NC SMA-VALVE

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OUTLINE

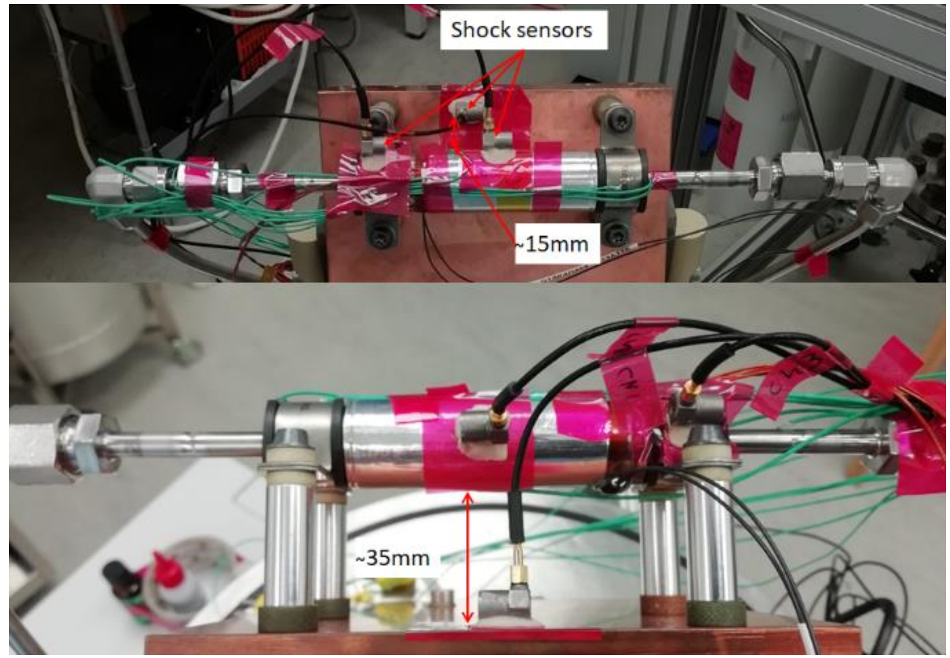
01
INTRODUCTION

BACKGROUND

Single actuation valves

Pyro-valves (PV) vs SMA Valves (SMAV)

- PVs have outstanding leakage performance, low mass and high reliability, however they have some drawbacks compared to SMAVs
- SMAVs have no lifetime limitations, simplified electrical activation, lower self-induced shock loads, no legal and safety constraints, possibility to perform acceptance tests on actuator level during MAIT, insensitive towards spurious signal induction in the heater power line (up to one minute of heating will not lead to a change in the valve's state) and SMAVs are not subject to REACH or other regulations.



SMAV overview

Normally Closed (NC) SMAV already qualified for inert gas, MMH and NTO

- The ongoing delta qualification target is to demonstrate its compatibility and reliability for N2H4 applications.

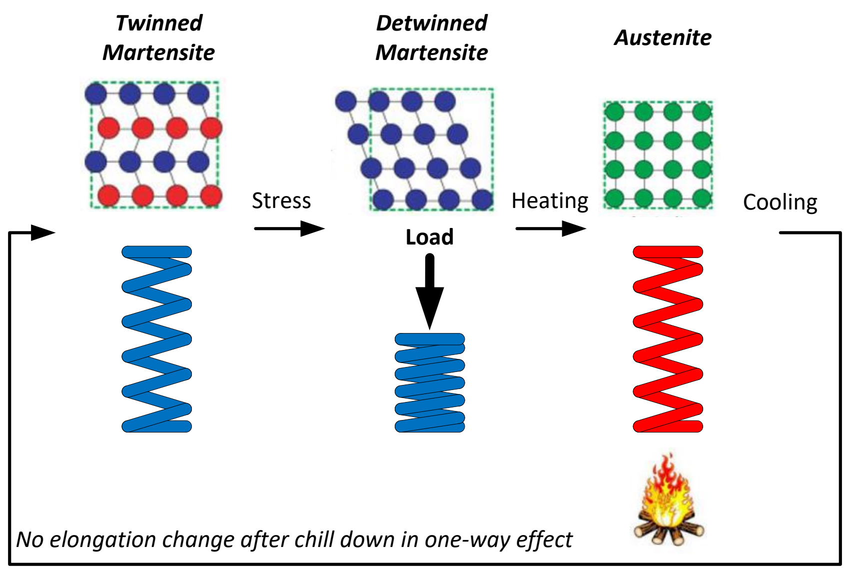
02
SMA METALLURGY

ACTUATOR MATERIAL

SMA manufacturing

A reproducible and controlled process during the melting and casting of the NiTi ingots is vital

