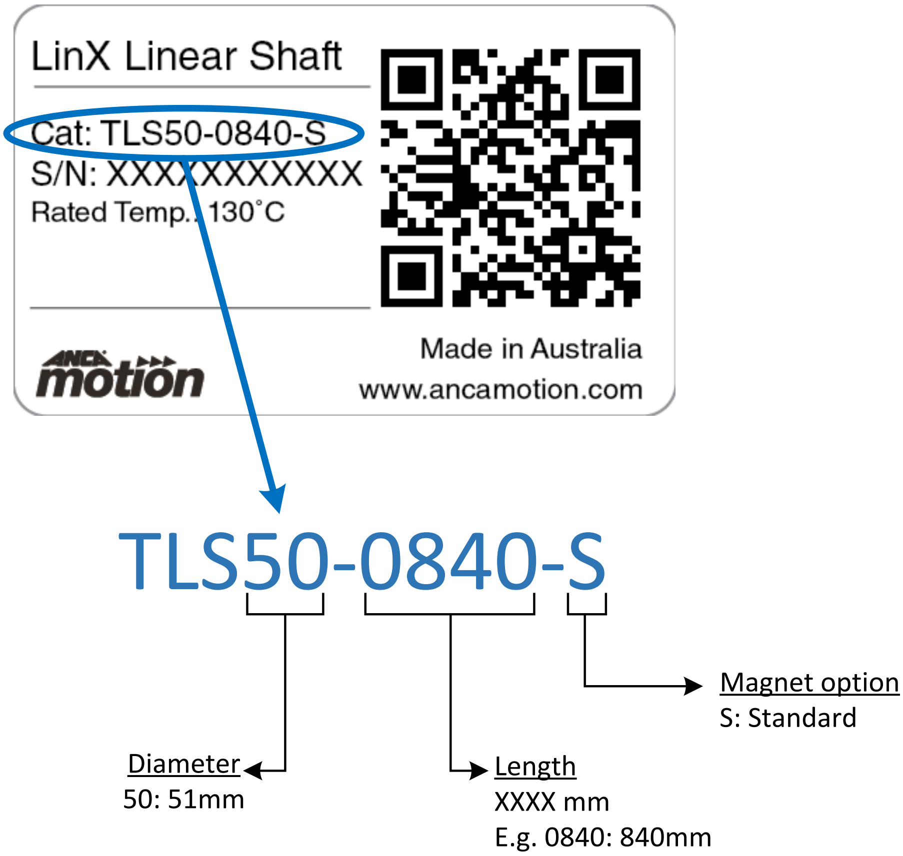


Figure 3-4 – Shaft Catalogue Number

4 System Design

4.1 System Components

The design of the LinX cylindrical motor allows for simple replacement of standard ball-screw motors. However, to achieve the best performance with LinX, the system must be optimized. This chapter will describe the main components to consider when designing a system.

The primary components of a LinX cylindrical motor system include:

1. LinX motor
2. Shaft support
3. Linear bearing
4. Cable carrier
5. Servo drive
6. Linear encoder
7. Forcer mount

Additionally the following secondary components may be required depending on the application:

8. Home sensor
9. End stop sensor
10. Brake

4.2 Cylindrical Linear Motor

4.2.1 Application

The Cylindrical Linear Motor provides relative motion between the shaft and the forcer; therefore, motion can be achieved in one of two ways. The shaft can be fixed in place while the forcer moves or the forcer can be fixed while the shaft moves. The method used depends on application. The motor can be mounted in any orientation.

The cylindrical linear motor should be mounted as close as possible to the center of gravity of the load and the operating point of the machine. Alternatively, two linear motors can be used in parallel equidistant from the operating point.

4.2.2 Shaft

DANGER: The shaft must be earthed to prevent the possiblility of electric shock during motor operation.

WARNING: The shaft emits a very strong magnetic field, always use caution when handling. To avoid injury, keep fingers and other body parts clear.

WARNING: The magnetic and non-load bearing nature of the shaft means that operator interaction around the shaft must be carefully considered. Ensure appropriate warnings and/or guards are installed to prevent damage to the machine or operator.

The LinX shaft produces a strong magnetic field and the effect of this field on surrounding parts and components should be considered during system design. Relevant effects of the strong magnetic field include:

1. Attraction between the shaft and ferrous or magnetic objects. This magnetic force may cause bending in longer shafts.
2. Ferrous objects and material can become magnetised if located close to the shaft or moved through a region close to the shaft. To avoid unwanted magnetisation of susceptible components the system should be designed with an air gap (non-magnetic region) of at least 150mm between the surface of the shaft and the component that may be magnetised.
3. In a machine tools application swarf may become trapped on the shaft due to magnetic attraction. This may occur even if the shaft is protected by a bellow. It is recommended that an air gap (non-magnetic region) of 150mm or greater be kept between steel swarf and the surface of the shaft.
4. When using a magnetic position sensor ensure that it is located far enough from the shaft that the magnetic field is within the working limits of the sensor. The shaft field strength as a function of distance from the shaft in isolation is shown in *Figure 4-1*.

The effects of the shaft magnetic field on surrounding components can be minimized by using non-magnetic materials wherever possible.

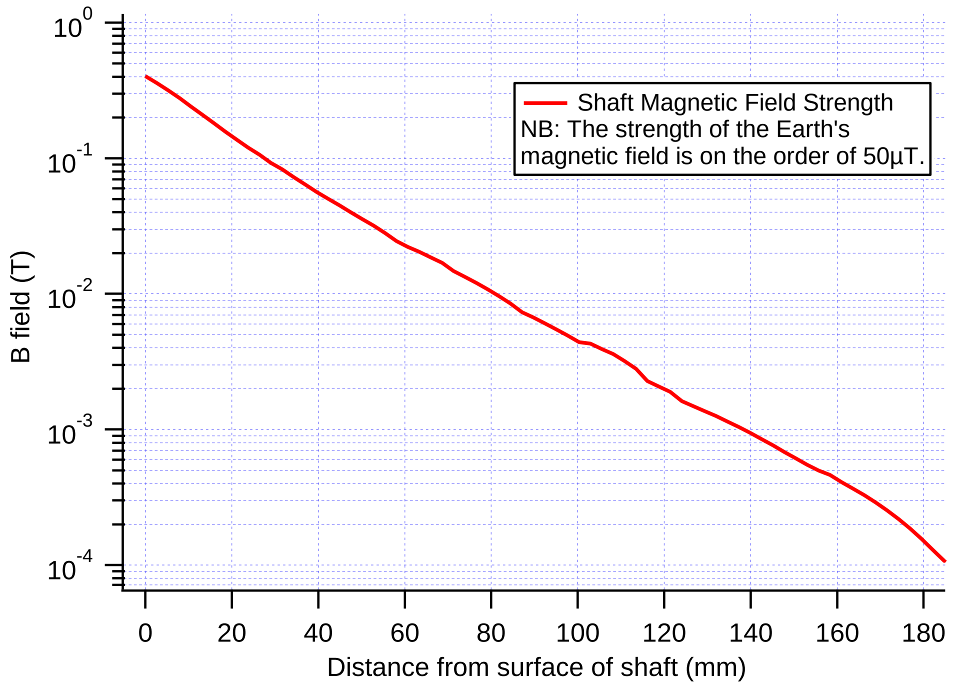


Figure 4-1 – Shaft magnetic field strength with distance

Note that Figure 4-1 shows field strength from the shaft in isolation, however when integrating into machinery the presence of ferrous materials can affect the distribution of magnetic fields. It is the responsibility of the equipment/machinery builder to undertake any required risk assessments relating to the presence of strong magnetic field around their machine. After installation of the LinX motor into a machine the local magnetic field strength can be easily checked using a hand held gauss meter to ensure it is within an acceptable level.

The shaft must be mounted to ensure that concentricity with the central bore of the forcer. The nominal radial air gap between the forcer and shaft of 1mm should ideally be maintained for the entire stroke. The air gap is non-critical for operation as long as the forcer and shaft do not come into contact. Contact will result in an increase in friction and wear on the cylindrical linear motor.

NOTE: The shaft is not designed to be a load bearing element. Additional elements must be added to the forcer to handle any load applied.

The shaft's performance can be reduced if subjected to temperatures above 130℃. Therefore, consideration must be given to the shaft's operating environment and the continuous operating current of the application for the expected ambient temperature.

4.2.3 Forcer

Forcer model selection is dependent upon the peak force, continuous force and peak velocity of the application. Each needs to be identified before a forcer can be accurately specified.

- Peak Force – Identify the peak force required for the application. A forcer will only be able to produce its peak force for a short period of time; the duty cycle also needs to be considered.
- Continuous Force – Identify the RMS force usage of the application. A forcer is able to exceed its continuous force rating by an amount depending on the duty cycle. Exceeding this can result in exceeding the motor temperature ratings and damage to the motor. Refer to *9.1.1 Application Continuous Force Calculation Example* for more information on how to calculate an applications continuous force requirement.
- Velocity – Identify the peak velocity required for the application. Available peak force may be reliant on velocity depending on the DC Bus voltage of the servo drive and the forcer model chosen. Refer to *5.2 Force vs Speed Characteristics.*

Cooling of the forcer must be considered for applications with a high continuous operating current. The forcer can be natural air cooled for low duty cycle applications or liquid cooled for increased continuous force output. Refer to *5 Specifications* for forcer capabilities under different cooling schemes.

The forcer provides 4 mounting holes on the front flange to attach the forcer to a payload or stationary surface. Depending on the application, the forcer can be affixed in a precision bore or to a simple bracket. It is recommended that the forcer mounting is nonmagnetic to prevent magnetic interaction with the motor.

Figure 4-2 - Air cooled forcer mounting example

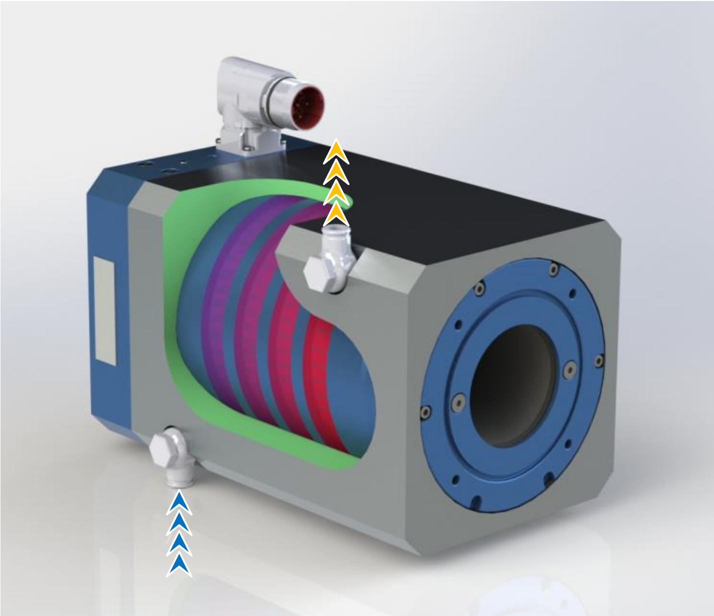


Figure 4-3 - Fluid cooled forcer mounting example

DANGER: The forcer must be earthed via the armature connector to prevent the possiblility of electric shock during motor operation.

