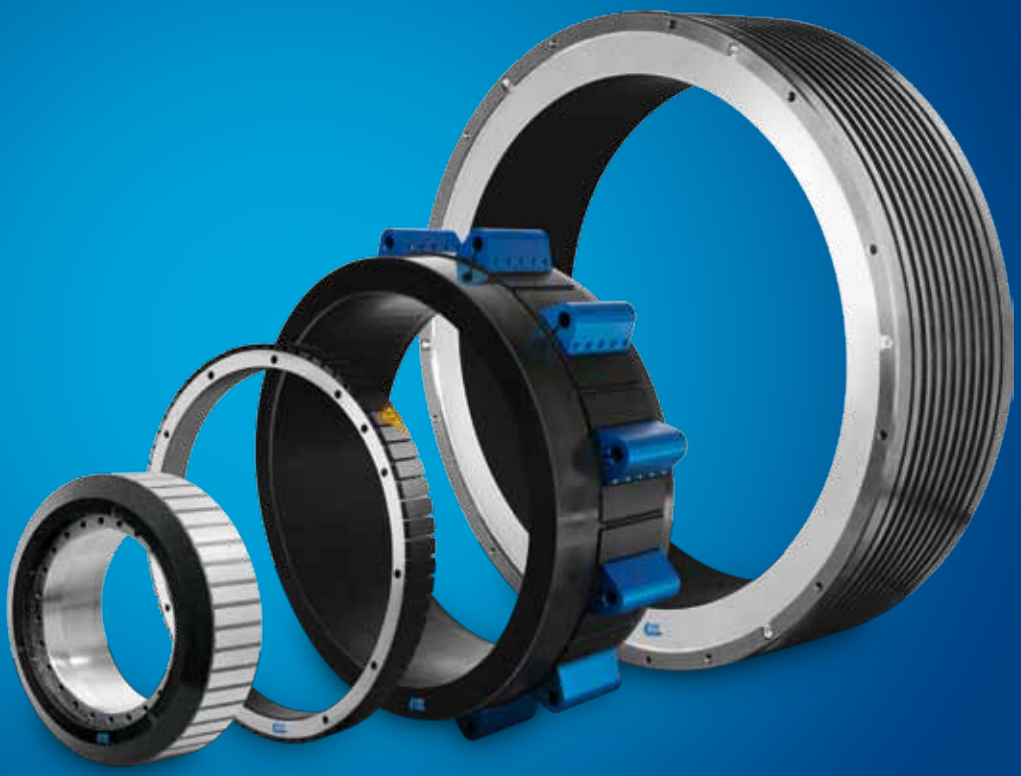


Torque **Motors**

ETEL
MOTION TECHNOLOGY

ABOUT ETEL TORQUE MOTORS

Over the last 20 years, direct drive torque motors have provided significant performance improvements in numerous applications covering a wide range of high-tech industries. Today, direct drive technology is recognized as a leading solution towards meeting the requirements of high productivity, improved accuracy, and increased dynamics of modern machinery.

Direct drive essentially means the load and motor are directly connected; or in other words, the motor "directly drives" the load. Significant improvement to stiffness and a more compact solution are among the benefits of this technology. In addition to providing high dynamic performance, torque motors reduce cost of ownership, simplify the design of the machine and eliminate wear and maintenance.

Since its founding in 1974, ETEL has been exclusively dedicated to the development of direct drive technology. Through numerous innovations and patented designs, ETEL continues to provide unmatched torque efficiency for the most optimized designs.

What is a torque motor?

Torque motors are a special class of brushless permanent-magnet synchronous motors. Since the payload is directly connected to the rotor without the use of transmission elements, torque motors are classified as direct drives.

Depending on your perspective, a torque motor is either a rolled-up linear motor or a classic servodrive with a large number of poles. It is the large number of poles that enables conventional torque motors to attain high torque at moderate speeds. Another attractive feature is their compact design which includes a narrow lamination stack and a large hollow shaft or bore.

As with linear motors, torque motors are a type of "frameless" motor. This means that the motor does not include a housing, bearings, or feedback device. These components can be selected by the machine builder and optimized according to the required performance, or purchased as part of an assembly.