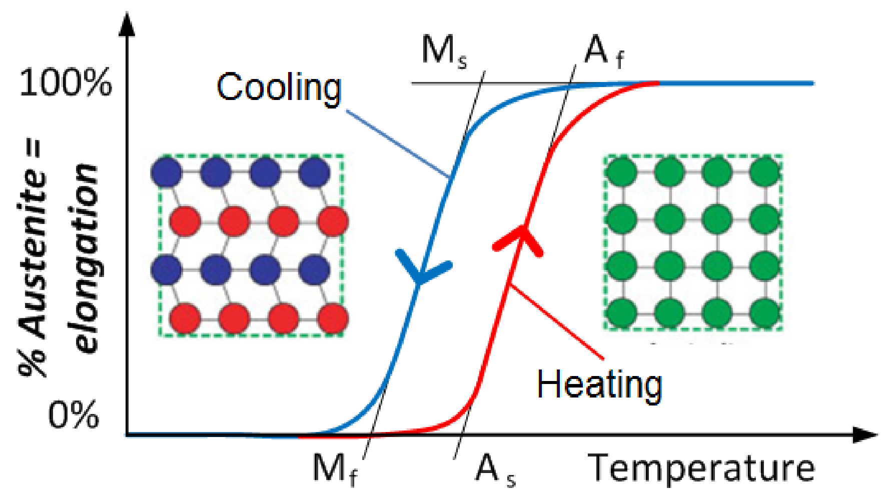
- A little deviation from the specified NiTi ratio has a strong effect on the shape transformation temperature, other unwanted trace elements have other unwanted effects. The process of NiTi manufacturing has been standardized with our suppliers and a good quality for valve manufacturing is achieved.



Principle of operation

One way shape memory effect

- The actuator is in twinned martensite state when at ambient temperature. Then the actuator is pseudo-plastically deformed by an external load, this changes the crystalline structure from "twinned" to "de-twinned" martensite. As soon as the material reaches the As temperature, the actuator transforms back, leading to force application by deformation of the actuator.



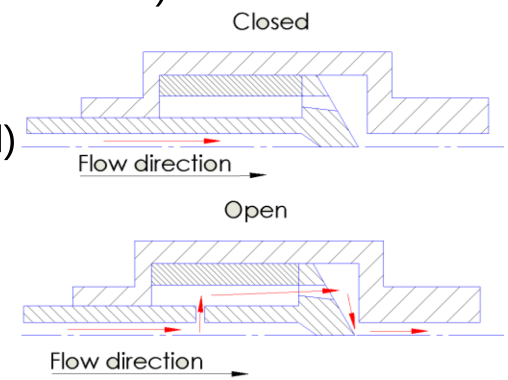
03
VALVE DESIGN

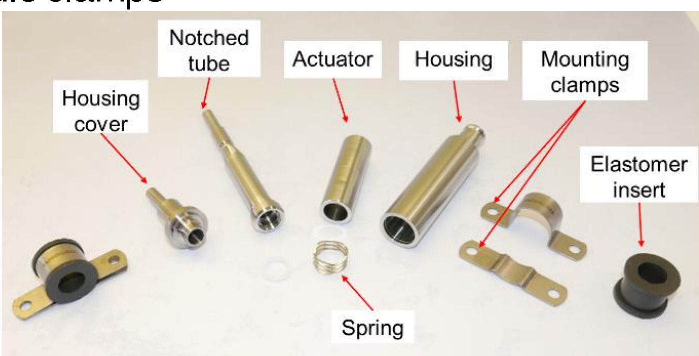
AG’S SMAV NC DESIGN

Valve main components

The valve is designed with 1/4" tube interfaces and possesses an all-welded, robust and lightweight design

- SMA Actuator
- Polyimide Heater (ESCC standard)
- Notched tube
- Housing (2-parts, welded)
- Spring
- Elastomer inserts
- Saddle clamps





