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MetHyInfra

EMPIR CALL 2020

Metrology infrastructure for high-pressure gas and liquified hydrogen flows

Dimensional calibration of CFVN

20IND11 MetHyInfra M27 SAB meeting, June 2023, Borås

Authors: Marc de Huu (METAS)

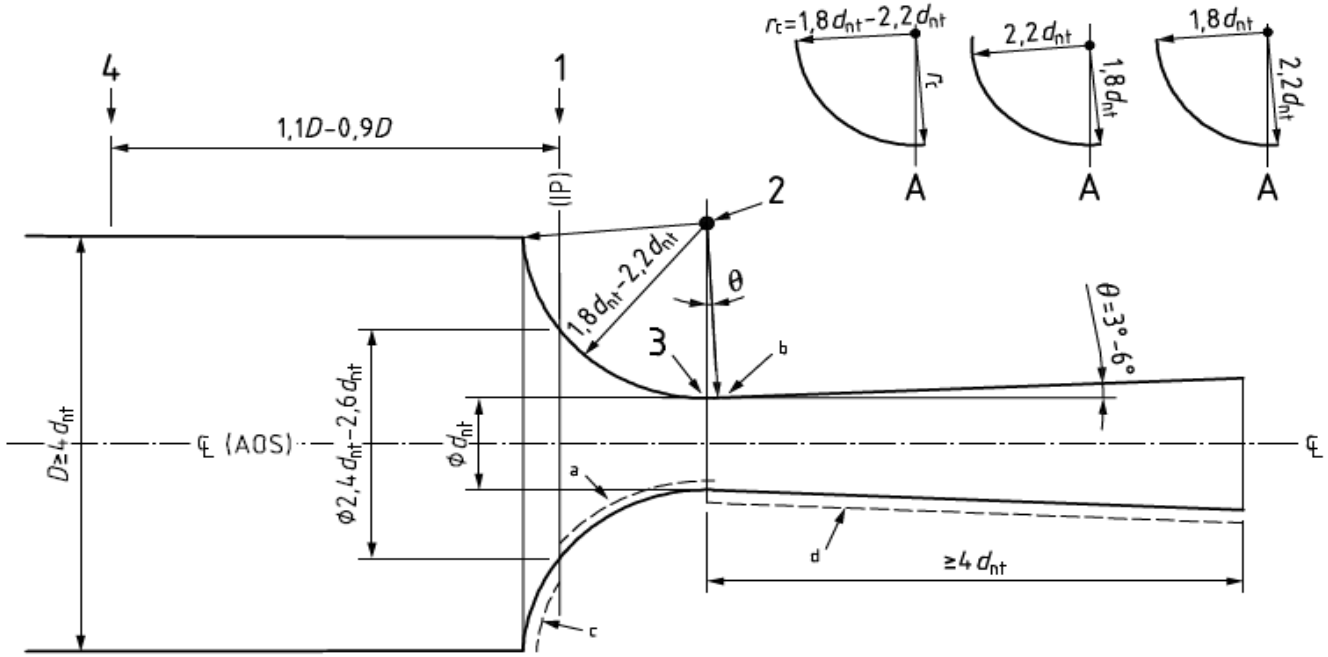
What is a sonic nozzle?

“Dry” Calibration	“Wet” Calibration
Using ISO 9300 Cd Model or From 1st principles e.g. CFD **Requires dimensional characterisation**	Flow calibration against a reference

The requirements vary for each calibration approach. Regardless, nozzles are usually based on the ISO 9300 shape