4.2.4 Brake

An external brake should be considered for all applications to prevent damage to systems or users in the event of a failure or fault. A brake is recommended for vertical applications regardless of whether a counter balance is used or not.

In applications that are deemed to require a brake, it is recommended that they are applied to the bearing or aligning rod systems used with the linear motor. A braking system should not be directly applied to the linear motor shaft as this could result in damaging the shaft.

The brake must be chosen so that it provides enough force to resist gravity, inertia and machine operation. The kinetic energy of the moving load will be converted into heat due to friction when the brake is applied. The amount of kinetic energy must be taken into account to prevent damage to the brake due to overheating.

4.2.5 Vertical Applications

If the LinX cylindrical motor is used in a vertical application, it is recommended to use a counter-balance. The counter balance should be designed to balance the gravitational forces on the system such that the motor is stationary when there is no force applied by the motor.

If a counter-balance is not used, the linear motor must constantly produce a force directly opposing gravity. This will add to the application's continuous force requirements and, therefore, impact the motor model selection. A brake is recommended for most applications but must be used to prevent damage in applications where the load will drop immediately after power is removed.

4.3 Support and Bearings

4.3.1 Shaft

WARNING: Failure to install the shaft to these requirements could result in damage to machinery and property as well as severe injury or death.

NOTE: Shaft deflection must be limited to ensure that the there is no contact with the forcer at any point over the entire stroke.

The shaft must be mounted with supports at its ends to restrict longitudinal movement and maintain concentricity with the forcer's bore. The shaft must not be drilled. The shaft supports need to be able to support the mass of the shaft and the forces generated by the motor. The supports must clamp the shaft for a length of at least 50mm with a minimum clamping force of 8kN at each end. A higher clamping force may be required if using low friction materials, please contact ANCA Motion for more information.

The shaft support can be designed into the structure of the machine or typical shaft hangers can be used. In either situation, the following points must be taken into consideration.

- It is recommended that supports are made of non-magnetic materials to prevent attractive forces being applied towards the end of stroke.
- There should be capability to adjust the shaft position to allow for fine tuning the alignment of the shaft to the forcer.
- It is recommended that the shaft supports are designed for an axial shaft load of twice the peak motor force.
- Design of the shaft supports should cater for any additional application specific load cases such as vibration or high frequency load cycling.
- Integrated soft bump stops are recommended to stop the motor directly contacting the shaft supports which may cause damage.
- Ensure that the shaft supports are properly earthed to the chassis of the machine.

As with any fixed beam, a long shaft will result in vertical displacement at its centre point. This is often referred to as sag. This displacement distance should be compensated for to ensure to maximise the clearance between the shaft and forcer.

The recommended method to compensate for shaft sag is to lift the supports relative to the forcer such that the centreline of the forcer bore matches the average centre line of the shaft. Figure 4-4 demonstrates this method, the centreline of the shaft supports is given by the centre line of the forcer bore, a, and the shaft midpoint vertical displacement, y:

$$\text{Compensated support centreline} = a + \frac{y}{2}$$

By lifting the shaft centre line by half the vertical displacement, a longer stroke can be achieved without additional support systems.

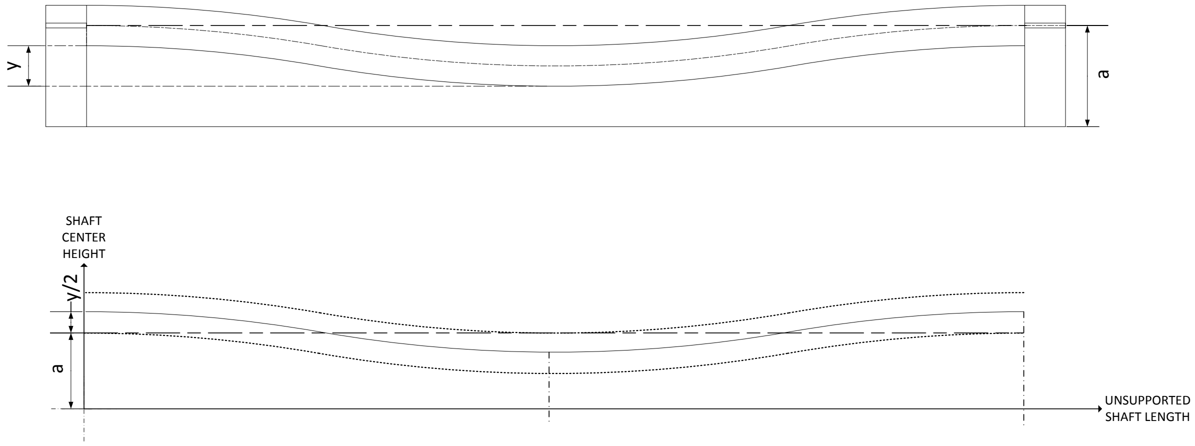


Figure 4-4 - Recommended shaft sag compensation method

NOTE: The recommended method for shaft sag only applies to for sag up to 1.6mm. If the sag exceeds this value, additional countermeasures should be taken. Please contact ANCA Motion for more information.

4.3.2 Forcer

WARNING: The shaft is not designed to be a load bearing element. Additional elements must be added to the forcer to handle any load applied.

As with a ball screw application, the forcer must be supported by a linear bearing or alignment rod system capable of supporting the forcer and its load. In many cases, the linear bearing or aligning rods are the only contact point between the moving and stationary components of the axis. Stiffness of the bearings and machine structure should be considered to minimize deflection between the encoder and the motor. Low friction in the bearings will result in smoother motion. Due to the high acceleration and velocity capabilities of the linear motors, the associated bearing capabilities also need to be taken into account.

4.3.3 Cable Carrier

When the forcer is the component moving relative to the servo drive, it is recommended that a cable carrier is used to guide and protect cables connected to the forcer. Where the machine has a very short stroke, a cable carrier may not be required. In all cases, strain relief is recommended. Refer to the cable supplier's information to ensure the cable bends and flexes within specification.

4.4 Servo Drive

ANCA Motion provides a range of servo drives that are designed to be used with the LinX cylindrical linear motor including the AMD2000 and AMD5x series. However, if desired, the LinX cylindrical motor can be used with any 3 phase AC brushless servo drive. Depending on the application, the motor can be controlled in torque, velocity or position mode with the drive receiving commands from various sources. In most cases, a linear encoder is required by the servo drive for field orientation and accurate velocity/position feedback.

Appropriate servo drive model selection for the application and selected forcer model is important for optimum performance. Considerations include maximum current rating, continuous current rating and DC bus voltage. These factors, in turn, impact the peak force, force duty cycle and maximum velocity of the motor.

Please *Contact ANCA Motion* for more information on the available range of servo drives.

4.5 Linear Encoder

The linear encoder is used to provide position feedback to the servo drive to allow for accurate control of the LinX motor. The type of encoder used depends greatly on the application; factors such as the required precision, operating environment and servo drive signaling requirements need to be taken into account. As the LinX motor does not have any backlash, it is recommended that any position feedback system chosen also does not contain backlash. The most commonly used encoders consist of an encoded surface, either solid rail or adhesive strip, mounted parallel to the shaft and a sensor read head mounted to the forcer.

NOTE: To maximise performance, the encoder should be placed as close as possible to the motor. If there must be separation, maximising the stiffness to minimise deflection is desired.

4.5.1 Resolution

Encoder resolution has a large impact on the precision, accuracy and smoothness of the LinX cylindrical motor system. The positional accuracy of the system can never be greater than the position feedback supplied by the encoder. Additionally, the response speed of the encoder must be taken into account when operating at the applications top speed. Finally, the servo drive's maximum encoder bandwidth must also be considered. Consult your servo drive manual on supported encoder signal types and bandwidths.

4.5.2 Magnetic Encoders

Due to the highly magnetic nature of the shaft, care must be taken when installing a magnetic encoder. It is possible that the shaft will affect the strip or read head resulting in inaccuracies or damage. Therefore, it is necessary to ensure the encoder components are a sufficient distance away from the shaft. Installing the encoder at a minimum distance of 150mm from the surface of the shaft is recommended.

4.6 Sensors

4.6.1 End Stop Sensors

End stop sensors, also known as limit switches, are used to prevent motor travel in the case of incorrect behaviour. In the event that the motor passes a defined maximum physical position, the end stop sensors will be triggered which can stop and/or disable the motor, minimizing potential damage. In addition to end stop sensors, it is recommended to incorporate end stop bumpers to absorb and stop the movement in the case of over travel.

4.6.2 Home Sensor

When an incremental encoder is used, the servo drive will not know the absolute position of the motor relative to the machine. To establish the absolute position, it is necessary to move the motor to a known 'home' location, often referred to as 'homing'. The servo drive can be informed that it has reached the 'home' location in many ways, the most common being via a proximity switch at one end of travel and/or an index (marker) pulse.

4.6.3 Temperature Sensor

The LinX cylindrical linear motor contains a KTY84/130 temperature sensor. The sensor increases in resistance as the motor winding temperature increases. When this temperature sensor is employed, the trip temperature should be set no higher than 120°C, and the accuracy of the circuitry involved should be no worse than +/-8°C including the sensor accuracy.

The temperature sensor is located in close proximity to the high voltage motor windings, therefore the sensor signals must have proper isolation within the servo drive. Sensor signals should not be directly connected to a general purpose IO for this reason.

Note that, although the sensor is located in the center of the motor, it is possible in certain use cases for an uneven temperature distribution within the forcer to result in the sensor reporting a lower value than the maximum temperature within the motor. Therefore, it is recommended that the current limits in *section 5.1* are obeyed through use of I2R overload protection within the servo drive. Both the AMD2000 and AMD5x servo drive series offer I2R overload protection functionality.

