A SPC Based System on for the off line Diagnosis of Thread Quality in internal Screw Tapping Operations -smart manufacturing-

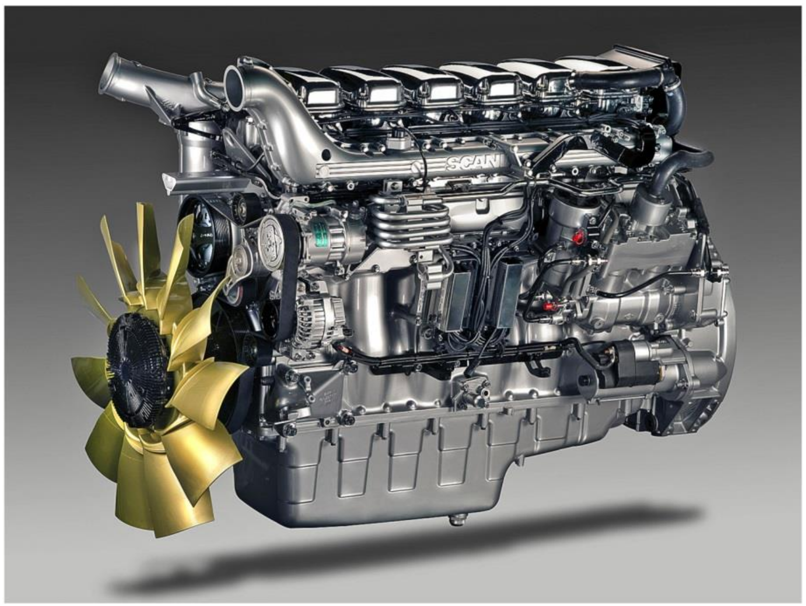
Alain Gil Del Val
Assistant Professor at Public University of Navarre

Outline

- Introduction
- Experimental set up and signal selection
- Experimental results and wear parameters
- Parameters Reduction: Principal Component Analysis (PCA)
- Thread Quality Diagnosis: Statistical Process Control (SPC)
- Conclusions and Further Work