Dimensional calibration

- Ensure nozzle geometry is within tolerances of ISO 9300



Dimensional calibration

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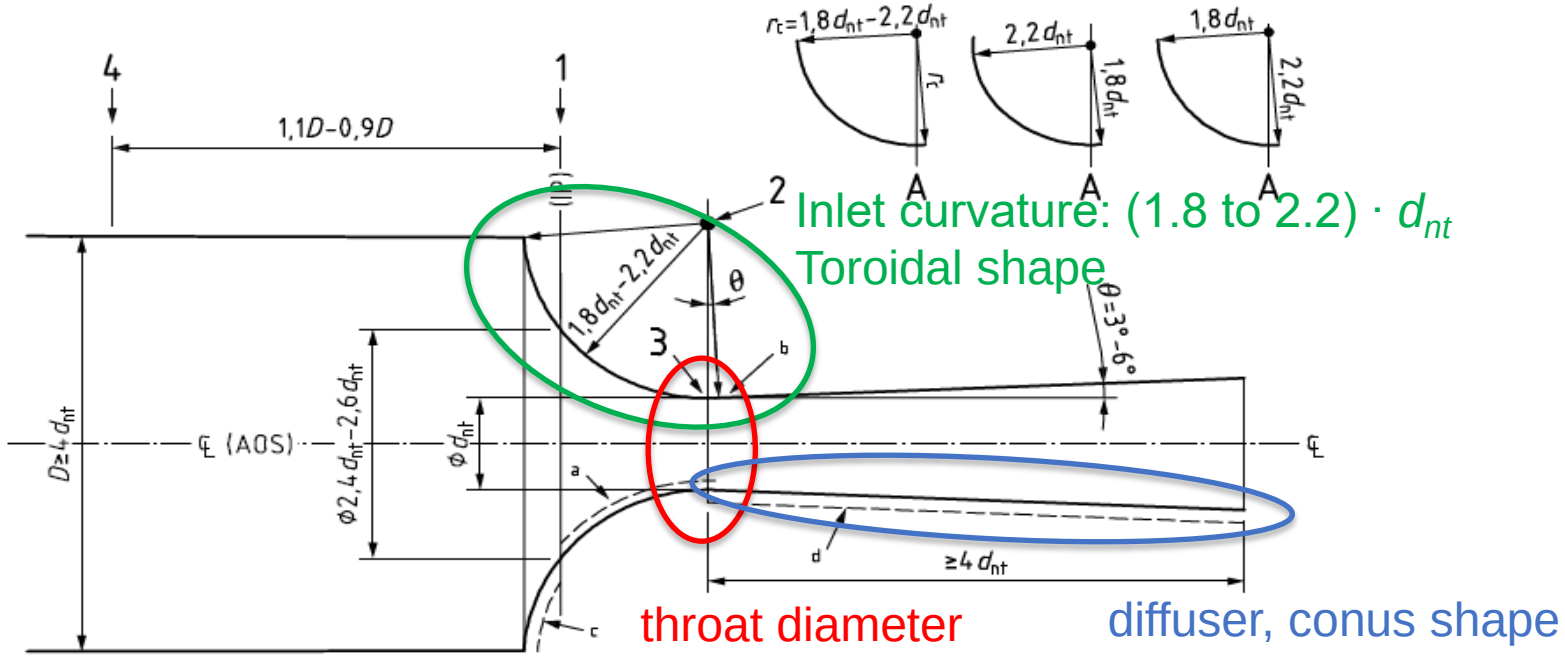
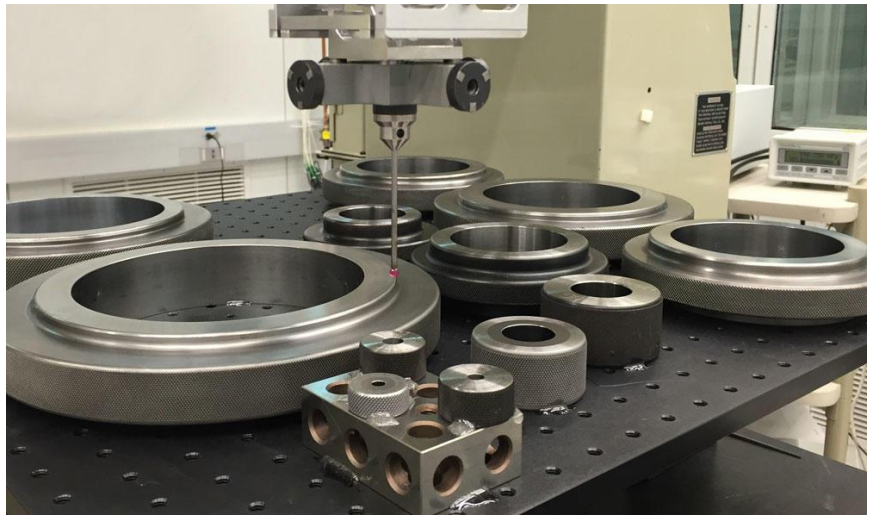