	Conditions	Min	Nominal	Max
Continuous sensor current (mA)[1]	25°C ambient	-	2	10
	300°C ambient	-	2	2
Sensed temperature (C)	-	-40	-	140
Sensor Resistance (Ω)	25°C	577R	603R	629R
Sensor Resistance (Ω)	140°C	1216R	1262R	1309R
Isolation between Sensor and UVW phases		Tested at 2400VDC for 1 second		

Table 4-1 - KTY84/130 Temperature Sensor Characteristics

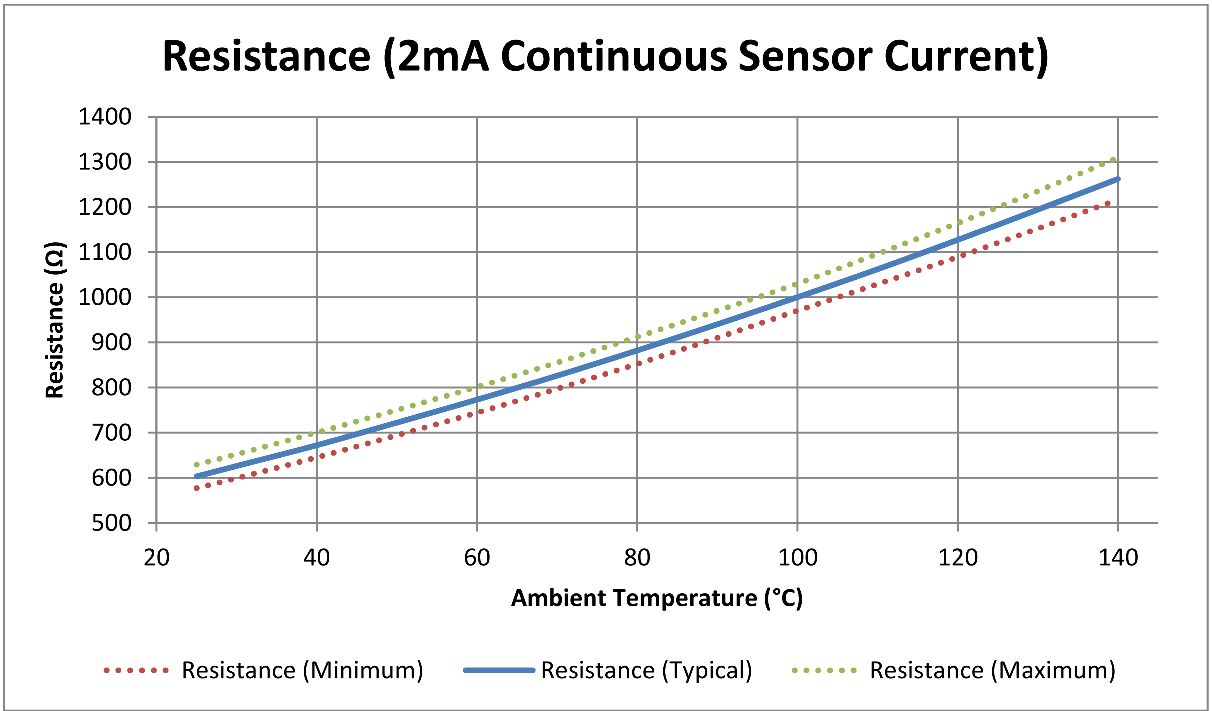


Figure 4-5 – KTY84/130 Temperature Sensor Characteristics

NOTE: The temperature sensor polarity is important to the correct operation of the temperature sensor. Incorrect wiring can result in incorrect motor temperature readings. Refer to *5.3.3 Connector* for wiring information.

4.7 Operating Environment

The temperature of the operating environment is critical when determining the appropriate motor model to use. When the motor is producing force, it will produce a temperature rise above ambient as described in *5 Specifications*. The higher the temperature of the motor's operating environment, the hotter the motor will become under the same duty cycle. The motor will also be subject to a temperature related reduction in the force produced.

Therefore, it is important that the motor cooling method is carefully considered. If air cooling is used, ensure that the motor is well ventilated to limit localized heating. If the motor is liquid cooled, ensure that the coolant and flow rates are sufficient to maintain the motor temperature within operating limits.

[1] For temperatures greater than 200°C, a continuous sensor current of 2mA must be used.

It is recommended that the inbuilt *Temperature Sensor* is monitored to prevent the motor exceeding absolute temperature limits.

4.8 Multi-Axis Systems

The LinX linear motor system allows for various multi-axis configurations. This can include a single drive and motor for each axis, multiple forcers on a single shaft or two motors moving a gantry. These various configurations can be combined as required for the application.

4.8.1 Single Forcer

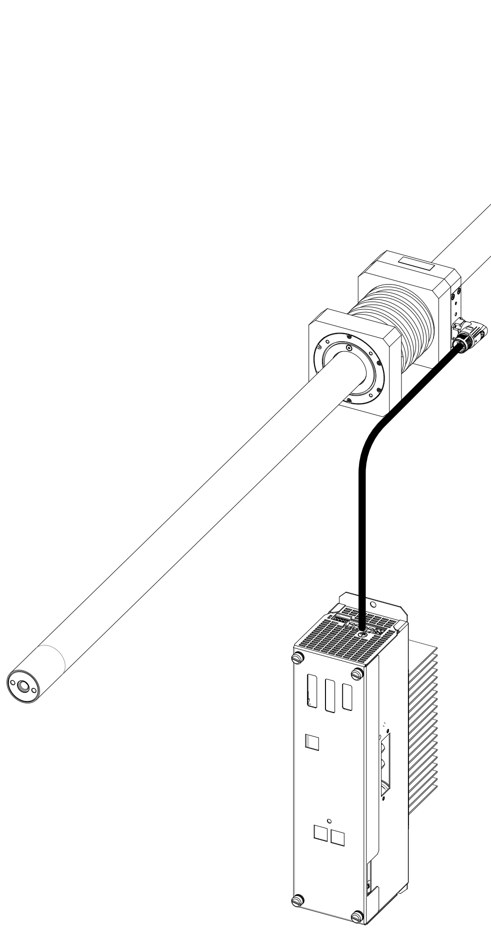


Figure 4-6 – Single Forcer

A single drive, forcer and shaft is the simplest setup. Each set represents an independent axis that can be combined to create a multi-axis machine.

4.8.2 Multi Forcer

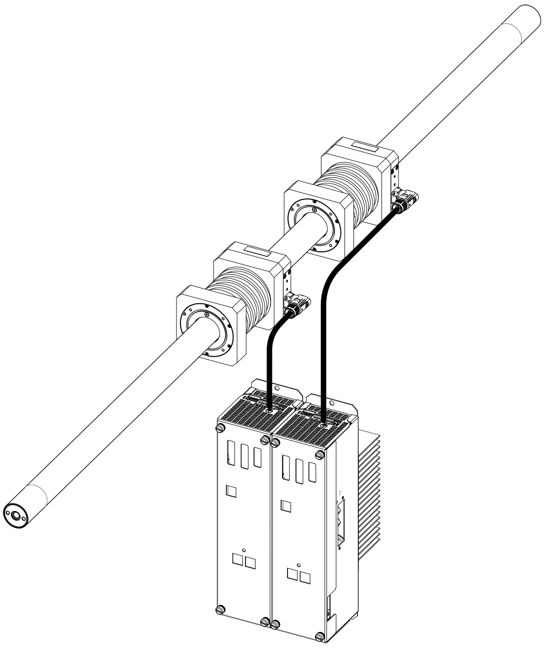


Figure 4-7 – Multiple Forcers

Unlike ball-screw systems, the multiple LinX forcers can operate on a single shaft to increase the force applied by an axis. These forcers can be synchronized or act completely independently depending on the application. This setup allows for increased flexibility in machine design while providing a compact and cost effective solution.

4.8.3 Multi Forcer with a Single Drive

In this type of installation multiple coupled forcers are controlled by one servo drive with a single linear encoder resulting in increased output force. This can be achieved either by having two or more motors each on their own shaft (Parallel Forcers) or by having two or more motors all on the same shaft (Tandem Forcers). In both cases the forcer spacing and orientation is important (see section 6.2.2 for more detailed installation instructions).

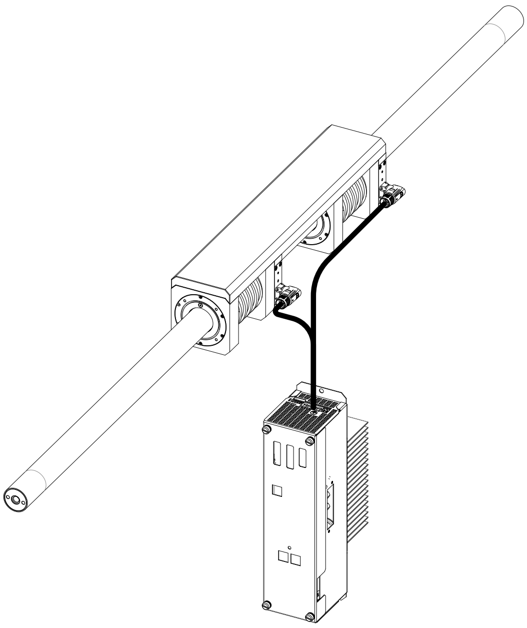


Figure 4-8 – Tandem Forcers

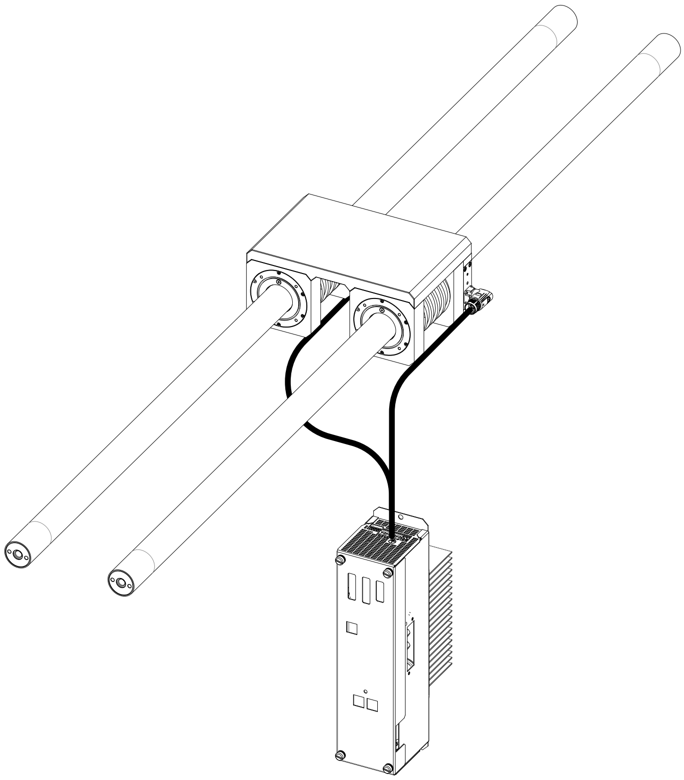


Figure 4-9 – Parallel Forcers

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5 Specifications

5.1 Electrical

	TLMS-18P	*TLMS-27P*	*TLMS-36P*	*TLMS-36H*
Max Continuous Force (N) Fluid/Air [1,2]	335 / 207	510 / 290	630 / 360	630 / 360
Max Continuous Current (Arms) Fluid/Air [1,2]	3.85 / 2.38	5.86 / 3.33	7.24 / 4.14	3.62 / 2.07
Peak Force over 1 second (N) [3,4]	2136	3204	4272	2860
Peak Current over 1 second (Arms) [3,4]	24.6	36.8	49.1	16.4
Peak Force over 16 seconds (N) [4]	522	783	1044	1044
Peak Current over 16 seconds (Arms) [4]	6	9	12	6
Force Constant [K_f] (N/Arms)	87	87	87	174
Back EMF Constant [K_e] ($V_{rms\ L\text{-}L}$/(m/s))	50	50	50	100
Resistance @ 25°C (Ω) [5]	10.4	6.9	5.2	20.8
Inductance (mH) [5]	29	19.3	14.5	58
Maximum Motor Voltage ($V_{rms\ L\text{-}L}$) [6]	420	420	420	420
Electrical Time Constant (ms)	2.8	2.8	2.8	2.8
Magnetic Pitch (N-N) (mm)	180	180	180	180