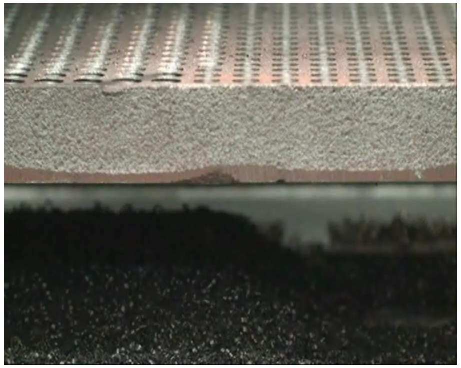
Introduction

- Threaded elements
  - Coupling of mechanical parts

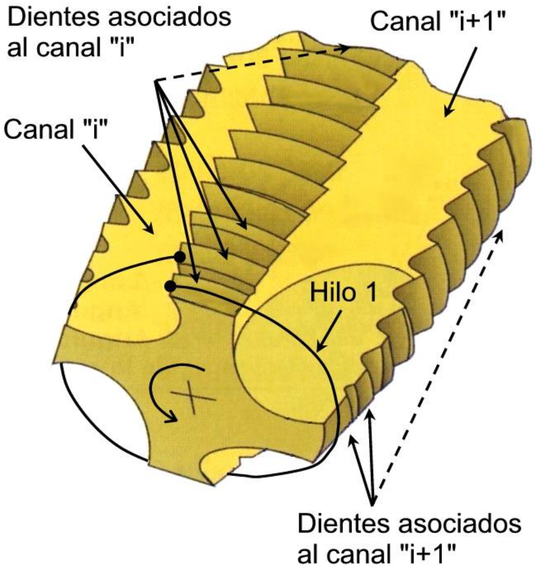


- Threaded elements
  - Not only in coupling of mechanical parts

Introduction



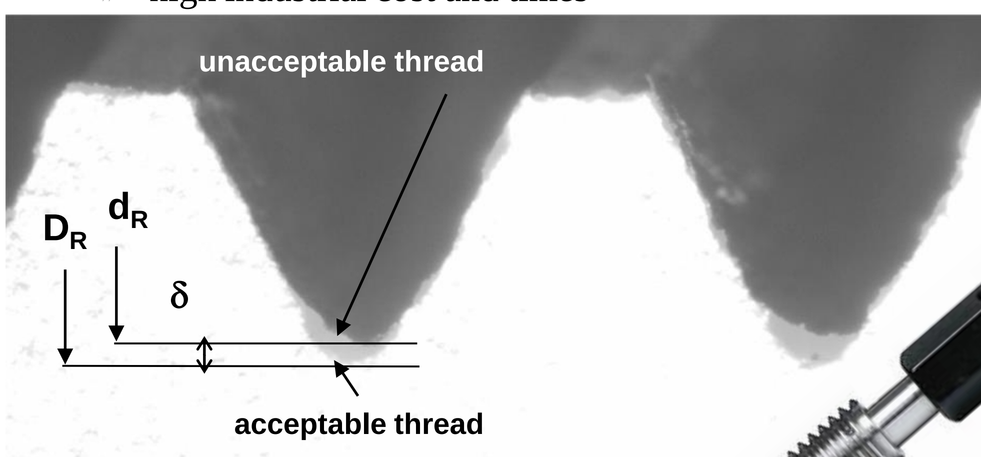
- Threaded elements
  - Coupling of mechanical parts
  - Tapping: widely known operation
- Problems expected as a result of
  - Complex geometry and large number of active teeth
  - Need of a strict synchronism between tap rotation and feed



Introduction

Thread Quality

- Experimental Facts show that:
  - As tap wear goes up:
    - Torque goes up ➔ the risk of tap or tooth fracture also goes up
    - And tap rotation and vertical feed are not synchronised ➔ over-sized threads
    - <u>The risk of under-dimension of tapped threads also goes up</u>
      - Threads dimension assessment: by a go-no-go gauge but it implies (<u>**manual inspection**</u>)
        - » high industrial cost and times



$d_R = D_R - 2\delta$

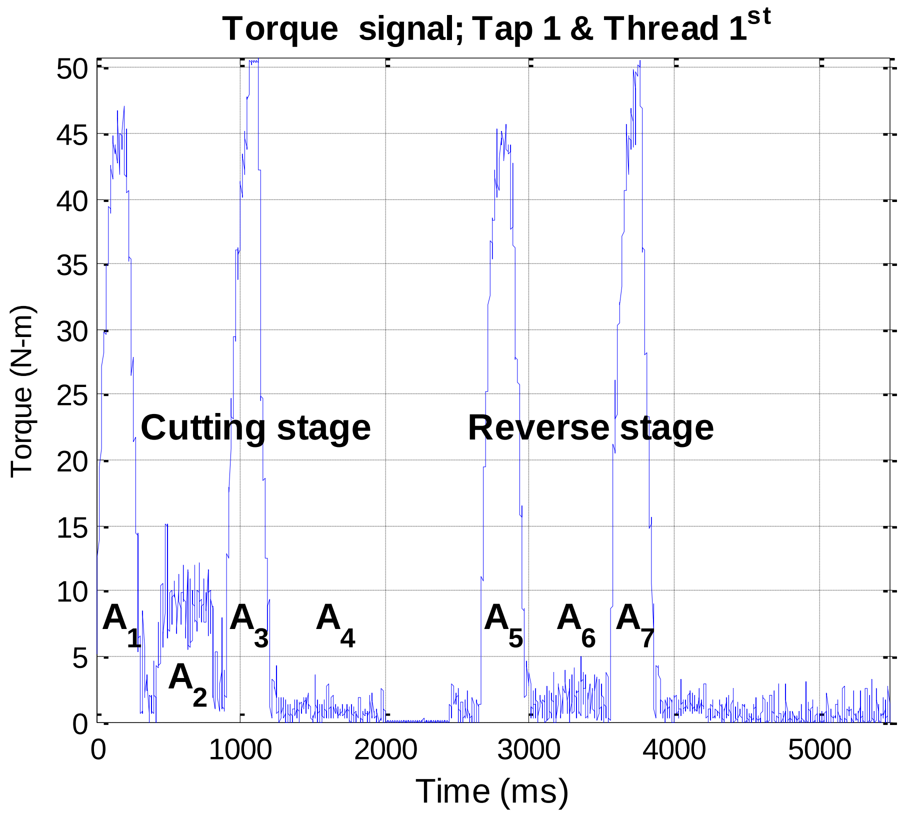
Go-no go gauge defines the end of thread quality (ETQ)

