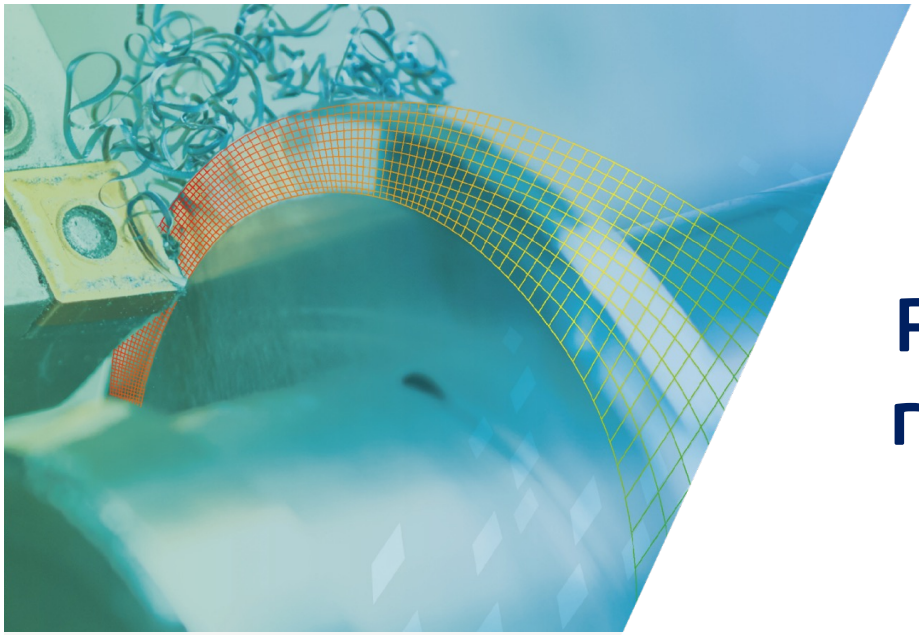


MISUTECH

Prédiction des contraintes résiduelles induites par les procédés d'usinage

joel.rech@misutech.fr

01/10/2025
Séminaire RDM du CNRS, Port-Barcarès

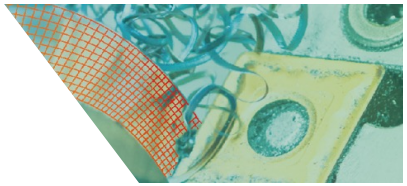
cnrs

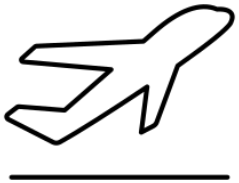
10e école technologique du Réseau Des Mécaniciens

RDM
Réseau Des Mécaniciens

La MÉCA en 2030

A propos de MISUTECH



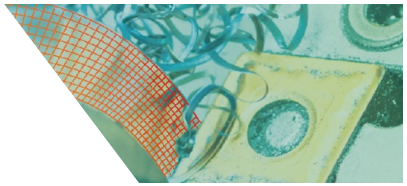


2023

8 collaborateurs

MISUTECH

Biographie



53 ans

Ecole Centrale de Lille => ENS Cachan

Agrégé de génie mécanique en usinage

Créateur de 2 ateliers d'usinage

Thèse de doctorat (Arts & Métiers)

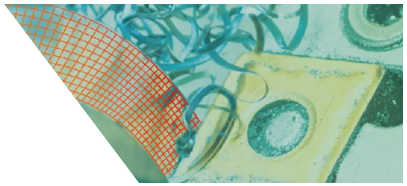
Professeur des Universités à CENTRALE LYON ENISE LTDS Tribologie et Dynamique des Systèmes UMR 5513

40 thèses dirigées

250 articles

MISUTECH

Sommaire



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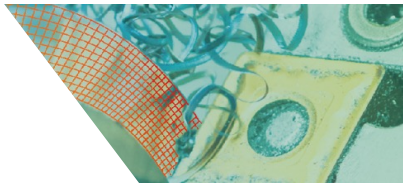
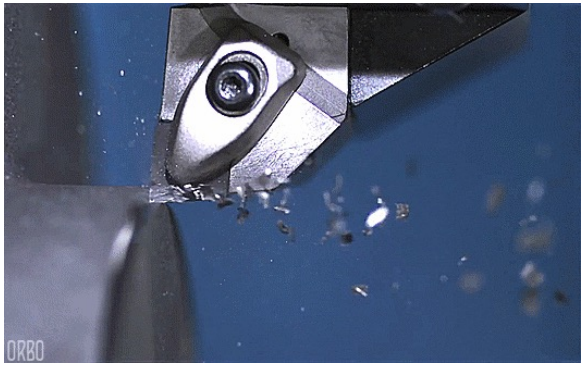
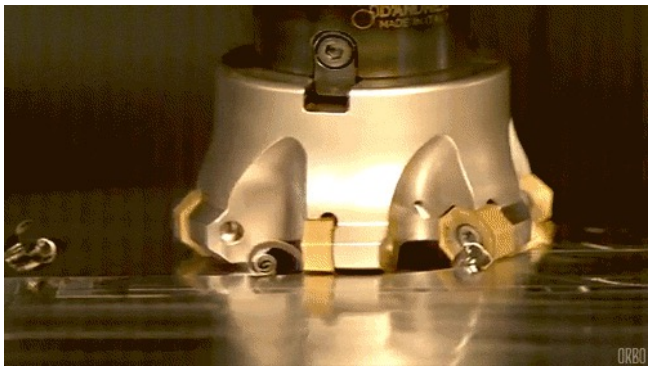
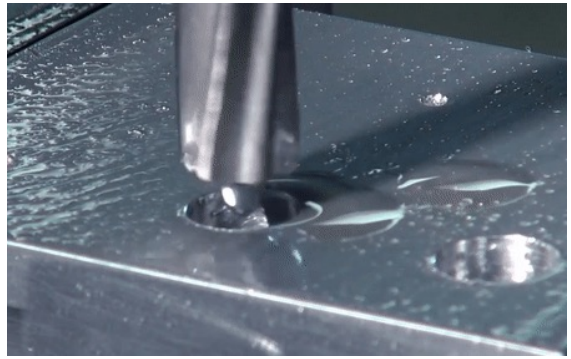
- Modélisation
- Paramètres influents
  - Usure des outils
  - Choix des outils
- Autres procédés
  - Fraisage, Perçage, Alésage, Toilage

Les procédés d'usinage : en première approche

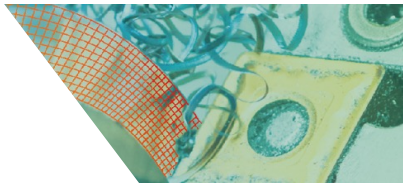




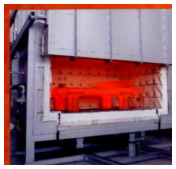


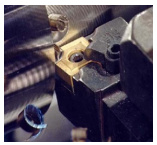


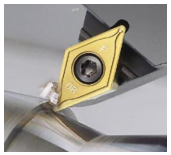
Finition des surfaces

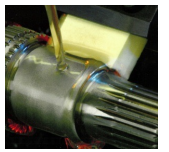


Forgeage → Traitement thermique → Usinage Ebauche → Usinage Finition → Superfinition



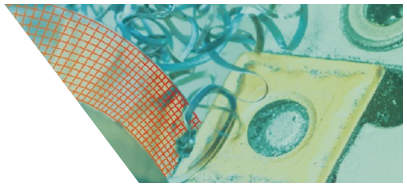






Les contraintes résiduelles concernent les opérations finales

Influence de l'usinage sur la durabilité des surfaces



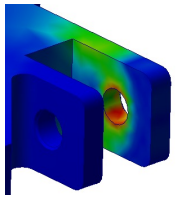
DESIGN

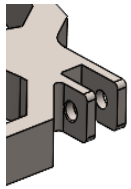
CONCEPTION

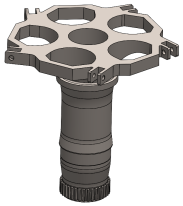
CALCUL FATIGUE

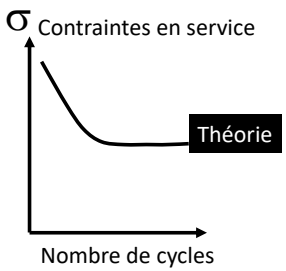
INDUSTRIAL.

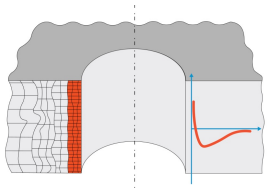
PROTOTYPE / FATIGUE

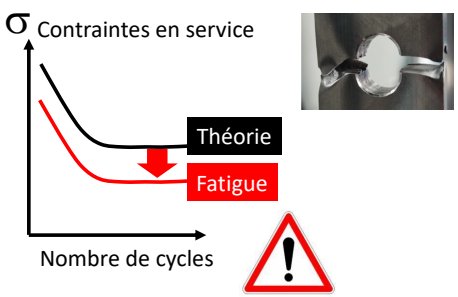


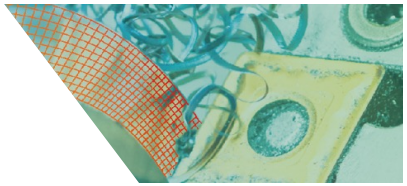


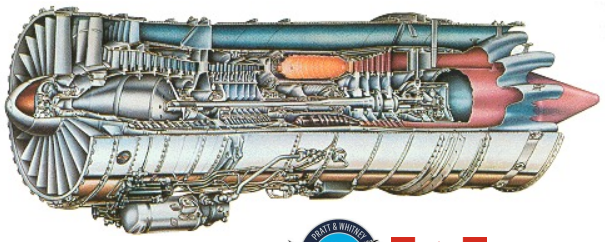




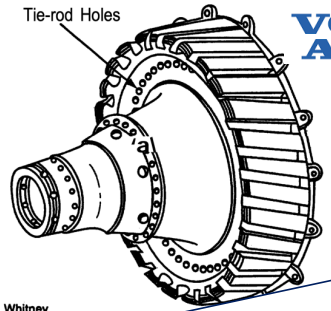








Pratt &Whitney JT8D-200 Series Engine Fan Hub

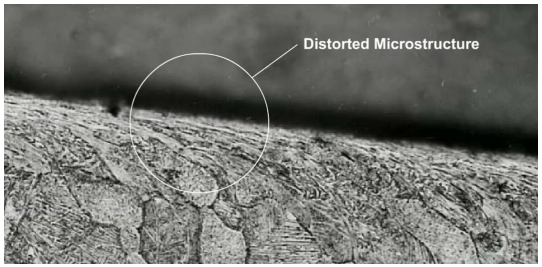


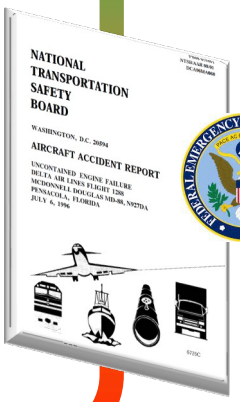
VOLVO AERO

Source: Pratt & Whitney

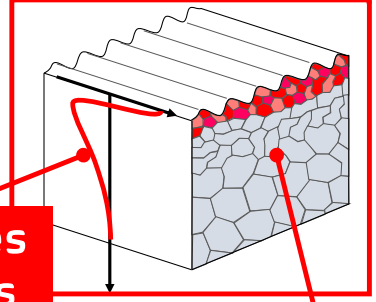
25% des accidents aériens sont provoqués par des usinages non maîtrisés

Pensacola (USA), 6 juillet 1996



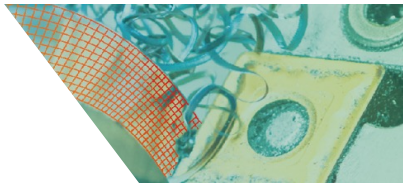


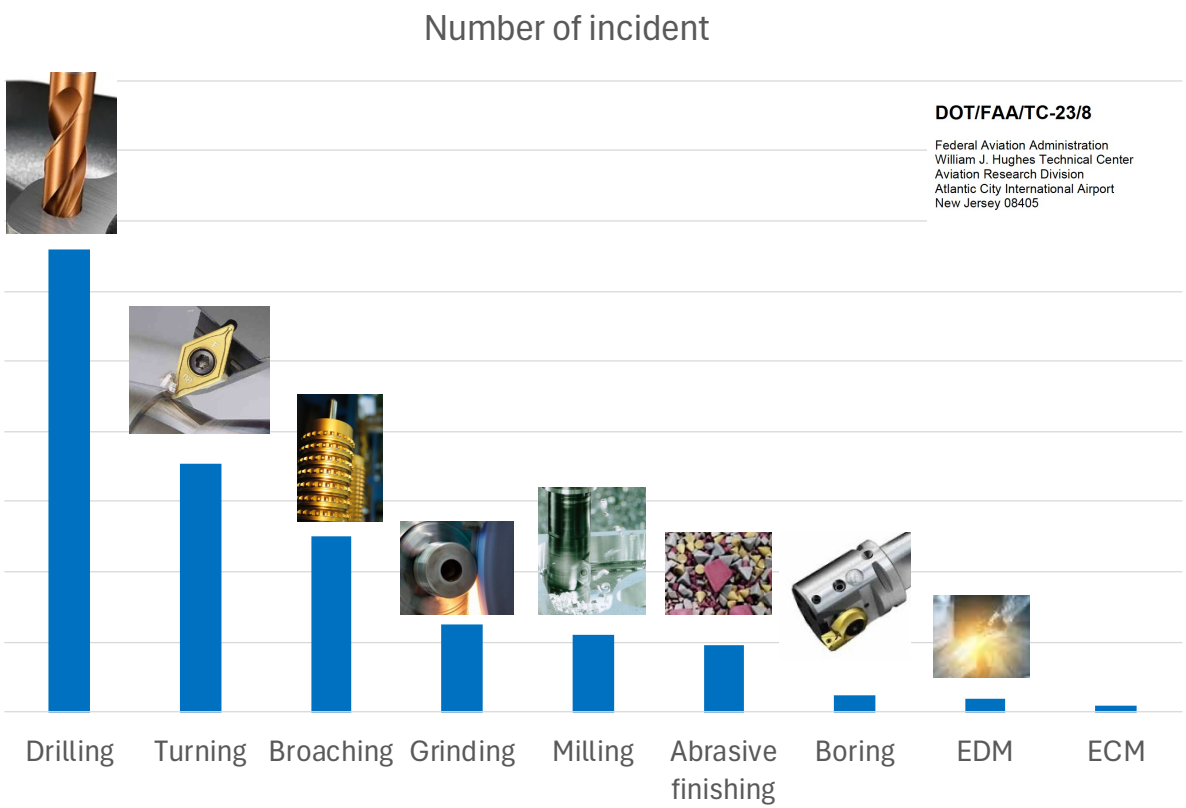
Contraintes résiduelles



Microstructure

Les procédés les plus critiques





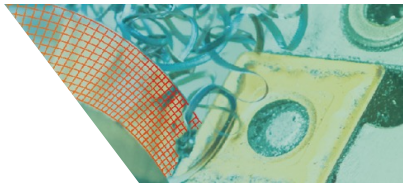
DOT/FAA/TC-23/8

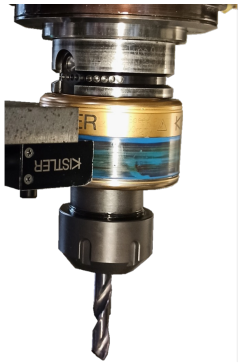
Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

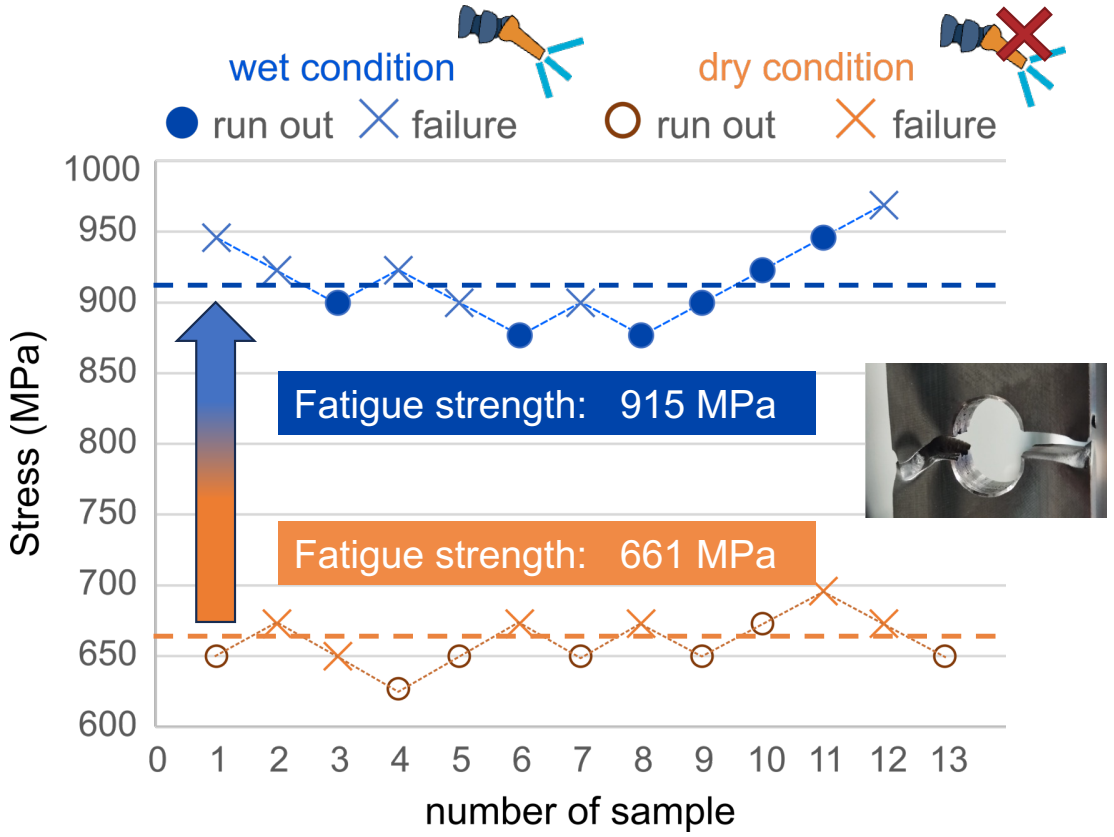
Guidelines to Minimize Manufacturing Induced Anomalies in Critical Rotating Parts – 2022 Revision

