ПРИЛОЖЕНИЕ НА ЛИНЕЙНИТЕ МОТОРИ В CNC МАШИНИ
APPLICATION OF LINEAR MOTOR IN CNC MACHINES

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Abstract: Today's linear motion applications on CNC machines are more demanding than ever before. Faster throughout, more exact positioning, longer life, less maintenance, fewer moving parts, this list is never ending and every day it increases. Motion control companies strive to meet and exceed these requirements by continual technological advancement and embedding on new technology in CNC machines.
Key words: CNC machines, linear motor.

1. Introduction

Basic linear motion elements rising to the high speed, high accuracy challenge is: linear bearing, linear encoders and linear driven.

Less than a decade ago, it was a difficult task to find a commercially available linear bearing that could travel 5 meters per second with straightness, load capacity and stiffness. Today there are many linear bearings with these attributes and they are fairly cost effective.

Advancements in linear encoder technology allow higher speed operation too. Today's linear encoders and other devices are able to meet this challenge, they are protected from dust, chips and splash fluids and are ideal for operation on machine tools, and cost less. Absolute linear encoders require no previous traverse to provide the current position value. The encoder transmits the absolute value for absolute position.

So with two of the three primary linear motion elements rising to the high speed, high accuracy challenge, the limiting factor is the drive drain.

Linear motors provide unique speed, acceleration and positioning performance advantages. Linear motors provide direct-coupled motion and eliminate mechanical transmission devices (Ball Screw).

Linear motors provide the following advantages:

– High repeatability – resolution to 0.1 microns (0.000004 inch) – this makes sure all parts produced are accurate and identical;

– Highly accurate – to 2.5 micron/300 mm (0.0001 inch/ft) – provides precise machine operation for precision parts;

– No backlash – direct drive has no backlash such as with lead screws, gears, etc. this improves the accuracy of the part or operation;

– Faster acceleration – from 1 to over 45 G's – this leads to shortened cycle times and improved productivity;[1]

– Higher velocities – speeds to over 8 meters/sec (300 inches/second) – to position the payload faster; [2]

– Long term reliability – only two parts with only one moving part – this leads to simplicity and improves the applications reliability;

– No wear or maintenance – no contacting parts, thus reducing component friction and wear;

– Ease of installation – linear motors are designed to allow for alignment tolerances. Misalignment produces no degradation of performance.

Due to the advantages of linear motors more companies engaged in the design and manufacture of machine tools embedded linear motors drive axles, removing existing actuators "ball screw – servo motors".

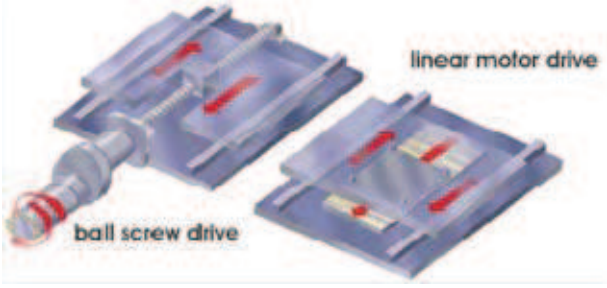

Fig. 1 Scheme of driven by "*ball screw*-servo motor" and linear motor

2. Companies embeds linear motors in CNC machines

Sodick – Japan [3]:

Utilising the linear motor drive system, *Sodick* die-sinker EDMs and wire-cut EDMs have enabled difficult machining operations that were not possible with conventional ball screw-type EDMs, resulting in the cumulative shipment of more than 31000 units by early 19.06.2012.

The linear motor-driven EDM, eliminates the need for ball screws and allows for non-contact motion. Use of the linear motor removes the deterioration in machining accuracy caused by the worn ball screw assemblies throughout the machine life. The most outstanding features of the *Sodick* in-house developed and manufactured linear motors are high-speed axis motion and quick response, which result from wear-free motion and without the need for old-fashioned ball screws. Conventional drive systems use ball screws to convert the rotational motion of the motor into the linear motion of the axis stroke, leading to the unavoidable deterioration in response of high speed servo motors due to back-lash and mechanical lost motion. However linear motors directly provide motion to each axis without converting rotational movements of motor to linear motion.

