Engineering Research Center for

Reconfigurable Manufacturing Systems

Internal Thread Measurement

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Project Overview

Goals:

- **Develop methodologies for the inspection of geometrical features of internal threads in machined automotive parts.**

Deliverables and benefits

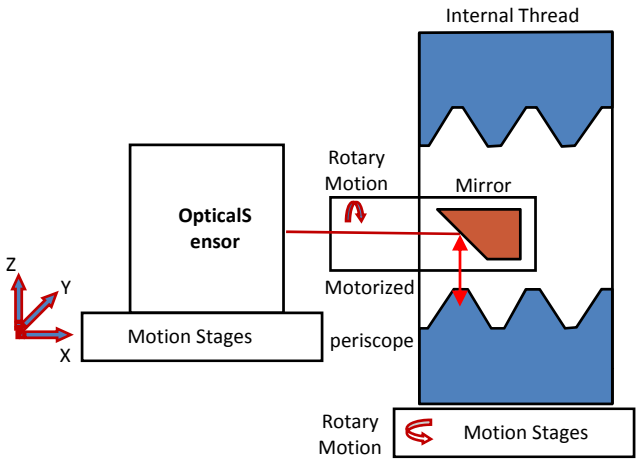
- **The two methods to be presented enable in-process internal thread quality verification using optical sensors.**
- **The approaches allow to extract thread pitch, major and minor diameter, flank angle and even the starting point of the thread with respect to a reference location on the perimeter.**

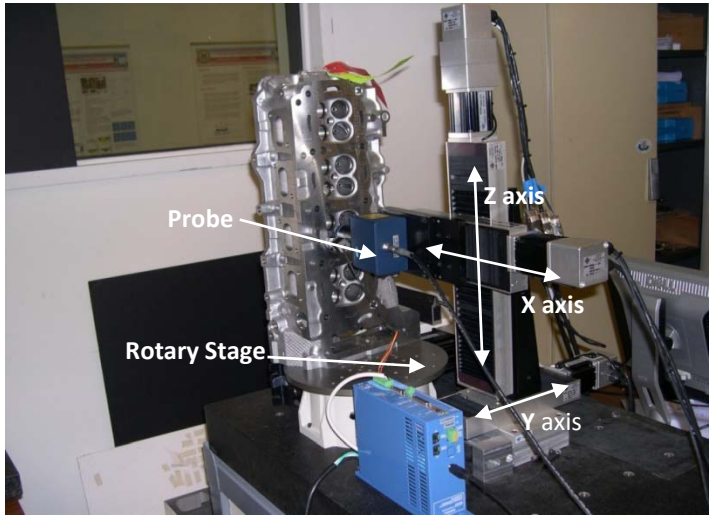
Main tasks

- **Laser scan measurement using Optimet sensor**
- **Optical inspection using a CCD camera with sightpipe**
- **R&R test to be done partially**

Methodology using a laser sensor and set-up

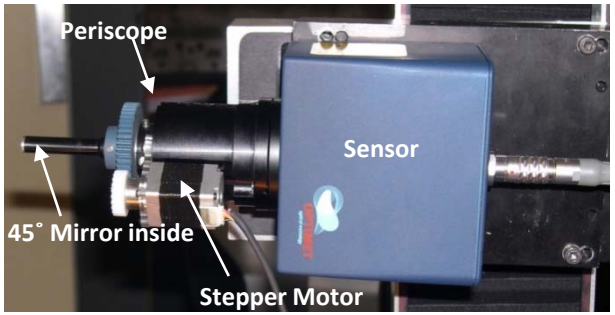
Principle





Method:

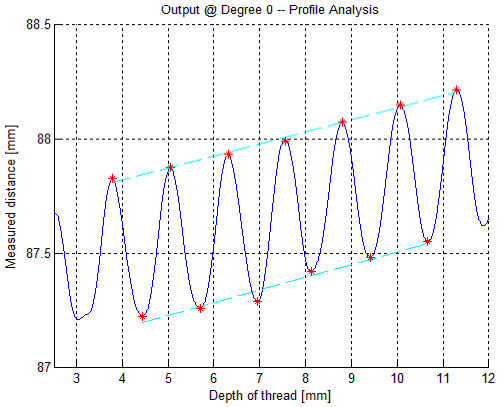
Measuring internal threads using a Laser Range Finder (Optimet Sensor) integrated with a motorized periscope designed at ERC.