MISUTECH

Exemple : Perçage d'un acier 42CrMo4







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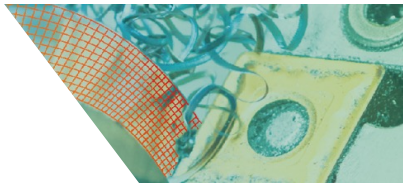
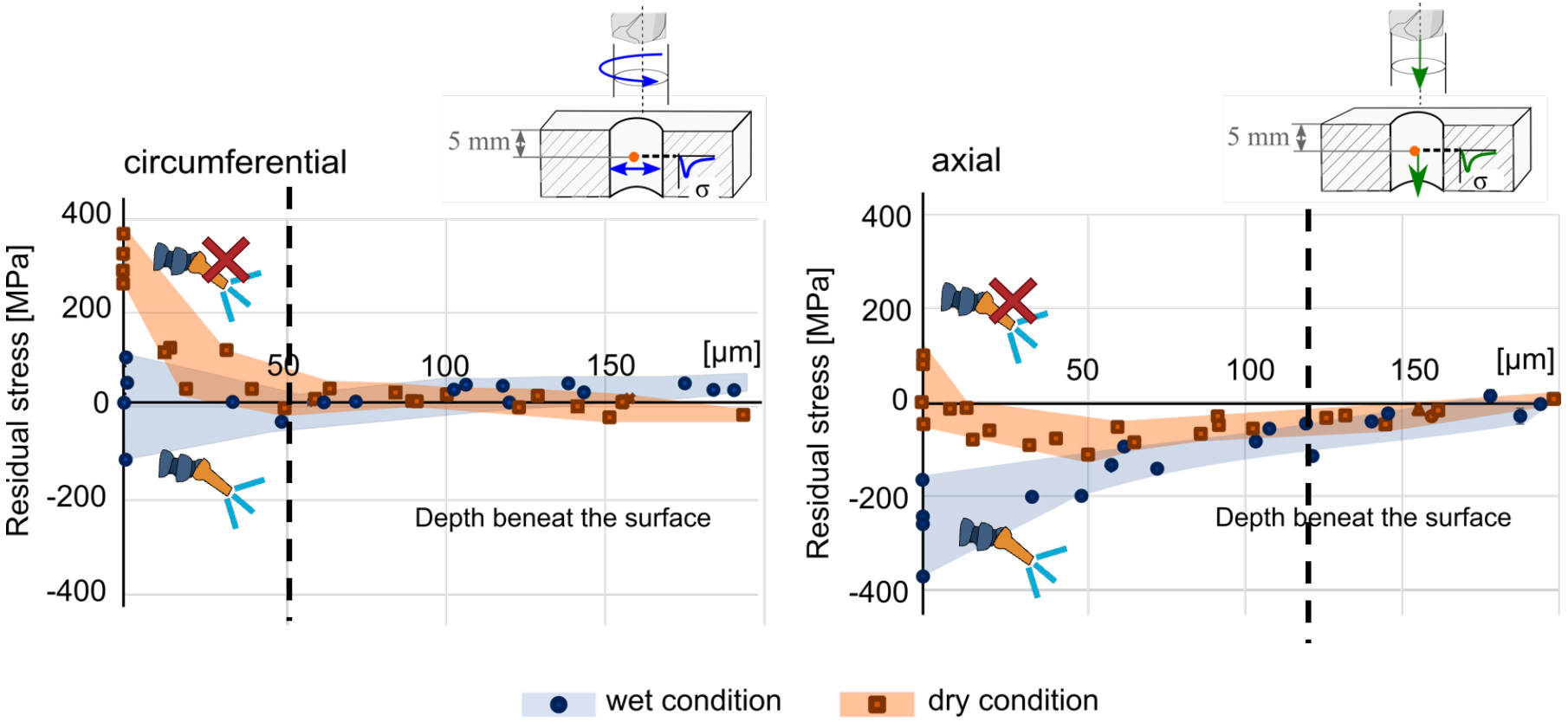
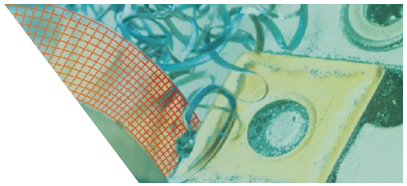


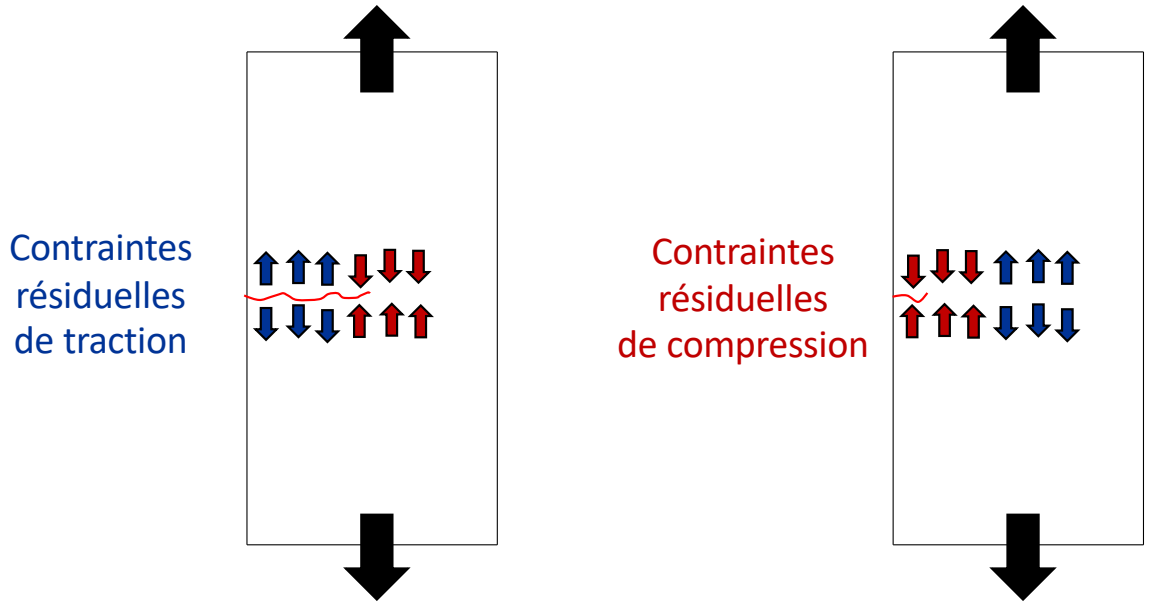


MISUTECH

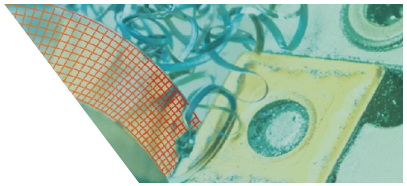
Pensée commune



- Les contraintes résiduelles de compression bloquent les fissures



Sommaire



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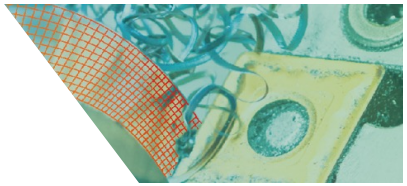
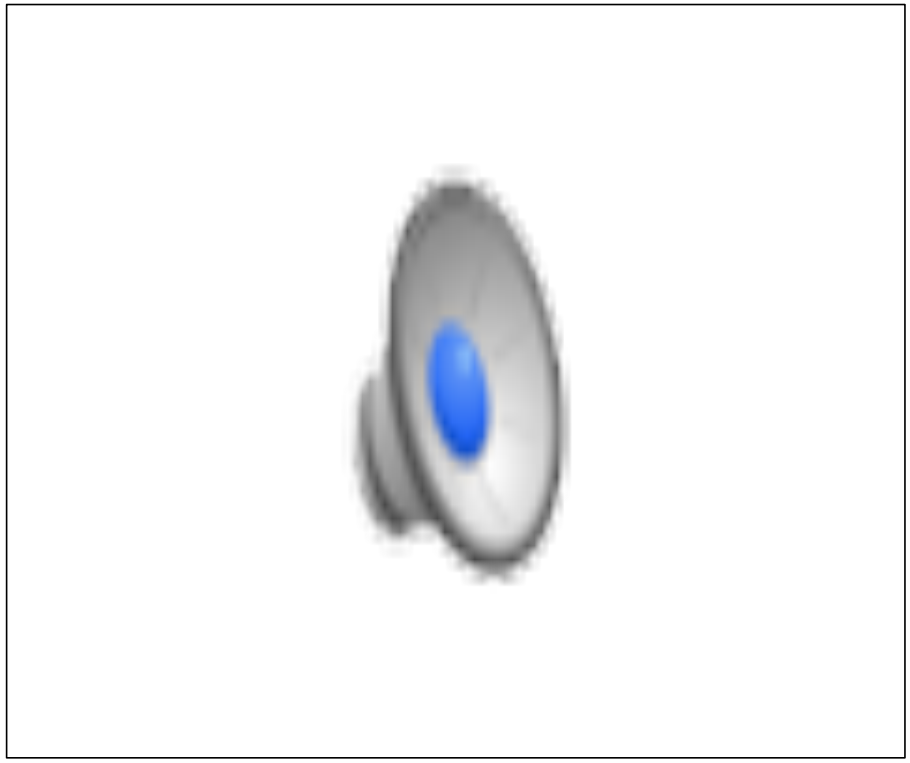
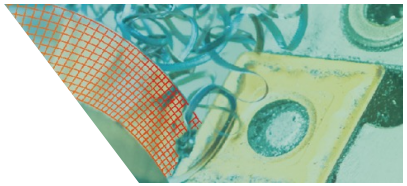
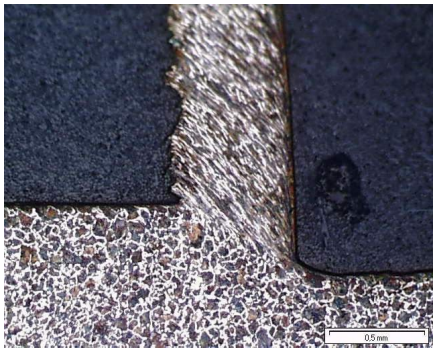
Mécanismes



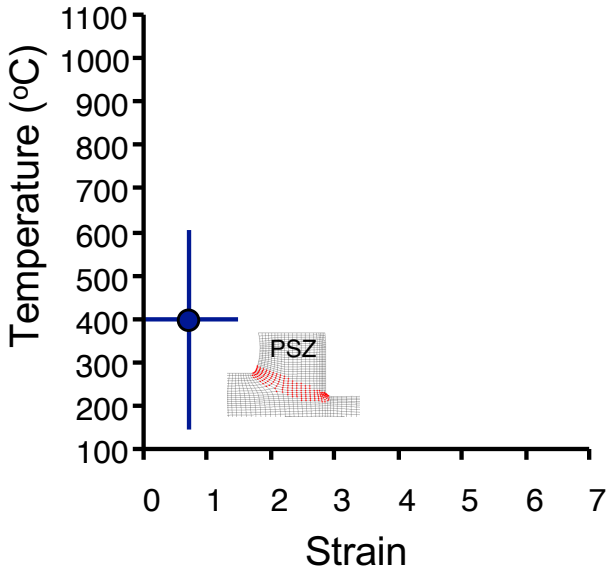


Conditions de sollicitations de la matière usinée



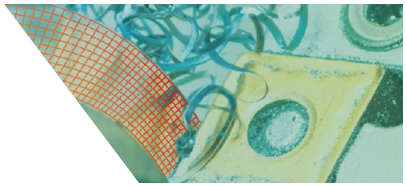


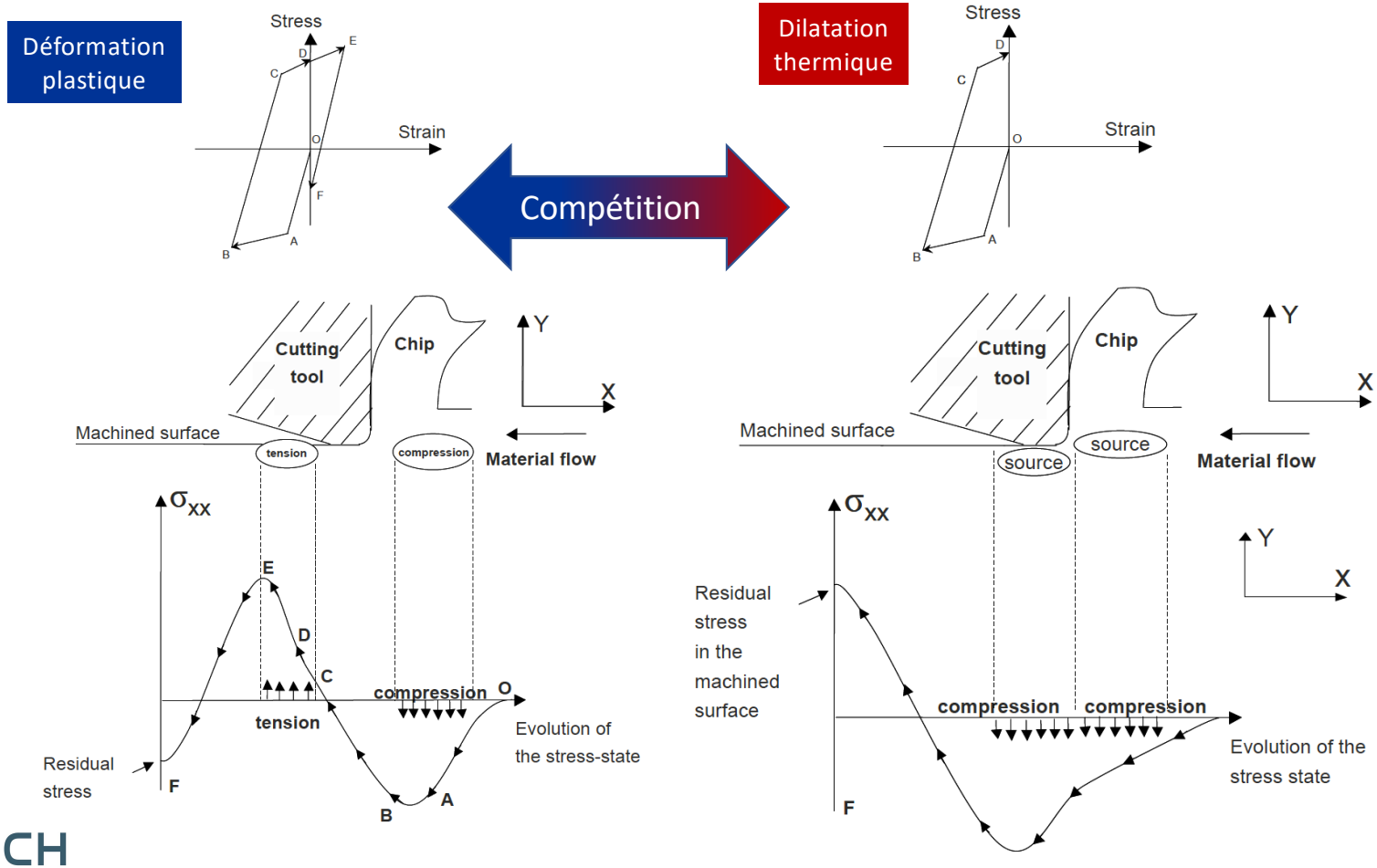
Matière usinée : acier C45 (180 HB)



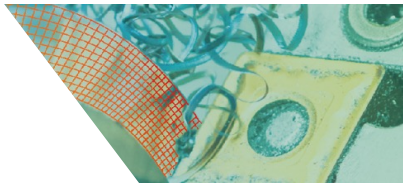
Courbon et al. (2008)