Sodick's confidence in the performance and accuracy of their machines over a 10 year period allows them to be the only manufacturer to offer a 10 year positioning accuracy guarantee on all their Linear EDM Machines.

Sodick offers a full range Wire EDM machines from small ultra-precise model to XXL size machine. Regardless of size, all series Wire EDM is available with linear motors of the 4 axes and ceramic components as standard to ensure the high performance cutting operations that customers expect from *Sodick*. Linear high wire EDM: AG400L, AG600L; introduced a new linear wire EDM: AQ750L, AQ900L, AQ1200L (large size); VZ300L, VZ500L (small size). The average AG Series is the best-selling range of Wire EDM machines.

Precision die-sinker EDM. The entire range of *Sodick* die-sinker EDM machines are also characterized by linear motors in 3's axes. The best selling range of *Sodick* die-sinker EDM machines "AG series" ensure speed and accuracy, while reducing wear of the electrode: AG40L, AG60L. Large size die-sinker EDM machines: AG80L, AG80L LST, AG100L. Largest die-sinker EDM machines: AQ15L. Introduced a new linear die-sinker EDM machines: AD30L, AQ45L.

Sodick EDM has developed and high centers that can achieve accuracy at the Nano technology. The linear motor drive precision Wire-cut EDM: AP250L. The linear motor drive precision Die Sinking EDM: AP1L, AP3L.

Hole drilling EDM machines. *Sodick`s* K-series range of machines can produce very small wire EDM start holes quickly and efficiently, as well as other small diameter drill holes. The K-series line up features K1C and K3HN, with a wide range of capabilities determined according to the application needs. The K1BL is an easy-to-use micro-hole EDM machine for hole diameters up to 0.08 mm. The high-end hole driller K3BL allows the use of electrodes with diameters of 0.08mm to 3.0mm.

High-speed milling machines. All the *Sodick* high-speed milling range, the "HS series" features linear motor. To complete successfully in today`s global market, manufacturers are looking for milling solutions which combine very high accuracy with minimum cycle times. The HS Series satisfies the most demanding application requirements: HS430L, HS650L, HS650L 5-axis.

Studer – Switzerland [4]:

In 2004, *Studer* presents high speed cylindrical grinding machine S12, using the drive axes X and Z linear motors. Speed on axis X and Z: 0.001÷30 000 [mm/min.], resolution 0.00001 [mm].

In 2005, *Studer* presents high speed cylindrical grinding machine S22, using the drive axes X and Z linear motors. Speed on axis X=0.001÷15 000 [mm/min.], resolution 0.00001 [mm]; Z=0.001÷30 000 [mm/min.] resolution 0.00001 [mm]. With conventional drive speed on axis X=0.001÷15 000 [mm/min.], resolution 0.00005 [mm]; Z=0.001÷30 000 [mm/min.] resolution 0.00005 [mm].

DMG (Deckel Maho, Gildemeister) [5]:

DMG has a large range of lathes and milling machines, which begins to embed linear drives one of the models:

CNC vertical lathes machines: CTV 160 linear, CTV 250 linear.

CNC swiss-type automatic lathes machines: SPEED 12|5 linear, SPEED 12|7 linear, SPEED 20|8 linear, SPEED 20|11 linear, SPEED 32|10 linear.

CNC automatic lathes machines: SPRINT 20 linear, SPRINT 32 linear, SPRINT 42 linear, SPRINT 50 linear, SPRINT 65 linear.

CNC multi-spindle turning centers/ multi spindle automatic lathes machines: GMC 20 linear / ISM, GMC 35 linear / ISM, GMC 25 linear / ISM, GMC 42 linear / ISM.

CNC universal milling machines for 5-sided/5-axis machines: DMU 40 eVo linear, DMU 60 eVo linear, DMU 80 eVo linear, DMU 100 eVo linear.

Travelling column milling machines: DMF 180 linear, DMF 260 linear.

High-speed cutting precision centres: HSC 20 linear, HSC 55 linear, HSC 75 linear, HSC 105 linear.

Machining of advanced materials: ULTRASONIC 20 linear.

Laser fine cutting of thin metal sheets: LASERTEC 20 Fine Cutting.

FOOKE – Germany [6]:

FOOKE produces 5-axis gantry milling machines more than 25 years. Since 2003 began using linear motors to drive axles.