Table 5-1 - Electrical Specifications

NOTES:

1. The maximum continuous force and current when the forcer is stationary (worst-case) is given for both fluid cooling (first figure) and air-natural cooling (second figure). Air-cooled ratings are based on an ambient temperature of 25°C and fluid cooled ratings based on a coolant temperature 25°C (flow rates in *Table 5-2*). The quoted air-cooled ratings assume a standard mounting configuration (see *Figure 3-2*) where the motor is attached to a steel carriage via two metal brackets.
2. The maximum continuous ratings for both Fluid and Air cooling are based on a winding temperature of 130°C absolute maximum. This is “Class B” operation. The windings however, are manufactured with “Class H” materials, and therefore have a safety margin of two full classes.
3. The maximum peak force and current is a limitation due to permanent magnet characteristics and should never be exceeded even for a short time.
4. If the linear motor is used repetitively at peak forces in excess of the nominal, the equivalent rms loading shall be taken into account, along with forces that are below the nominal figure. The application duty cycle should be calculated over a period of 10 minutes. Further, sufficient Voltage must be available from the Servo Drive to overcome both the resistance, and the back-emf of the linear motor (depending on the speed). Refer to *5.2 Force vs. Speed Characteristics*.
5. The Resistance and Inductance values are “between phases” or “line to line” and are twice the per-phase parameters. The resistance is taken at 25°C. Resistance values will increase by 40% at the design operating temperature of 130°C. Inductance measurement is performed at 1kHz.
6. The linear motor winding insulation is designed for PWM operation at a maximum motor voltage of 420V rms line-line from a maximum DC Bus Voltage of 680V DC.

	TLMS-18P	TLMS-27P	TLMS-36P	TLMS-36H
Maximum Shaft Temperature (°C)	130	130	130	130
Maximum Winding Temperature (°C)	130	130	130	130
Motor Temperature Class	H (180°C)	H (180°C)	H (180°C)	H (180°C)
Thermal Time Constant (minutes) Fluid/Air	40 / 80	45 / 90	50 / 100	50 / 100
Fluid Cooling Medium Temperature (°C)	25	25	25	25
Flow rate for fluid cooling (litres/minute) Water/Oil	2.0 / 4.0	2.0 / 4.0	2.0 / 4.0	2.0 / 4.0

Table 5-2 - Thermal Specifications

WARNING: The maximum shaft temperature is a function of permanent magnet characteristic limitation, and should never be exceeded. Exceeding this limit can result in demagnetization of some or all of the magnets inside the shaft.

WARNING: Exceeding the maximum winding temperature will reduce the lifespan of the motor and potentially cause overheating of the shaft if the forcer is stationary.

5.1.1 Air-Natural Cooling Behaviour

For Air-Natural cooling, the forcer is installed without the external water jacket.
The forcer is intended to be operated under “Class B” conditions, which is a maximum winding temperature of 130°C. This 130°C is made up of an ambient air temperature of 25°C, a winding temperature rise of 100°C and a winding hotspot allowance of 5°C. Under these conditions, the external surface of the forcer will reach a temperature between 75 and 80°C. The performance figures for Air cooling in *Section 5.1* are based on these conditions.

5.1.2 Fluid Cooling Behaviour

For Fluid cooling, the forcer must be fitted with an external fluid cooling jacket. The forcer is intended to be operated under “Class B” conditions, which is a maximum winding temperature of 130°C. This 130°C is made up of a coolant temperature of 25°C, a winding temperature rise of 100°C and a winding hotspot allowance of 5°C. Under these conditions, the external surface of the forcer (inside the jacket) will reach a temperature of approximately 30°C. *Table 5-2* shows the required flow rates for both Water and Oil in order to satisfy the fluid cooling requirements.

5.2 Force vs. Speed Characteristics

In addition to the limits listed in *Section 5.1*, the maximum force achievable at a particular speed will be limited by the voltage rating of the drive. The motor force limits as a function of velocity with DC bus voltages of 300V and 600V are plotted in the figures below.