2 mécanismes de base en compétition

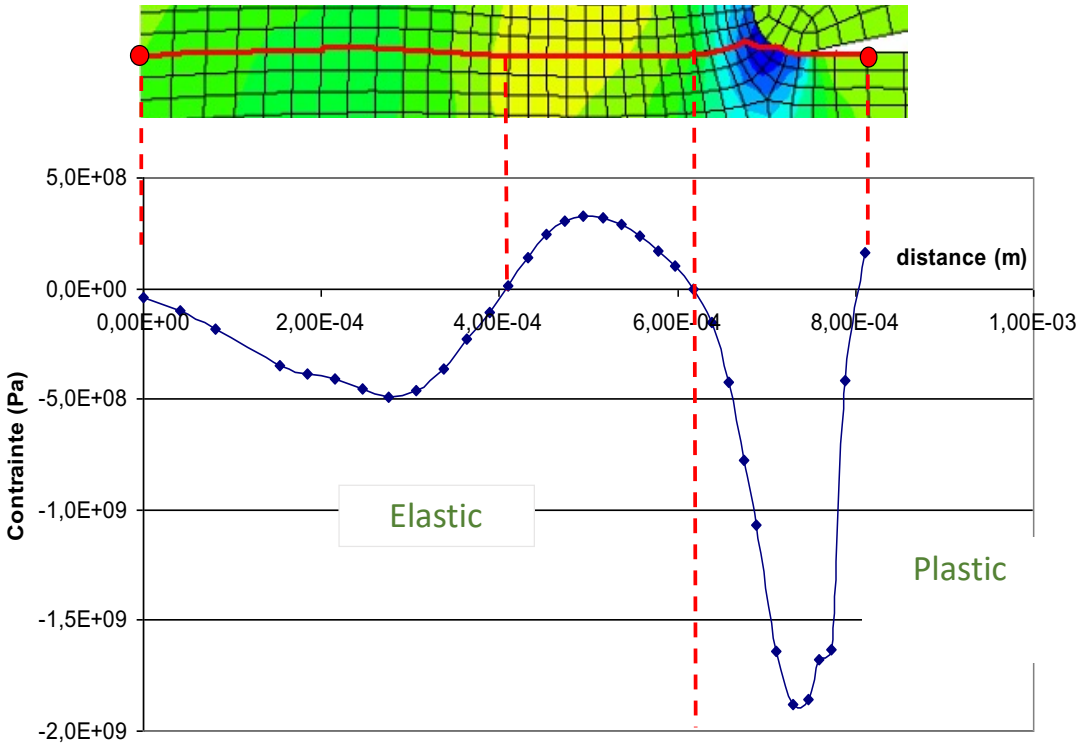




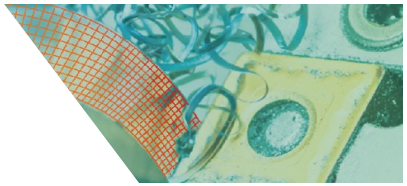
Exemple : tournage d'un acier inox 316L



Matière usinée : 316L
Conditions de coupe. Vc=120 m/min – f=0.2 mm/tr



Exemple : tournage d'un acier inox 316L



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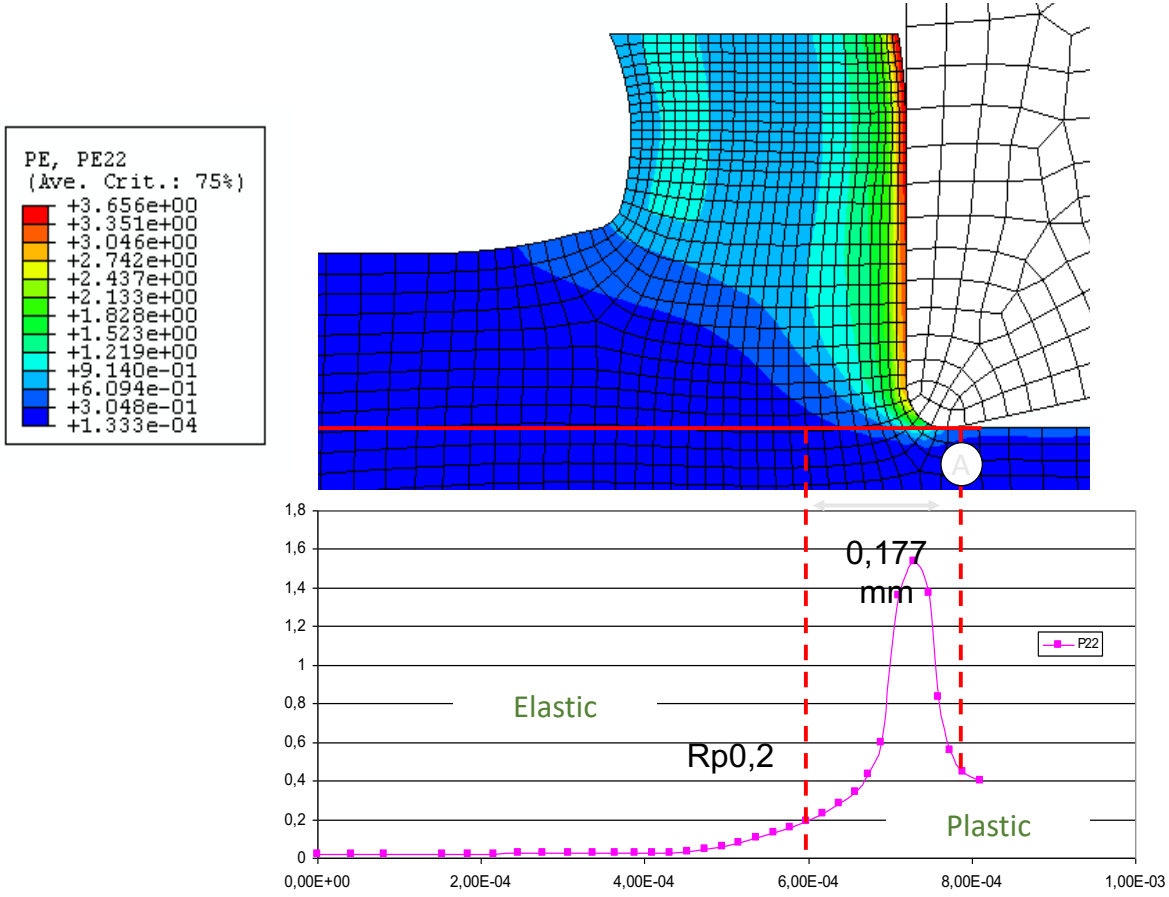
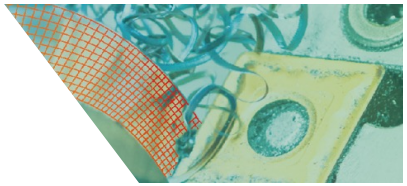
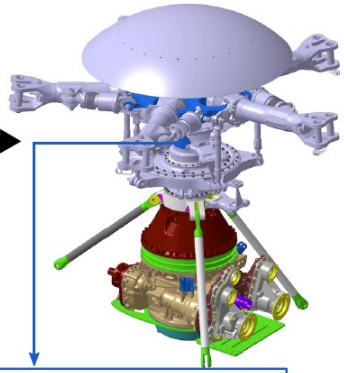
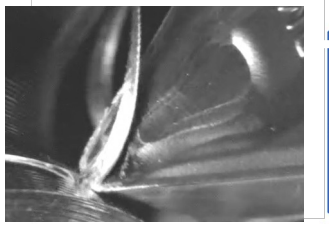


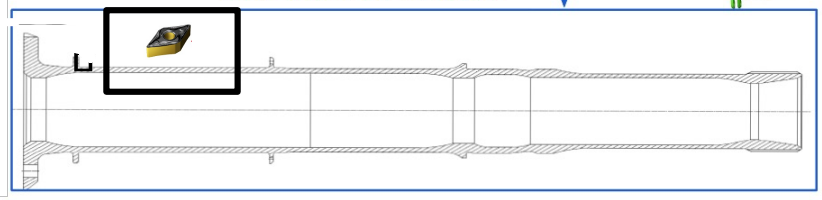
Exemple : tournage d'un acier 15-5PH





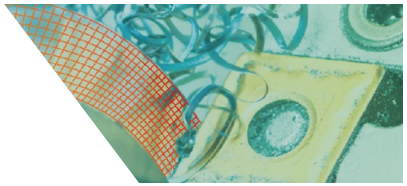


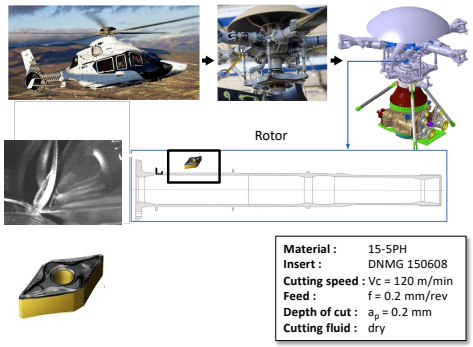
Rotor

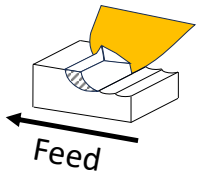


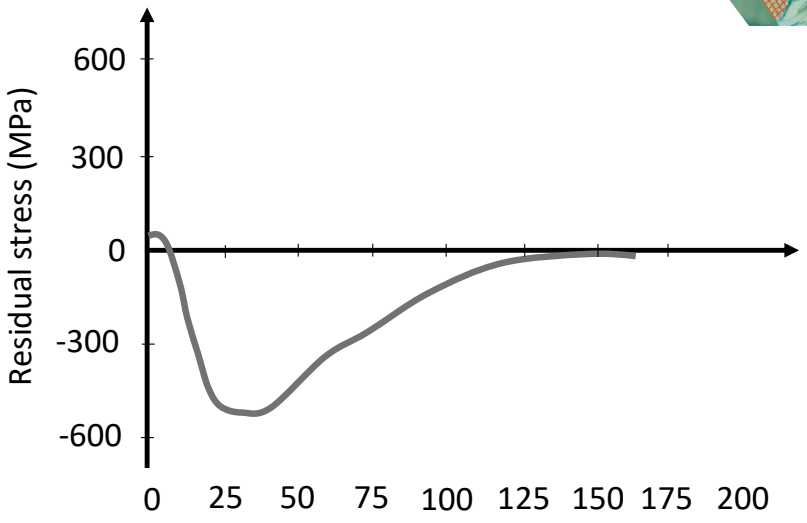
Material :	15-5PH
Insert :	DNMG 150608
Cutting speed :	Vc = 120 m/min
Feed :	f = 0.2 mm/rev
Depth of cut :	a_p = 0.2 mm
Cutting fluid :	dry

Exemple : tournage d'un acier 15-5PH





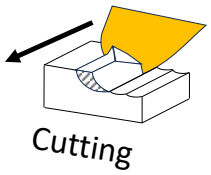


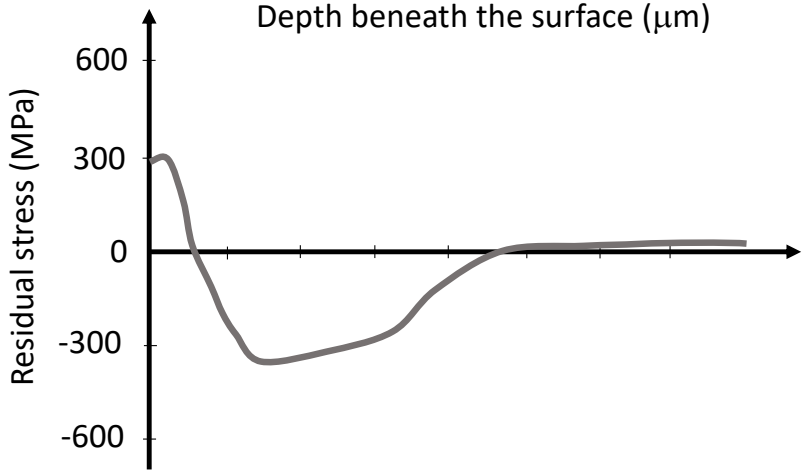


Diffraction conditions:
- Cr Kα Radiation with 18kV, 4mA
- λ = 0.229 nm, plans {211}
- Bragg's Angles: 2θ = 155,00°
- Ω acquisition mode

Acquisition conditions:
- 7 β-angles (from -30° to +30°) in both directions X and Y
- β Oscillations: ± 6°

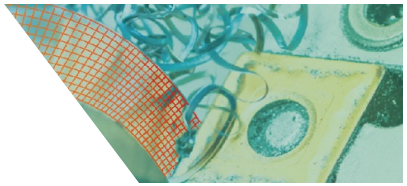
Stress calculation:
- Elliptic treatment method
- Radio crystallographic elasticity constants:
  ½ S_2 = 5.92x10^{-6} MPa^{-1} - S_1 = -1.28x10^{-6} MPa^{-1}