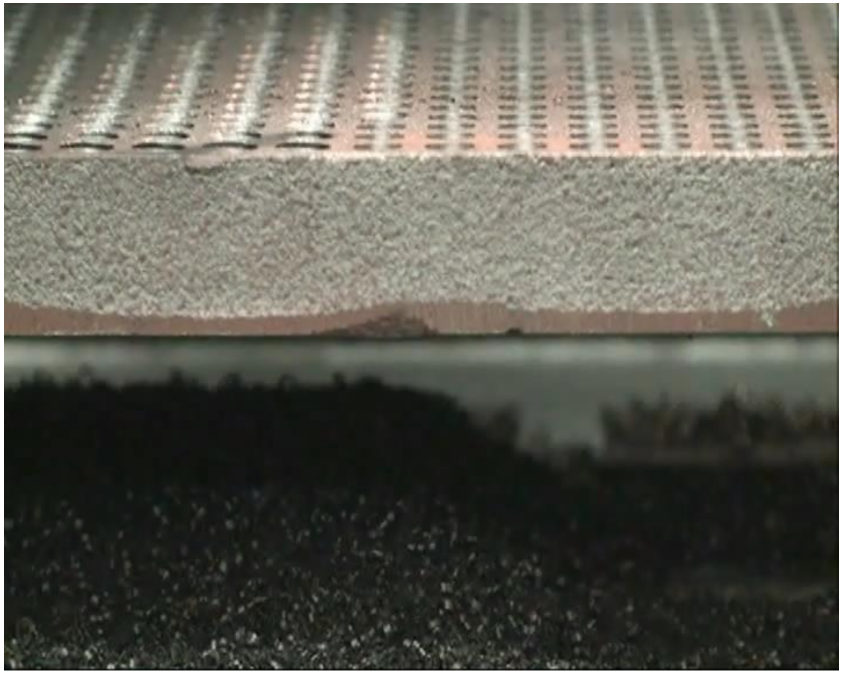
The **AIM**

is to develop an off line diagnosis strategy that:

