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Application Note NM 4

Considerations For Using Nanomotion Motors in Vertical Applications

1. Introduction

The intrinsic friction of the Nanomotion motor offers an interesting solution for Z applications, where gravity functions as a permanent load. Nevertheless, some considerations must be taken into account to ensure safe and reliable system operation. This report highlights these considerations and shows that in order to achieve successful implementation in Z direction the load should not exceed 1/3 of the nominal static holding force.

2. The Set Up

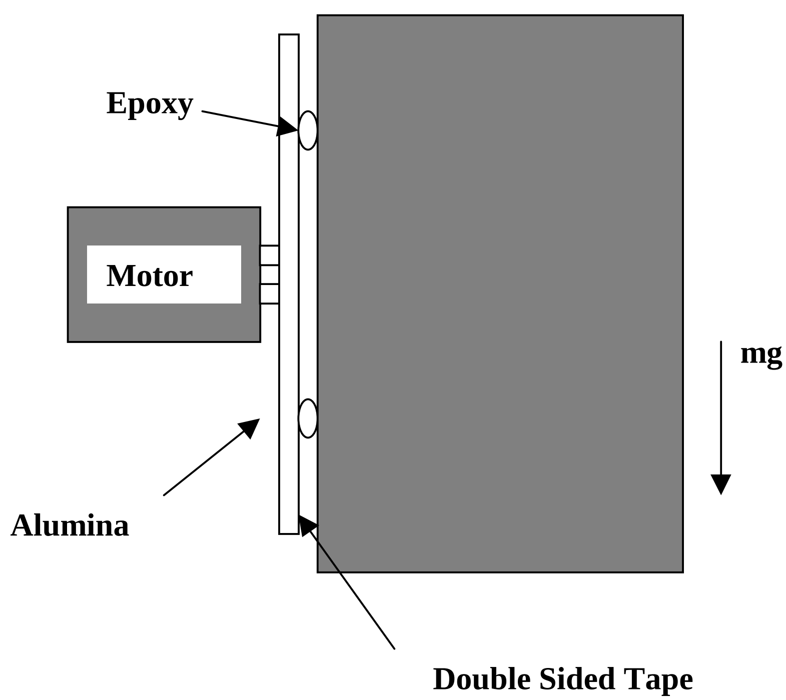


Figure 1

3. Motion Control Under Gravity

This application is very asymmetric, where much higher forces are required to move upwards as compared to downwards.

Tuning of the control set up with different parameters for each direction is required. The proper control tuning is described in other application notes. This Application Note concentrates on the intrinsic friction and the static holding force.

4. Design Margins

Figure 1 above shows the correct installation of the Nanomotion motor as stipulated in the motor manuals.

While operating Nanomotion motors in the Z direction, the following points should be considered:

1. Intrinsic friction.

2. Shearing of the double sided tape and the epoxy.

3. Vibrations

The analysis in the attached appendix yields the following conclusions regarding the Design Margins for vertical operation.

1. Stiffness -
   Without epoxy drops, stiffness is low. Each drop gives stiffness of 12.5 N/μ . For multiple motors on a small ceramic strip, more drops should be used to achieve high stiffness and high accuracy.

2. Holding force -
   Taking into consideration the friction coefficient change with time and standard industrial vibrations, a vertical set up would hold 117 gr/motor element. For a higher mass/motor element counter balance provisions must be used.

5. Summary

Considerations for the motor operation in the Z direction overcoming gravity were described. It is clear that with proper system design, the unique feature of the intrinsic holding force can be utilized maintaining precise position with no power.

This report did not consider close loop functions, but position can be better maintained under close loop, overcoming vibration.

For further information please consult Nanomotion Customer Support Division.

Appendix

1. Intrinsic Friction

The nominal static holding force is typically 4N per motor finger tip in the HR series of motors. The intrinsic friction may be slightly reduced with time due to humidity and adsorption of other contaminants on the alumina surface.

With a safety margin, we shall assume an actual static holding force of 2 N/μ after very long periods of non-use (this is an exaggerated precaution).

2. Shearing

The shearing of the double sided tape may be very noticeable for a small contact area, nevertheless, the shear of the tape is overcome by the epoxy.