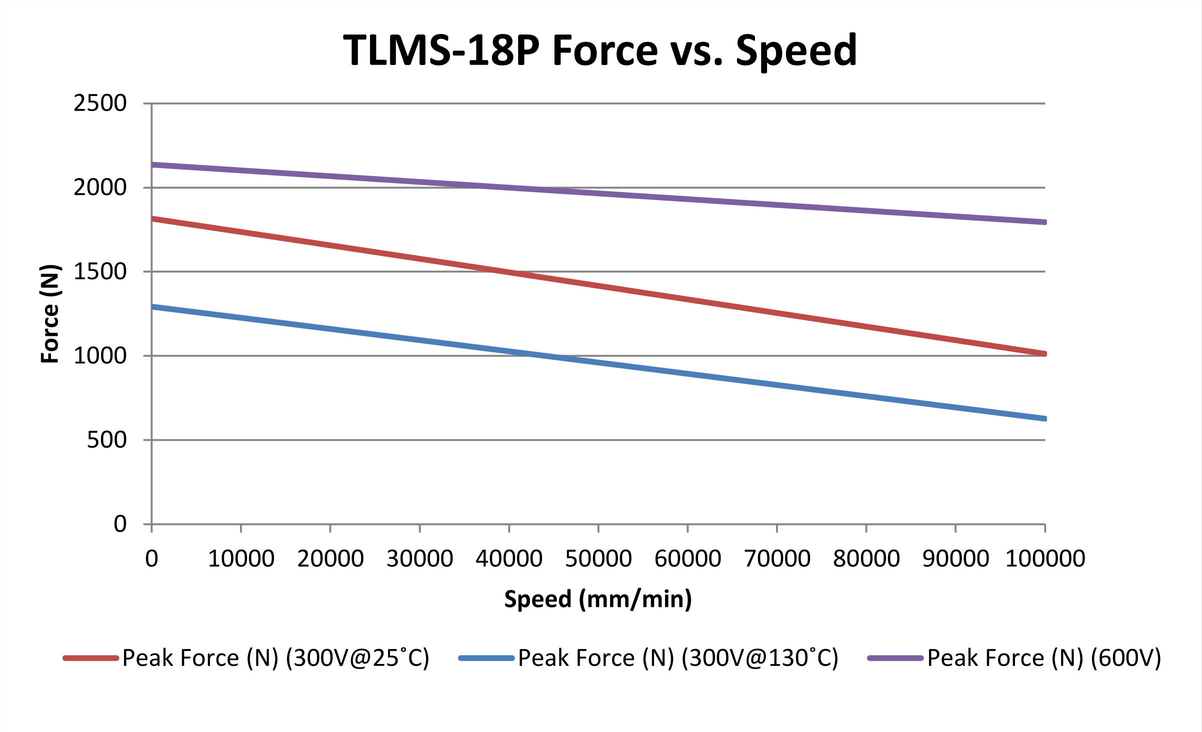

Figure 5-1 - TLMS-18P Peak Force vs. Speed

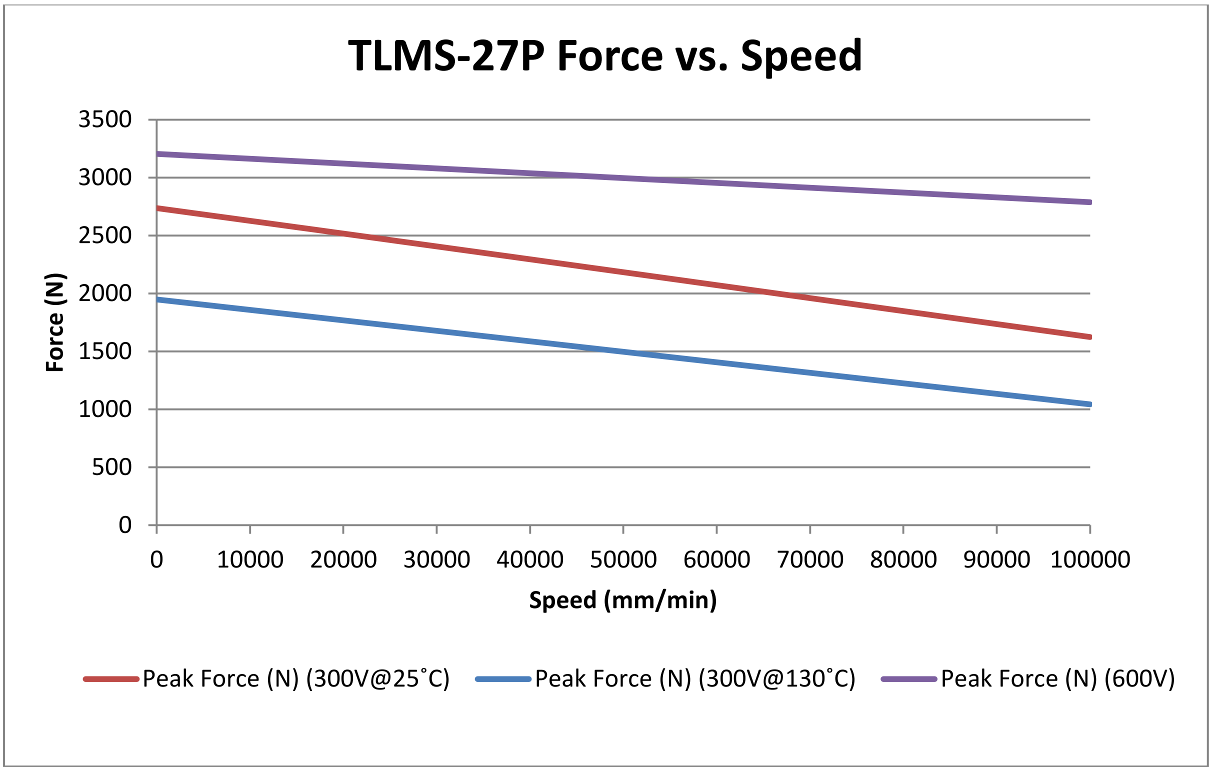

Figure 5-2 - TLMS-27P Peak Force vs. Speed

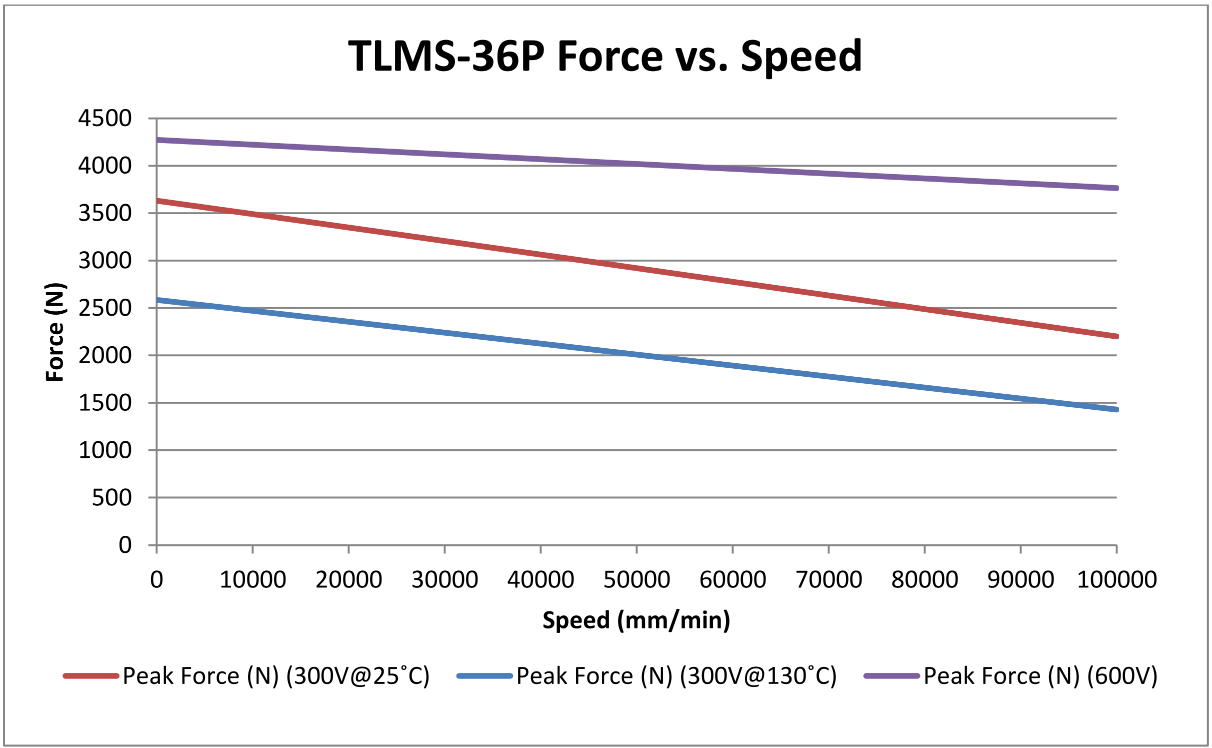

Figure 5-3 - TLMS-36P Peak Force vs. Speed

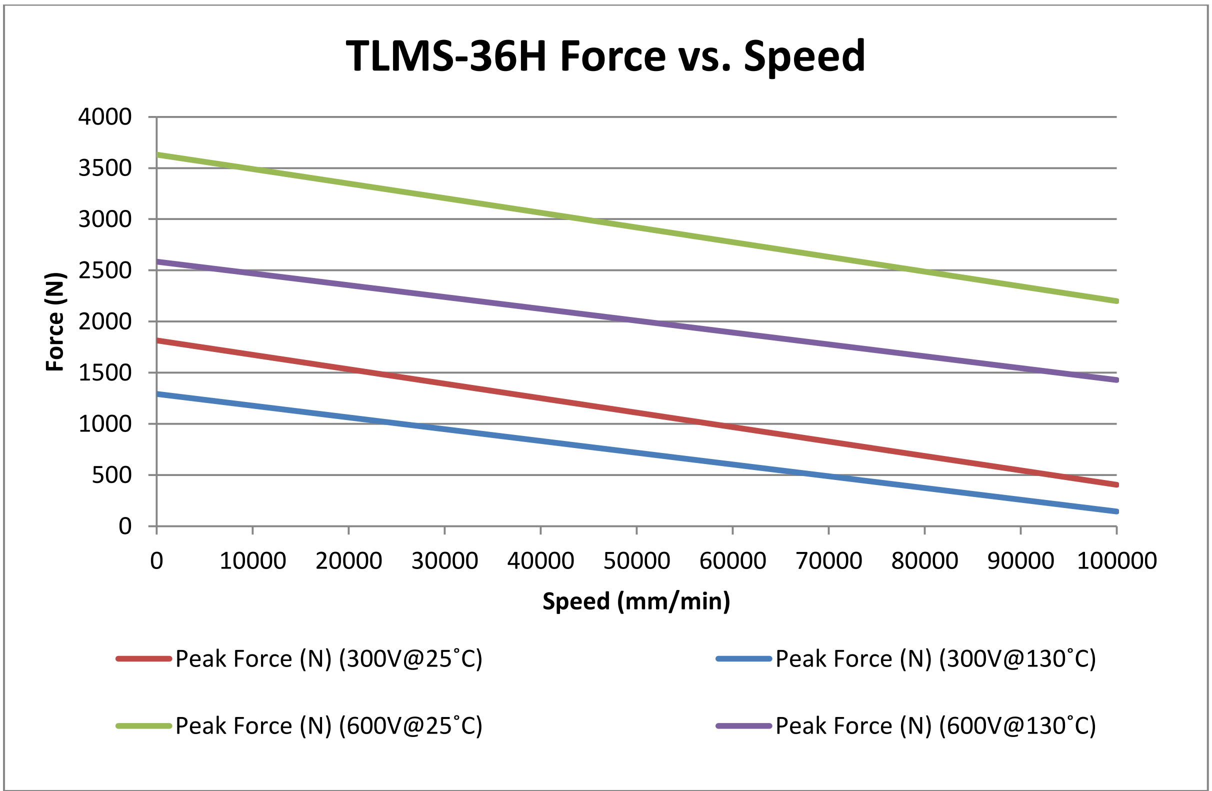

Figure 5-4 - TLMS-36H Peak Force vs. Speed

5.3 Mechanical

NOTE: The motor housing tolerances must be considered when designing a system for fluid cooling.

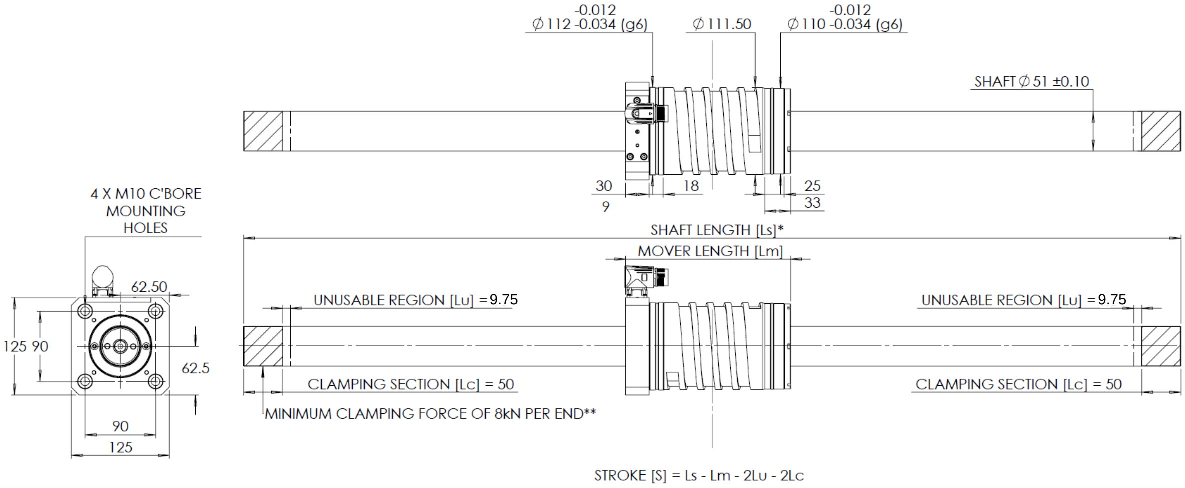

Figure 5-5 - Mechanical Dimensions

5.3.1 Forcer

	TLMS-18P	*TLMS-27P*	*TLMS-36P*	*TLMS-36H*
Length [Lm] (mm)	210.5	300.5	390.5	390.5
Weight (kg)	6.5	8.8	11.4	11.4

5.3.2 Shaft

Shaft length [Ls] (mm)	Stroke [s] (mm)		
	TLMS-18P	*TLMS-27P*	*TLMS-36(P,H)*
360	30	N/A	N/A
390	60		
420	90		
450	120	30	
480	150	60	
510	180	90	
540	210	120	30
570	240	150	60
600	270	180	90
630	300	210	120
660	330	240	150
690	360	270	180
720	390	300	210
750	420	330	240
780	450	360	270
810	480	390	300

840	510	420	330
870	540	450	360
900	570	480	390
930	600	510	420
960	630	540	450
990	660	570	480
1020	690	600	510
1050	720	630	540
1080	750	660	570
1110	780	690	600
1140	810	720	630
1170	840	750	660
1200	870	780	690
1230	900	810	720
1260	930	840	750
1290	960	870	780
1320	990	900	810
1350	1020	930	840
1380	1050	960	870
1410	1080	990	900
1440	1110	1020	930
1470	1140	1050	960
1500	1170	1080	990
1530	1200	1110	1020
1560	1230	1140	1050
1590	1260	1170	1080
1620	1290	1200	1110
1650	1320	1230	1140
1680	1350	1260	1170
1710	1380	1290	1200
1740	1410	1320	1230
1770	1440	1350	1260
1800	1470	1380	1290
1830	1500	1410	1320
1860	1530	1440	1350
1890	1560	1470	1380
1920	1590	1500	1410
1950	1620	1530	1440
1980	1650	1560	1470
2010	1680	1590	1500
2040	1710	1620	1530
2070	1740	1650	1560
2100	1770	1680	1590

5.3.3 Connector

Note that the right-angle armature connector on LinX motors are non-rotatable. The forcer body is fully potted including the connector, so any attempt to turn the connector or remove the connector will cause permanent damage which cannot be repaired.