Coordinate measuring machine (CMM)

U (k=2) = 50 nm

Measure geometry by sensing discrete points on the surface of the object with a probe



Source: NIST

µ-CMM characteristic properties

Measuring volume:	80 mm x 80 mm x 40 mm
Position measurement:	3-axis Laserinterferometer, no Abbe offset
Reference system:	Zerodur cube corner with mirrors
Stage:	Vacuum air bearings
Frame:	Aluminium metrology frame
Control:	METAS LabView controller 3D track control
High level SW	QUINDOS, Leitz protocol
Operating modes:	Point probing Closed loop freeform scanning

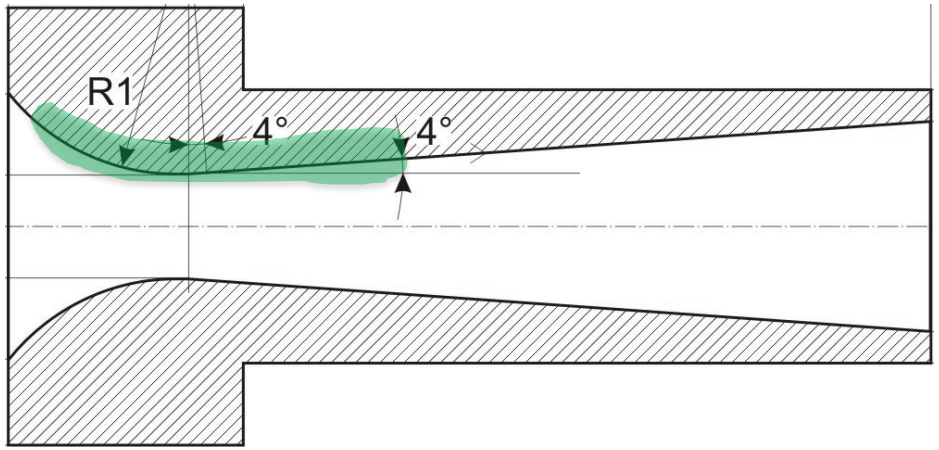
Probing repeatability (1s): 5 nm, single point

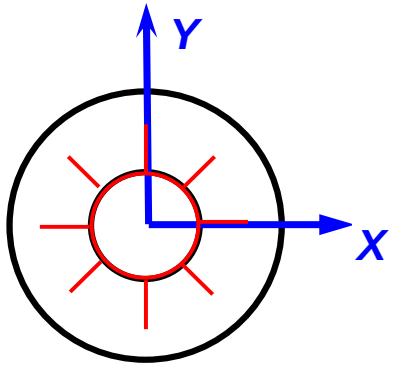
Source: METAS

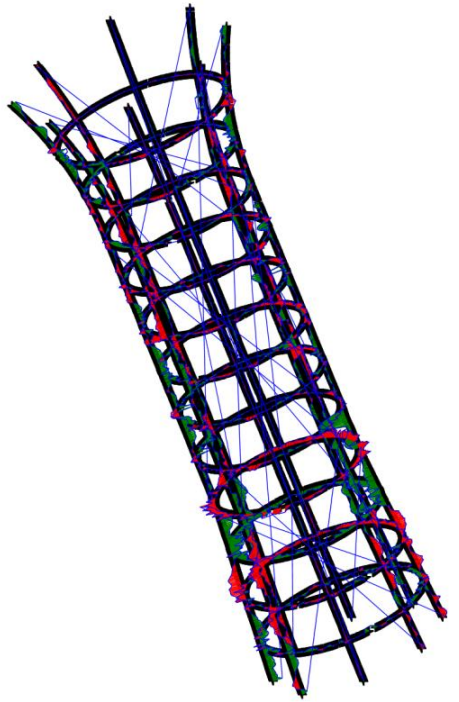
Measurement procedure (example)