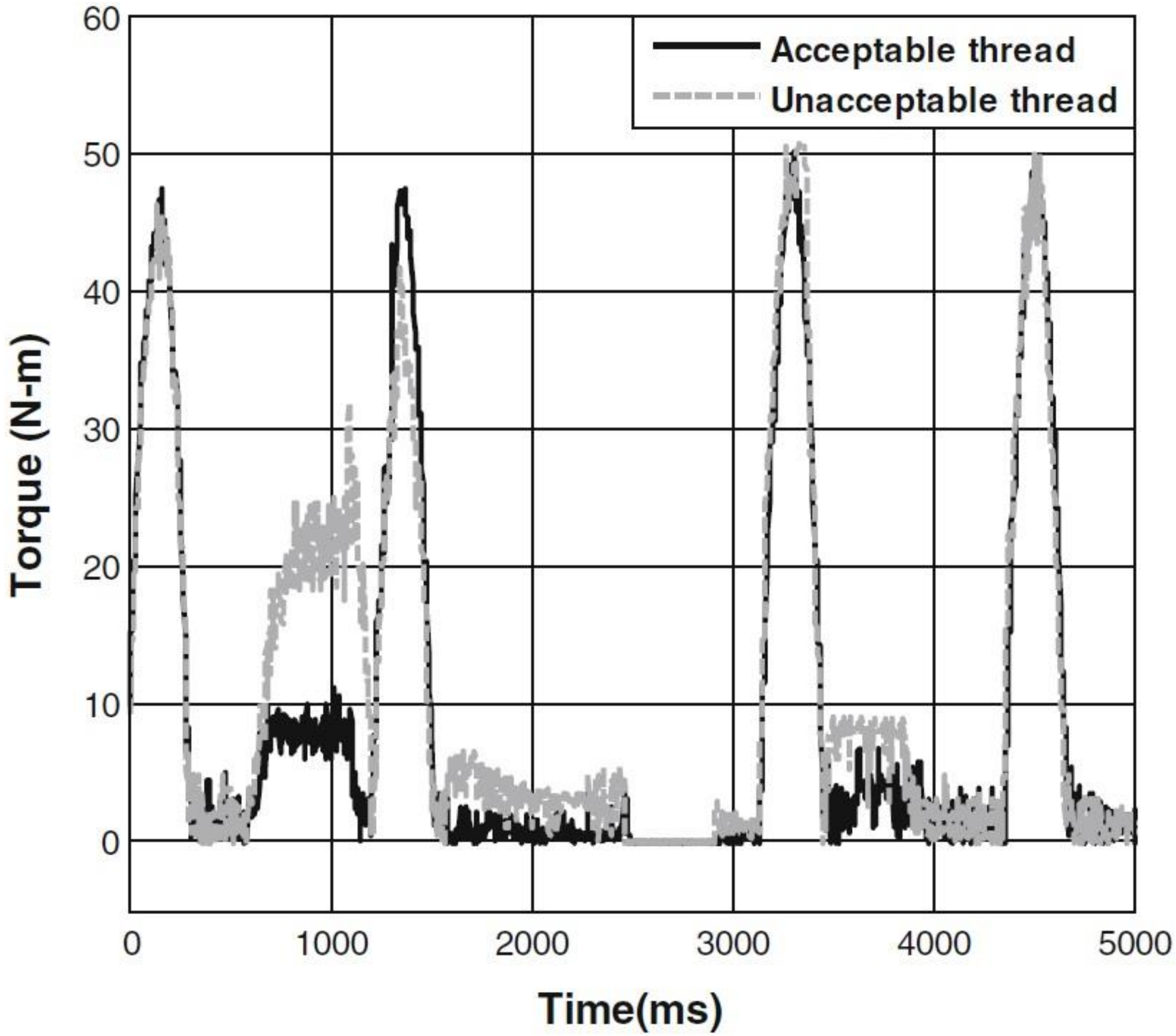
warns when quality thread is about to become out of control (go gauge does not go: undersized threads), so that red alarm could switch on and tap replacement could be done immediately.