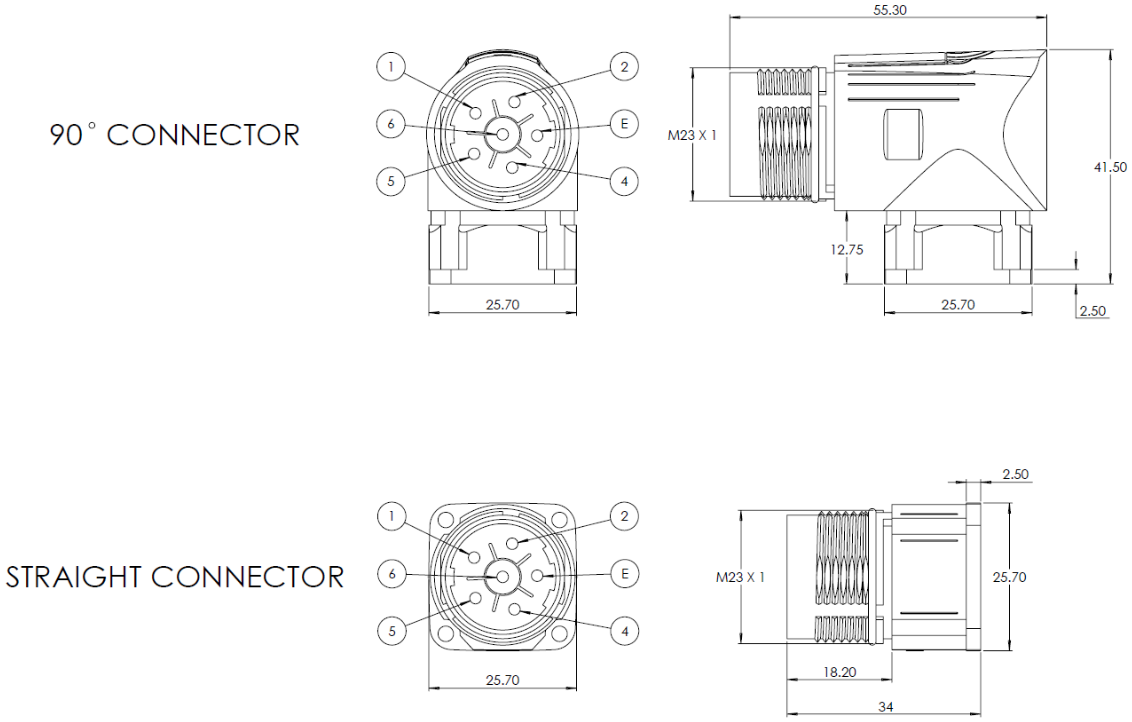

Figure 5-6 – Connector Dimensions

Pin Number	Label
1	U Phase
2	V Phase
3	PE
4	Temperature +
5	Temperature -
6	W Phase
Connector Case	⏚

Table 5-3 - Motor power pin allocation

Model	Recommended Ø wire gauge	
	AWG	mm^2
TLMS-18P	16	1.5
TLMS-27P	14	2.5
TLMS-36P	14	2.5
TLMS-36H	16	1.5

Table 5-4 - Recommended wire gauge for motor power

6 Installation

6.1 Unpacking

WARNING: Cylindrical motor shafts contain powerful permanent magnets. People with a pacemaker, AICD or similar medical devices should maintain a minimum distance of 50cm from the shaft.

WARNING: The shaft emits a very strong magnetic field, always use caution when handling. To avoid injury, keep fingers and other body parts clear.

Due to the magnetic nature of the shaft, it is recommended that protective material around the shaft is left on as long as possible during installation. During installation, ensure that the shaft is kept on a clean surface away from any other magnetic and ferrous materials.

If the shaft is to be left unattended, precautions should be taken to prevent accidents or damage due to its strong magnetic field. All personnel involved in transporting, storing, installing and/or maintenance of the shaft must be made aware of the potential hazards involved.

6.2 Mechanical

WARNING: Surface temperatures of up to 80°C can be present during operation of the LinX system. Allow the forcer and shaft to cool before touching the motor.

WARNING: Always isolate the motor from the electrical supply. The motor could move unexpectedly and present a crushing hazard.

6.2.1 Shaft

WARNING: The shaft emits a very strong magnetic field, always use caution when handling. To avoid injury, keep fingers and other body parts clear.

Due to the strong magnetic nature of the shaft, proximity to magnetic parts and items sensitive to magnetic fields must be considered at all times. It is recommended that non-magnetic packing material is used when making adjustments to the shaft to prevent the shaft being attracted to any magnetic parts e.g. linear bearings.

The shaft must be mounted to ensure that concentricity with the central bore of the forcer. The nominal radial air gap between the forcer and shaft of 1mm should ideally be maintained for the entire stroke. On longer strokes, this may not be practical. The air gap is non-critical for operation as long as the forcer and shaft do not come into contact. Contact will result in an increase in friction and wear on the cylindrical linear motor. Refer to *4.3.1 Shaft* for more information.

WARNING: The shaft is not designed to be a load bearing element. Additional elements must be added to the forcer to handle any load applied.

One end of the shaft is identified as the datum as indicated by a stamped “0” marking. This marker will be on the opposite end from the label sticker and can be used to identify the polarity of the magnet sequence inside the shaft. Note that for standard assembly and motor commissioning of a single shaft system it is generally not required to know the magnetic orientation of the shaft (see *6.2.3 Linear Encoder* for more details on commissioning and motor travel direction). The marker is used for diagnostic purposes or when multi-shaft installations are required.

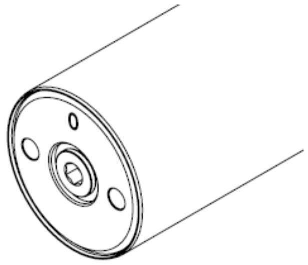

Figure 6-1 – Marking on one end of the shaft indicating the datum end.

6.2.1.1 Example Installation Procedure

NOTE: The shaft installation method is application specific, the following instructions are provided as an example only.

1. Ensure area is clean of all metal tools, debris and any other magnetic material that may be attracted to the shaft.
2. Mount the linear guide system (rail or bars) as per manufacturer instructions. Ensure that it is running true to system components along the length of the stroke.

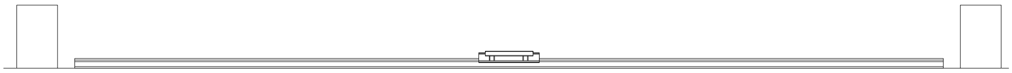

Figure 6-2 – Mounting the linear guide system

3. Mount shaft clamps ensuring they are aligned correctly with the linear guide system.
4. Attach the linear motor mount to the linear guide system allowing for later alignment.
5. Attach the linear motor to the mountings and secure the motor.

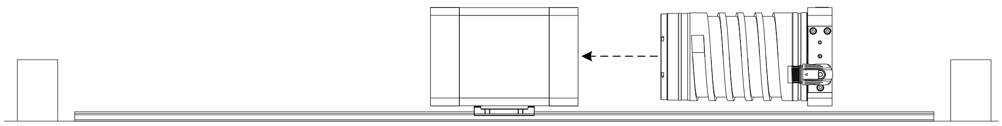

Figure 6-3 - Mounting the forcer

WARNING: When handling the magnetic shaft do not have any ferrous or magnetised material on your person, this includes watches, keys and electronic devices, that could be attracted to the shaft.

ATTENTION: The LinX shaft weighs approximately 15kg per metre, it is recommended that a minimum of two people lift the shaft for installation.

6. Place temporary nonmagnetic spacers in front and behind one shaft support. These should be spaced so that the shaft can rest on them securely.
7. Begin to slide the shaft towards the forcer bore, move the nonmagnetic spacers as needed to continue supporting the shafts weight.

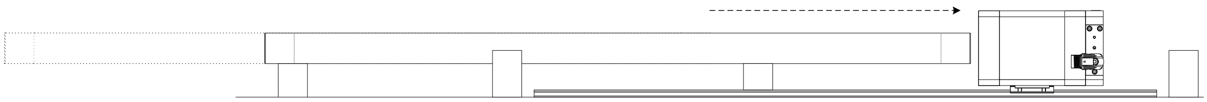

Figure 6-4 - Mounting the shaft

8. Move the forcer over the end of the shaft and move a spacer so that the shaft is supported on both sides of the forcer.

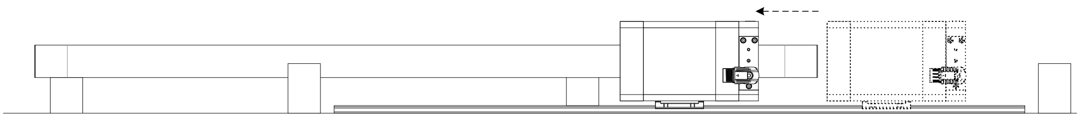

Figure 6-5 - Inserting the shaft into the forcer

9. Slide the shaft into the final position and remove all spacers. Clamp and secure the shaft.
10. Move the forcer back and forward along the length of the stroke and adjust the forcer and shaft mounts to achieve the maximum clearance between the forcer and shaft.

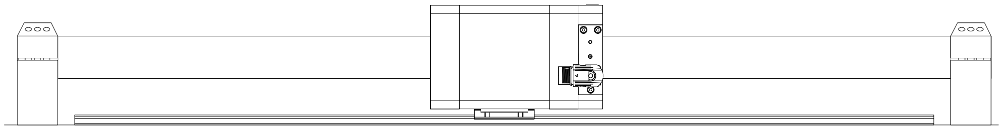

Figure 6-6 - Assembled LinX motor

6.2.2 Forcer

WARNING: Surface temperatures of up to 80°C can be present during operation of the LinX system. Allow the forcer and shaft to cool before touching the motor.

NOTE: The right-angle armature connectors on LinX motors are non-rotatable due to an internal resin filling. No attempt should be made to rotate the connector as it may result permanent motor damage.

The forcer is affixed to the load via 4 screws on the flange end of the forcer. The type of forcer mount depends whether the forcer moves or is fixed and if the forcer is air cooled or liquid cooled.

The motor orientation with respect to the marked end of the shaft will not affect operation or motor travel direction. However, the motor orientation relative to the positive direction of the linear encoder *does* influence operation and the two must be matched for the motor to function. Refer to *6.2.3 Linear Encoder* for more information on how to align encoders.

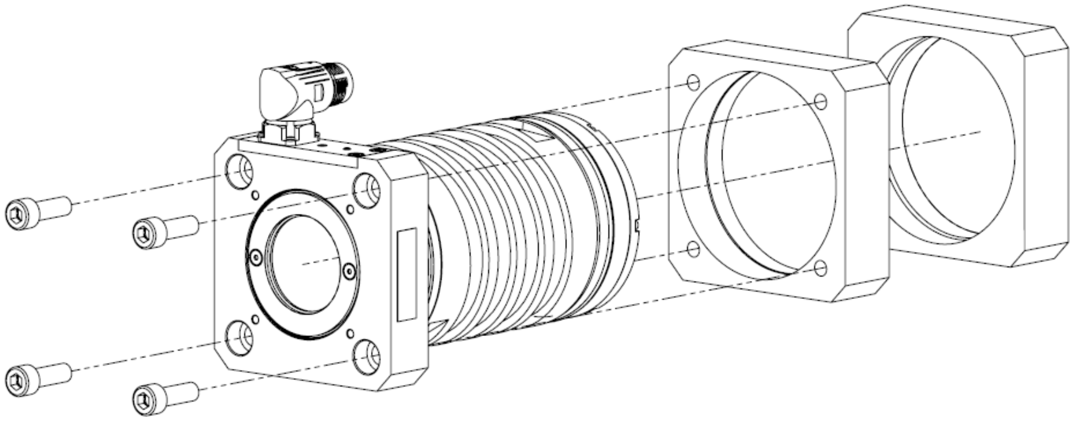

Figure 6-7 - Example of air cooled forcer mounting

6.2.2.1 Parallel Forcers

WARNING: The shaft emits a very strong magnetic field and will be attracted to other shafts. Extra care should be taken when installing LinX motor shafts in close proximity to each other.