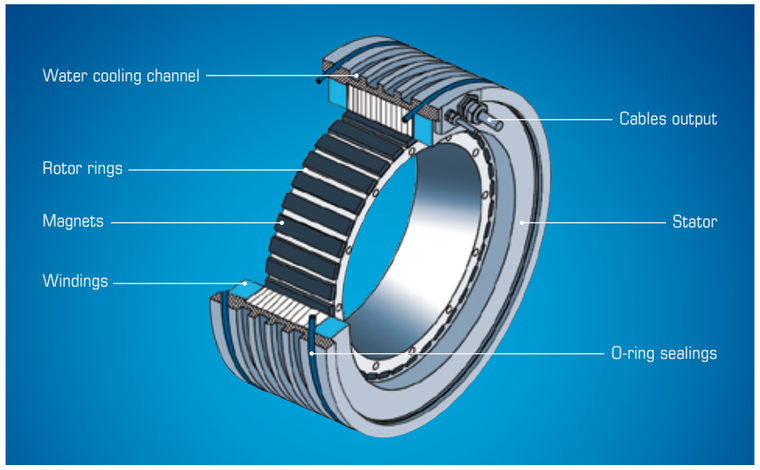
Torque motors produce high torque at moderate speeds and even when stationary or "stalled". Contrary to traditional drives, the sizing and selection of a torque motor is purely based on torque, not power. Fundamentally, the peak torque determines the maximum torque that the motor physically produces and the continuous torque defines the amount of torque the motor can continuously supply. The duty cycle of the application will define the dependency on peak or continuous torque.

Torque motor advantages

Key benefits inherent to the adoption of torque motor technology include:

- High dynamics
- High accuracy
- Optimal speed control
- Very compact design
- Outstanding MTBF
- Low maintenance

These advantages are further explained in the following pages.

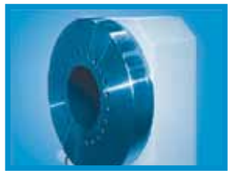


INDUSTRY SECTORS

Below are some examples of industry sectors where torque motors are successfully used, providing our customers in these areas a distinct competitive advantage.

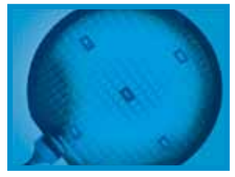

Machining


Finishing / grinding


Tables / milling heads


Stamping / laser cutting


Electronics


Semiconductor


Packaging


Printing / scanning


Telescopes


Robotics

WHY ADOPT TORQUE MOTORS?

Reduced cost of ownership

Direct coupling of the payload to the rotor eliminates the need for mechanical transmission elements such as gearboxes, timing belts, speed reducers and worm gear drives. And unlike brushed rotary motors, there is no contact between rotor and stator; therefore there is no mechanical wear resulting in excellent reliability and long lifetimes. Fewer mechanical parts also minimizes maintenance and reduces the system cost. The direct drive technology intrinsic to a torque motor system results in an efficient and effective gearless assembly.

Easy integration

ETEL's torque motors are available in a wide range of sizes and can be easily adapted to most applications. ETEL's unmatched standard product offering includes motors with external diameters from 140 mm to 1290 mm. The use of magnets and limited air gap results in a large hollow shaft or bore for easy integration of cables, cooling tubes, or other application related equipment. The ring-like configuration of a torque motor minimizes the volume required for mounting. This gives the machine designer great flexibility in locating the motor to work with bearings, feedback devices, and payload.

Dynamic performance

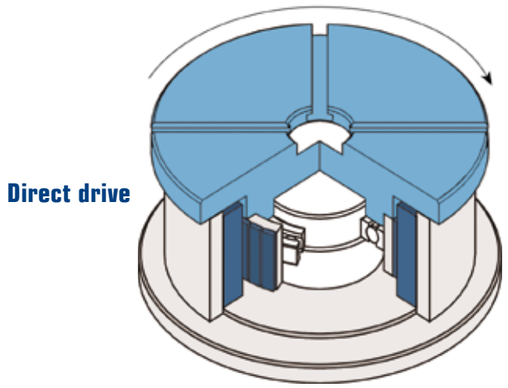
Dynamic performance is drastically improved by using direct drive due to the very high control loop bandwidth that can be achieved on the overall system. The direct coupling of the load and position feedback to the motor has the advantage of eliminating all phenomena that limit the dynamic performance on non direct driven machines. Eliminating long-time drift, elasticity, and backlash is a huge advantage for machine performance and lifetime.

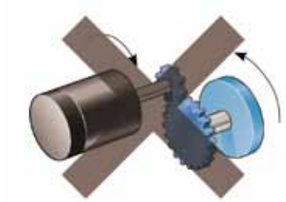
Torque motor applications have a wide range of dynamic performance requirements. Depending on the specifics of a system's duty cycle, the peak torque, continuous torque, or both will drive the selection of a motor. An application with a light duty cycle that requires high peak torque for a short period of time will typically utilize an air cooled motor like ETEL's TML series. As the continuous torque requirement increases so will the temperature of the motor. The integrated liquid-cooling capability of the ETEL TMB motor provides an efficient means of temperature control ensuring high dynamic performance that can be maintained even for the most demanding applications.

