

# DEVELOPMENT AND TESTING OF A HIGH-TEMPERATURE SHAPE MEMORY PIN PULLER PUSHER ACTUATOR

F. Fouché<sup>(1)</sup>, A. Hautcoeur<sup>(2)</sup>, J. Sicre<sup>(3)</sup>

<sup>(1)</sup> Nimesis Technology, 4, Rue des Artisans - 57245 Mécleuves - France, Email: [f.fouche@nimesis.com](mailto:f.fouche@nimesis.com)

<sup>(2)</sup> Nimesis Technology, 4, Rue des Artisans - 57245 Mécleuves - France, Email: [a.hautcoeur@nimesis.com](mailto:a.hautcoeur@nimesis.com),

<sup>(3)</sup> CNES, 18 avenue Edouard Belin – 31401 Toulouse – France, Email: [jacques.sicre@cnes.fr](mailto:jacques.sicre@cnes.fr)

## ABSTRACT

Pin Pullers are largely used in space applications to hold rigidly a mobile part of a mechanism. Most of these Pin Pullers can only be reset manually and therefore do not allow reusability in cycling without human intervention. The objective of this study is to develop a Pin-Puller-Pusher (named PinLoader) applying a high continuous load which can be removed during electrical actuation in a relatively short time.

Shape-memory alloys are the best candidate to offer these types of high-performances actuators but, unfortunately, standard SMAs such as Ni-Ti offer transformation temperatures below 100 °C. This type of component can therefore trigger unexpectedly when exposed to the sun heat.

To develop its PinLoader actuator, NIMESIS and CNES used NIMESIS high temperature SMA named CN250X that can trigger at a temperature above 120 °C and up to 230°C. Thus, PinLoader actuator will meet the operational temperature range requirement.

This work was done within CNES R&D Program.

## GENERAL SPECIFICATIONS

PinLoader applies a constant unpowered load of 500N. When activated by electrical power, PinLoader moves back and can pull a load up to 300N. Once electrical current is stopped PinLoader resets automatically and applies again a 500N load. PinLoader uses a SMA component to actuate. This SMA component is activated by an electrical high temperature heater.

Technical specifications:

- Non-Powered constant axial load: 500 N  $\pm$ 10%
- Dynamic load: > 300N  $\pm$  10%
- Stroke on charge: > 1 mm
- Mass: < 50 grams
- Triggering time < 30 sec
- Powering current: < 10A
- Electrical power: < 20W
- Maximum volume: 30 mm in diameter and 30 mm in length.
- In orbit operational temperature range: -120°/+120°C (no activated below 120°C)
- Functioning cycles: > 50 and auto resettable

## PINLOADER DEVELOPMENT

### CN-250X alloy

Shape memory alloys (SMA) are recognized as reliable and efficient materials particularly to design actuators. The major drawback of these shape memory actuators is the triggering temperature which is lower than 100°C with standard Ni-Ti alloys. The Nimesis Cu-Al-Ni single crystal wire shows transformation temperature higher than 100°C and is available in round section with a diameter from 0.5 mm to 25 mm. The state of the art and a detailed characterization work made for several recent CNES R&T program demonstrated that Cu-Al-Ni single crystal wire is a very good candidate for space applications which need triggering temperatures between 100°C and 200°C.

A dedicated alloy has been manufactured during this program. The casting shows transformations temperature at 102°C. After casting, the alloy is transformed in semi-finished products and then NIMESIS performs its patented single crystallization process to obtain a high performances SMA component.