Signal selection and experimental set up





Signal selection and experimental set up

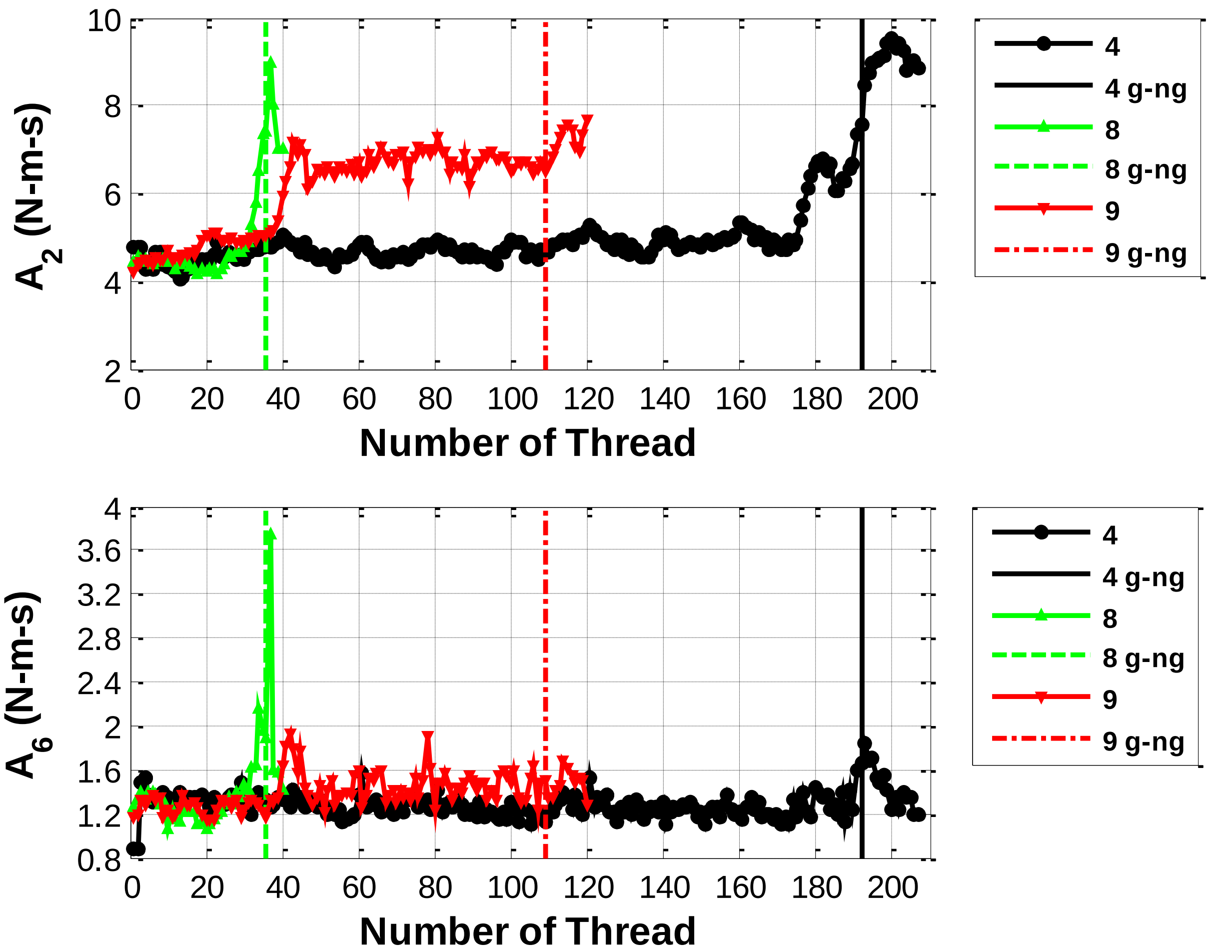


Signal selection and experimental set up

Tap	Total Threads	Correct Threads
1	235	222
2	120	108
3	100	82
4	205	192
5	100	81
6	80	60
7	40	28
8	40	36
9	120	109
10	80	68
11	72	70
12	76	62

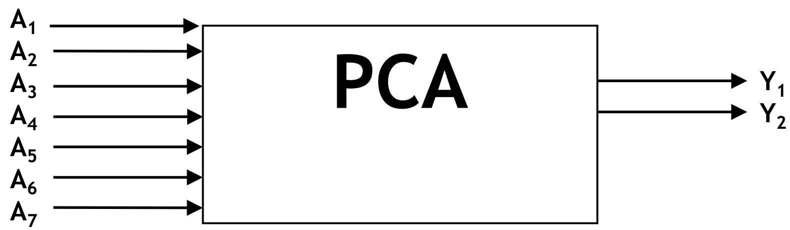
Experimental results and wear parameters -Data exploring analysis-

A_2, A_6 & go-no go lifes; taps: 4, 8 & 9



Principal component analysis

- **Principal component analysis (PCA)**
  - **Reduces parameter numbers without losing data information**



$$\boldsymbol{Z} = \left(\boldsymbol{X} - \overline{\boldsymbol{X}}\right)\boldsymbol{S}, \quad \text{where} \quad \boldsymbol{S} = diag\left\{1/s_{x_i}\right\}$$