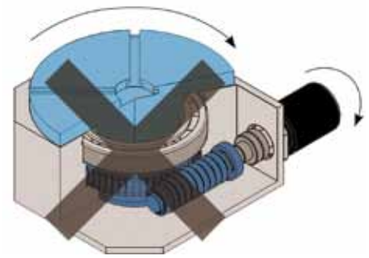
Wide torque-speed range

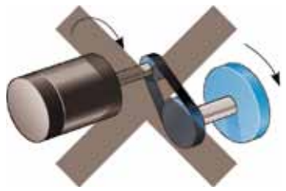
Direct drive torque motors deliver high torque over a wide range of speed, from a stalled or low speed condition to high angular velocities. While torque motors can achieve high velocities (up to 5000 rpm), there is a trade-off in torque as the motor becomes limited by speed dependent losses increase. The performance of a torque motor over its velocity range is illustrated in its torque/speed curve. An example is shown opposite.

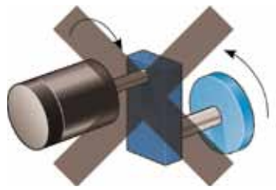
The torque motor is part of a complete direct drive solution which includes a position controller. High-end digital controllers like the ETEL position controllers, which have been designed specifically for direct drive applications provide excellent control loop quality ensuring optimum stiffness, smooth motion, and excellent velocity control with low torque ripple.



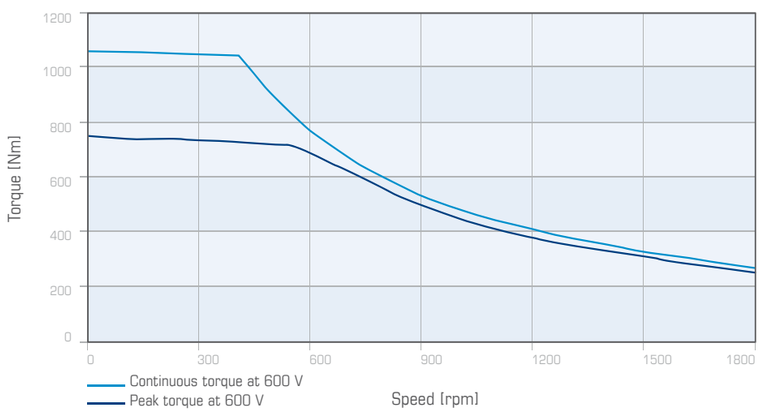

Gear train


Worm gear


Timing belt


Reducer

Torque vs. speed for: TMK0360-070-3UFS



WHY CHOOSE ETEL?

Patented technology

ETEL's patented ironcore design provides the industry's most efficient direct drive torque motors.

Unmatched performance

ETEL's patented design is well known in the worldwide direct drive market as a high performance product. For many years, the most high-end applications in the field have been driven by ETEL's motors. A continuous development effort is done to keep ETEL's leading position in the market.

Direct drive expertise

ETEL has been working strictly on direct drive technologies for more than 30 years. In addition to the motor technology know-how, through the years, ETEL has developed valuable knowledge about motion control by developing control electronics and fully integrated motion systems. Our deep understanding of the overall motion system helps us find the appropriate solution for our customers' needs.

High quality

High product quality is guaranteed by ETEL's use of modern development tools and thorough qualification procedures. All ETEL motors are manufactured in Switzerland according to highest quality standards.

Ease of integration

Compatibility of ETEL's torque motors with a wide range of control electronics results in easy integration of a direct drive solution.

Product range

With standard motors from 140 to 1290 mm in diameter and 38 to 31200 Nm of peak torque, ETEL offers the largest selection of torque motors on the market.

The majority of ETEL torque motors can be ordered with or without water cooling channels. Furthermore, different winding types are available to best fit our customers' applications.

TORQUE MOTORS

ETEL offers the most comprehensive standard torque motor range in the industry. With more than 100 models to choose from, almost any requirement can be successfully fulfilled. ETEL also excels in developing custom motors to meet a specific application need.

ETEL's TM series are the industry's most popular ironcore frameless torque motors. Powerful magnets are used to maximize torque and acceleration while minimizing the size of the motor. The performance of ETEL's torque motors have been further increased by the use of "buried magnet" technology on the latest TMK family.