Measurements results of M12X1.25 internal thread

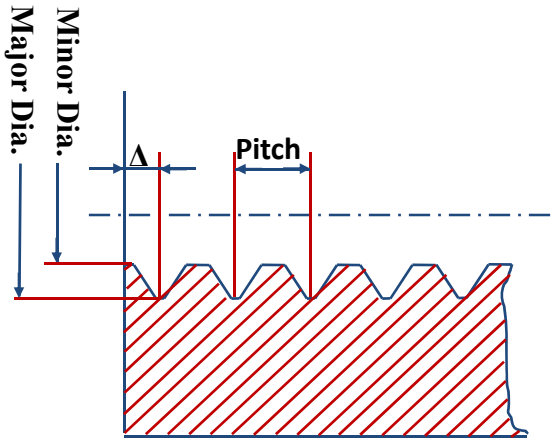
STANDARD: ANSI/ASME B1.13M-1983 (R1995)
M12 X 1.25 Unit: mm

Minor Diameter --D_1		Pitch Diameter --D_2			Major Diameter --D	
Min.	Max.	Min.	Max.	Tol.	Min.	Max.
10.647	10.912	11.188	11.368	0.18	12	12.360



Measured Parameters

	0˚	180˚	90˚	270˚	Average
Pitch (mm)	1.248	1.251	1.252	1.246	1.249
Height (mm)	0.639	0.696	0.539	0.615	0.622
Major Dia. (mm)	12.014		12.127		12.071
Minor Dia. (mm)	10.667		10.871		10.769



axial cross section

Conclusion 1:

Compared to the standard data, all the parameters we get are within acceptable limits for the designated thread type.

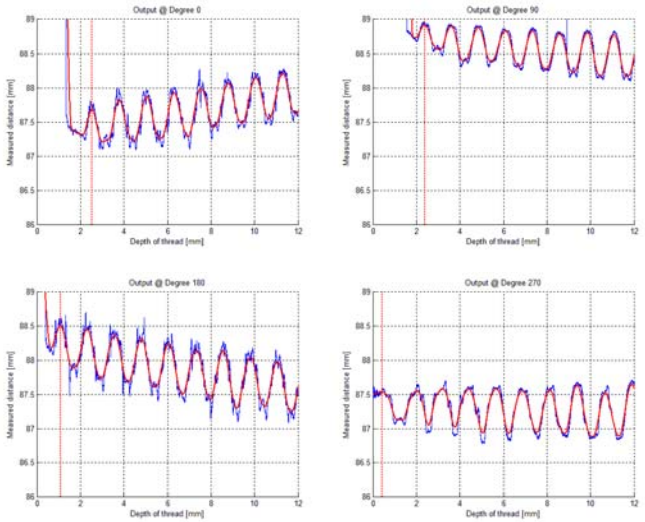
Measurements results of starting location of a thread

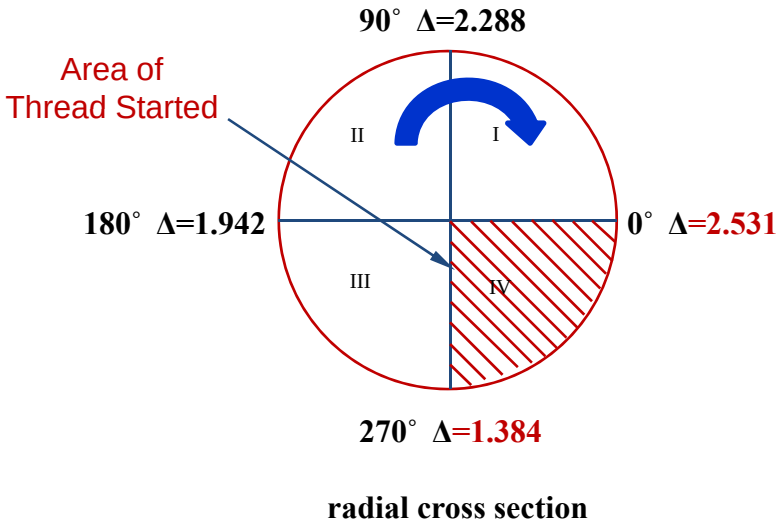
Method:

- Measuring the axial distance between the edge of the threaded bore and the center point of the bottom of the first thread tooth.

- Four measurements were taken at four different angles. The area of thread started is determined by comparing these four values.

- Theoretically, the largest and smallest must be neighbors and the starting point of the thread is located between them.





