

SUR DEUX PROBLEMES THERMOMECHANIQUES COMPLEXES:

- 1. Distorsion d'un flasque de turboréacteur obtenu par soudage
- 2. Propagation de fissure de fatigue en présence d'un champ de contraintes résiduelles complexes

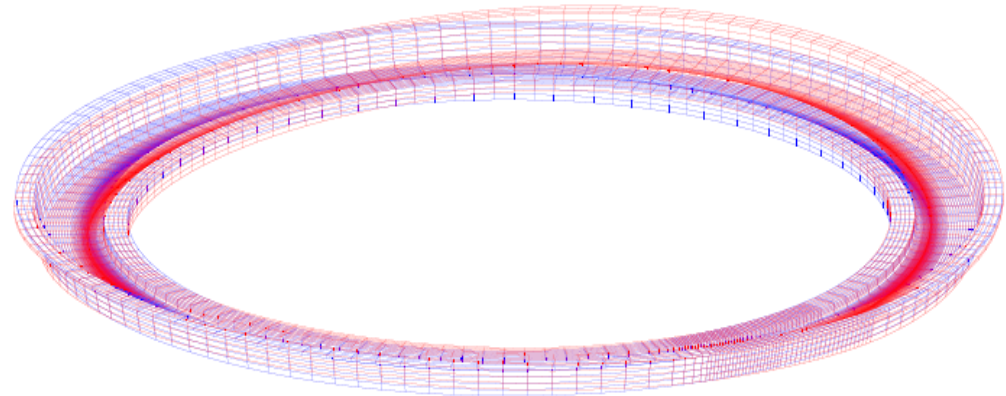
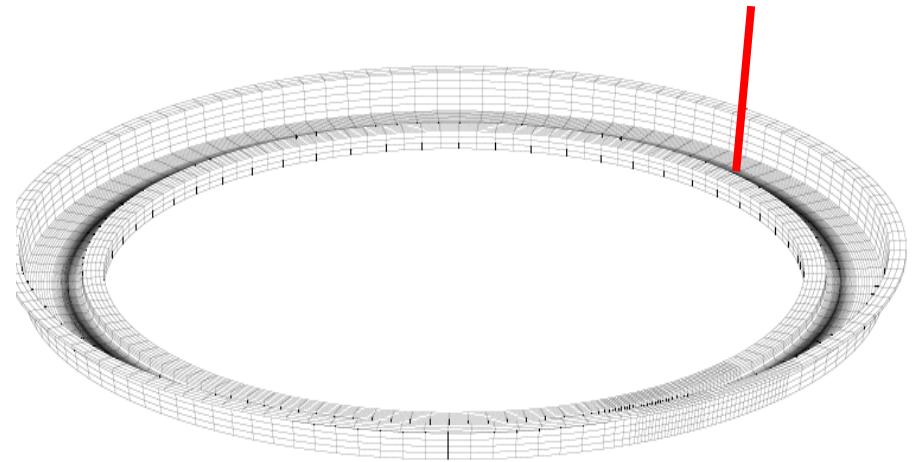
K. Dang Van