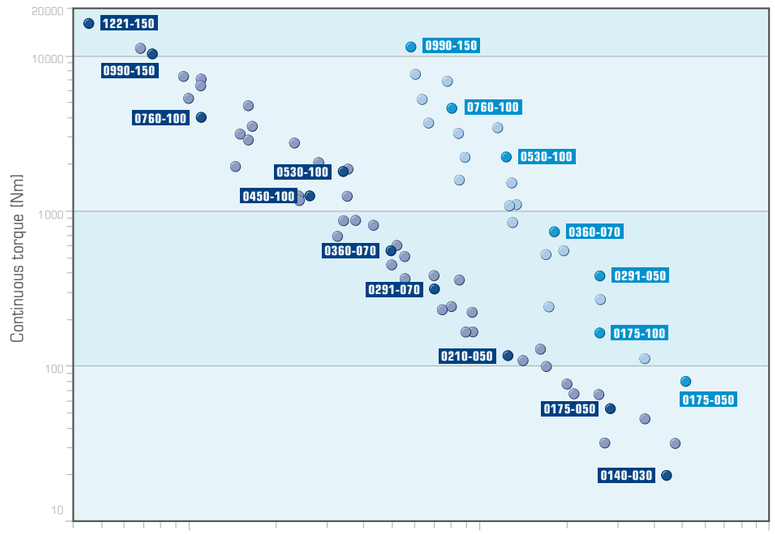
The TMB motor series is today's industry preferred torque motor solution. This renowned family is designed with a precision stator and has been optimized to achieve very high continuous torque while minimizing the dissipated heat when liquid cooling is used. For more demanding applications, the TMK family can achieve more torque and significantly faster speeds than TMB motors thanks to its unique rotor design. In addition, the TML family can be used to reach high performance at a lower price in less demanding applications. All families of torque motors benefit from ETEL's patented ironcore design that provides unmatched torque efficiency and low torque ripple.

PERMANENT MAGNETS SYNCHRONOUS TORQUE MOTORS

		MODEL	DESCRIPTION	APPLICATIONS
TRADITIONAL FLUX	 **With cage** • More than 50 models • External diameter from 160 to 1290 mm • Large hollow shaft from 60 to 1070 mm • Peak torque from 38 to 31200 Nm • Maximum rated speed up to 4500 rpm • Low torque ripple	TMB	• Designed for the most demanding applications • Liquid cooling channels • 600 VDC bus voltage • Very high continuous torque • Very high peak torque	• High speed milling / turning tables • High precision machining centers • Grinding / finishing machines • Boring / drilling / tapping machines • Milling heads • Transfer lines • EDM • Laser / ultrasonic cutting machines • Stamping machines • Lathes • Indexing tables • Electronic chip testing equipment • Pick-and-place machinery • High-end printing / scanning machines • Packaging equipment • Handling equipment • Composite materials manufacturing • Telescopes
	 **Without cage** • External diameter from 140 to 581 mm • Large hollow shaft from 60 to 420 mm • Peak torque from 38 to 4990 Nm • Maximum rated speed up to 4500 rpm • Low torque ripple	TML TMM	• TML: TMM motors with lugs • No liquid cooling option • 600 VDC bus voltage • Very high peak torque	
CONCENTRED FLUX	 **With cage** • External diameter from 198 to 1050 mm • Large hollow shaft from 50 to 800 mm • Peak torque from 113 to 19900 Nm • Maximum rated speed up to 5170 rpm • Low torque ripple	TMK	• Powerful high speed ironcore torque motor • TMK stator (up to Ø530 mm) compatible with the mechanical interface of the TMB series • Liquid cooling channels • 600 VDC bus voltage • Continuous torque increased by up to 30% vs TMB • Very high peak torque • Up to 8 times speed increase vs TMB • Field weakening compliant	

Torque motors range

ETEL's standard torque motors are available in a wide range of torque and sizes.



Custom motors

With over 30 years of direct drive innovation, ETEL has the expertise to quickly and efficiently adapt existing products into custom solutions. The process is made simple due to the modular and flexible design of our torque motors. ETEL can also develop a completely new motor design to address a particularly demanding or unusual requirement.

ETEL's experience also includes:

- Ironcore and ironless motors
- Integrated cooling
- Transverse flux
- Segmented motor
- Combination with linear axis
- High and low temperatures
- Vacuum
- Hazardous duty rating
- UL certified
- Aerospace motors

DIRECT DRIVE SOLUTION

To achieve optimum performance from a direct drive motor it must be built to the necessary standards of precision and stiffness as part of a complete direct drive solution. In addition to the motor, the four key components of a direct drive system are the electronics, encoder, bearings and machine structure. Each of the four components is briefly described in the following paragraphs.