LinX linear motors can be run in parallel either independently or mechanically joined. A set of mechanically joined motors can be run in parallel with only a single encoder and servo drive.

When using parallel forcers, the shafts and forcers must both be aligned to run in the same direction and the motor windings should be connected in parallel with the standard UVW sequence for both motors (connection diagram in *Figure 6-10*). The marked end of each shaft should be located at the same end as shown below.

.

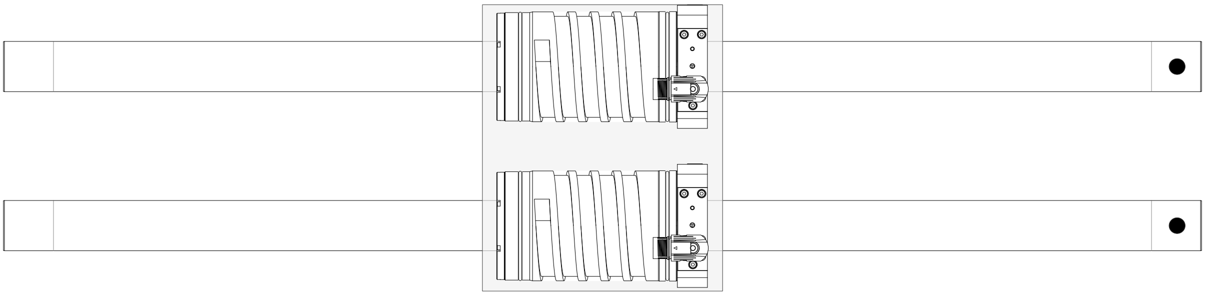

Figure 6-8 - Parallel forcers

Parallel motors must not operate too close together to avoid curvature caused by magnetic fields. There must be a minimum distance of 180mm between shafts. Due to the large attractive force between two shafts it is strongly recommended that non-magnetic spacers or guides are used when installing parallel shafts.

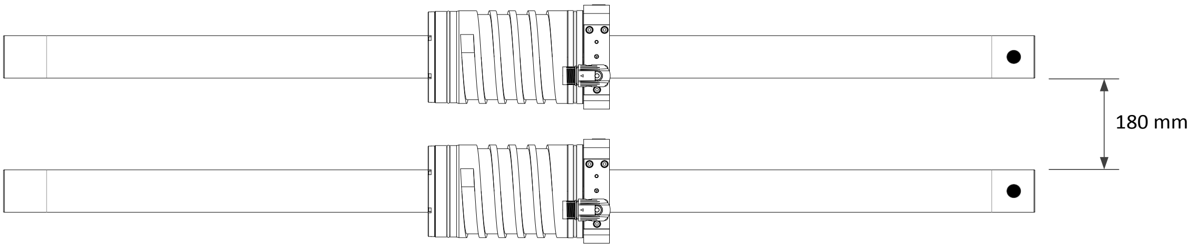

Figure 6-9 - Parallel forcer shaft spacing

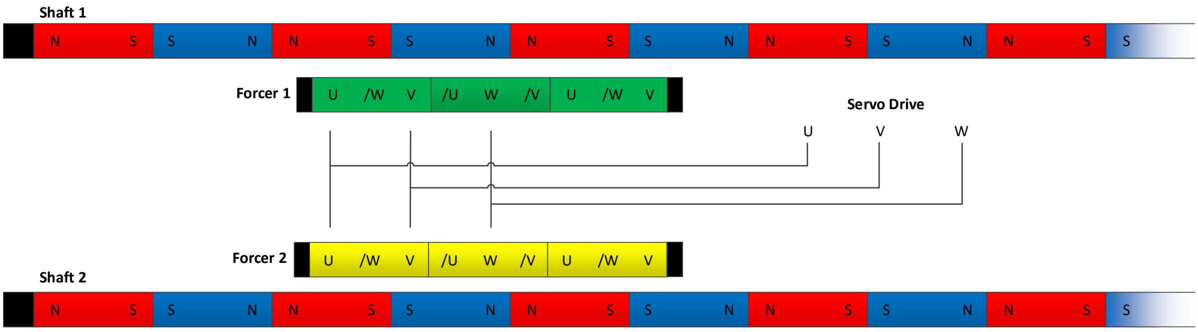

Figure 6-10 – Armature connections for parallel forcers with a single servo drive.

6.2.2.2 Tandem Forcers

For tandem forcer installation there are several motor spacing and phase connections which will give the correct phase sequence in the windings. The option that provides the smallest separation distance between the two motors, and therefore the longest stroke, is with the motors mounted flange to flange with a 31.5mm separation (*Figure 6-11*). The flange to flange orientation works for all motor model combinations. It requires a custom armature cable which swaps the W and V connections on the second forcer to ensure the correct direction of travel for both motors (see *Figure 6-12* for connection diagram).

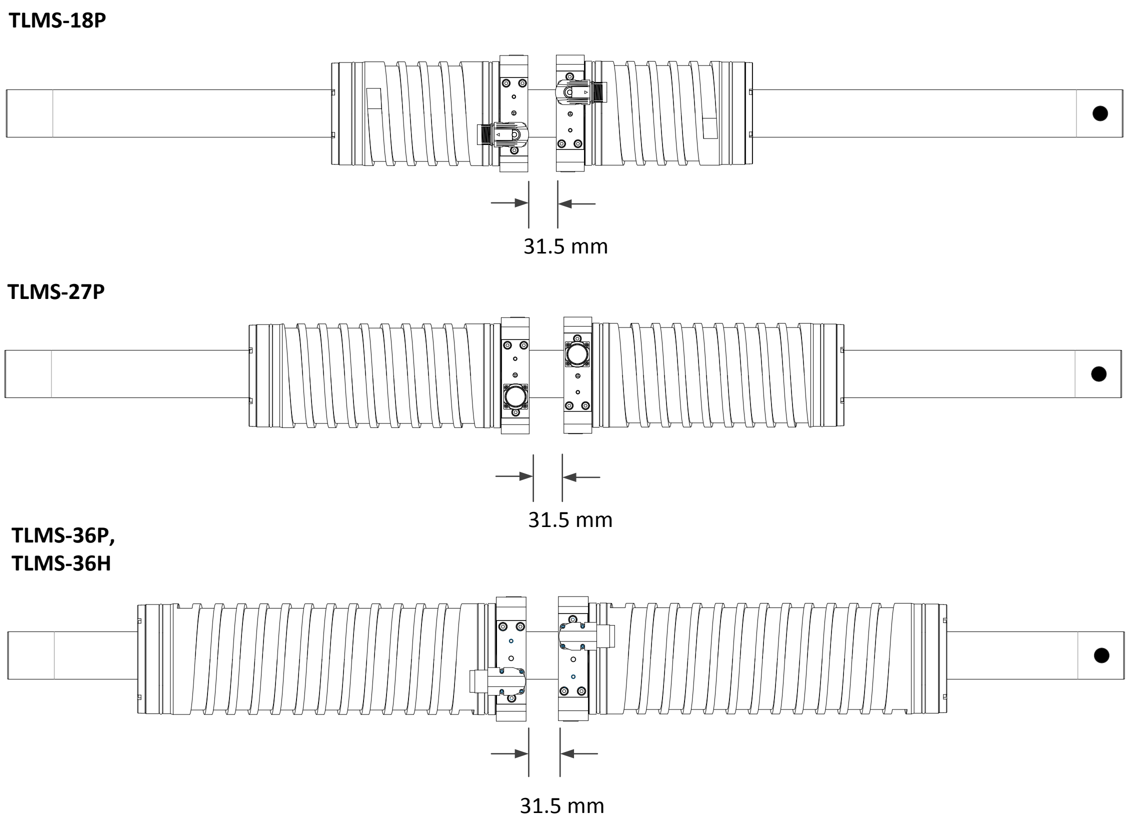

Figure 6-11 - Tandem forcer spacing and orientation

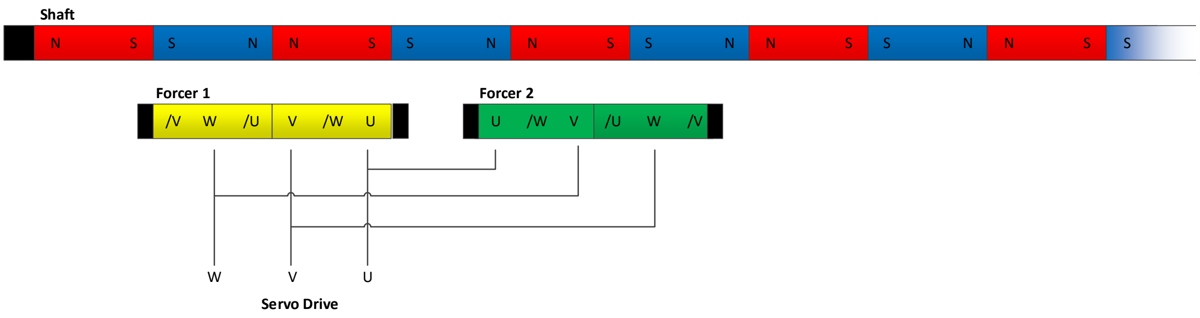

Figure 6-12 - Armature connections for tandem forcers mounted flange-to-flange.

6.2.3 Linear Encoder

Encoders should be installed according to the encoder manufacturer's instructions. Care should be taken with the sensitive electronics of the encoder near the strong magnetic field of the shaft. Particular care should be taken with magnetic encoders as close proximity to the shaft could cause inaccuracies or damage. Installing the encoder at a minimum distance of 150mm from the shaft is recommended.

The positive and negative directions of the linear encoder need to be correctly aligned to the direction of motor movement. The direction corresponding to positive movement can be adjusted in multiple ways:

1. Software configuration on the servo drive.
2. Mechanical orientation of the encoder.

3. Electrical wiring between the encoder and servo drive (On an incremental encoder, inversion of one of the quadrature signals is sufficient).
4. Swap any two phases of UVW.

The recommended method for matching the movement direction of the motor and encoder is updating the software configuration in the drive (1) as this involves no physical change to the system.

6.3 Electrical

DANGER HIGH VOLTAGE: Ensure power has been completely disconnected before touching electrical connections. Electrical shock can cause serious or fatal injury.

6.3.1 Motor Power and Temperature Feedback

DANGER: The shaft must be earthed to prevent the possiblility of electric shock during motor operation.

The power supply and temperature signal feedback are both supplied via the LinX forcer connector. Connector pin allocations and recommended wire gauge can be found in section *5.3.3 Connector*. Please refer to the servo drive documentation for further information on how to wire in the motor power supply and temperature sensor.