The shear of the epoxy is as follows:

Let - shear modulus G=800 MPa

Epoxy drop diameter 2r=2mm

Shear section (thickness of the double sided tape) d=0.1mm

Number of drops = n

It can be shown that the shear ΔX as a result of an applied force F is given by:

$$F = \frac{G \bullet n \frac{\pi r^2}{2}}{d} \bullet \Delta X$$

$$F = \frac{800 \bullet 10^6 \bullet \frac{\pi}{2} \bullet 10^6 \bullet n}{10^{-4}} \Delta X$$

$= 12.5\ 10^6\ n\ \Delta X$

For n=2 drops we get

$F=25 \bullet 10^6\ \Delta X$ or stiffness of 25 N/μ

2.1 Conclusion

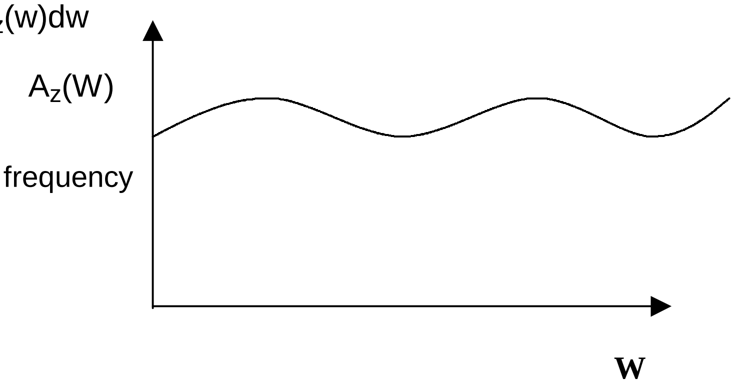
This value is far beyond the motor stiffness and hence does not affect the performance. However, in applications with multiple HR-8 motors, obviously more epoxy drops should be used.

3. Vibration

Assuming a vibration spectra A_z (W) at the mass m in the gravitational direction, the vibration force F_v is given by:

$F_v = m \bullet \text{Integral } w^2 A_z(w)dw$

Where-W is the radial frequency



3.1 Equilibrium

As the vibration is symmetrical and the gravity is not, the system will be stable when:

$F_v + mg < F_H$

Where F_H is the actual static holding force under the intrinsic friction assumption made above.

Lets take a numerical example:

a) Let m be 200 grams and an HR-1 motor, we get:

$F_v + 2 = 2$

Thus we get:

$F_v = 0$

Any vibration will cause the stage to slip.

b) Let m be 100 grams and an HR-1 motor:

Here $F_v \leq 1N$ for stability

At 100 Hz, the maximum vibration amplitude allowed is calculated as follows:

$A \bullet (2\pi \bullet 100)^2 = 10$

$A = 10^{-3} / 36$

$= 30\ \mu$

3.2 Consideration for Actual Industrial Vibration

Vibration levels in various environments can be found in reference books. The ISO work shop value is a typical industrial standard.

We see a value of 32000 μ inch/sec @ 50 – 100 Hz.

The vibration amplitude A is given by:

$$A = \frac{32 \bullet 10^3 \bullet 10^{-6}}{40\Delta f} m$$

As $\Delta f = 50Hz$

We get:

$A = 16\ \mu$

Taking a center frequency of 75 Hz, the acceleration a is given by:

$a = Aw^2 = 16 \bullet 10^{-6} \bullet (2\pi \bullet 75)^2 = 3.55\ m/sec^2$

Bearing in mind that the vibration is a statistical effect, an additional factor of 2 is suggested to overcome local fluctuations.

Thus, $a_v = 7\ m/sec^2$

3.3 Conclusions

Going back to $F_v + mg < F_H$

Where $F_v = m\, a_v$

We get for a single HR-1 motor

$$m = \frac{F_H}{a+7} = \frac{2}{17} = 117\,gr$$

An HR-1 motor will safely hold position, overcoming gravity and standard vibration, for a mass no larger than 117 grams. This statement can be generalized as follows: <u>In an industrial environment, a Nanomotion motor can maintain vertical position for a mass which is 1/3 of the nominal static holding force</u>.

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