Electronics

The best torque motor performance is achieved when integrated with a fully digital controller with extremely high bandwidth capability like the ETEL AccurET position controllers family.

In a direct drive system, the controller can benefit from a very precise position feedback due to the fact that there is no transmission in between the feedback device and the load. Because of this high quality feedback signal, a high-end controller (such as ETEL's AccurET) can compute advanced control algorithms at a very high frequency. Ultimately, the precision and the dynamics of the axis are drastically increased.

Some key factors to be taken into account when selecting a controller are listed below:

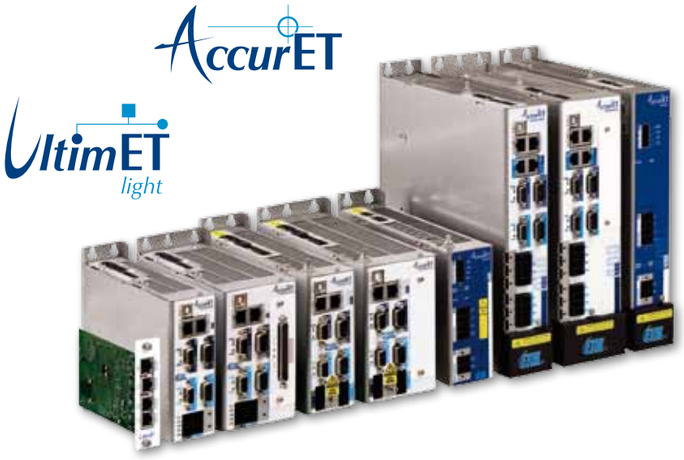
- High frequency control loops (current, speed, and position loops).
- High current and position loop bandwidths (typically >2 kHz and >100 Hz respectively).
- High encoder interpolation factor to ensure adequate speed and position resolution.
- Advanced control algorithms (PID with feed-forward, state space regulators, observers, notch filters, etc).
- Advanced features: ability to compensate for cogging torque, stick slip, and other system repeatable phenomena.

ETEL's torque motors have been successfully integrated with most major brands of servo controllers and CNC including: Heidenhain, Siemens, Fanuc, Bosch, B&R, Kollmorgen, and Num.

Encoders

High precision, high resolution feedback is essential for achieving optimum performance using direct drive. Direct coupling of the load to the drive improves accuracy but the best performance can only be achieved with the appropriate feedback device. This requires an absolute or incremental optical encoder with a high line count. When combined with the interpolation capability of the electronics, resolutions of less than 1 arcsec can be achieved.

Picture courtesy of Dr J. Heidenhain GmbH



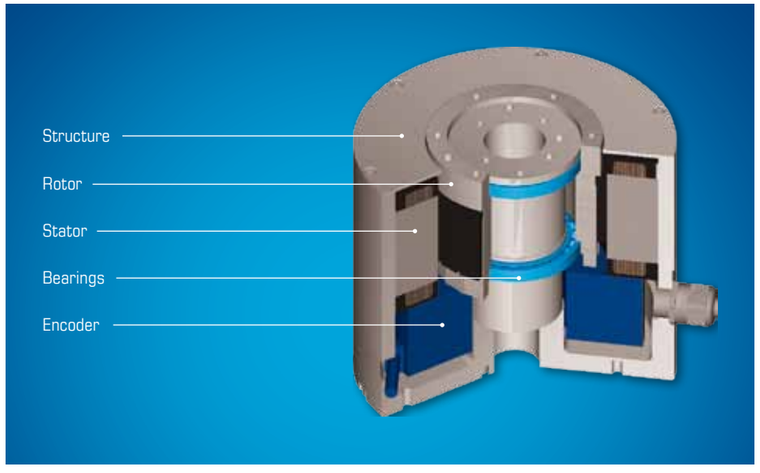
Electronics

ETEL's AccurET/UltimET controller family is especially designed for a variety electronics and semiconductor related applications, where extremely high precision is needed without any compromise on throughput.

They can provide:

- High position accuracy
- Close to zero settling time
- High dynamics
- Multi-axis interpolation
- Fast communication bus
- And much more…

For more information, refer to our **Motion Control** brochure.