1/4" SMA Valve characteristics	
Media	Inert gases, MMH, MON, N2H4
Heater design	Polyimide foil
Integrated Thermistor	Per request & qualified
Heater Power	12 W nominal
Outlet filter	Not included
Elastomeric inserts	viscoelastic rubber
Activation time	< 15 Min from 20°C
MEOP	345 bar
Proof pressure	690 bar
Design burst pressure	1380 bar
Int. & Ext. Leakage	<1e-6 sccm/s
Valve weight	118g
Bracket	COTS saddle clamps
Tube interface	Ti 1/4" TIG
Non-operating temperature range	-40 to 88°C Inert gases. 10 to 60°C MMH, MON & N2H4
Operating temperature range	-34 to 71°C Inert gases. 10 to 50°C MMH, MON & N2H4
Random vibration loads	34 gRMS

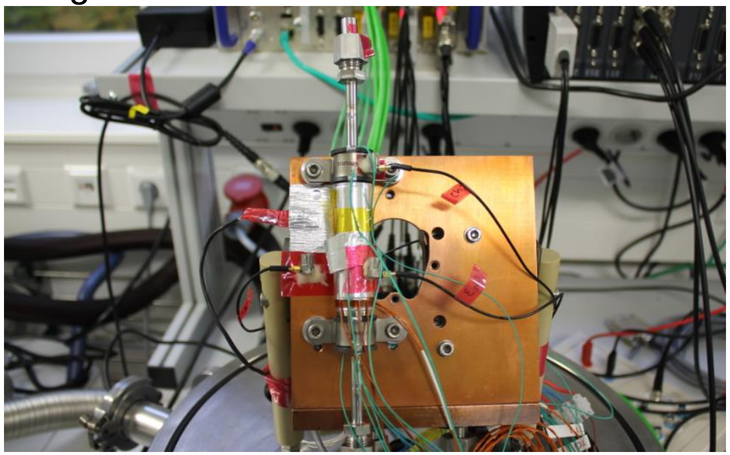
04
QUALIFICATION STATUS

CONDUCTED QUALIFICATION TESTS

5 SMA Valves tested

Successfully finalized

- The qualification units were subjected to an extensive standard testing sequence as summarized in this table. All listed tests were successfully finalized. CT Scans before and after valve activation were performed.
- Vacuum activation tests were conducted at min., max. and ambient temperatures, response measurement, catching of generated particles and self induced shock recording were conducted.



Qualification test sequence
Subcomponent LAT
Valve Acceptance Test
Pressurised sinus and random vibration test
Shock test (all three axes)
Water hammer test
Proof/MEOP pressure cycling
Thermal ambient cycling [5]
Cleaning, Cleanliness Verification and thermal vacuum drying
Vacuum activation test (MMH, MON and GHe)
Extended heater / heater bonding verification test
Heater cable pull out test
External leakage
Electrical checkout
Pressure drop tests (inert gases and water)
Burst pressure and burst to rupture test

N2H4 QUALIFICATION TESTS

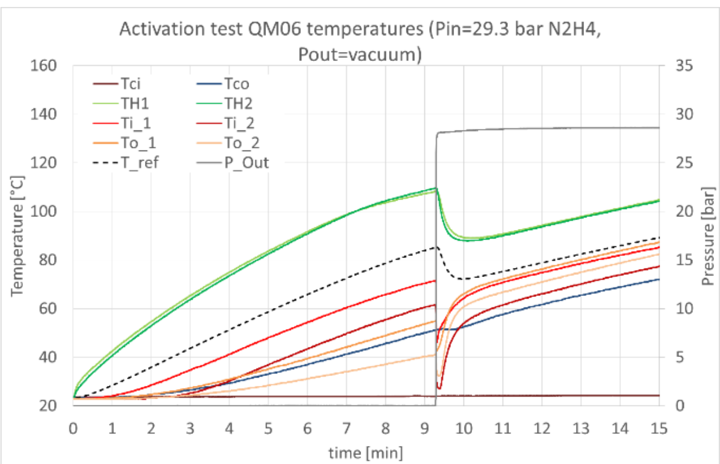
3 SMA Valves tested

Valve test sequence mostly finalized

- Only the heater bonding test is ongoing, all other activities were successfully conducted.

Immersion test sequence mostly finalized

- During the immersion test the temperature and pressure of the vessels was recorded. The immersion phase is finalized, the samples inspection is ongoing with no negative findings.