- Measure shape of the nozzle in the axial direction
- Measure throat diameter

1. 8 x 45° (8 surface lines), or more
2. Around 200 points per surface line
3. Locate the throat position
4. At throat position, measure circle with at least 120 points

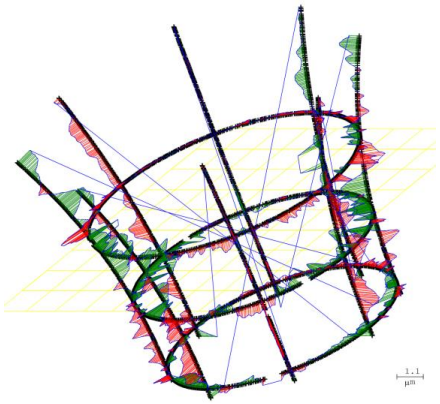




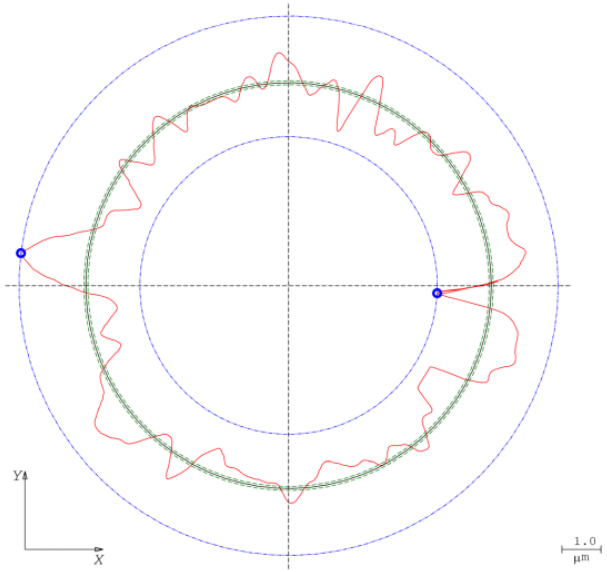


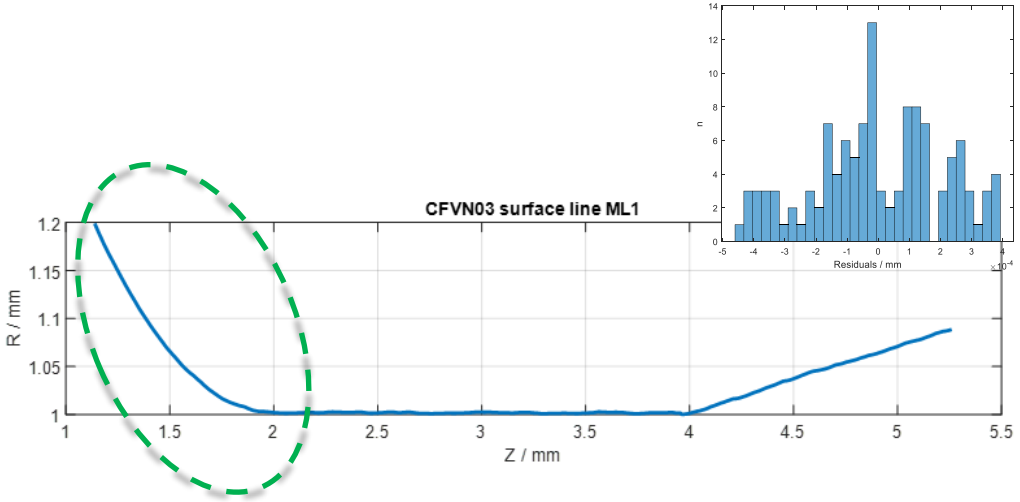
Results from CMM

Inlet curvature

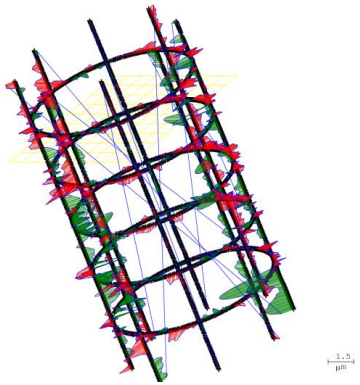


form error





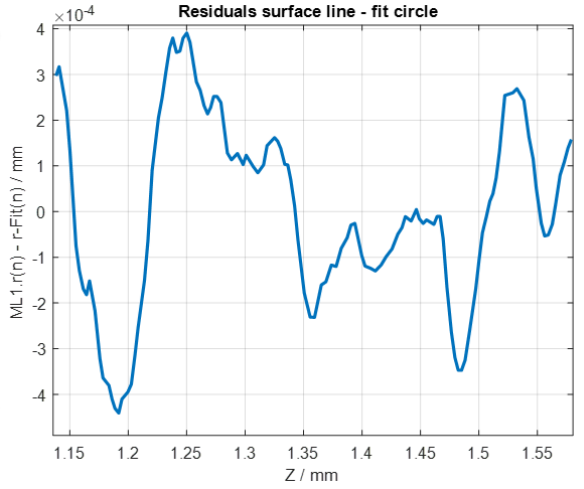
throat diameter



Diameter in mm

Durchm. :	2.003282	Form ....:	0.002958
X-Koord. :	0.000151	Toleranz :	0.000100
Y-Koord. :	-0.000126	Ueberh. .:	100
Z-Koord. :	-2.667187	Punkte ..:	616

± 400 nm



Summary

- Dimensional calibration: verification of form and dimensions