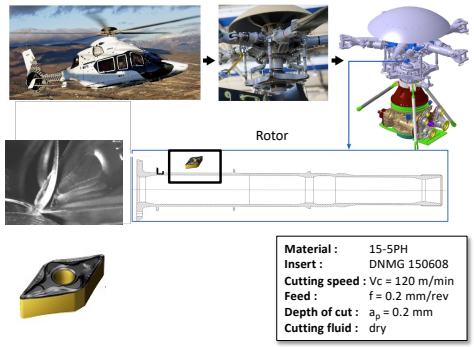


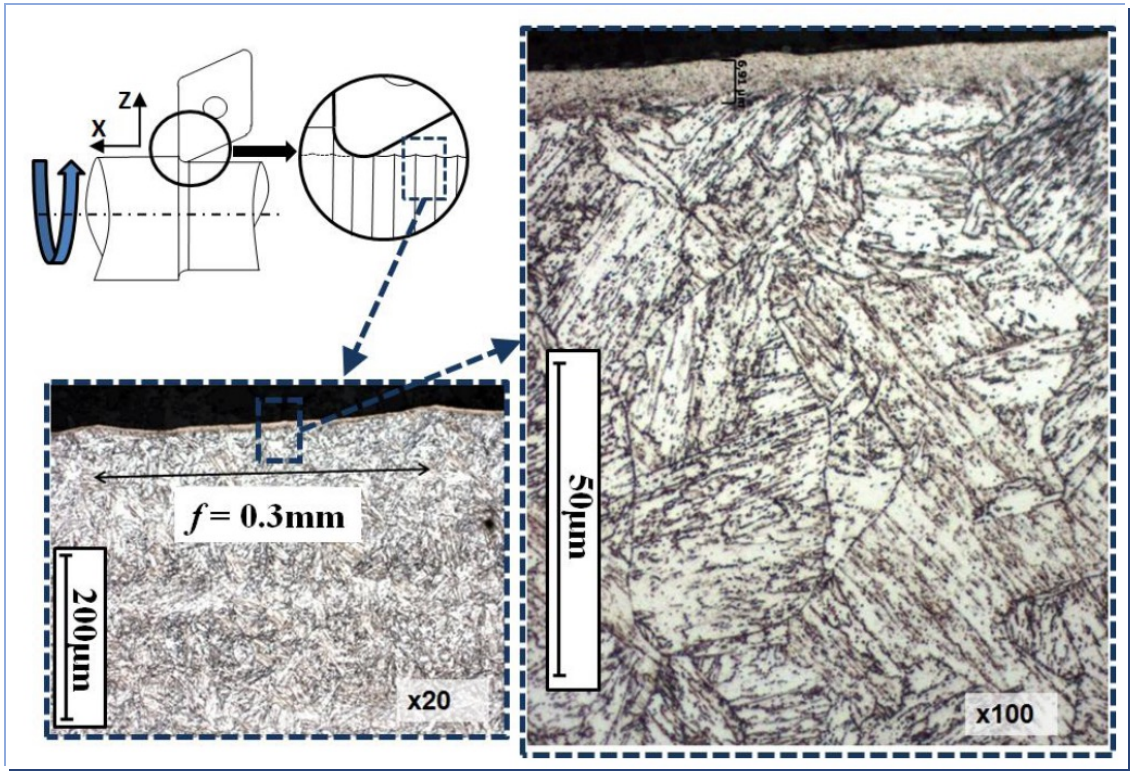


MISUTECH

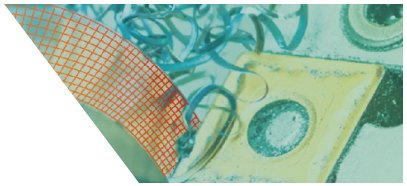
Exemple : tournage d'un acier 15-5PH

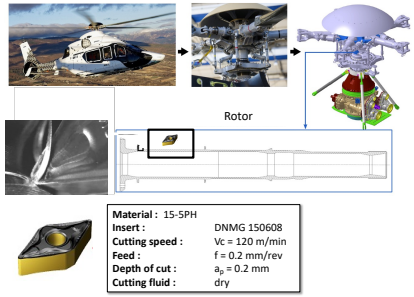


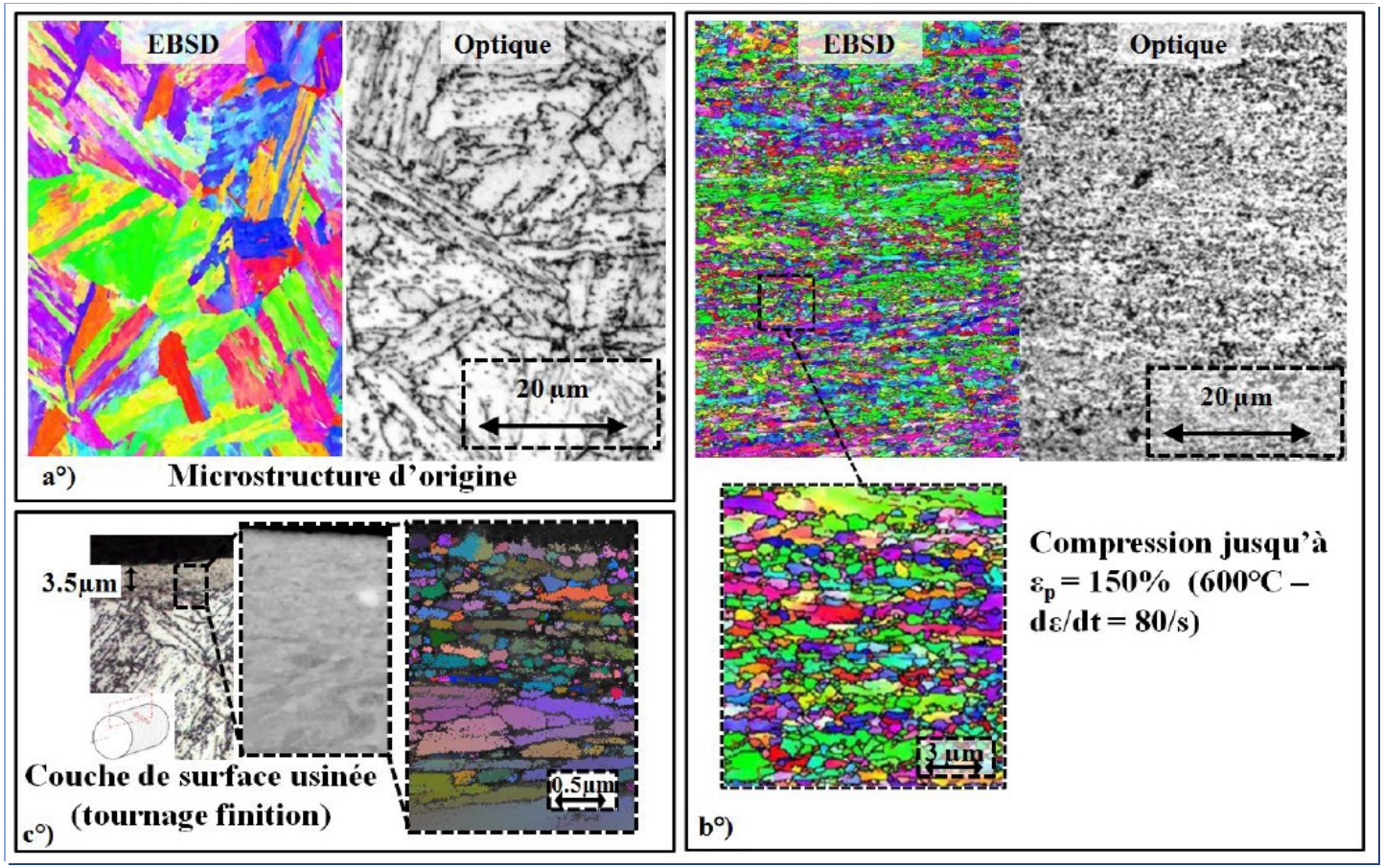




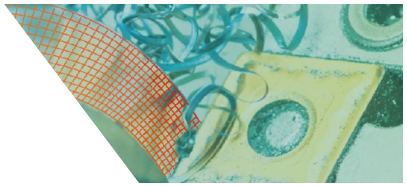
Exemple : tournage d'un acier 15-5PH





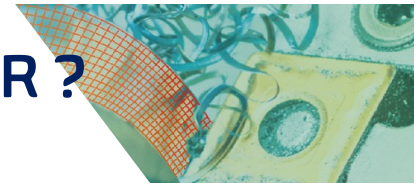


Sommaire

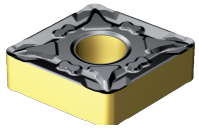


- Contexte
- Genèse des contraintes résiduelles en tournage
- Modélisation
- Paramètres influents
  - Usure des outils
  - Choix des outils
- Autres procédés
  - Fraisage, Perçage, Alésage, Toilage

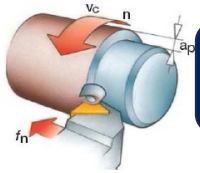
De quelles données a-t-on besoin pour simuler les CR ?



MATIERE USINEE

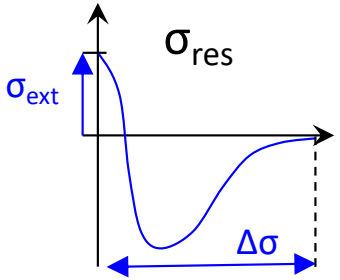


OUTIL

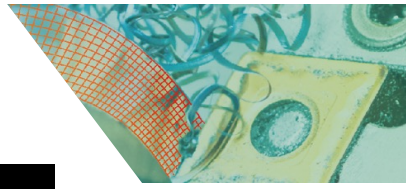


CONDITIONS DE COUPE

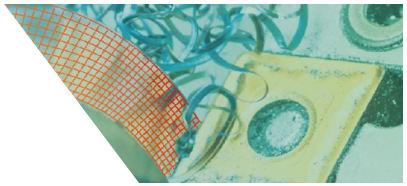
FLUIDE DE COUPE

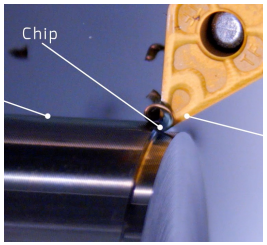


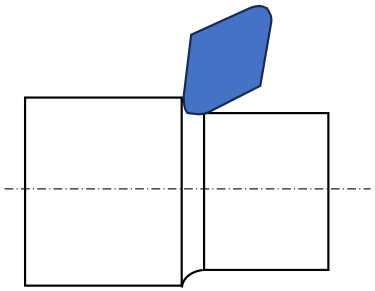
Principe de génération des contraintes résiduelles

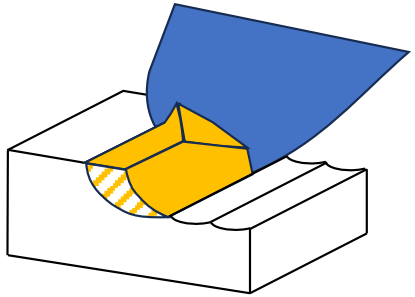


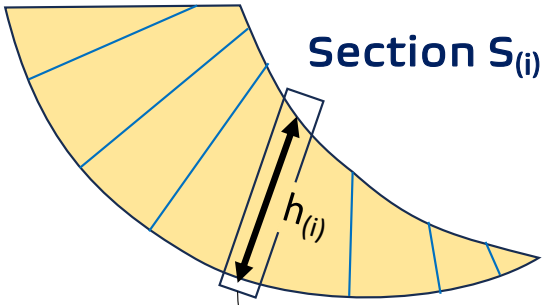
La méthode « 3D hybride multi-passe »



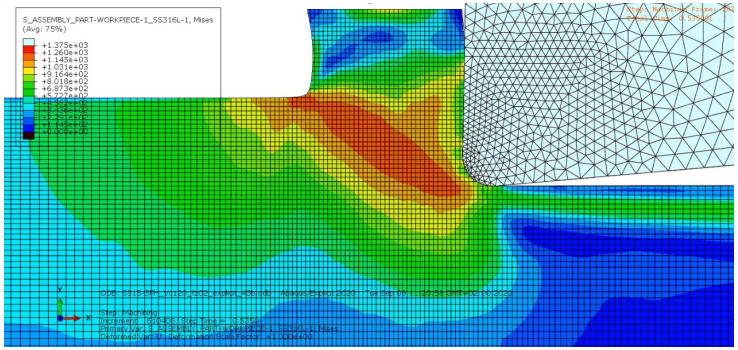






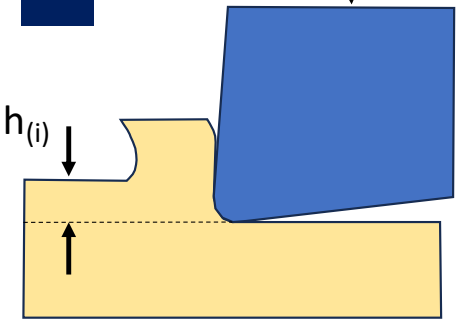


2D



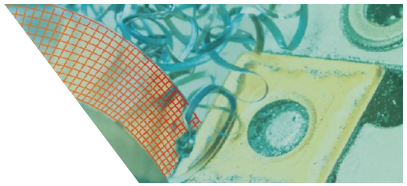
SIMULIA ABAQUS

2D



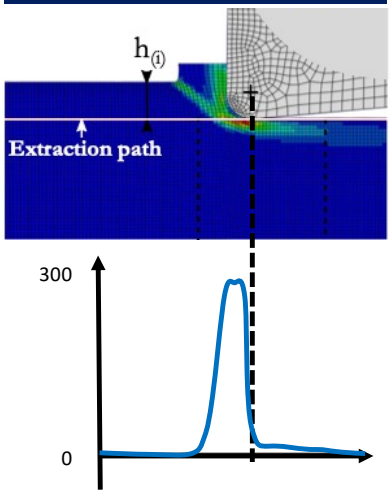
MISUTECH

La méthode « 3D hybride multi-passe »

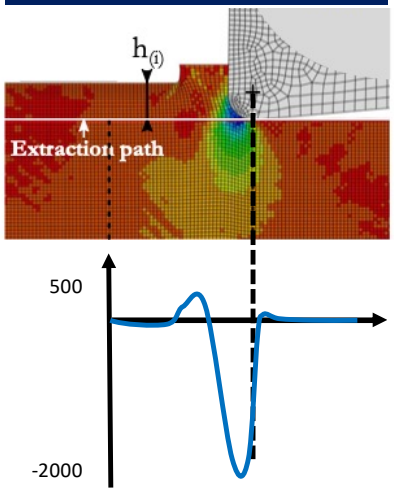


Chargement équivalent 2D

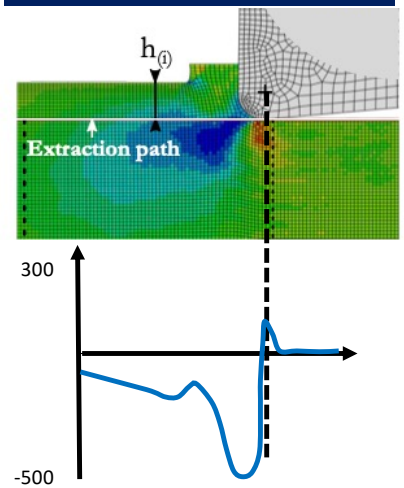
Flux de chaleur

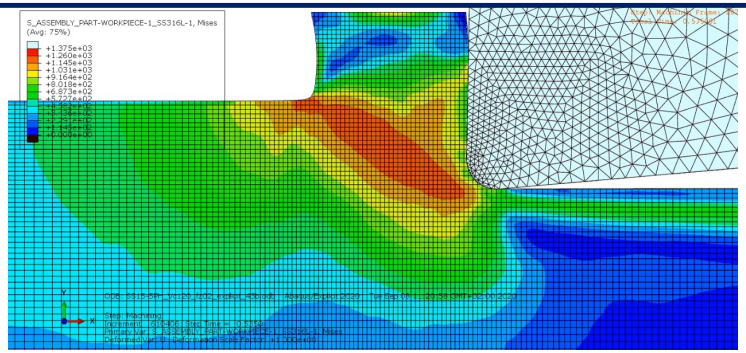


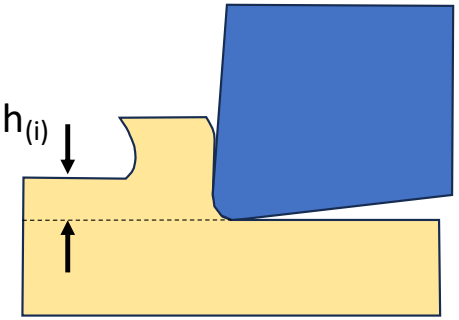
Contrainte normale



Contrainte tangentielle

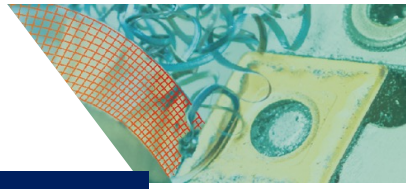


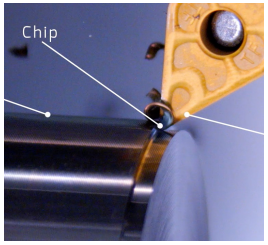


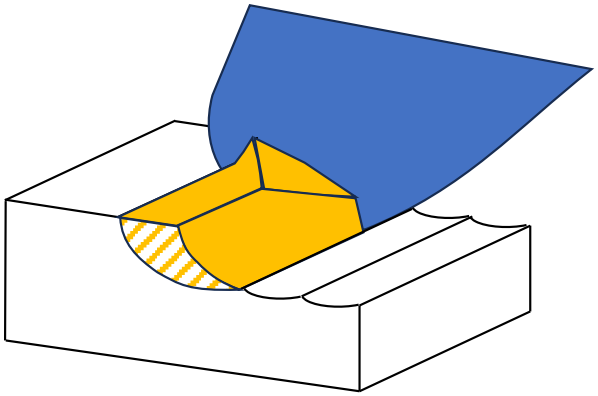


MISUTECH

La méthode « 3D hybride multi-passe »