Valve test sequence
Subcomponent LAT
Valve Acceptance Test
Cleaning, Cleanliness Verification and thermal vacuum drying
Vacuum activation test with Hydrazine
Pressure drop test with water
Burst pressure test
External leakage
Electrical checkout
Heater Bonding test

Immersion test sequence
Preparation of test rig
Preparation of test samples
Immersion test (N2H4 and MMH), 6 months at p>25 bar T=70°C
Chemical analysis of propellant and samples inspection

N2H4 QUALIFICATION TESTS

Severe tests planned on 2 units

Currently in preparation

- Objective: assess a specific reliability objective, the principle of the method is to determine a severity coefficient to be applied to the predominant functional parameter of a device and to demonstrate that this device will operate "without failure" via tests at the level of severity. This kind of testing is typical for pyrotechnical devices → GTPS No 11F
- The integration of the SMA Valves is the next step to be conducted.

Test
Manufacturing notched tubes with an increased design breaking force
Tensile testing of the notched tubes to confirm the force and elongation at break
Integration of two SMA Valves with the increased force notched
Visual inspection
After manufacturing of the SMA Valves the gap between notched tube and Actuator must be measured by CT scan.
Performance of internal leakage
Performance of one thermal cycle of the valves from -40°C to 88°C with a hold time on the extremes of at least 2 h.
Performance of internal leakage
Activation test under vacuum conditions, ambient temperature, 12 W heater and no inlet/outlet pressurisation, one shock sensor on the valve to detect valve opening (severe test itself). Test is successful if the breaking of the tube happens within 30 minutes
Performance of internal leakage

05
SYSTEM ACCOMMODATION

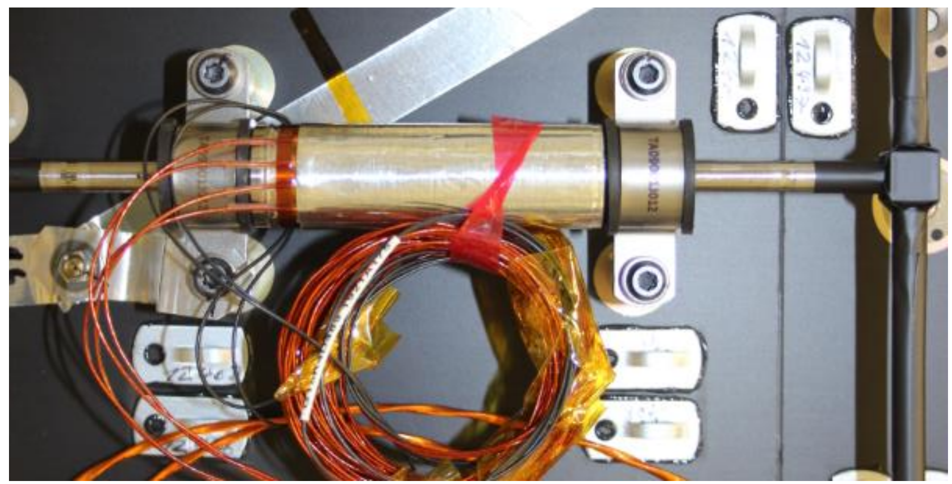
VALVE INSTALLATION

Connected to system via TIG welding

¼" Titan interfaces

- To accommodate the valve to stainless steel tubing, a friction welded tube transition joint can be used.
- Valves mechanically and thermally decoupled by elastomeric inserts compliant to ECSS outgassing requirements
- The 2-part COTS saddle clamp provides a weight-optimized mechanical mounting solution with 4 x M4 clearance holes.
- Possible health checks on system level are:
  - electrical internal leakage testing
  - electrical checkout (heater circuit resistance, insulation resistance)

Type	Application	Main benefit of SMA based single actuation valves
NC	End of life venting (passivation)	Unlimited lifetime
	Re-pressurisation	Unlimited lifetime



