# Use of a Stochastic Model for Updated Remaining Useful Life Estimates

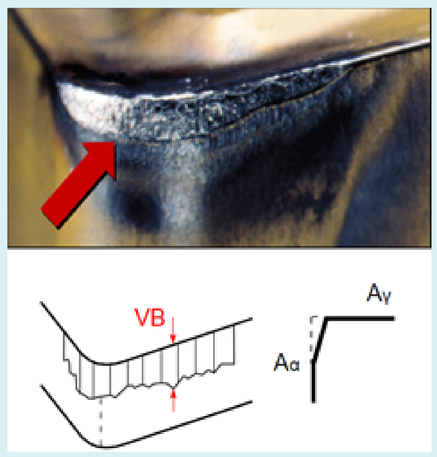
Université de Mons
GMECA Polytech Mons
risques — Institut de recherche en sciences et management des risques de l'UMONS
INSA — Institut National des Sciences Appliquées Centre Val de Loire

## Résumé

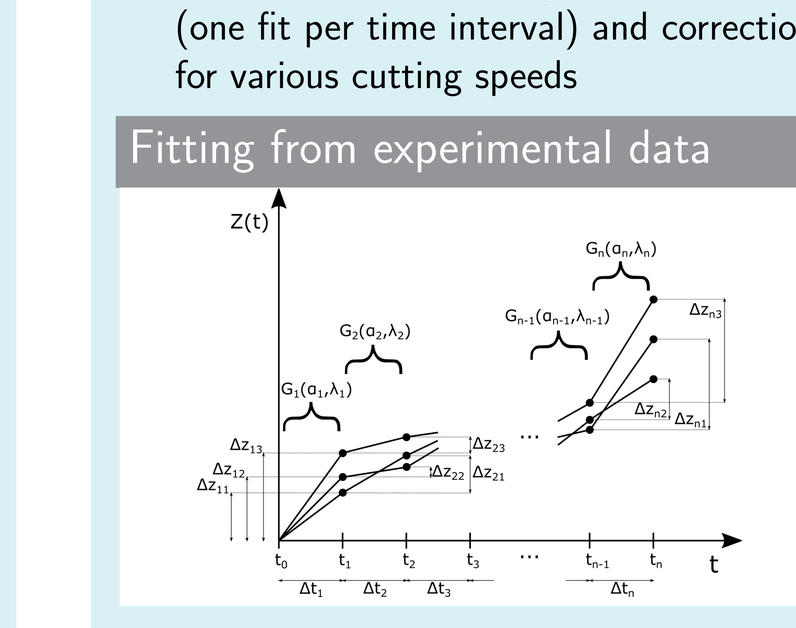

- Remplacement optimal des outils coupants
- **Simulation de la dégradation des outils de coupe par un procédé gamma [1] : génération de trajectoires de dégradation**
- Ajustement du procédé gamma par parties de la durée de vie totale
- Prise en compte de l'influence de la vitesse de coupe sur la durée de vie
- **Peu d'observations effectives**
- Analyse probabiliste de l'évolution de l'usure
- Estimation statistique remise à jour au fil des observations


## Context

- Turning operations on iron alloys
- Wear of cutting tools
- **Remaining Useful Life assessment**

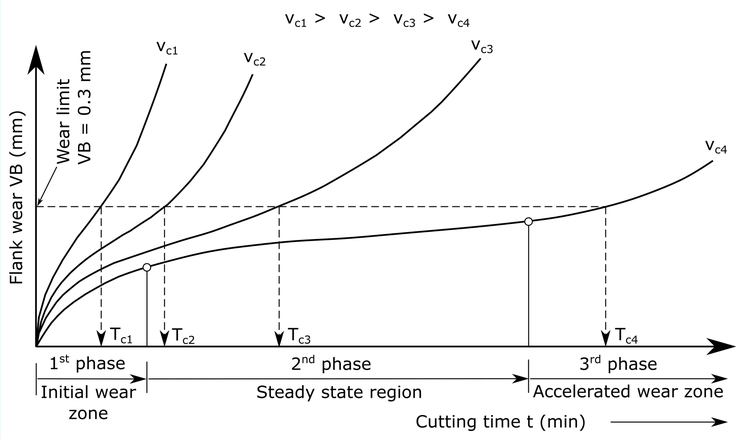



### Flank wear of cutting tools




## Wear evolution

### Influence of cutting speed

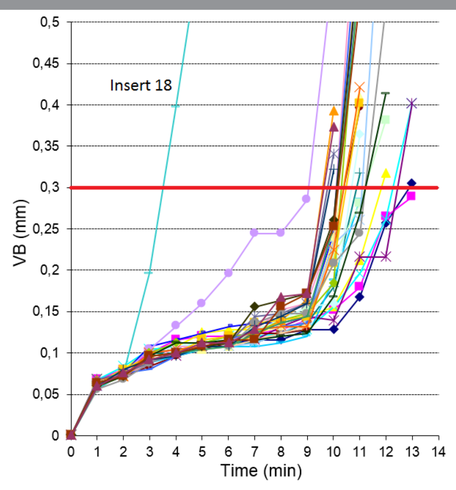



- 3 phases of wear
- **Influence of cutting parameters**
- Taylor's law $v_c T^n = C_T$
- Wear limit according to ISO 3685:1993

