Improvement of MSPA Module of Stepping Piezo Actuator and industrial applications in piezo motors

Alexandre PAGES 1[1,*], Adrien GUIGNABERT 2[1], Jonathan STENTZ 3[1], Frank CLAEYSSEN 4[1], Jolan GAUTHIER 5[1]

[1] *Cedrat Technologies, 59 Chemin du vieux Chêne, 38240 Meylan*

*alexandre.pages@cedrat-tec.com

Abstract— **The following paper is based upon the latest improvements of MSPA Module of Stepping Piezo Actuator to provide an option for appropriated linear and rotary motional applications. Starting from breadboards, MSPA modules and stages have been developed to reach series of complex mechanisms.**

I. Introduction

The EU project "EUREKA EUROSTAR ELVISA", involving CTS-Noliac (Denmark) and CEDRAT TECHNOLOGIES (CTEC), France, as coordinator, has funded part of the development of this MSPA piezo module. This paper presents three technical challenges encountered during the development of the product and the most recent developments with both linear and rotary motors.

II. The technical challenges

A. Noise reduction

The excitation from the contact can mainly be divided into two parts: i) the periodic components due to the frequency of the piezoelectric actuator (corresponding to the stick-slip frequency); ii) a large band excitation due to the impulsive excitation corresponding to each phase of macroscopic slip. In fact, the macroscopic slip phase corresponds to an impulsive release of elastic energy of the system, which occurs periodically [1]. The immediate consequence of the excitation coming from the contact is both a localized acoustic emission from the contact interface and the vibration of the system components due to its dynamic response. These vibrations, in turn, are at the origin of the acoustic emission due to the noise radiation from the component surfaces. Several approaches are proposed to reduce the typical noise from 80dBa down to 45dBa.

The first proposed approach involves elegant configurations in order to cancel micro vibration resulting from stick slip accelerations. Such a design is being tested and is believed to cancel first order vibrations. Another approach leading to noise reductions is to introduce decoupling features within the motors. Decoupling modules are used to damp undesired vibrations responsible for noise, without reducing the efficiency of the force transmission as well as the coupling coefficient with the load. The choice of material for the dampers is deemed critical, since it has to remain compatible with thermal/vacuum environment. Stability of performances is essential.

B. Miniaturization at low voltage

Several prototypes have been designed. One is "macro-sized" (30x20x10mm) working at 48V, the second is "micro-sized" powered at low voltage below 60V. It is proposed to address the limitations by means of technological investigation: For macroscopic, larger size applications a preliminary test bench has been realized, using one preliminary breadboard module of an MSPA, associated with off the shelf long stroke linear guide. Such a test bench is useful to extract data and prioritize limitations. In that regard, measurement of noise, linearity, repeatability and accuracy is established as the base line performances. The scope of this bench is to run the life time endurance testing before designing a final prototype.

For small-size, embeddedapplications the idea is to get the smallest available low voltage piezo material from CTS-Noliac and to prove the possibility to manufacture and mount the mechanical parts of the motor. The machining feasibility is evaluated using electro-discharge machining. Beyond the manufacturability method, there is also the requirement to assemble the micro actuators and achieve the correct preload.

C. Integration of the MSPA module

A demonstrator has been developed in order to evaluate performances of a MSPA used for a rotating stage. Magnets on the bearing are used to add an inertia representative of the component to position. The aim of working on a small radius bearing is to have a high rotation speed (keeping the same linear speed at a different radius). Rotation speed up to 2.5 rad/s are achieved. However, the motor is noisy at around 67 dBA at 50 cm, therefore it has been decided to introduce decoupling technics for noise insulation: The result is currently 50 dBA at 50 cm.

The origin of the noise has been localized. It arises mostly from the vibration of the plate on which the elements are fixed. This vibration is transmitted from the APA and the bearings to the plate. On this basis, another solution to reduce the noise is to reduce the size of the plate. The noise in this configuration is now around 45 dB at 50cm. The loss of stiffness of the plate is without remarkable consequences on the performances of the MSPA.

III. Latest developments

A. Micro rotary piezo motor using MSPA for tracking and shutter applications

A demonstrator has been developed in order to evaluate performances of a micro MSPA (integrating the micro size APA) used for a rotating stage aimed to tackle a specific customer requirements.

FIGURE 1. Rotating MSPA30UXS

A polarizing cube of 1cm^3 is placed directly on the bearing to add an inertia representative of the final load. The aim of working on a small radius bearing is to have a high rotation speed (keeping the same linear speed at a different radius). Rotation speeds up to 2.5 rad/s are achieved. However, the motor is noisy at around 67 dBA at 50 cm, therefore it has been decided to introduce decoupling technics for noise insulation: The result is currently 50 dBA at 50 cm. A test aimed to evaluate the maximal speed and acceleration of the micro rotary stage has been performed. It consisted in a back and forth motion while driven at optimal performance signal.

One of the main objective of the customer is for the motor to be able to track a constantly evolving angular position target with a precision close to 1mrad. Using integrated position sensor and CTEC SPC45 controller, a position tracking with an error of less than 2mrad RMS was reached.

Another rotary piezo motor using MSPA is in development phase for a shutter application with the expected performances in table 1.

TABLE 1. shutter expected performances

Type	Value	Unit
Power in Stand-by	50	mW
Power on	500	mW
Max mass	20	g
Switching time	0,3	s
Rotation angle	45	°
Speed	2,5	rad/s

B. Linear MSPA-based stage

A compact 100mm stroke linear MSPA-based stage was designed and prototyped. At the core of the stage there is the macro MSPA35XS 45V module, supplied and controlled with the CTEC SPC45 power supply. The linear stage allows a 100mm stroke but can easily be adapted to longer or shorter strokes depending on customer requirements, keeping the same core MSPA and power requirements [2]. The characteristics are listed in table 2.

TABLE 2. Linear MSPA-based stage characteristics

Type	Value	Unit
Holding force	6	N
Max. Lift force	3	N
Max. speed	50	mm/s
Travel range	100	mm
Dimensions	160x44x28	mm^3
Positioning accuracy	2	µm
Supply voltage	45	V

C. Switch to series production for complex mechanisms

Industrial series of piezo motors and complex mechanisms using piezo motors are currently built at CTEC. Two examples are given hereafter, showing that complex and various functions can be achieved using MSPA modules.

A Point Ahead Mechanism (PAM) is a 3 degree of freedom mechanism managing Tz,Rx Ry. It is based on 3 MSPA35XS modules which permits a 3D positioning of the head over a 2x2x5 mm volume and a less than 10µm resolution. Typical production batches are 50 units (meaning up to 150 piezo motors per batch).

FIGURE 2. Typical batch of PAM assembly & The PAM with its driver

The Fine Slit Tuning Mechanism (FSTM) is based on two opposite blades moved each by a MSPA35XS module. It provides the displacement of 2 blades on the same axis over a 5 mm stroke and without positioning overshoot. The mechanism is nonmagnetic and is embedded in a box in order to be able to run in a vacuum environment. Typical production batch is larger than 100 products per year.

IV. Conclusion

The main challenges of the improvement of MSPA are accomplished and industrial applications find answers in this mature technology. Series production cater customer needs by reaching a TRL9 maturity.

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