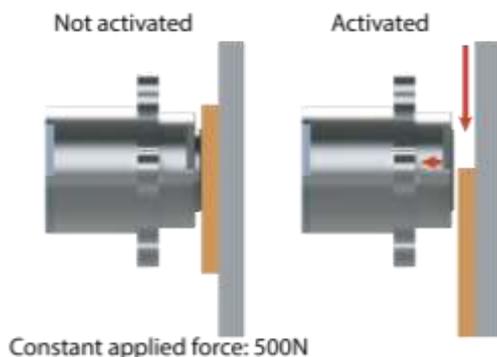


Figure 1: Pin Puller Pusher concept



Figure 2: CN-250X ingot from NIMESIS TECHNOLOGY

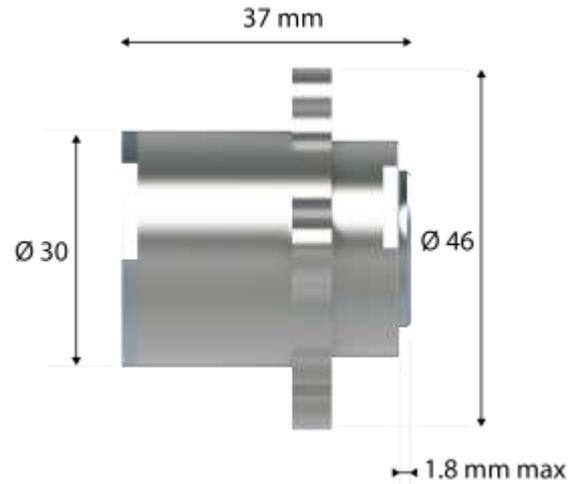


Figure 4: PinLoader dimensions

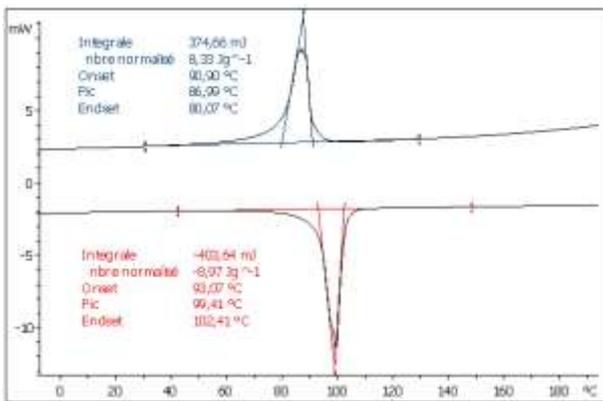


Figure 3: DSC results of CN-250X casting

## Manufacturing

A prototype of the actuator has been manufactured. The shape memory component has been realized by NIMESIS with CN-250X alloy.

Dimensions of the actuator are:

- Diameter: 30 mm
- Length: 37 mm
- Diameter with connecting part: 46 mm
- Stroke: 1.8 mm maximum

Each part of the actuator is made of aluminum 7075 to reduce mass. Assembling screw are made of TA6V. Actuator's mass is 66 grams.

PinLoader is equipped with one thermocouple type K and one Pt1000 temperature sensor. It has a single heater to trigger the SMA component but a redundant one will be implemented in future version.

## TESTING

NIMESIS performed a functional characterization at ambient pressure and temperature. More tests will be done soon by the CNES.

Prototype testing plan:

- Triggering under ambient environment
- Power consumption measurement
- Triggering time measurement
- Cycling test under ambient environment
- Axial compression
- Ageing under 120°C for several hours
- Cycling test after ageing
- Axial compression after ageing



Figure 5: Comparison between triggered and non-triggered state

### Triggering under ambient environment

The objective of this test is to measure the maximum stroke of the actuator under a nominal power of 16W. PinLoader is triggered under 8 V and 2 A. The power increases SMA temperature and thus triggers the actuator. During cooling, the actuator will automatically reset itself and come back to its initial position. Stroke is measured with a LVDT displacement sensor. Figure 6 shows a maximum stroke of 1.5 mm after 30 second of heating. SMA temperature increased up to 230°C.

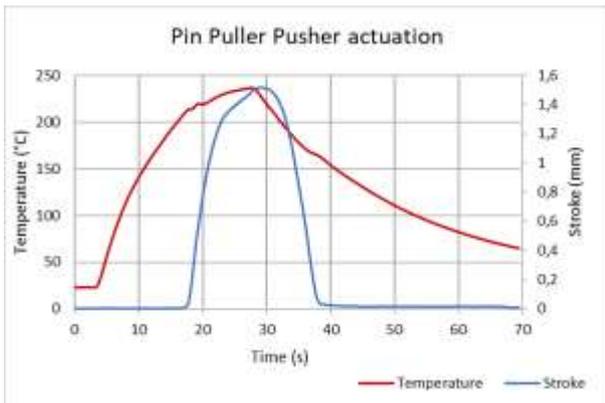


Figure 6: Triggering curve of PinLoader

### Cycling test under ambient environment

Cycling tests aims at qualifying the actuator for more than 50 cycles. PinLoader is resets automatically when it cools down. During test we inject electrical power during 30 seconds each 60 seconds Figure 7 and 8 show 100 cycles.