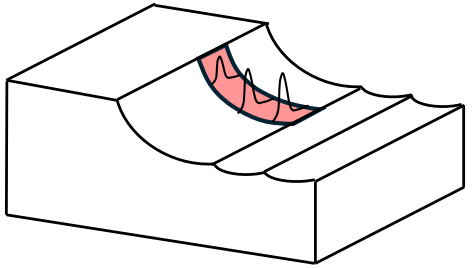




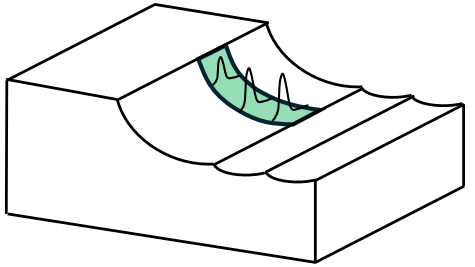


Chargements thermo-mécaniques Équivalents 3D

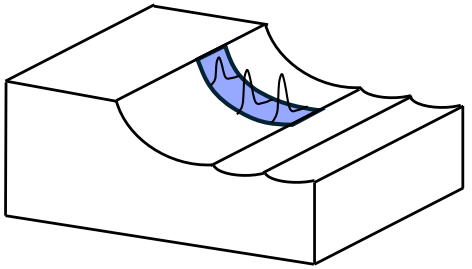
Flux de chaleur



Contraintes tangentielles



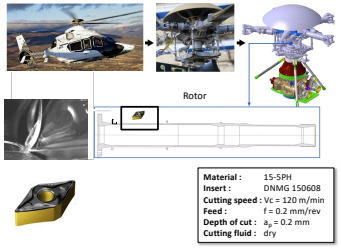
Contraintes normales

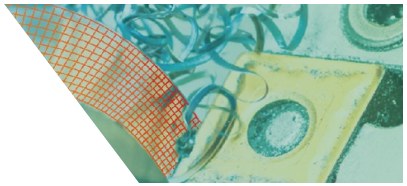


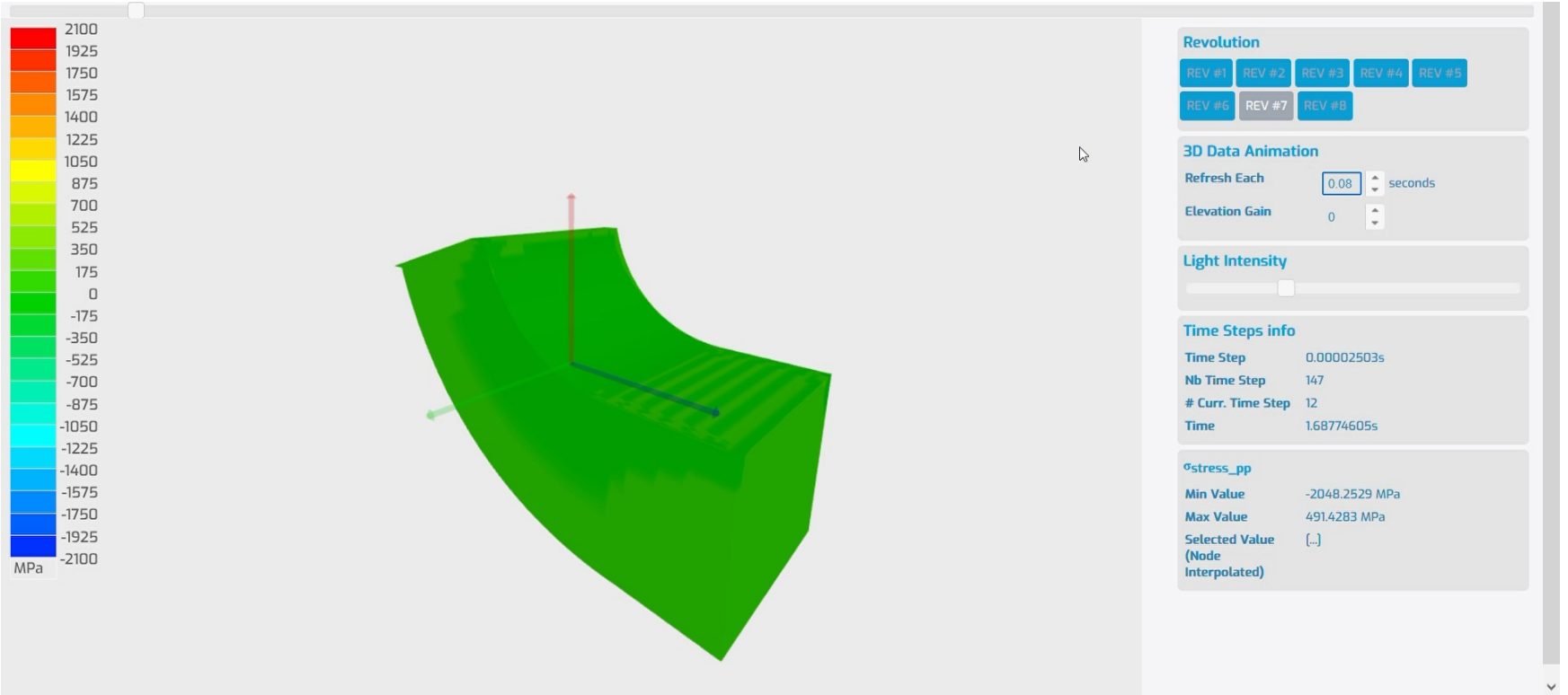
MISUTECH

Tournage d’un acier 15-5PH

Contraintes normales

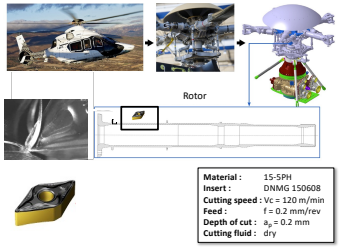


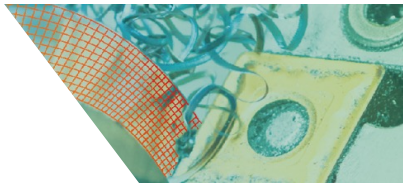


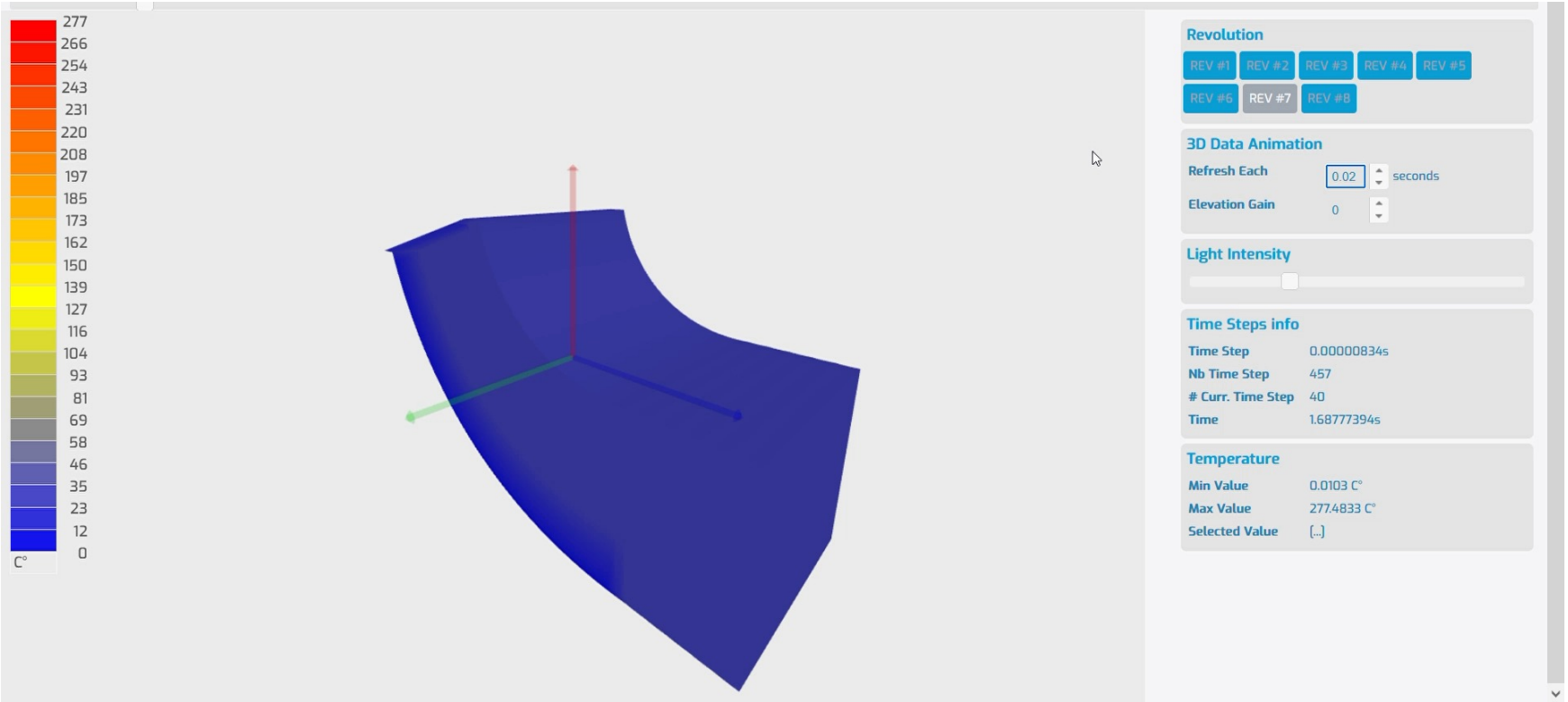


Tournage d’un acier 15-5PH

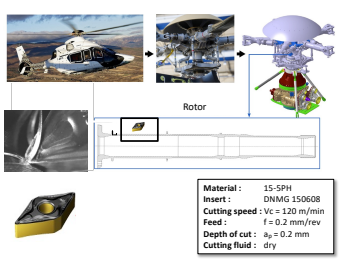
Température de surface

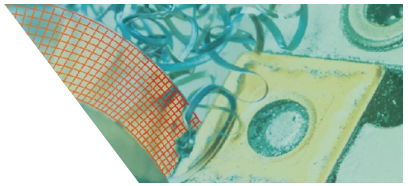


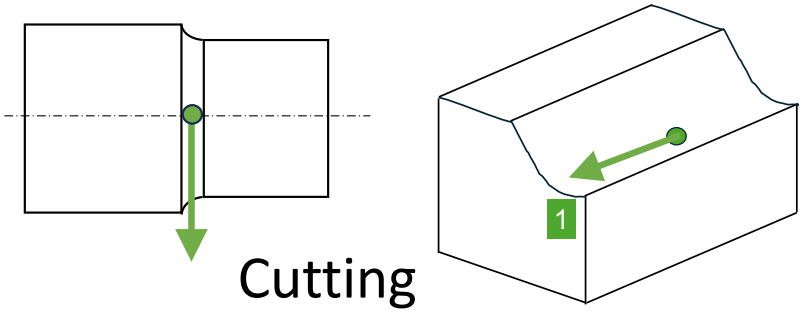


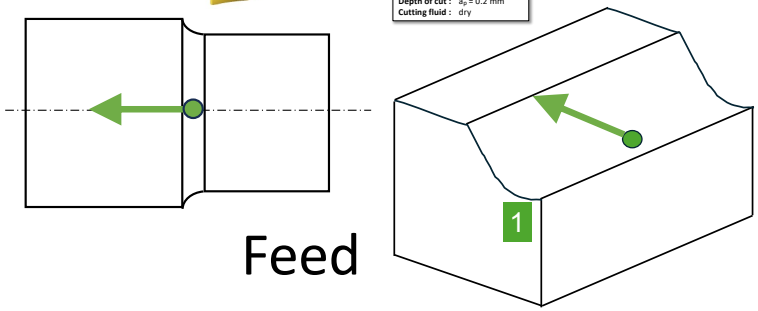


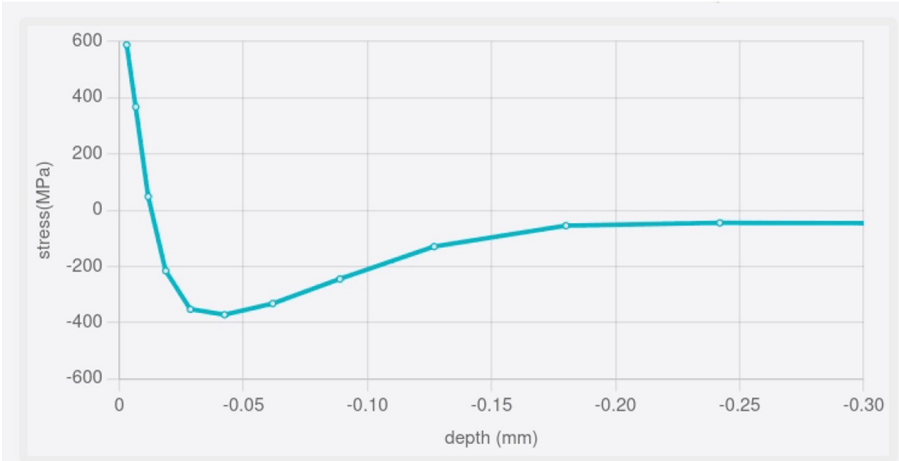
Génération des CR durant le 1er tour

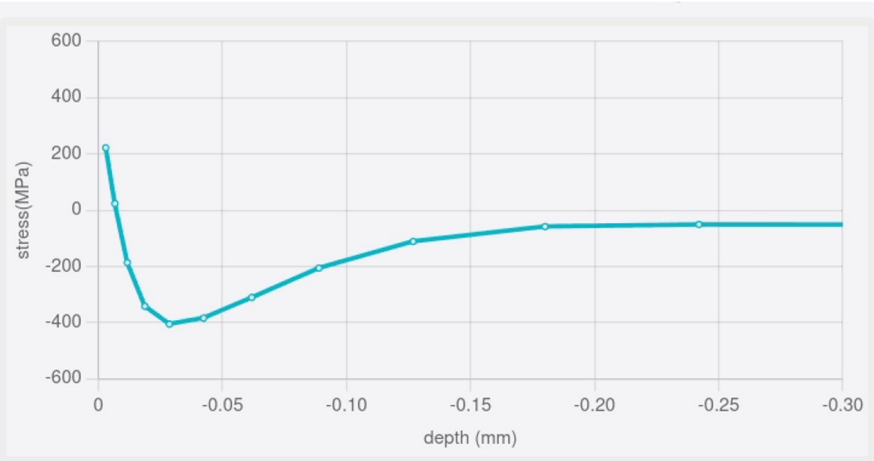






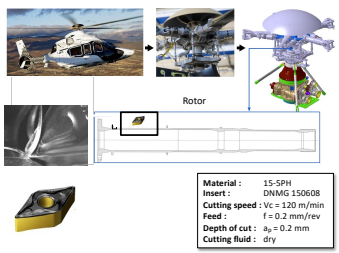


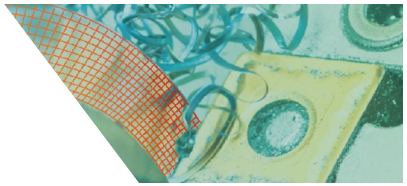


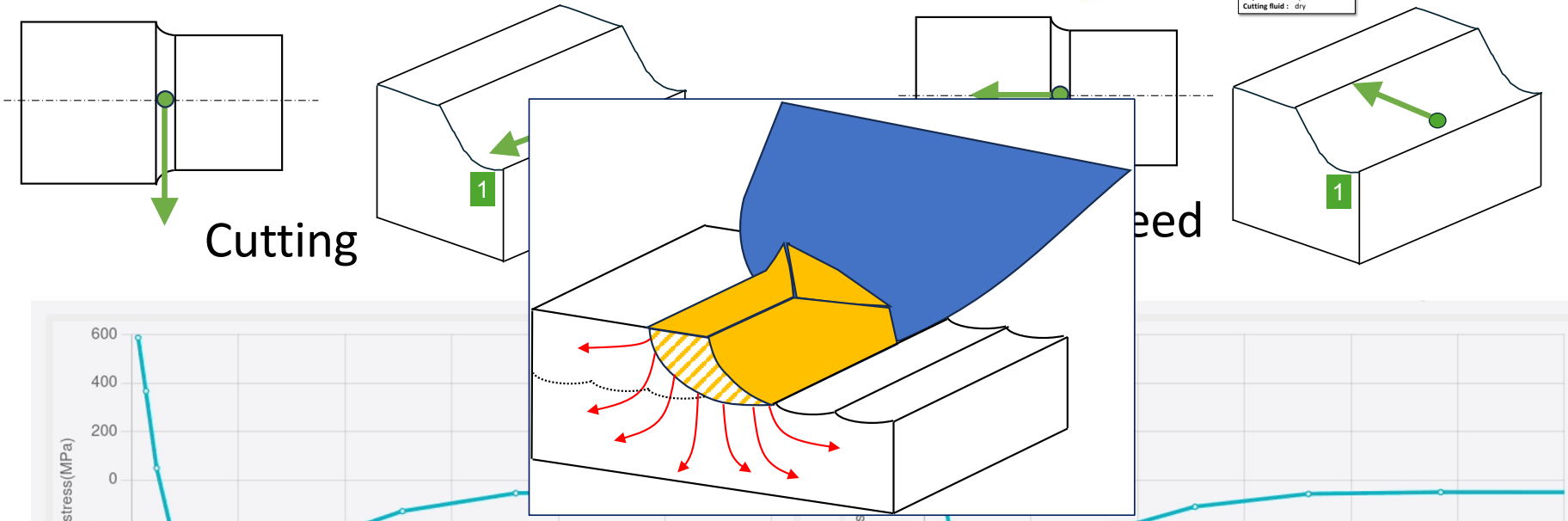


MISUTECH

Génération des CR durant le 1er tour

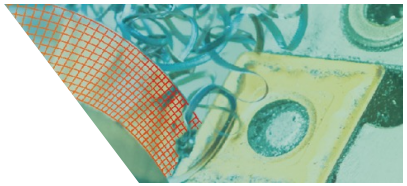


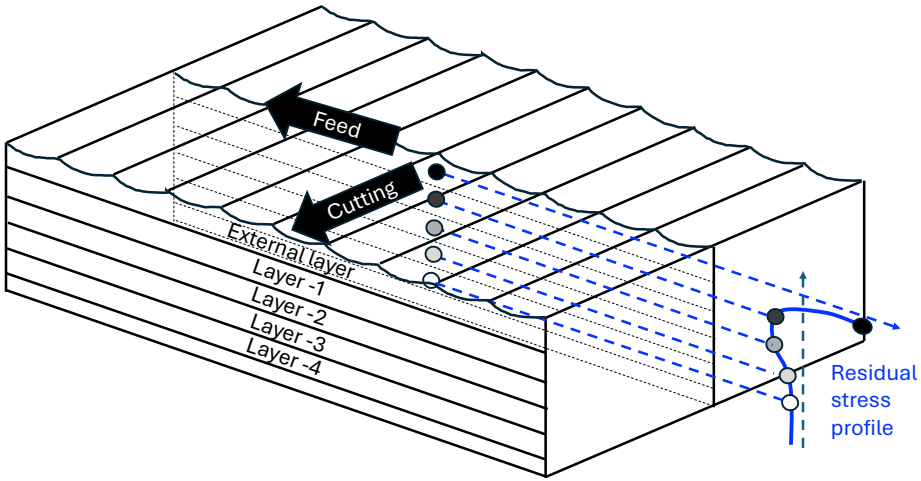