MECAMIX- XTECH

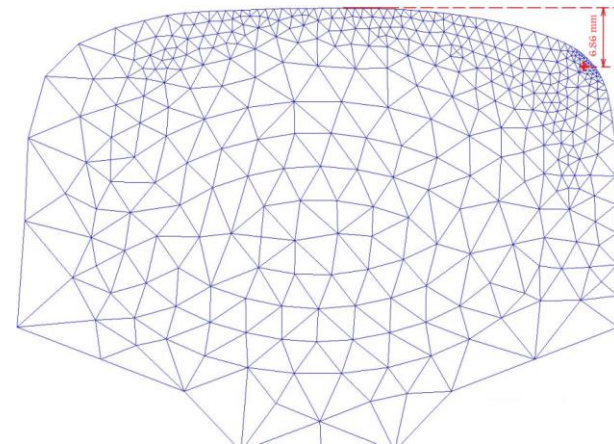
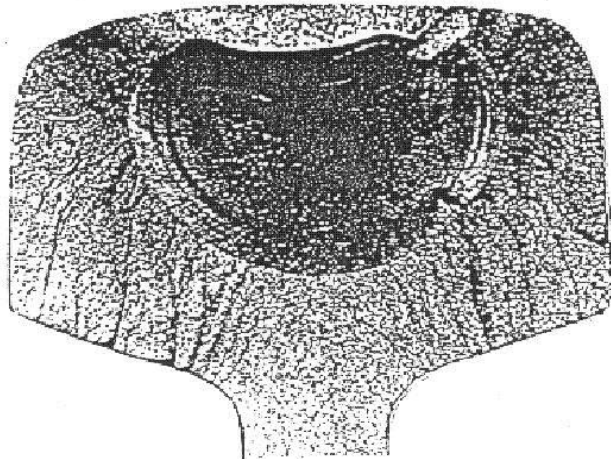
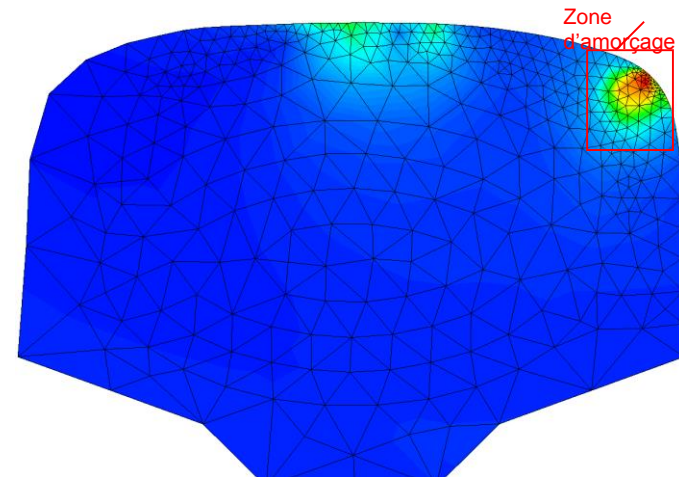
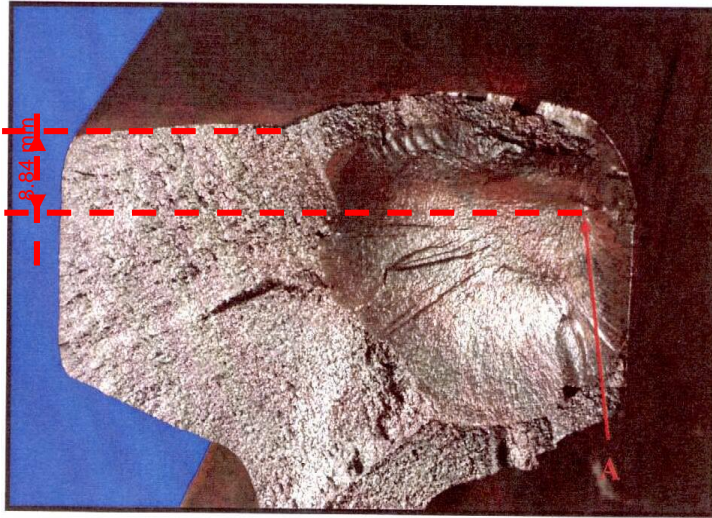
1. Modélisation du soudage du flasque: prise en compte de la distorsion



Soudage TIG



2. Initiation et **PROPAGATION** en présence d'un champ de **contraintes résiduelles complexes à fort gradient (contact entre solides...soudage)**