- Inlet curvature
- throat diameter
- diffuser angle

REPORT: Good Practice Guide on the dimensional characterisation of sonic nozzles (CFVNs) with different size, shape and surface roughness

A2.3.4:

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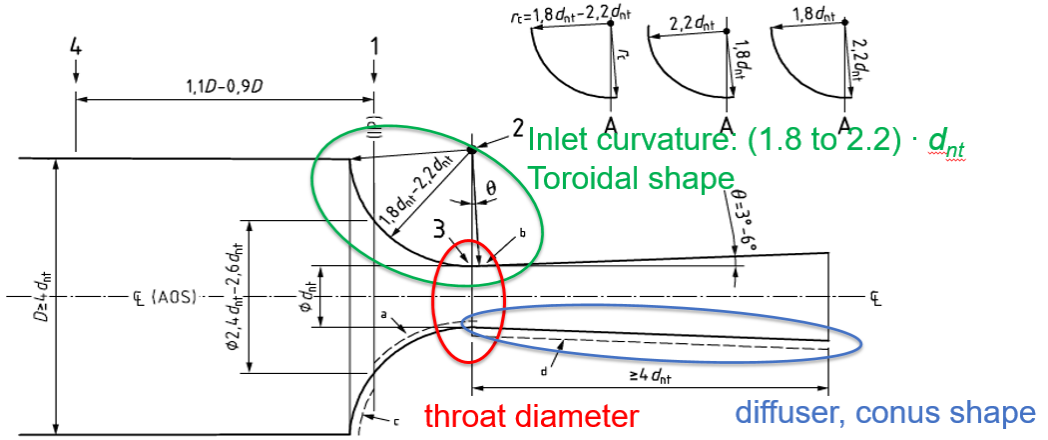

- Tolerances are very challenging for small nozzles
- CMM measurements are challenging for small nozzles ($d_{nt} \leq 2mm$)
- Outline of procedure for CMM measurements
- Personalised analysis of CMM data also possible
- Uncertainty (k=2) on throat diameter with state of the art CMM and accurately machined nozzles: (1 to 3) µm

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external

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