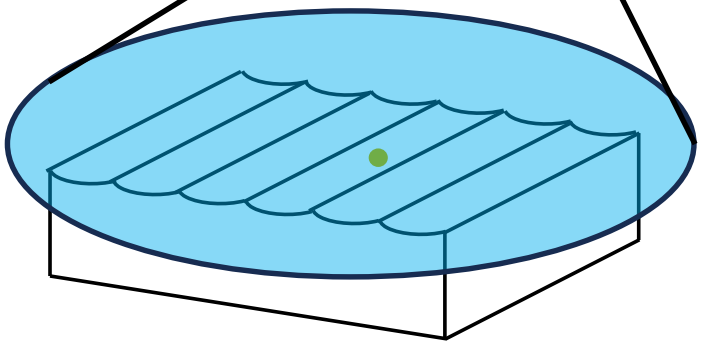
MISUTECH

En régime stabilisé





X-Ray beam : 1 – 2 mm

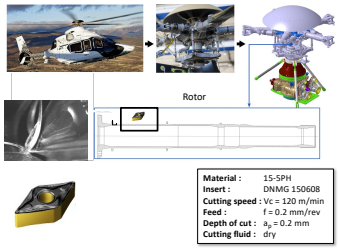


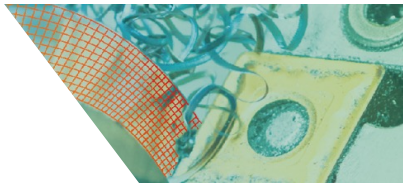
MISUTECH

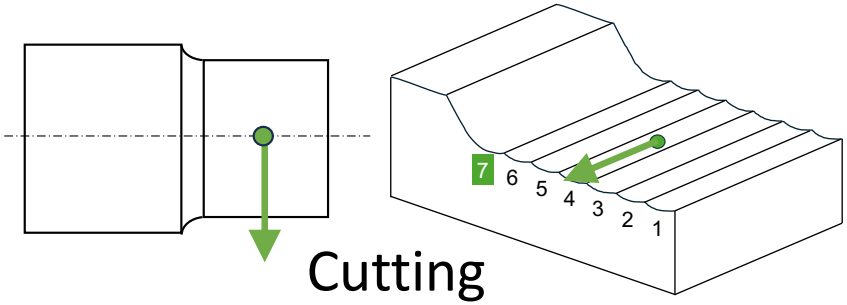
Les CR sont variables dans l'espace

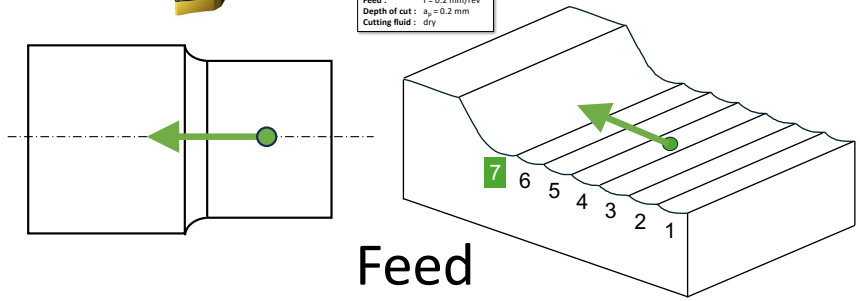
MISUTECH

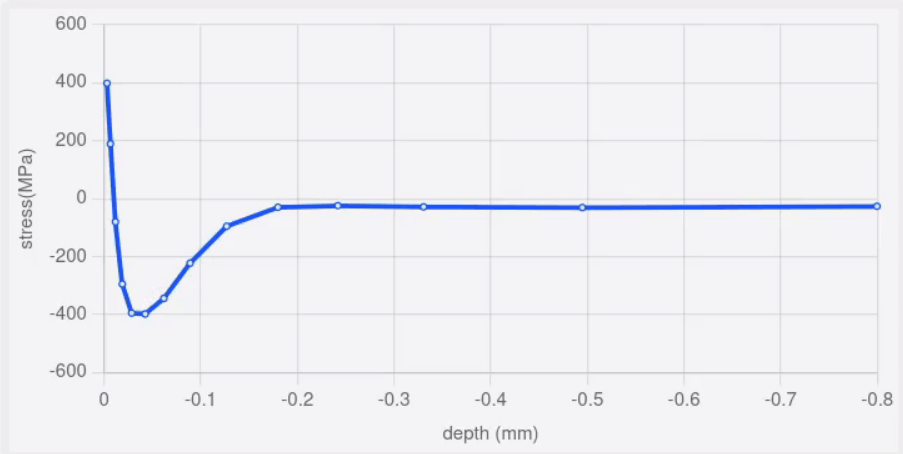
Génération des CR durant le 7ème tour

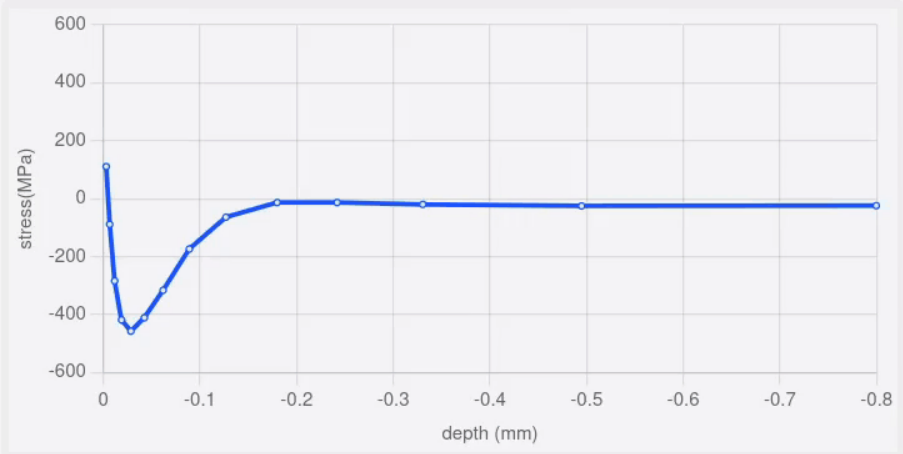






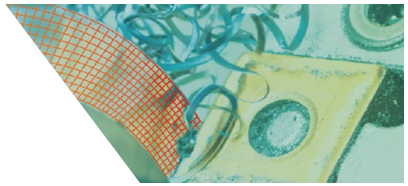


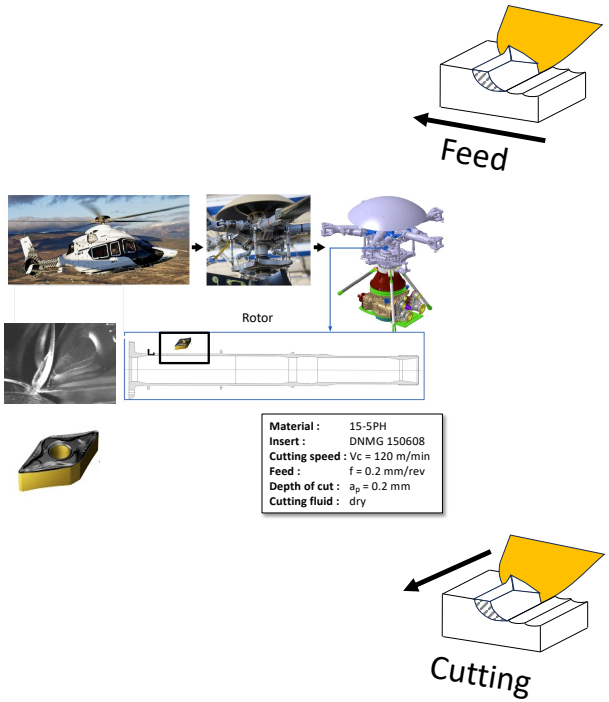


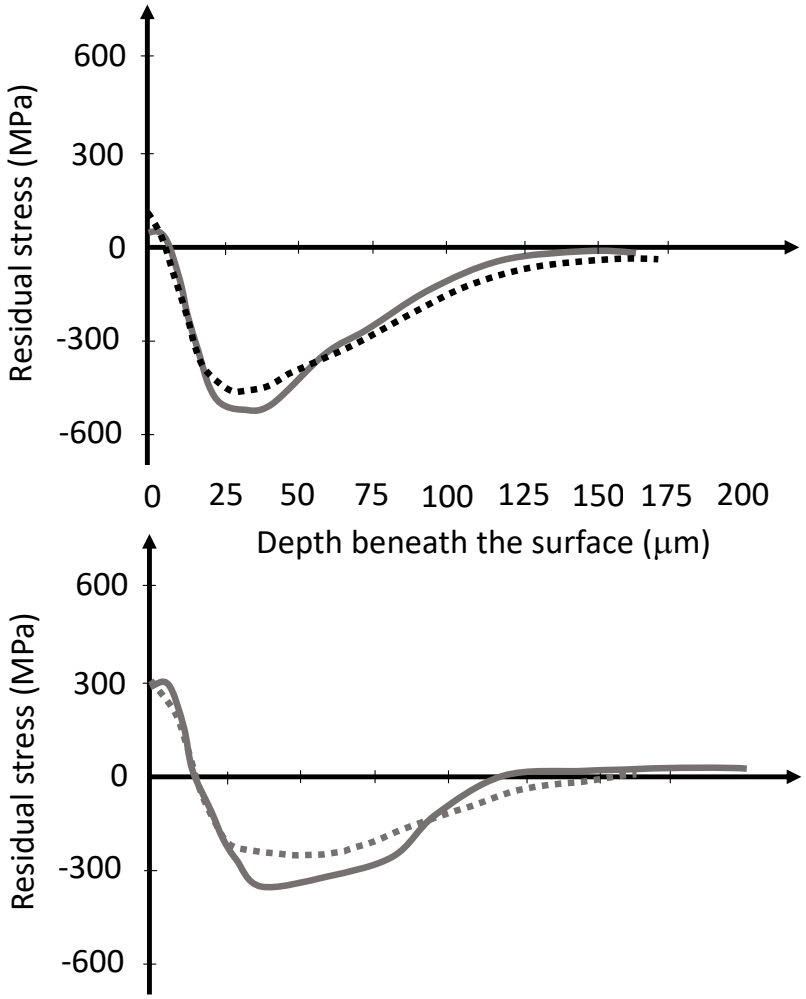


MISUTECH

Comparaison num. ⇔ exp.

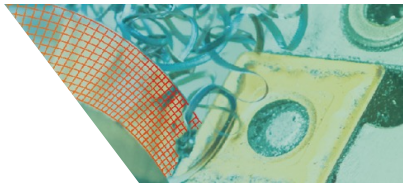


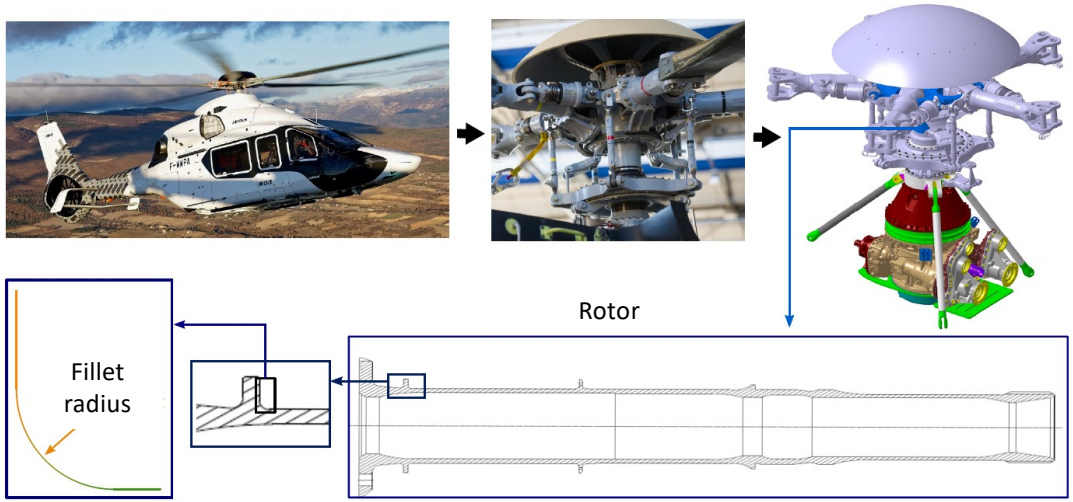


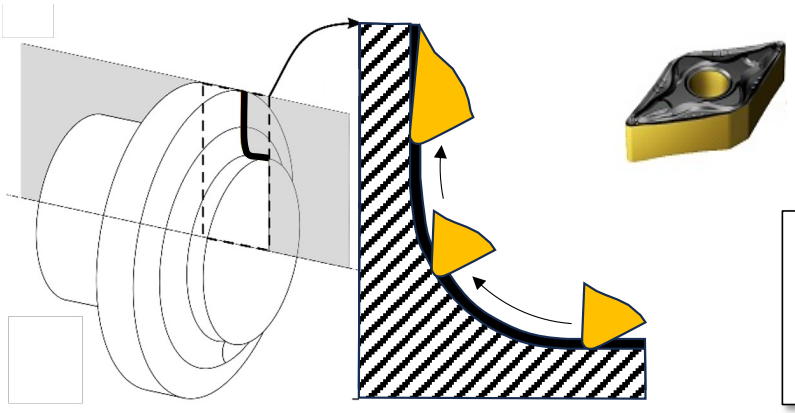


MISUTECH

Tournage d'un congé de raccordement



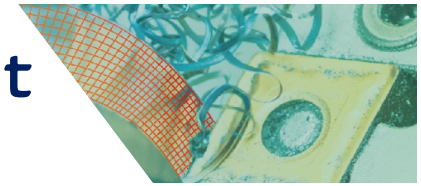


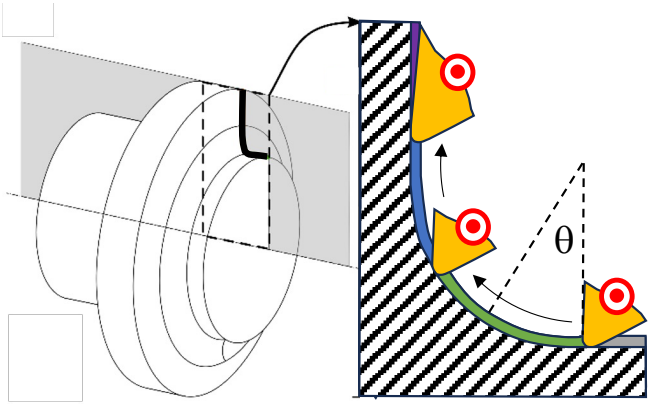


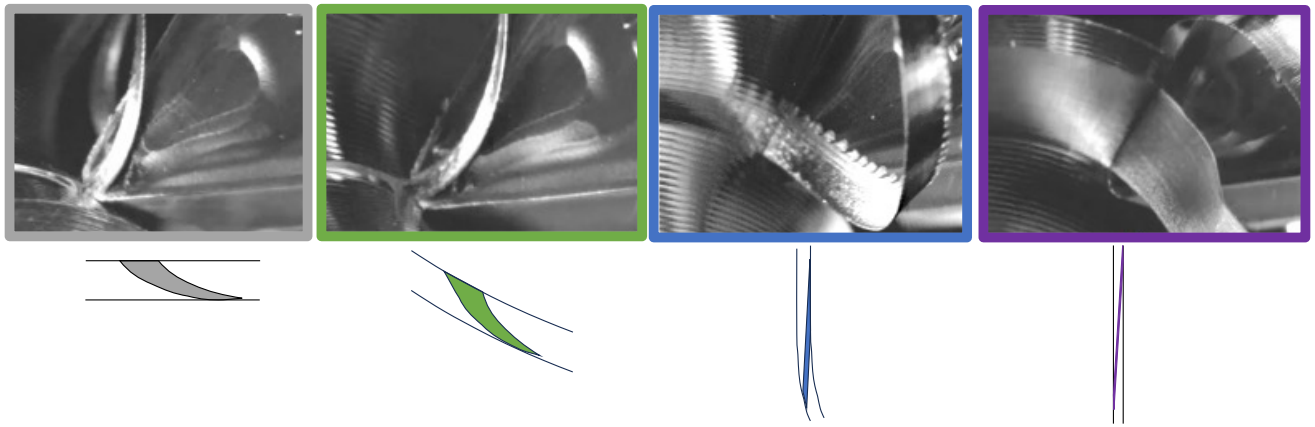
Material :	15-5PH
Insert :	DNMG 150608
Cutting speed :	Vc = 120 m/min
Feed :	f = 0.2 mm/rev
Depth of cut :	a_p = 0.2 mm
Cutting fluid :	dry

MISUTECH

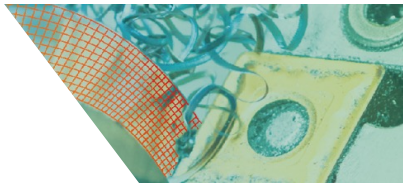
Evolution des efforts dans le congé de raccordement