$$\boldsymbol{Y} = \boldsymbol{Z}\boldsymbol{V}$$

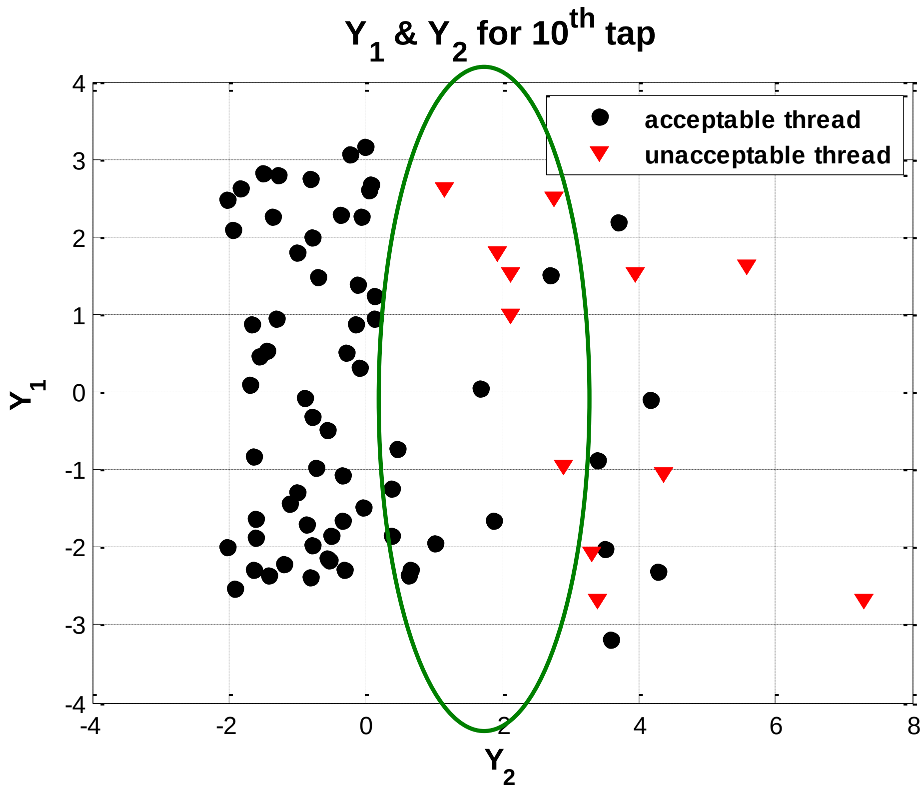
$$\mathrm{cov}(\boldsymbol{Y}) = \boldsymbol{V}'\mathrm{cov}(\boldsymbol{Z})\boldsymbol{V}$$

$$Y_1 = 0.25\left(A_1 + A_3 + A_5 + A_7\right)$$

90% explained variability of the process

$$Y_2 = 0.5(A_2 + A_6)$$

Principal component analisys



- Solution?

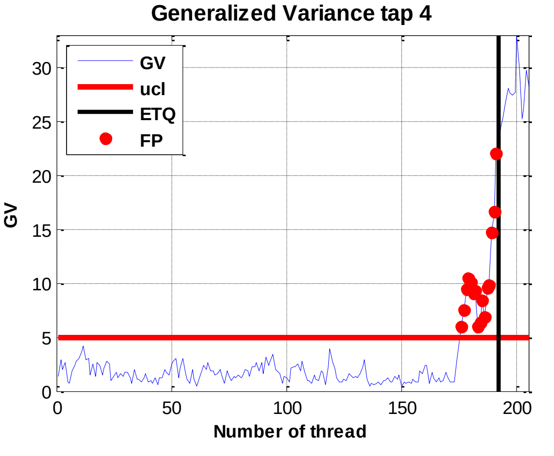
Statistical process control

- **SPC** is method of quality control in order to monitor and control the process

$$GV = \left(\frac{\left(Y_{1,m} - \overline{Y_{1,m}}\right) + \left(Y_{2,m} - \overline{Y_{2,m}}\right)}{n-1} \right)^{1/2}$$