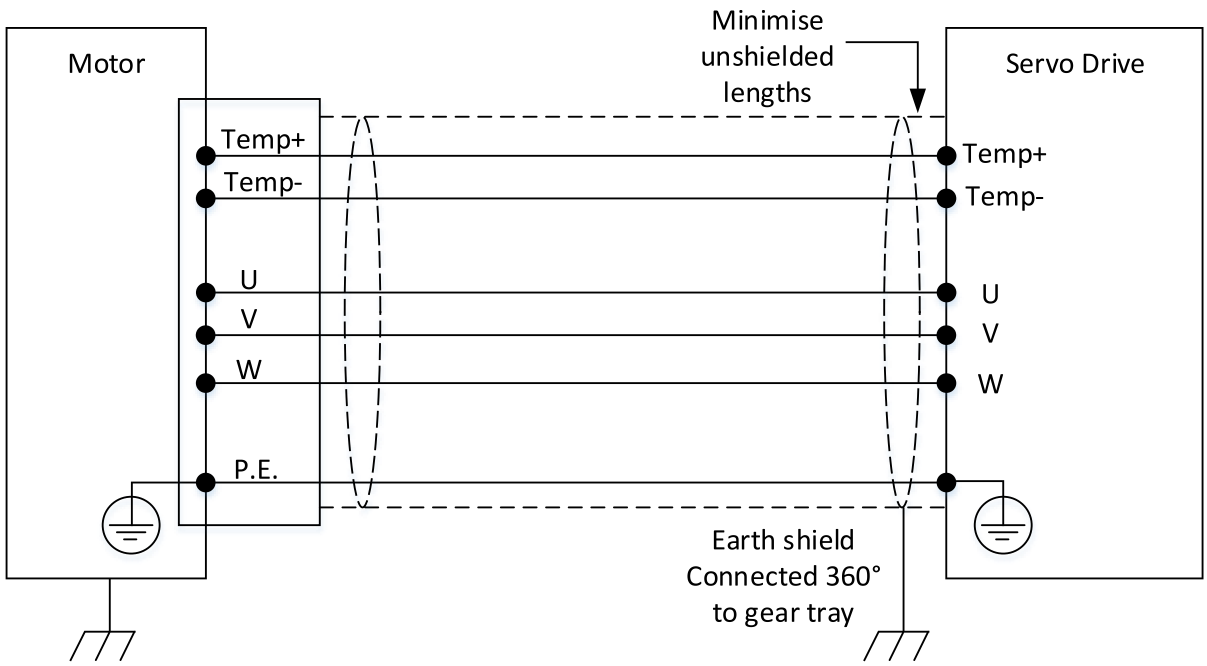

Figure 6-13 - Connection between motor and servo drive

If using Tandem Forcers and the orientation of the 2nd forcer is reversed, then the V and W wires also need to be reversed to ensure both forcers move in the same direction. Refer to *Section 6.2.2.2* for more information.

6.3.2 Sensors

Connect the sensors such as home switches and dead stops that are to be used to the servo drive as specified in the sensor and servo drive documentation.

6.3.3 Electromagnetic Compatibility (EMC)

While the ultimate responsibility for a system's EMC compliance lies with the system builder, the LinX motor's design provides good EMC performance as a system component. The aluminum forcer housing that contains the motor windings effectively limits both radiated noise emission from the motor during operation and external sources of noise from impacting connected electronics.

The following are general recommendations when using the LinX motor to minimize Electromagnetic Interference (EMI) in the system.

- Keep all cable routing as short and direct as possible.
- Separate low voltage signal cables from power cables and noisy components.
- Ensure cable shielding is terminated correctly.

Other sources of EMI in the system, such as servo drives, must also be considered for EMC, refer to component documentation for further information.

6.4 Servo Drive Configuration

In general, servo drives will need the following configuration to control the LinX motor. Servo drives that do not specifically support linear motors can be configured as a two pole rotary motor. Configuration requirements will depend on the specific servo drive and linear encoder used; refer to product documentation for specific information.

Parameter	Units	Linear Motor	Linear as Rotary Motor
Motor Type	-	Linear	Rotary
Distance between magnet poles	Distance or encoder counts	As per motor specification	As per motor specification
Number of Motor Poles	Integer	-	2
Rotary encoder pulses per revolution	Encoder counts/lines	-	$\frac{\text{Magnet Pitch}}{\text{Linear Encoder Pitch}}$
Linear encoder pitch	Distance	As per encoder specification	-
Peak Current	Amps	As per motor specification	As per motor specification
Continuous Current	Amps	As per motor specification	As per motor specification

Table 6-1 - Servo drive configuration

7 Maintenance

Due to the contactless nature of the LinX cylindrical linear motor, a LinX system requires very little maintenance. However, the following activities are recommended for periodic maintenance.

- Ensure the forcer can move freely over the entire stroke
- Check for evidence of wear on the shaft that could indicate contact with the forcer
- Clean any accumulated debris from the shaft
- Check the shaft deflection is within specifications
- Ensure all parts are secured
- Check cables for signs of wear or damage
- Lubricate bearing if required (refer to manufacturer)

8 Accessories

8.1 Drives

ANCA Motion has two ranges of servo drives that can be used to power and control LinX motors. These are the AMD2000 and AMD5x drive series. More information on these products can be found on the ANCA Motion website.

Drive Catalogue Number	Description
D2103-2C2-A	AMD2000 Servo Drive 3A STO CoE
D2103-2S2-A	AMD2000 Servo Drive 3A STO SoE
D2109-2C2-A	AMD2000 Servo Drive 9A STO CoE
D2109-2S2-A	AMD2000 Servo Drive 9A STO SoE
AMD5-10300-BA00	AMD5x Series 3A Drive
AMD5-10600-BA00	AMD5x Series 6A Drive
AMD5-11200-BA00	AMD5x Series 12A Drive
AMD5-12000-BA00	AMD5x Series 20A Drive
AMD5-13500-BA00	AMD5x Series 35A Drive
AMD5-P6150-BA00	AMD5x Series Passive Infeed Unit 15kW

AMD5x servo drive

AMD2000 servo drives

8.2 Cables

ANCA Motion supplies armature cables for connecting LinX motors with the drive series listed above. Part numbers of relevant cable types are listed below. Note the 'xxx' designation is simply a placeholder for the required cable length. For example, K2L-TSMD-050 would be a 5 meter long cable.

Cable Catalogue Number	Description
K2L-TSMD-xxx	AMD2000 Armature Cable for LinX Motors
K5L-TSMD-xxx	AMD5x Armature Cable for LinX Motors

9 Appendix

9.1 Motor Selection Guide

9.1.1 Application Continuous Force Calculation Example

The following example demonstrates calculation of a motor duty cycle simple positioning move with a trapezoidal velocity profile. The profile is broken up into sections i.e. acceleration, constant velocity and deceleration in order to determine the RMS force and duty cycle.

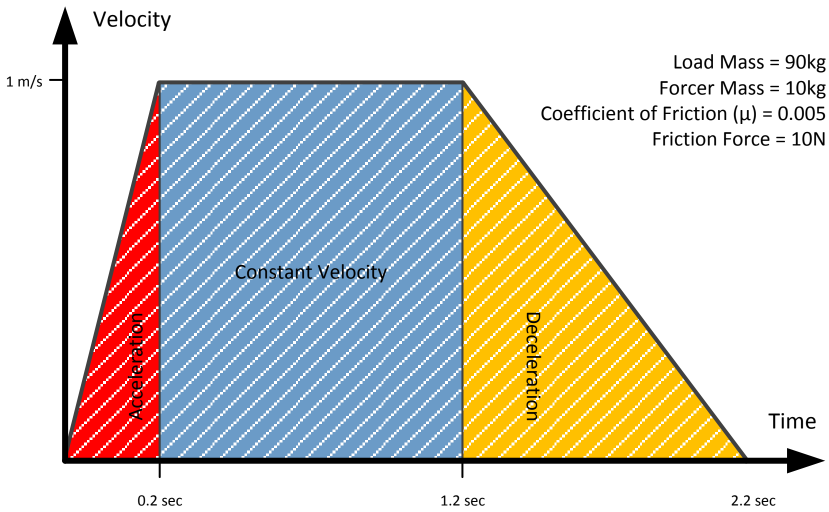

Figure 9-1 - Positioning example velocity profile

In this example, friction is taken as a combination of the Coefficient of Friction (µ) and a constant force.

$$Friction = \mu \times Mass \times 9.81 m/s^2$$

$$0.005 \times (90kg + 10kg) \times 9.81 = 4.9N$$

Referring to *Figure 9-1*, the positioning move can be broken down into the following segments:

Acceleration:

$$Force = Mass \times Acceleration + Friction$$

$$= (90kg + 10kg) \times \frac{\frac{1m}{s}}{0.2s} + 4.9N$$

$$= 504.9N$$

Constant Velocity:

$$Force = Friction$$

$$= 4.9N$$

Deceleration:

$$Force = Mass \times Deceleration - Friction$$

$$= 100kg \times \frac{1m/s}{1s} - 4.9N$$

$$= 95.1N$$

Other application forces also need to be taken into account such as friction and external forces; however, for the sake of simplicity, they will be ignored in this example.

Force RMS:

$$Force\ RMS = \sqrt{\frac{F_1^2 T_1 + F_2^2 T_2 + F_3^2 T_3}{T_1 + T_2 + T_3}}$$

$$= \sqrt{\frac{504.9^2 \times 0.2 + 4.9^2 \times 1 + 95.1^2 \times 1}{2.2}}$$

$$= 165.2N$$

If this move were to continue cyclically then this result could be used with a forcer's continuous force rating for forcer model selection. However, in many applications, a positioning move such as this would have a delay before the next move which impacts the overall continuous force rating. If the above example were to have an additional 1 second delay before the next positioning move, with no force required during this period:

Force RMS:

$$Force\ RMS = \sqrt{\frac{F_1^2 T_1 + F_2^2 T_2 + F_3^2 T_3 + F_4^2 T_4}{T_1 + T_2 + T_3 + T_4}}$$

$$= \sqrt{\frac{504.9^2 \times 0.2 + 4.9^2 \times 1 + 95.1^2 \times 1 + 0^2 \times 1}{3.2}}$$

$$= 137N$$

The result is a significant reduction in the required continuous force rating of the forcer.

9.1.2 Duty Cycle Calculation

The duty cycle of a linear motor is defined in terms of power usage and can be used to determine whether the application RMS current (I_{RMS}) is too high for the chosen forcer. A total duty cycle less than 100% is required to keep the linear motor within its specifications. Exceeding 100% duty cycle could result in damage to the motor.

$$Duty\ Cycle\ (\%) = \left(\frac{I_{RMS}}{I_{Continuous}}\right)^2 \times 100\%$$

10 Product, Sales and Service Enquiries

If after reading the User Manual you still require assistance for installation, training or other customer support issues, please contact the closest ANCA Motion Customer Service Office in your area for details.

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