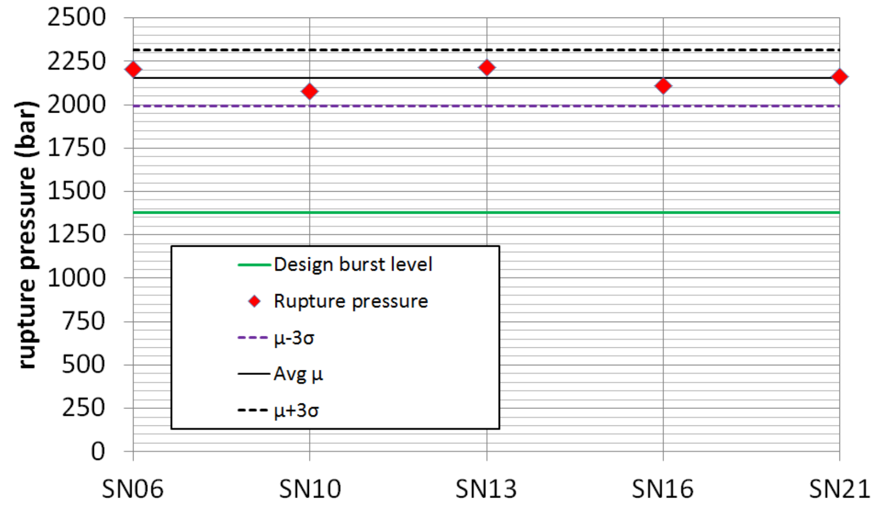
06
VALVE TESTS

COMPONENT DLAT

Notched tubes testing

Lot wise testing (min. 3 per lot)

- Burst to rupture testing
- Tensile testing for rupture force and rupture elongation determination



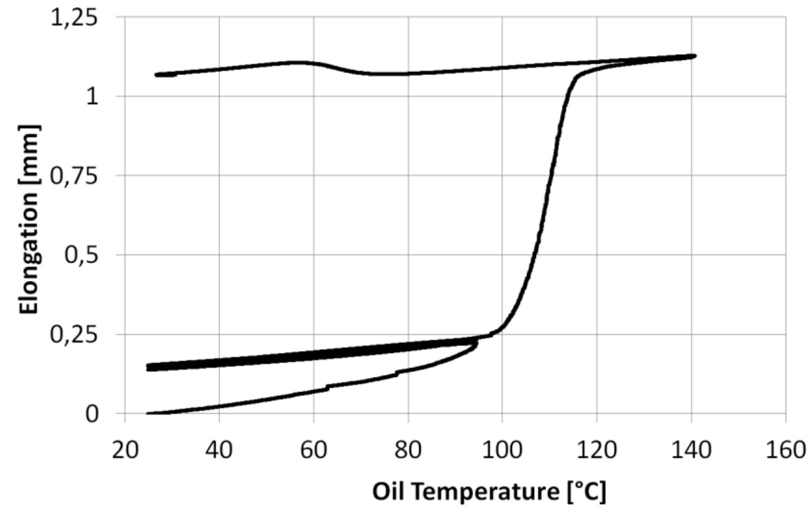
Actuator testing

Raw material testing (per melt)

- On raw material level a chemical composition analysis and a differential scanning calorimetry and texture analysis is conducted

Actuator testing (min. 3 per lot)

- Detwinning (mechanical characteristics)
- Stress free elongation test
- Preconditioning
- Blocking force measurement



07
SUMMARY AND CONCLUSION

SMAV IS ON ITS WAY TO FULL QUALIFICATION FOR N2H4

11 SMA Valves activated

All valves activated in flight like conditions

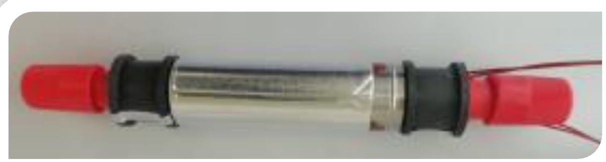
- Tests conducted all under different boundary conditions including outlet pressure, heater power. For all activation tests a one minute heating test prior to activation was.

Valve	Start T	Inlet pressure and fluid	Activation time
[-]	[°C]	[bar]	[s]
QM01	22	17 | MMH	575
QM02	22	17 | MON-3	605
QM03	22	345 | GHe	566
QM04	-30	50 | GHe	1380
QM05	71	Vacuum	180
QM06	23	29 | N2H4	557
QM07	52	29 | N2H4	292
QM08	7	29 | N2H4	1582
SN10	24	19 | GN2	635
SN11	-31	Vacuum	1245
SN12	77	349 | GN2	245

First flights and customers

First valve successfully installed on system

- First demonstration flight is planned on board of the H2Sat operated by OHB, further SMA Valves have been sold to Mitsubishi Electric Corporation to be used by JAXA in the projects ETS-9 and SLIM.



thank you!

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