Figure 7: Cycling test. Red and blue curves show triggered and reset position

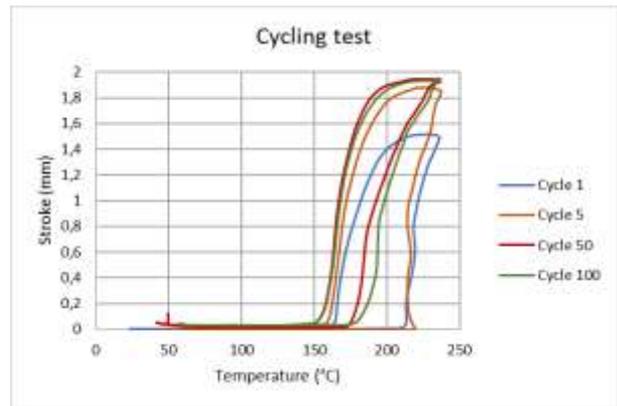


Figure 8: Cycling test

Both figures show a stabilization of the SMA component during the first 5 cycles. After this stabilization phase, it remains perfectly stable. Mean stroke is 1.8 mm and maximum temperature is 230°C.

### Axial compression

Axial compression consists in measuring the resistance to a compression load. To have the unpowered constant load, PinLoader must enter in compression when it is placed on a mechanism. The curve below shows that, it needs 0.15 mm compression to have 500 N.

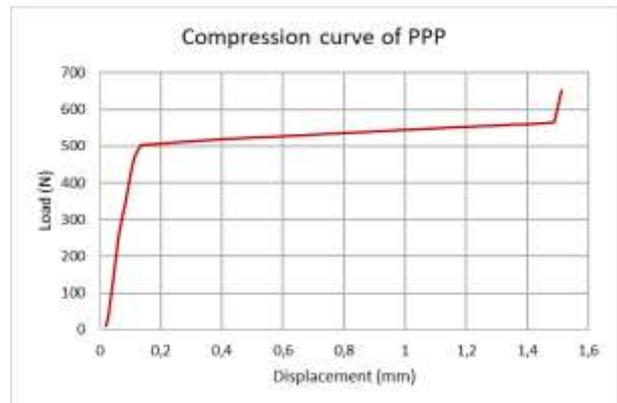


Figure 9: Compression curve with mechanical stop

Maximum stroke of the mobile pin is 1.8 mm but there is a mechanical stop if PinLoader enter in contact with the load surface.

### Ageing

PinLoader is aged during several hours at 120°C. The objective is to verify its performances after an exposition to the sun. Ageing is performed in a furnace at ambient pressure for several hours.

### Cycling test after ageing

After several hours at 120°C, cycles remain perfectly stable and minimal and maximal position are still the same. A 120°C ageing does not damage the SMA component behavior.



Figure 10: Cycling test after 120°C ageing

### Axial compression after ageing

Same test as Figure 9 is done. With 0.15 mm of compression, load is at 450N. It means that PinLoader lost 10% of its non-powered load.

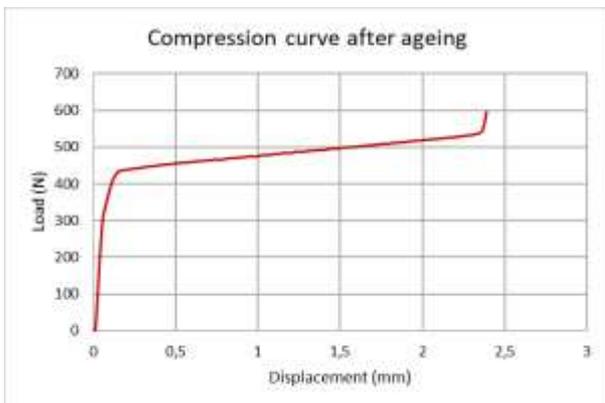


Figure 11: Compression curve after 120°C ageing

After analysis, it appears that, standard spring kept some permanent strain after staying several hours at 120°C. For the next version of PinLoader, material of the standard spring will be change to a high temperature stainless steel.

## CONCLUSION

### Performances

PinLoader shows some very good performances with more than 1.5 mm of stroke and a constant unpowered load of 500 N. The mass is only 66 grams for a Ø30 x 37 mm actuator. PinLoader behavior is excellent with more than 100 stable cycles. It needs 16 W for 30 seconds to trigger under ambient temperature.

### Next steps

This prototype has been delivered to the CNES to perform testing in space environment. Thermal vacuum test and vibration test should be done in the next months. Those results will be presented in the NIMESIS poster during ESMATS 2019.

A patent is filling on this PinLoader actuator.

### Other dimensions

NIMESIS has the objective to provide a complete range of Pin Puller actuators using high temperature SMA. Other dimensions imagined are:

- Stroke increasing to more than 10 mm
- Size and power adapted to Cubesats
- Reverse actuation



Figure 12: High temperature SMA Pin Puller actuator with more than 10 mm of stroke