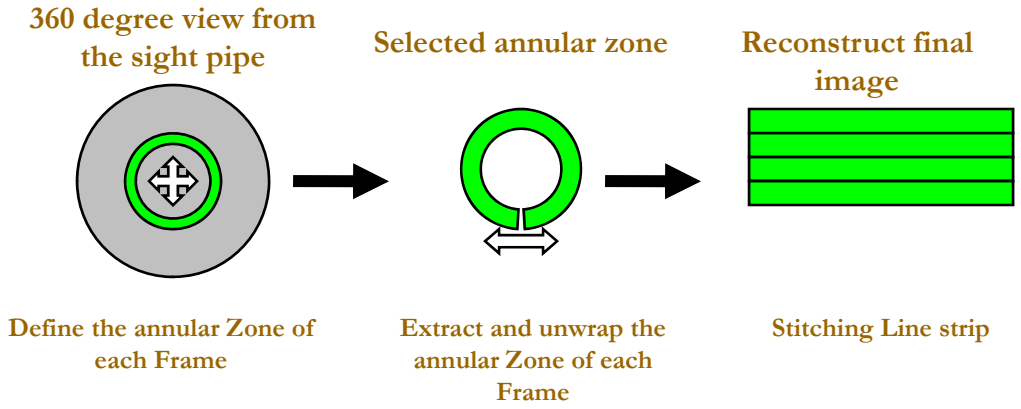
radial cross section

Conclusion 2:

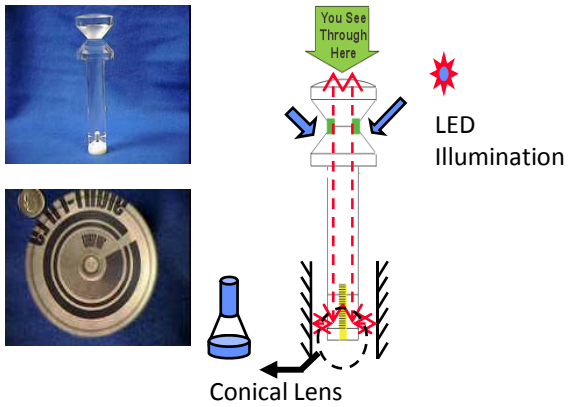
*** The starting point of the thread is located in quadrant IV.**

*** The helix is clockwise.**

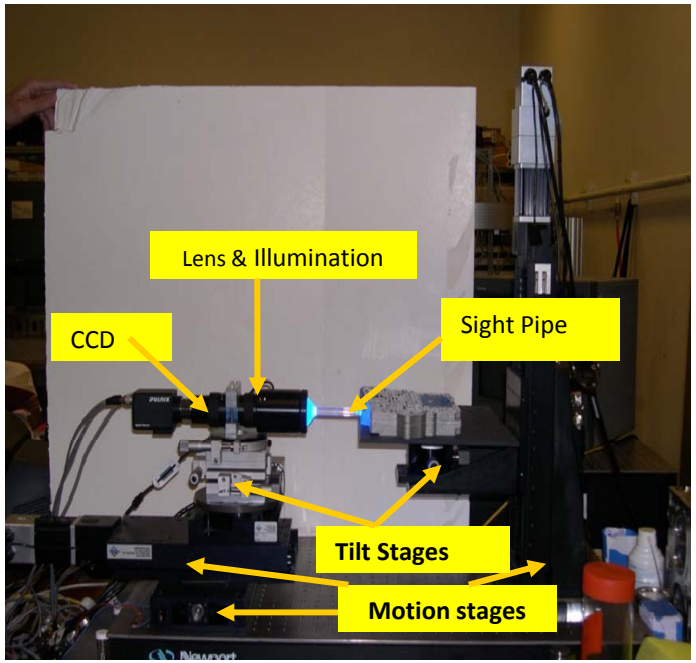
Methodology and setup based on a CCD and a Sight-pipe