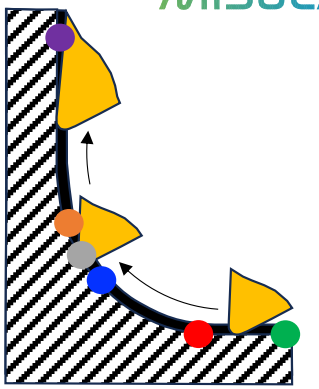


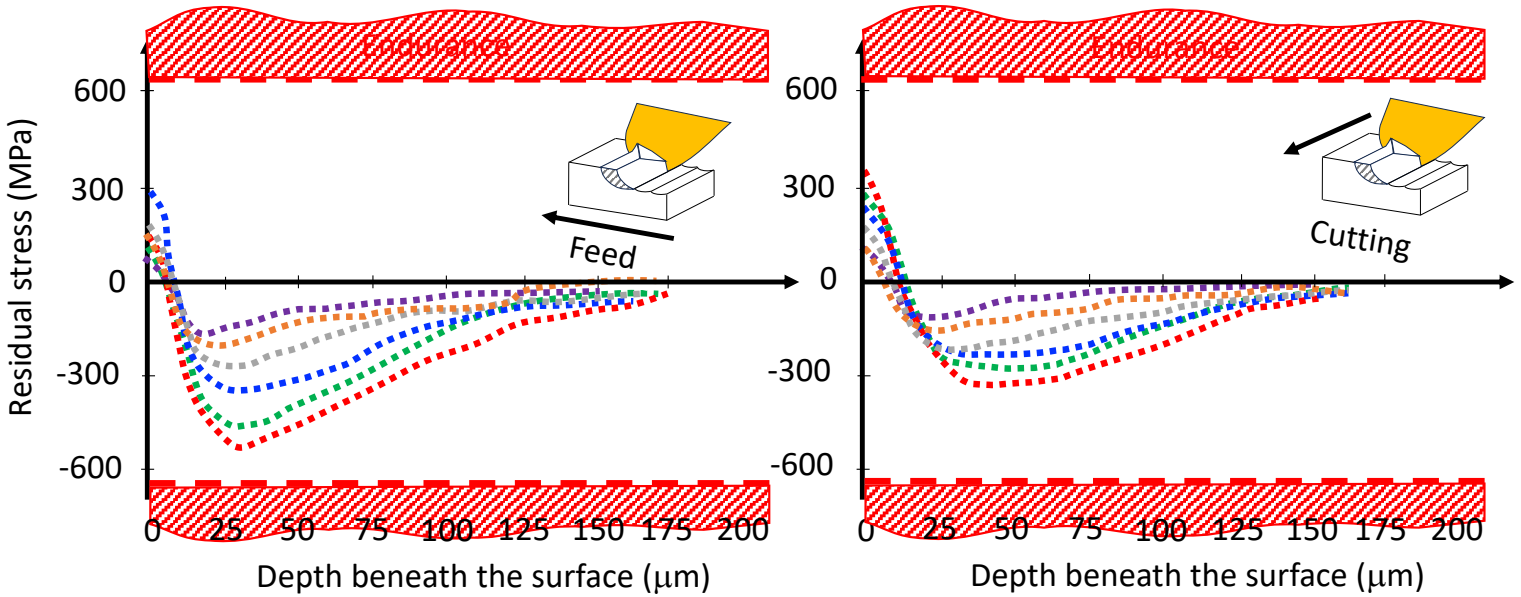




Evolution des CR







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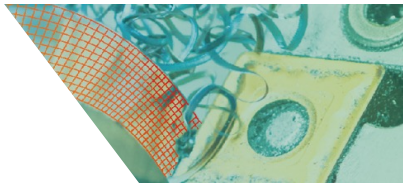

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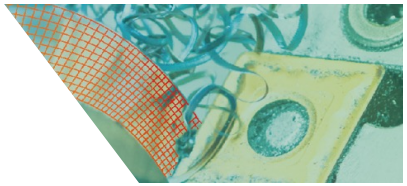
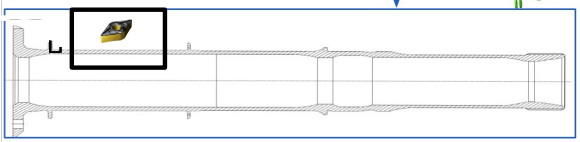
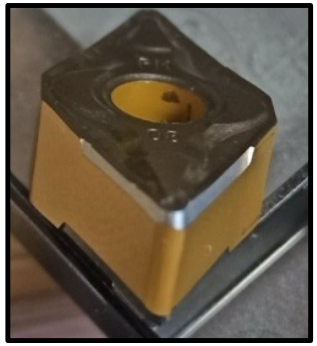
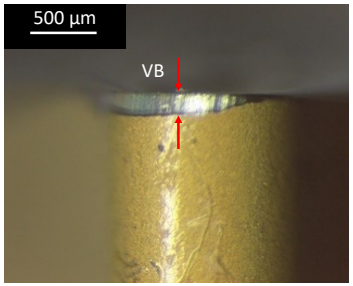
Un outil de coupe s'use !



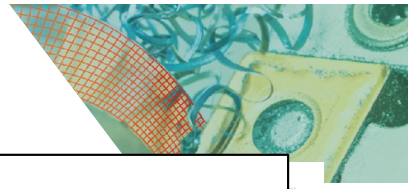


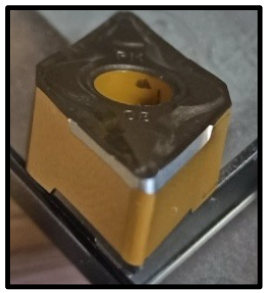
Material :	15-5PH
Insert :	DNMG 150608
Cutting speed :	Vc = 120 m/min
Feed :	f = 0.2 mm/rev
Depth of cut :	a_p = 0.2 mm
Cutting fluid :	dry

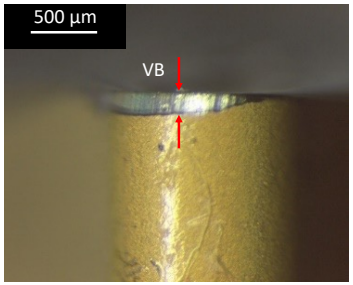


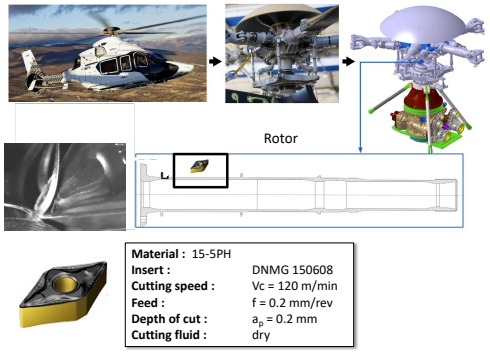


L'usure a une influence majeure sur les CR

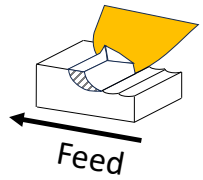


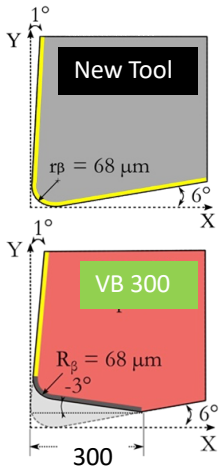


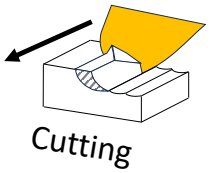


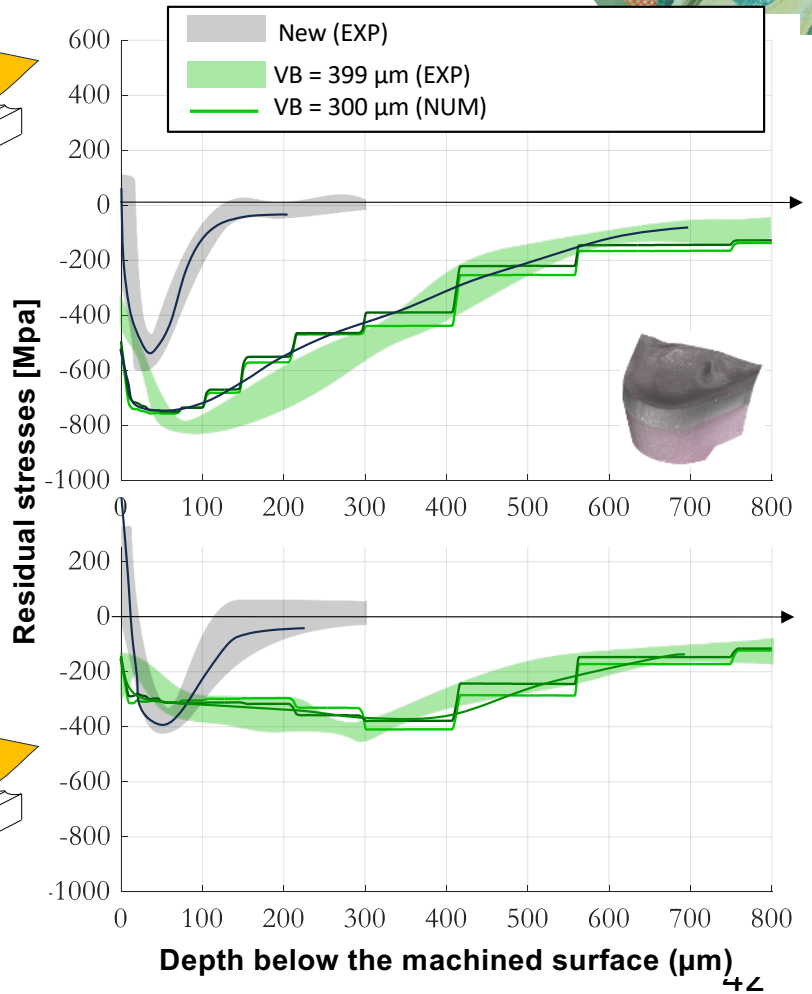


Material :	15-5PH
Insert :	DNMG 150608
Cutting speed :	Vc = 120 m/min
Feed :	f = 0.2 mm/rev
Depth of cut :	a_p = 0.2 mm
Cutting fluid :	dry









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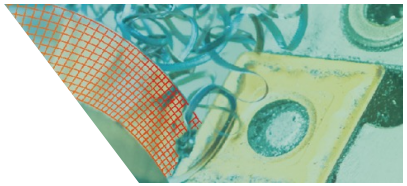

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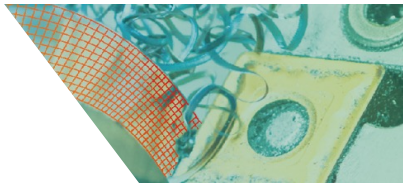
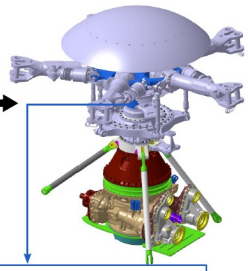
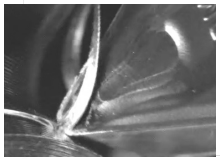
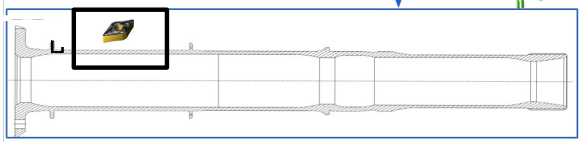
Comment choisir un outil de coupe ?







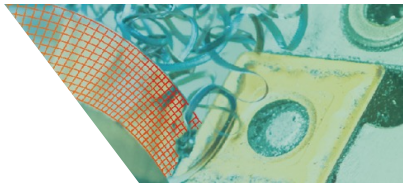
Rotor

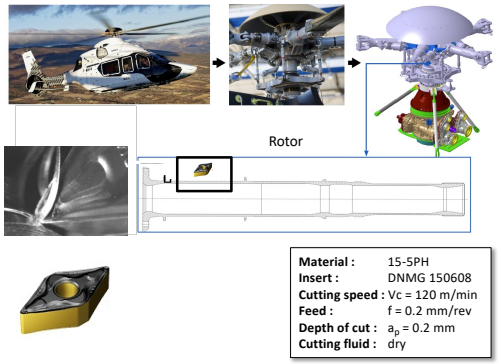


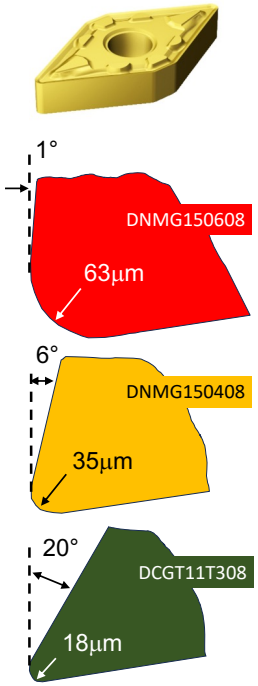
Material :	15-5PH
Insert :	DNMG 150608
Cutting speed :	Vc = 120 m/min
Feed :	f = 0.2 mm/rev
Depth of cut :	a_p = 0.2 mm
Cutting fluid :	dry

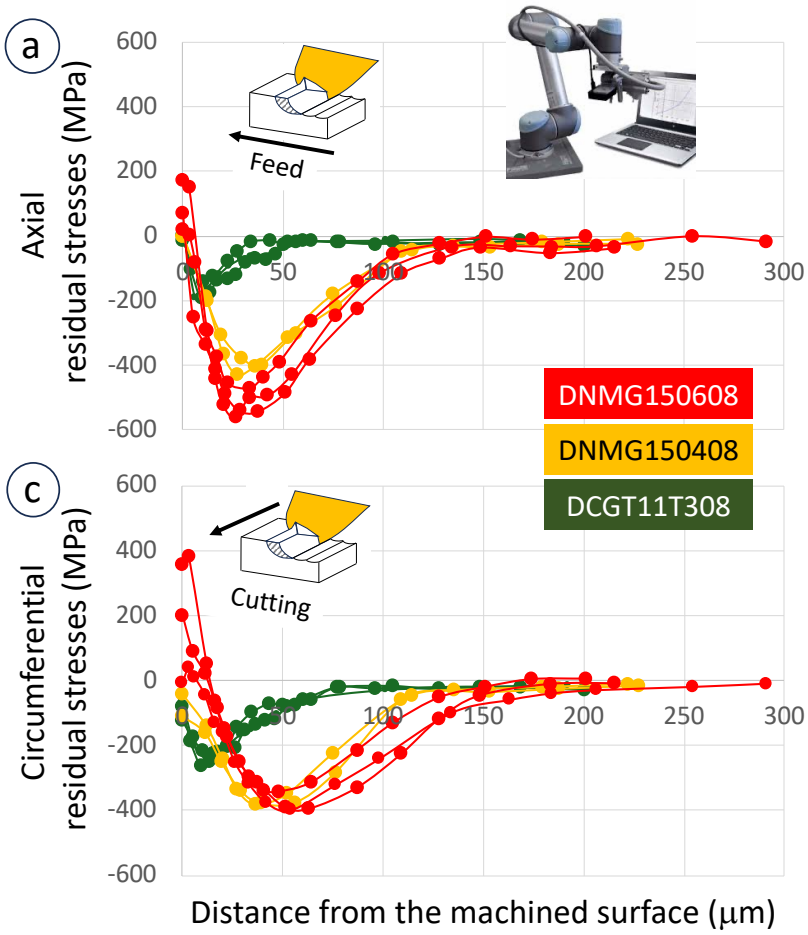
?

Numerical ⇔Experimental residual stresses









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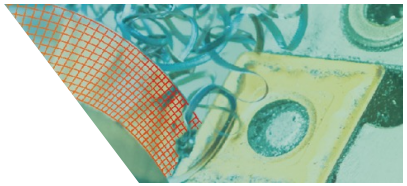

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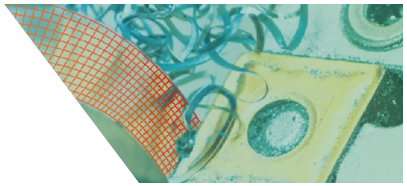
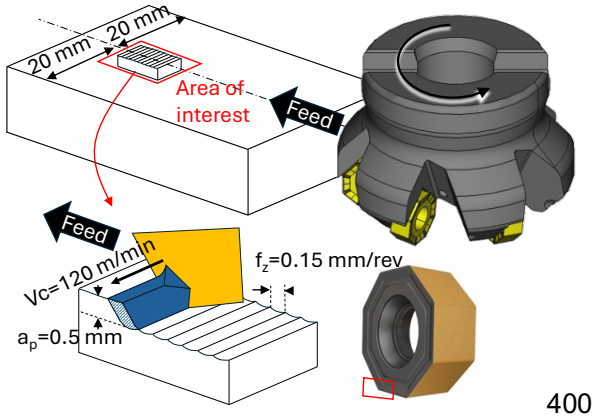
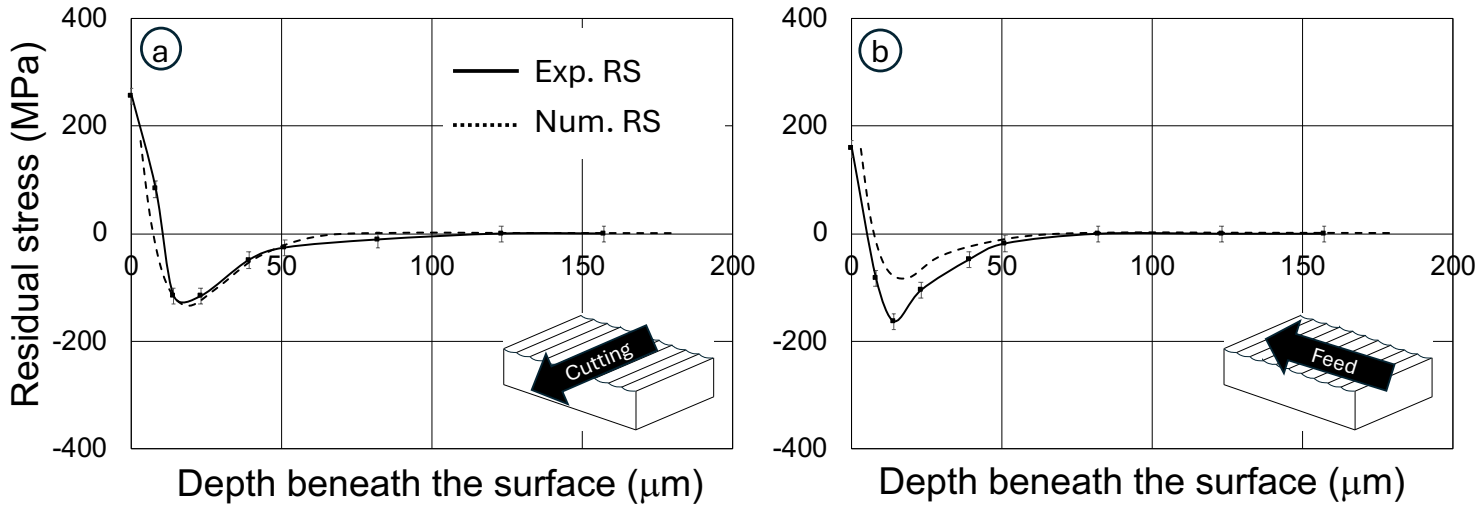
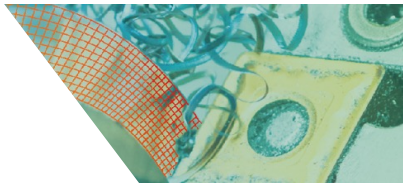
Fraisage surfaçage d'un acier 15-5PH