Bearing

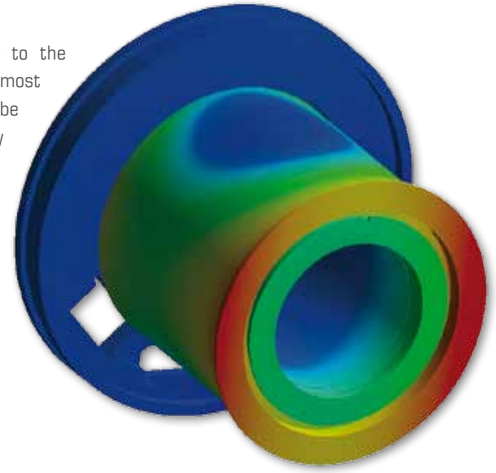
Bearing selection depends on system properties like dynamic load, accuracy… Applications that require high stability, accuracy, and repeatability will typically use high stiffness bearings to meet their performance needs. Mechanical bearings are often the only wear-prone components in a direct drive based system. The most commonly used bearings are:

- **Deep groove ball bearing**
  High speed capability, low cost
- **Angular contact ball bearing**
  High speed capability, suitable for combined loads (axial & radial), high precision
- **Crossed roller bearing**
  Suitable for combined loads, high stiffness, low speed, high precision, assembly with one single bearing
- **Axial-radial roller bearing**
  Very high stiffness, suitable for combined loads, high precision
- **Axial-radial ball bearing**
  Very high stiffness, suitable for combined loads, high precision

In addition to mechanical bearings, air and hydrostatic bearings are often used for ultra-precision applications such as diamond turning/milling, silicon dicing, precision grinding and high accuracy metrology axes.

Structure

Special attention must be paid to the machine's structural stiffness. In most applications the structure should be designed with a natural frequency above 200 Hz. Finite element analysis is typically used as a design validation tool. Below is an example of typical FEM simulation of radial load stiffness on an ETEL rotary table design.



TORQUE MOTOR SELECTION

Many factors must be taken into consideration when choosing a torque motor to ensure outstanding system performance. This brochure provides a basic overview of some of the key selection factors that should be taken into account when choosing a torque motor. For detailed calculation and sizing information, please refer to the ETEL torque motors handbook, or ask an ETEL application and support engineer for assistance.

Motor sizing

The first step in a torque motor sizing is to define the torque and speed requirements for the application. The torque required for each move within the cycle can then be used to determine the continuous torque. When calculating the continuous torque it is important to include all sources of torque such as friction, machining torque, static force due to an offset load, and external perturbations.

Power dissipation of the motor is estimated calculating the continuous torque. The amount of heat produced by motor power dissipation will determine the temperature increase of the structure and if liquid cooling is required.

Under static conditions with an applied load, one motor phase can get disproportionately hot, because the power dissipation is not shared equally among all three phases. To ensure safe operation under these conditions a stall torque calculation should be performed.

ETEL's motors are available in several winding configurations. The winding should be chosen to match the speed requirements of the application and the voltage and current specifications of the electronics. Note that the torque/speed characteristics of a motor change with the winding.

Detent effects

Thanks to a patented design, ETEL has the expertise to manufacture ironcore torque motors with very low detent effects. The patented design uses an innovative combination of open slots, orthocyclic windings and fractional pole pitch. This solution significantly reduces detent effects without any skewing of laminations or magnets which would result in lower torque density.

Motor constant

The motor constant, Km, is one of the key parameters for comparing permanent magnets synchronous motors. It shows the relationship between torque produced and resulting power losses. A motor with a higher value of Km is a more efficient generator of torque.

Km is determined by the design and construction of the motor. This parameter is related to the internal design of the motor (copper filling factor, electromagnetic design, etc). Therefore, it is a better indicator of motor performance than the torque constant, Kt (Nm/Arms), which relates torque output to the supplied current. In ETEL motors, Kt can be easily adjusted by changing the winding type. Kt is useful for matching a motor to a servo amplifier, but it does not provide information about the motor's efficiency.

Thermal considerations

Like all servo motors, torque motors generate heat in operation. In order to reduce thermal expansion of the machine, this heat has to be removed as efficiently as possible. ETEL TMBs and TMKs torque motors provide optimized cooling channel design to ensure a maximum heat evacuation through the coolant. Keeping the machine structure cold is mandatory to reach high precision and repeatability levels.

Torque motors can be cooled either by free air convection or with a coolant. Liquid cooling is recommended for demanding applications where a coolant is available. Due to their optimized electromagnetic design, ETEL's torque motors produce much more torque for the same input power than competitive products.