Etapes de la simulation du soudage

*Assembly configuration
*Process weldability

→ Test of material weldability

→ Evaluation of a range of parameters

Arc model

Heat flux

Weld pool model

$T(\underline{x}, t)$

Mechanics

Metallurgy

$z_i(\underline{x}, t)$

$f(t)$

$\sigma_{rés}$

$\epsilon_{rés}$

Fatigue 3D

Mechanics

Metallurgy

Heat transfer

$\sigma_{rés}$

$\epsilon_{rés}$

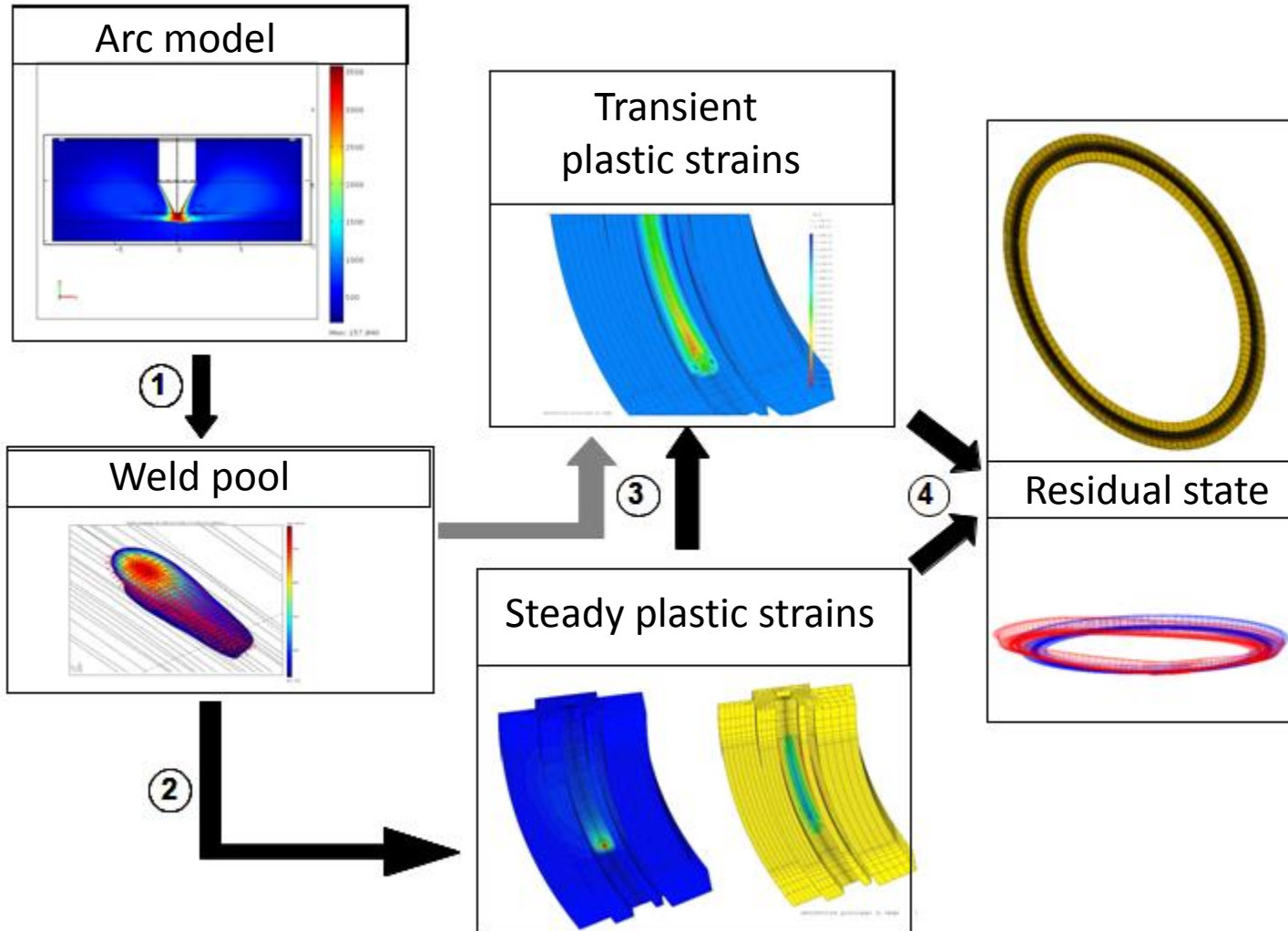