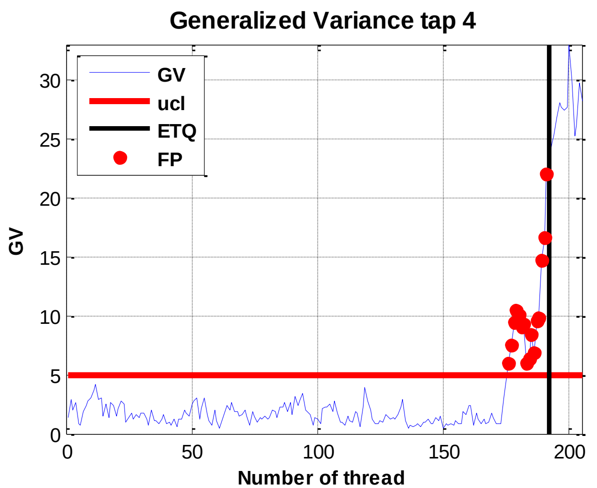
$$UCL = B_4 \overline{GV}$$

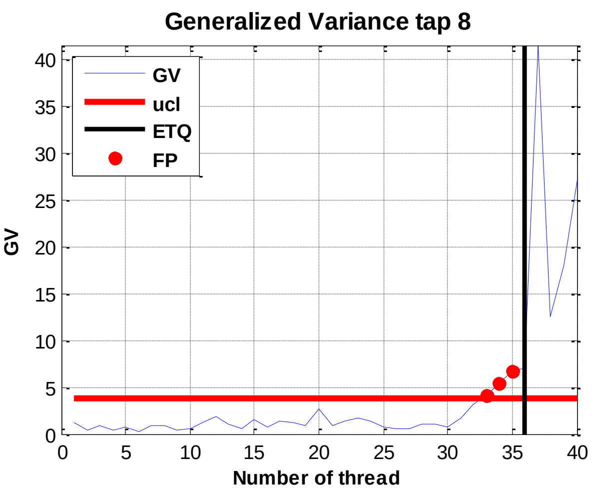
- m=learning period (10 first threads)
- n= 2 principal components (PCs)

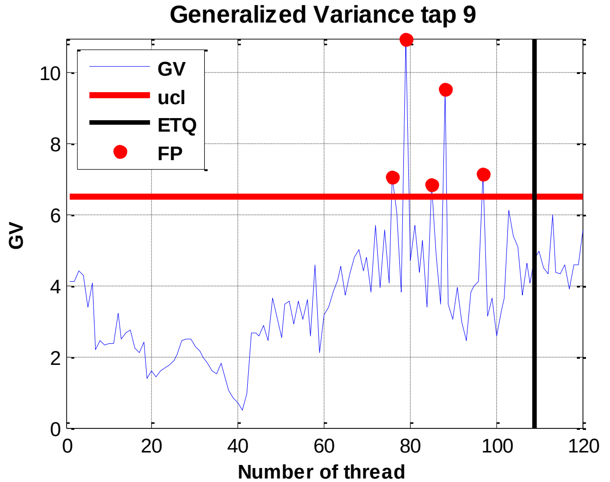


- The process is deemed "out of control" when $GV_j > UCL$
  - This produces FPs (tool cost) before ETQ
- If $GV_j < UCL$ after ETQ, this is a FN and a unacceptable thread has been tapping

Statistical process control -off line SPC charts-







Tap 4	8% TC	0% FN
Tap 8	6% TC	0% FN
Tap 9	30% TC	0% FN
12 taps average	**16% TC**	**0% FN**

Conclusions

- An off line strategy for assuring good quality of M10x1.5mm threads machined with TiN Coated HSS taps and using torque signals of the spindle motor has been developed and validated for cast iron GGG50
  - Anticipates "on line" wrong threads with reliability even in operator absence with very small tool cost (TC) penalty,
  - There are no FNs.

- As Further Work
  - This smart manufacturing tool will be validate on line at the Lab and an industrial partner enterprise.
  - The strategy will be validated for different types of work-piece and tap materials, cutting speeds, tap diameters, geometries and coatings.

Acknowledgements

- The author would like to thank:
  - The Basque Government for the support given to this research project (IT-2005/0020) through the INNOTEK,
  - to Neco-Tivoly as a tool manufacturers,
  - also to CYTED organization group.

- Finally, **thank you for your attention!**

A SPC Based System on for the on line Diagnosis of Thread Quality in internal Screw Tapping Operations -smart manufacturing-

Alain Gil Del Val
Assistant Professor at Public University of Navarre