On any direct drive application, the thermal management is of major importance and closely related to the final machine performance. In fact, in a direct drive axis, the motor is located very close to the working point. This is a big advantage in terms of mechanical stiffness and leads to unmatched machine performance. However, the fact that the motor is highly integrated also means that the heat generation is closer to the critical area than in a conventional worm gear system for example.

ETEL has a long experience in torque motor integration and heat management. Do not hesitate to contact your ETEL's representative to get support during machine design.

Torque motors - Data sheets

ETEL torque motor specifications are available in the ETEL torque motors data sheets.

This booklet includes the performance specifications, torque/speed curves and mechanical dimensions of each standard ETEL motor. In addition, an overview of the ETEL torque motor product range and a motor comparison chart is provided.

Torque motors - Handbook

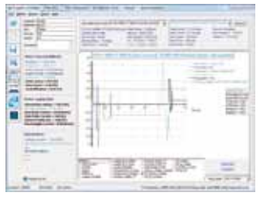
For more information on motor selection and integration, ask for the ETEL torque motors handbook from our website.

ETEL Website

For more information about the torque motors or to download the data sheets booklet, refer to our website: www.etel.ch

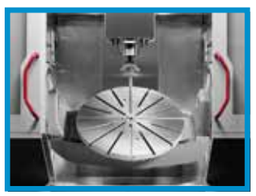
ETEL Sizing Tool

ETEL has developed a powerful sizing tool that can simulate the customers' machine operation. This tool will help you getting the very best "performance/price" ratio that can be obtained on your specific application. Do not hesitate to contact your local ETEL sales office to get technical support during the machine design phase.



CASE STUDIES

Large TMKs enable milling / turning feature



ETEL has been active and present for many years in the machine tool industry, particulary with high-end machines using the TMB motor range. Nowadays, the TMK motor range strongly contributes to customers' success and uniqueness by providing substantial adding value to their products. In this case, the integration of TMK motors in a CNC 5-axis machining center made the "Milling/Turning" option possible on these large high-end machines. For instance, using a large TMK motor size made the milling and rotational machining at 500 rpm of parts that could weigh up to 1000 kg in a single clamping possible. This specific Milling/Turning feature drastically increases the machine productivity without any comprise on precision and performance.

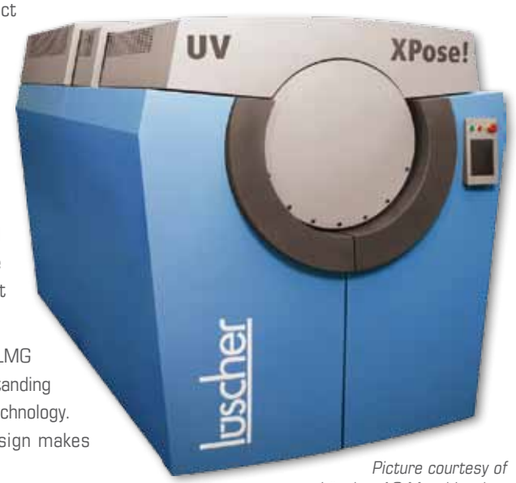
In addition, the upgrade of an existing TMB based machine to a high speed TMK based machine is made easy thanks to the fact that TMB and TMK motors are nearly pin-to-pin compatible. The TMK series is available in a very wide range of sizes to fit any applications *(see pages 6 and 7)*.

Pictures courtesy of
Maschinenfabrik Berthold Hermle AG

Small TMKs in high-end printing

In high-end printing machines, smooth and accurate motion is a key factor to success. On machines targeting 8000 dpi and more with a precision down to 50 nanometers, the choice of the motor is crucial. Speed stability has to be perfect to ensure good printing quality while maximizing machine throughput which, like in many other applications, is a key specification to be successful in the market. In this case, the use of a TMK high speed motor allows both a stable high speed operation and very short acceleration/deceleration times. In addition to that, in this specific application, the TMK motor has been slightly customized to reach optimal machine performance in forced air cooling mode (see picture). Finally, the very high torque density of the TMK motor contributes to the overall compact size of the machine to best fit the industry standards.

ETEL linear motors are also integrated in the presented machine. ETEL's LMG motors are used for the linear motion of the exposing drum. To reach outstanding performance, the full motion system has been designed based on direct drive technology. The combination of ETEL motors and optimized control and mechanical design makes this machine very successful in its industry.



Picture courtesy of
Lüscher AG Maschinenbau

TMBs in high-end machine tool

ETEL's longstanding and renowned TMB motor range is still widely used and valued in the machine tool industry. The well known advantages of direct drive technology associated to the outstanding performance and reliability of ETEL products contributes to our customers' success.