Gantry milling machine ENDURA® 600LINEAR. Travers paths: X-axis=5÷10 [m], Y-axis=2.8/3.5 [m], Z-axis=1.2/1.5 [m]; feed rates on axis X=Y=Z=5÷65000 [mm/min]; acceleration up to 3.0 [m/s2].

Compact gantry milling machine ENDURA® 700LINEAR. Travers paths: X-axis=2.2 [m], Y-axis=2.8 [m], Z-axis=1.2 [m]; feed rates on axis X=Y=Z=5÷65000 [mm/min]; acceleration up to 3.5 [m/s2].

Gantry milling machine ENDURA® 900LINEAR. Travers paths: X-axis=2÷20 [m], Y-axis=2÷4 [m], Z-axis=0.8÷3 [m]; feed rates on axis X=Y=Z=5÷65000 [mm/min]; acceleration max. 10 [m/s2]; repeatability on axis X=Y=Z=±0.010 [mm]; position accuracy on axis X=Y=±0.015 [mm], Z=±0.010 [mm].

Travelling column milling machine ENDURA® 1000LINEAR. Travers paths: X-axis=8÷60 [m], Y-axis=2÷5 [m], Z-axis=0.8÷3 [m]; feed rates on axis X=Y=Z=5÷55000 [mm/min]; acceleration max. 5 [m/s2]; repeatability on axis X=Y=Z=±0.015 [mm]; position accuracy on axis X=Y=±0.025 [mm], Z=±0.020 [mm].

Lateral milling machine ENDURA® 1100LINEAR. Travers paths: X-axis=2÷20 [m], Y-axis=0.8÷3.5 [m], Z-axis=0.4÷1.2 [m]; feed rates on axis X=Y=Z=5÷65000 [mm/min]; acceleration max. 10 [m/s2]; repeatability on axis X=Y=Z=±0.010 [mm]; position accuracy on axis X=Y=±0.015 [mm], Z=±0.010 [mm].

Matsuura – Japan [7]:

Matsuura produces 5-axis machining centers. Since 2011 began using linear motors to drive axles.

At the moment proposes 5 milling center, the drive be carried out with linear motors: LX-160, LS-160, LF-160/LV-500, LX1 и LX1500.

Mazak – Japan [8]:

Mazak machining centers producing machine. To be competitive start to use linear motors to drive the axes in some of their machines.

Horizontal Machining Centers: Triple F-660L.

Vertical Machining Centers: HYPERSONIC 1400L, SUPER VELOCITY CENTER 2000L/200-II.

Multi-Tasking Machines: HYPER VARIAXIS 630.

Laser Processing Machines: Hyper Turbo-X 510.

These are some of the manufacturers of machine tools, which commenced in the last 2 ÷ 13 years using linear motors to drive its axis. Worldwide there are more small machinery manufacturers that take advantage of the linear motors up to current conventional driven “ball screw – servo motor”.

3. Manufacturers of linear motors

Due to high demand for linear motors companies engaged in the manufacture of drives included in the assortment, and linear motors: “Fanuc”- Japan [9]; “Etel” - Switzerland [10]; “Tecnotion” – Netherlands [11]; “Siemens” – Germany [12]; “Baldor” – USA [13]; “Aerotech” – USA [14]; “Kollmorgen” – USA [15]; “Hiwin” – Taiwan [16]; “Boschrexroth” – Germany [17]; „Omron” – Japan [18]; “Yaskawa” – USA [19]; “Parker” – USA [20]; “Iko Nippon Thompson” – Japan [21]; “Baumuller” – Germany [22]; „H2W

Technologies” – USA [23]; “Schaeffler Technologies AG & Co” – Germany [24]; “CHIEFTEK PRECISION CO” – Taiwan [25]; “Airex” – USA [26]; “Rockwell Automation” – USA [27]; “PBA Systems” – Singapore [28].

These are not all manufacturers of linear motors in the world, but one of the greatest traditions in the production of machine tool drives.

4. Conclusions

The use of linear motors in machine tools becomes greater. This is due to advantages of linear motor over conventional driven “ball screws – servo motor”.

CNC machines with linear motors are more accurate and faster than the machine driven “ball screw – servo motor” and the ability to provide high-precision processing.

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