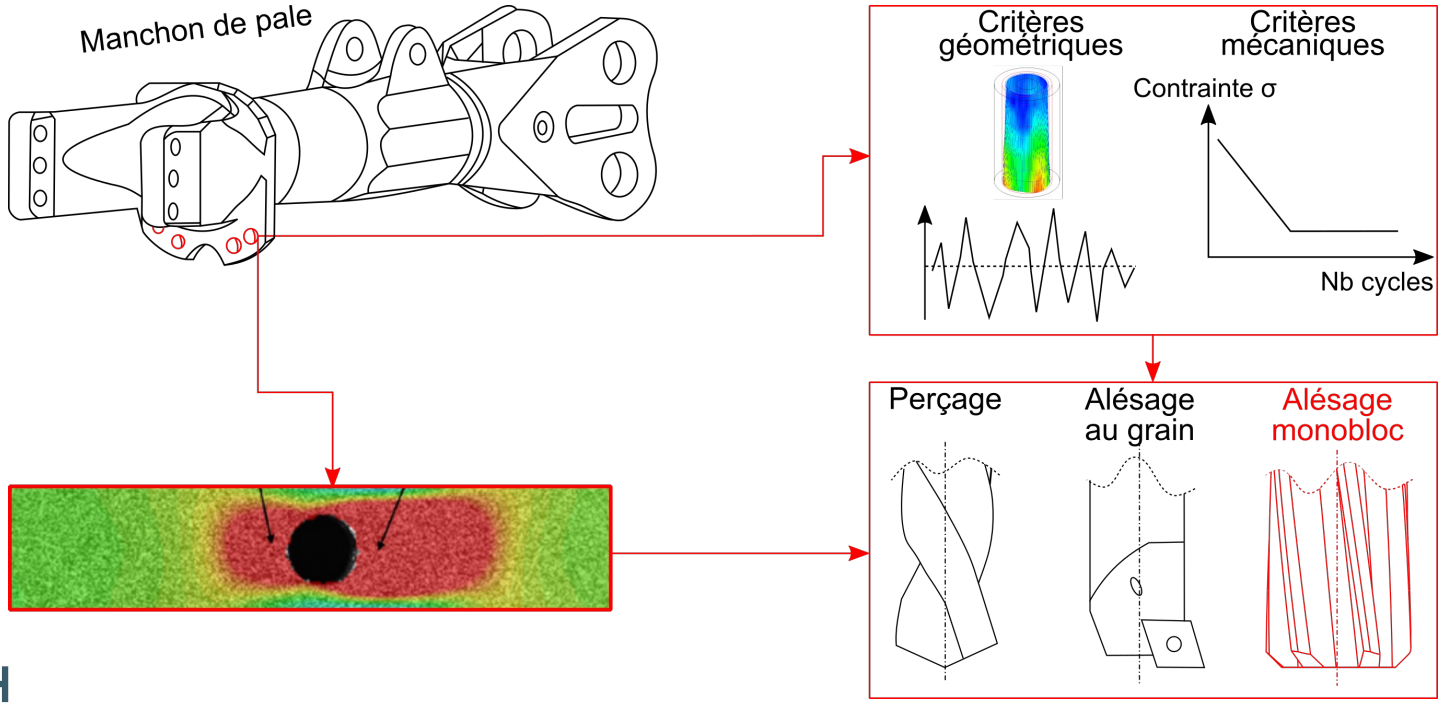




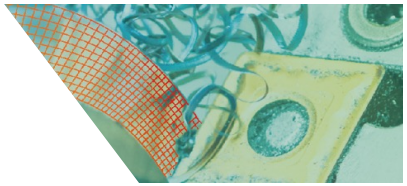


Fabrication d'un alésage en acier 15-5PH

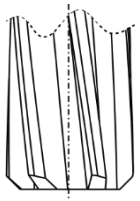




Fabrication d'un alésage en acier 15-5PH

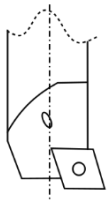


Alésage monobloc



V_c = 5 m/min
a_p = 0.05 mm
f = 0.18 mm/tr

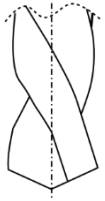
Alésage au grain



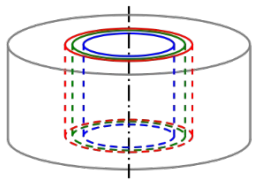
V_c = 15 m/min
a_p = 0.1 mm
f = 0.116 mm/tr

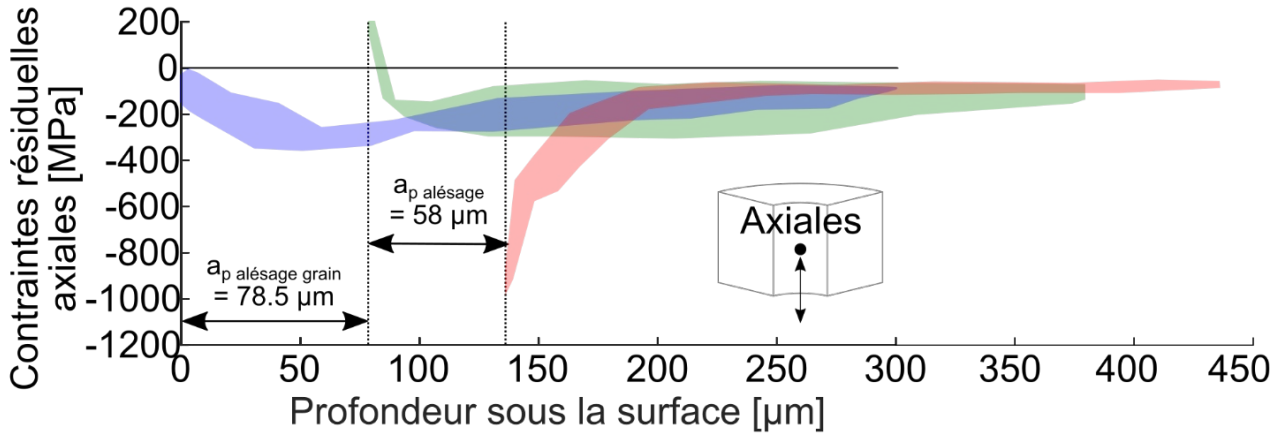
+

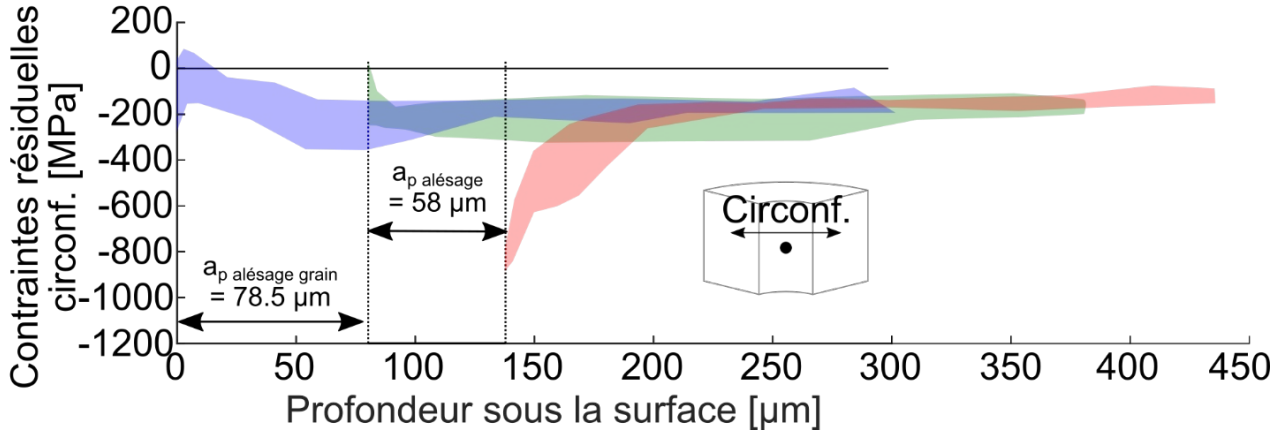
Perçage



V_c = 52 m/min
f = 0.17 mm/tr







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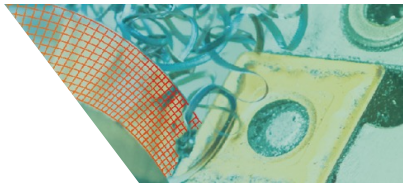
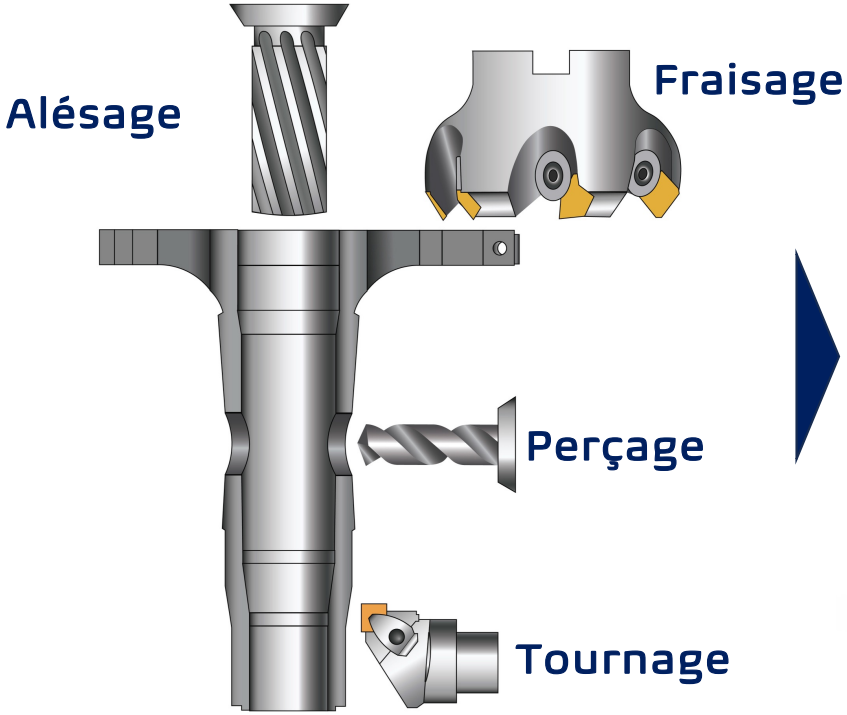
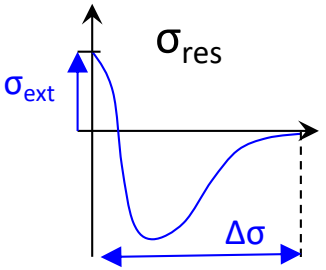
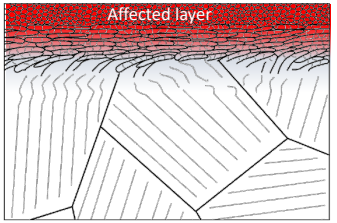
Les procédés simulés









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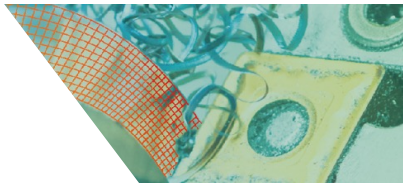
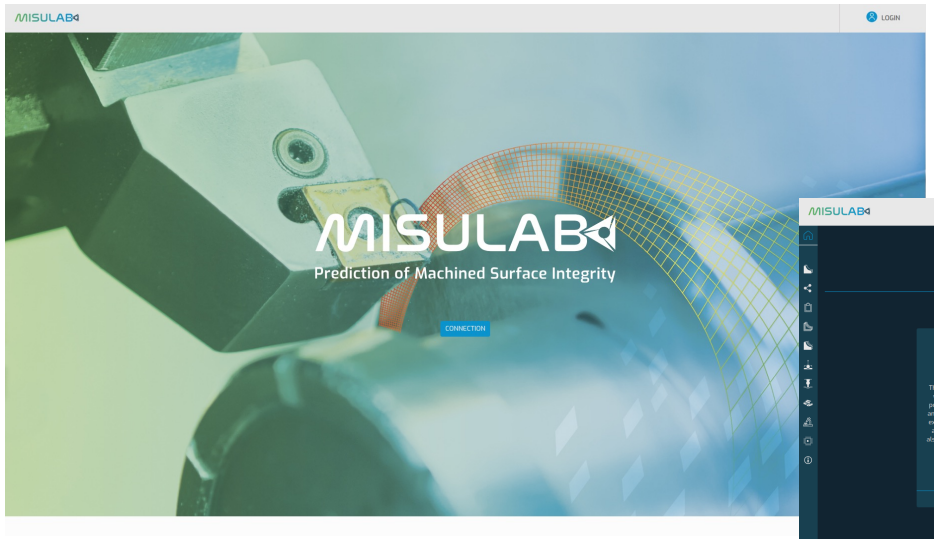
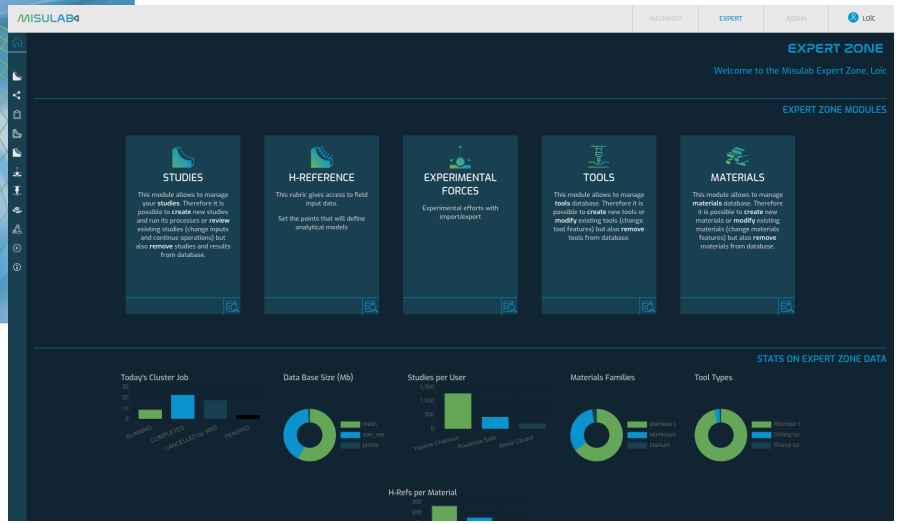
Vidéo de MISULAB



https://www.misulab.fr/the-software

Select : « See our software in action »





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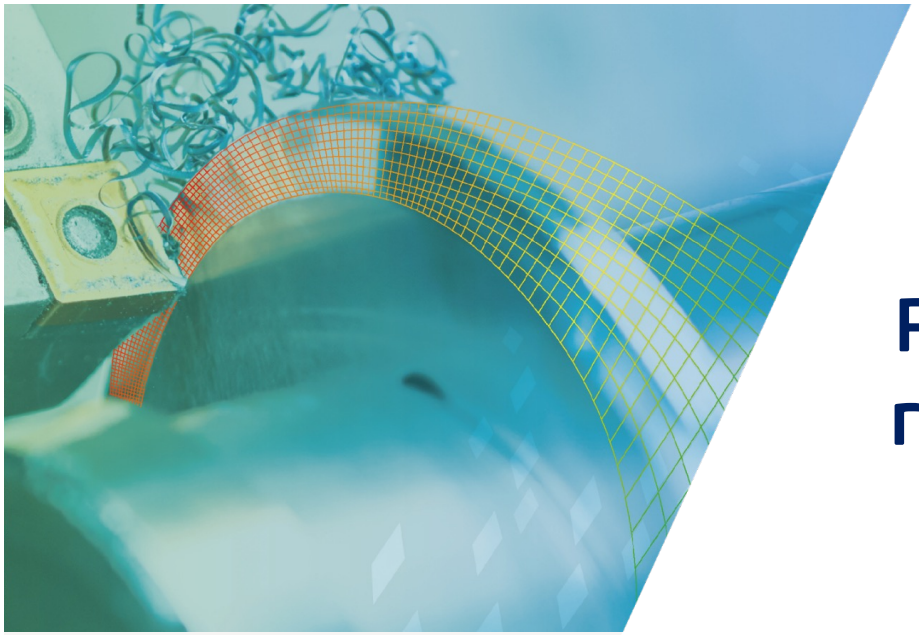

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Prédiction des contraintes résiduelles induites par les procédés d'usinage

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01/10/2025
Séminaire RDM du CNRS, Port-Barcarès

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10e école technologique du Réseau Des Mécaniciens

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La MÉCA en 2030