In some fields of applications like aerospace or power generation, precision and quality are a must in component machining. For instance, in these 5- or 6-axis machines, the key criteria for productivity are stability, dynamics, and agile contouring capabilities. Meeting the specifications of the machine becomes even more challenging when materials to be machined are "difficult-to-cut" materials such as titanium or super-alloys. In this case, direct drive technology and more precisely ETEL's TMB motors play a major role in the overall machine performance.

The limited production related to this specific high-end market naturally defines some key factors such as: flexibility, optimal performing and low cost of ownership. With 10 different motor diameters (from 140 mm to 1290 mm) the very wide TMB range perfectly fits these kinds of applications where flexibility on standard products is needed with absolutely no trade-off on performance and quality.

Pictures courtesy of
Liechti Engineering AG

CASE STUDIES

ETEL torque motors in rotary tables

In addition to ETEL's long-lasting collaboration with high-end market-leading machine tool manufacturers, ETEL also closely collaborates with sub-components makers such as rotary table builders. These companies concentrate their effort to build a highly-optimize single axis product to reach outstanding performance. The wide range of standard torque motors offered by ETEL is a key element in helping table makers meet the needs of the most demanding customers.

Picture courtesy of Weiss GmbH

ETEL provides the widest range of standard torque motors on the market with diameters from 140 mm up to 1290 mm. As such, table designs can be made flexible to fit with different standard TMB sizes as well as with the new high speed TMK motors. This flexibility provides the final customer with a dedicated solution based on a proven and stable design. The optimal selection of bearings, encoders, and torque motors finally results in one of the most advanced rotary tables with undeniable advantages. These are mainly linked to the absence of mechanical elements and gears. The result is high speed, high stiffness and zero backlash table that is more compact than conventional tables.

ETEL is part of pioneering challenges

In addition to supplying high technology products to our main markets, we are also proud to improve our existing competencies by addressing new technological challenges that push back the limits of the impossible. ETEL torque motor technology, for instance, is being used in many challenging scientific undertakings to do just that. The ultra-lightweight revolutionary airplane from Solar Impulse, capable of flying days and nights without fuel, is fascinating case study. This airplane is combining the most advanced scientific knowledge in terms of aeronautics, materials, photovoltaic energy, and electrical motors.

For this unique aircraft; reliability is not just a nice-to-have, it is vital! The quality of the ETEL torque motors operating in the most extreme environmental conditions is a key success factor. The performance has to be maintained optimal and constant during non-stop flights for multiple tens of hours for which failure is not an option. In addition, the motor efficiency must reach extremely high values to maximize the use of the precious solar energy. By using the same base technology ETEL is using in standard TMB and TMK motors, an efficiency of 96% can be reached. Finally, in such a project, the weight reduction is a continuous effort.

ETEL torque motors in 5-axis machines

About twenty years ago, ETEL started to develop direct drive motors to serve the industry. It took a few years to convince the machine tool industry that direct drive torque motors were the solution for their future needs. ETEL being the first supplier of torque motors, had the chance to set what became the standards in terms of dimensions and performances. At that time, this very fast evolution of machine tool toward direct drive was lead by the most renowned European machine tool makers.

Today, machine tool makers are present all over the globe and are becoming stronger in some Asian countries like Taiwan for instance. ETEL followed this trend by opening offices in five key Asian countries to provide the best possible local support starting collaboration in the very early phases of new machine development. The use of high-end core components like TMB motors and NC Controllers allowed Asian companies to develop award winning 5-axis machines. These machines meet the most demanding specifications in diverse applications including die and mold, energy, and automotive markets. By using direct drive TMB motors in both A and C axes, parts up to 1000 kg can be machined with the highest level of precision and surface qualities. In addition, the machine reliability benefits from the quality of ETEL products and can proudly compete with the most advanced European 5-axis machines.

Pictures courtesy of WELE Mechatronics Co., Ltd.

All components down to the smallest screw are designed to have the best performance-per-weight ratio. This weight optimization was also applied to the torque motors to get the very best mechanical power out of the smallest possible space. Once again, the ETEL technology was perfectly suited to serve these needs as well.

Finally, it is a combination of ETEL torque motor technology together with the most advanced technologies from other fields that allowed this airplane to successfully fly days and nights across Europe. The next step will be a round trip of the globe, and ETEL is proud to be part of this new challenge.

Picutres courtesy of Solar Impulse SA www.solarimpulse.com

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