## Experimental data [3]

- Discrete-time tool observations
- Constant cutting speed turning; 30 replications

### Experimental evolution of wear




## Gamma process fitting [1]

- Discrete-time tool observations
- Monotonous piecewise gamma process (one fit per time interval) and correction for various cutting speeds

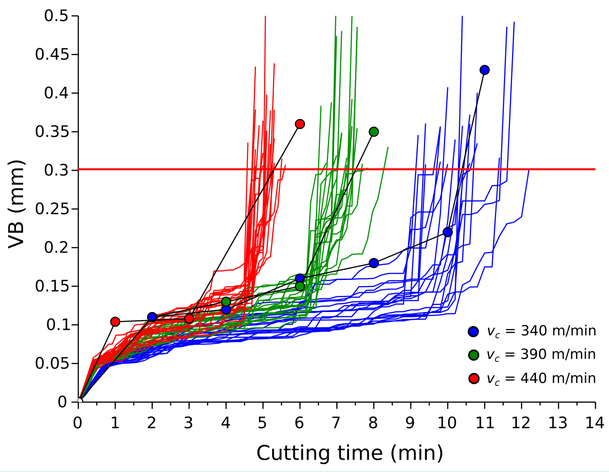
### Fitting from experimental data



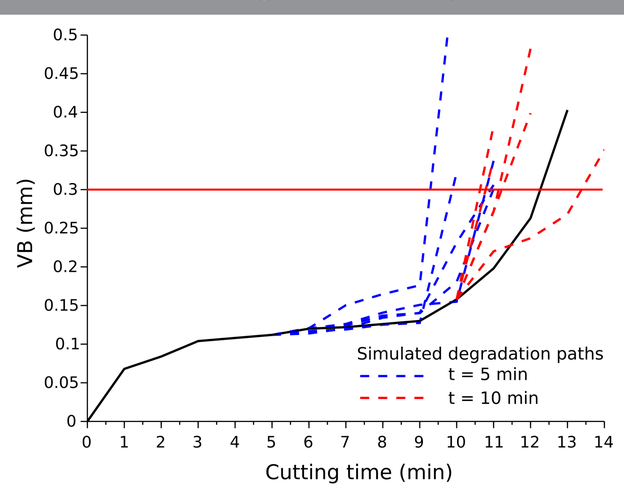

## Validation and use in the case of few observations monitoring

Validation:

- Constant cutting speed ✓
- Varying cutting speeds ↓ ✓

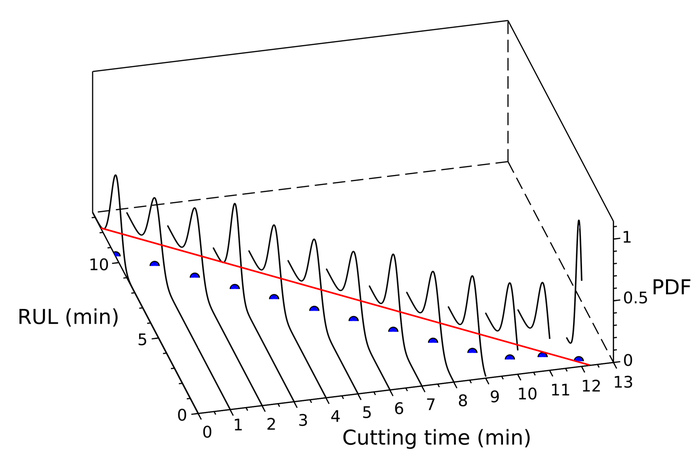



### Simulation of degradation paths




- Updated simulations (few monitoring observations)
- Progressive updates of the trajectories

### Probabilistic Remaining Useful Life




- Remaining Useful Life updated at each inspection
- Probabilistic aspect of the evolution (gamma process)
- Confidence interval assessment

## Keypoints and perspectives

- Degradation model matching experimental behavior
- Motivation for industrial applications
- Validation of the model for constant and various cutting speeds
- Use of condition monitoring as update input
- Varying parameters matching industrial uses
- Probabilistic aspects
- Updated RUL estimate on inspections
- Trajectories simulations can provide data for other approaches [2]

## References


[1] Lucas Equeter, Christophe Letot, Pierre Dehombreux, and Roger Serra. Cutting tool life management in turning process : a new approach based on a stochastic wear process and the Cox model. In *Qualita*, Bourges, France, 2017.

[2] Lucas Equeter, Christophe Letot, Roger Serra, and Pierre Dehombreux. Estimate of Cutting Tool Lifespan through Cox Proportional Hazards Model. *IFAC-PapersOnLine*, 49(28):238–243, 2016.

[3] Christophe Letot, Roger Serra, Lucas Equeter, and Pierre Dehombreux. Apport des modèles physiques de défaillance et des processus stochastiques pour la prédiction de la durée de vie d'outils de coupe (Contribution of Physical Failure Models and Stochastic Processes for Cutting Tools Lifetimes Prediction). In *JFMS*, Nancy, France, 2016.


**Université de Mons**

L. Equeter[1], Chr. Letot[1], C. Dutoit[1], R. Serra[2], F. Ducobu[1], P. Dehombreux[1]

[1]University of Mons, lucas.equeter@umons.ac.be, [2]INSA Centre Val de Loire

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