360-degree-view Line Scan Flow



Optical principle of the sight-Pipe



Internal Thread Measurement System

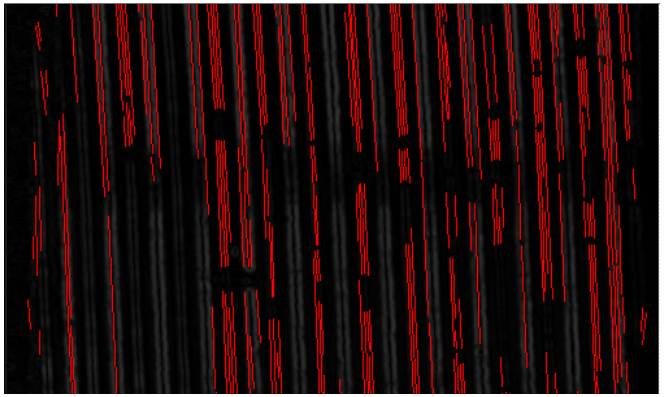
The integrated sensor

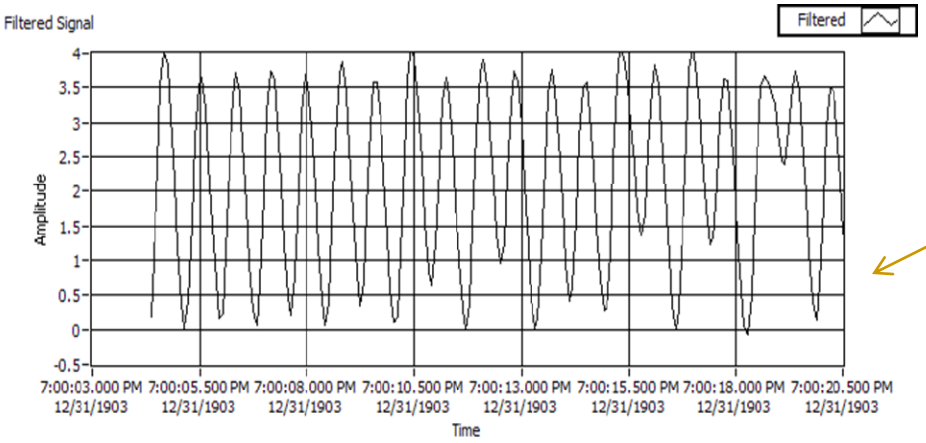
Measurements results

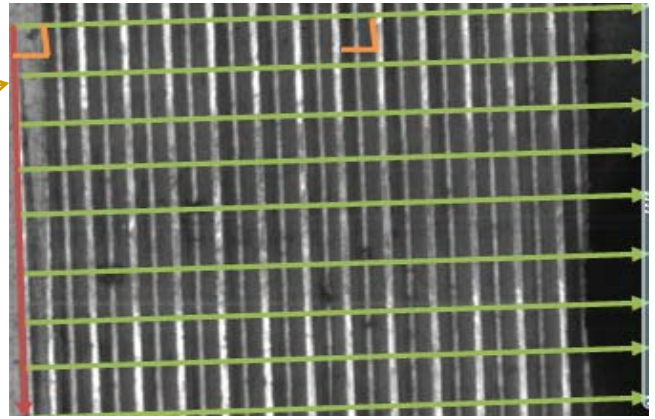
1. **A smoothing filter followed by Prewitt filter is used to bring out edges.**

2. **LabVIEW Shape detection is used to extract average angle of threads.**

3. **A series of line profiles are generated perpendicular to the thread lines and peaks are detected.**







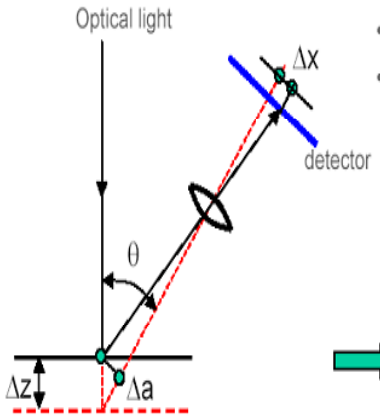
$$\overline{Pitch} = \frac{Distance\ from\ first\ peak\ to\ last\ peak}{\#\ of\ peaks - 1} * 2$$

Discussion on Method 2 (3D Digitalization)

Principle

- The principle of 3D-Digitization is based on the optical triangulation.
- Fig. 1 shows the fundamental of the optical triangulation (cf. the next page). The Eq. 2 shows the distortion Δx has a relationship with Δz. The k is called sensitivity factor.

Principle of optical triangulation:



- Δx is a distortion on the detector
- Δz is the information of surface shape
- θ is the illumination angle

$$\Delta x = M \cdot \Delta a \quad (1)$$

M is the magnitude of the camera

$$\Delta a = \Delta z \cdot \sin\theta$$

$$\Delta x = M \cdot \sin\theta \cdot \Delta z = k \cdot \Delta z \quad (2)$$

Fig. 1. Spot of light triangulation

- k is called as sensitivity factor

Phase Shift Technique

What is the phase shift technique?

Phase shift technique is method to quantitatively determine phase values of Δ from recorded intensity distributions (equations):

$$I = a(x,y) + b(x,y)\cos\Delta$$

There are three unknowns in the above intensity expression. They are the background a(x,y), the term b(x,y) which is related contrast and the phase angle Δ.
In order to determine the unknown Δ from a equation with three unknowns, at least three equation are required:

Principle for determining Phase angle using three recorded intensity equations:

$$I_1 = a + b\cos\Delta$$
$$I_2 = a + b\cos(\Delta+120°)$$
$$I_3 = a + b\cos(\Delta+240°)$$

$$\Delta = \arctan\frac{\sqrt{3}\,(I_3 - I_2)}{2I_1 - I_2 - I_3}$$