$z_i(\underline{x}, t)$

$T(\underline{x}, t)$

Critical nodes

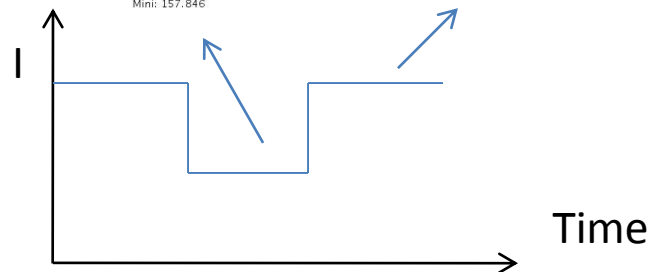
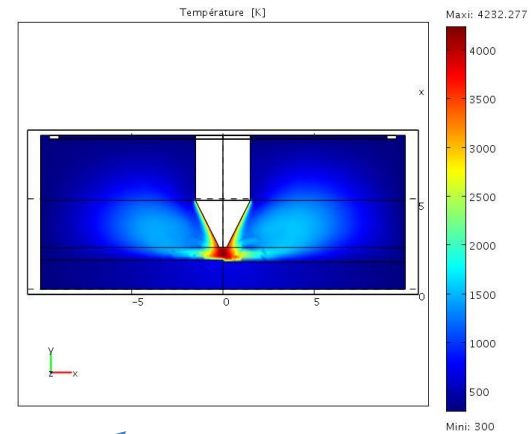
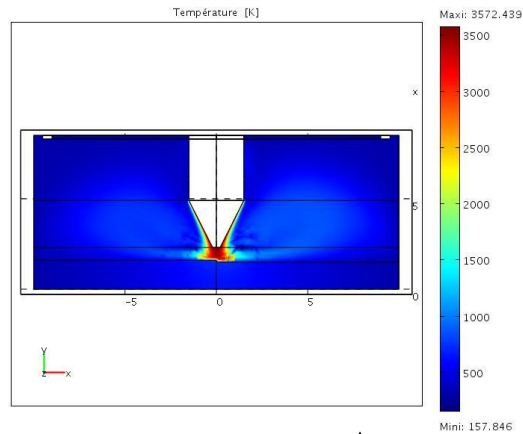
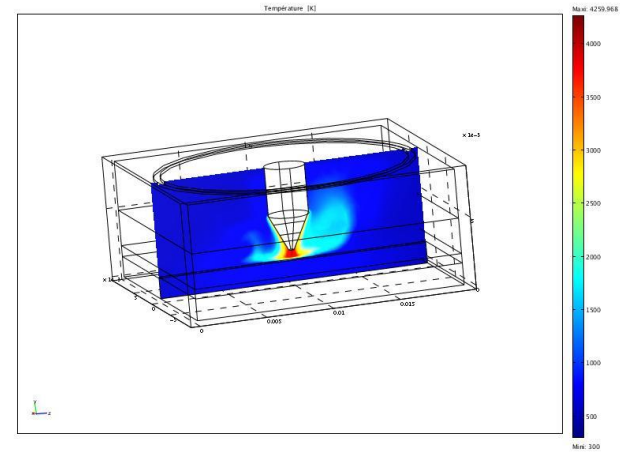
Parametric welding heat source

Les différentes étapes de la modélisation



Etape 1: modélisation du plasma d'arc

Model the arc

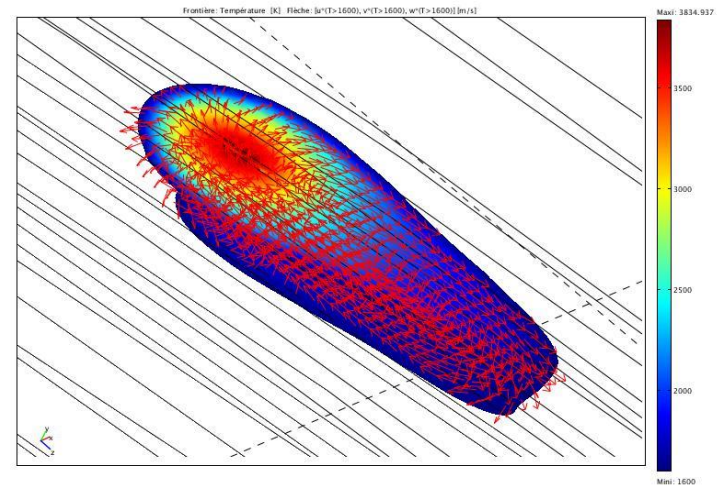
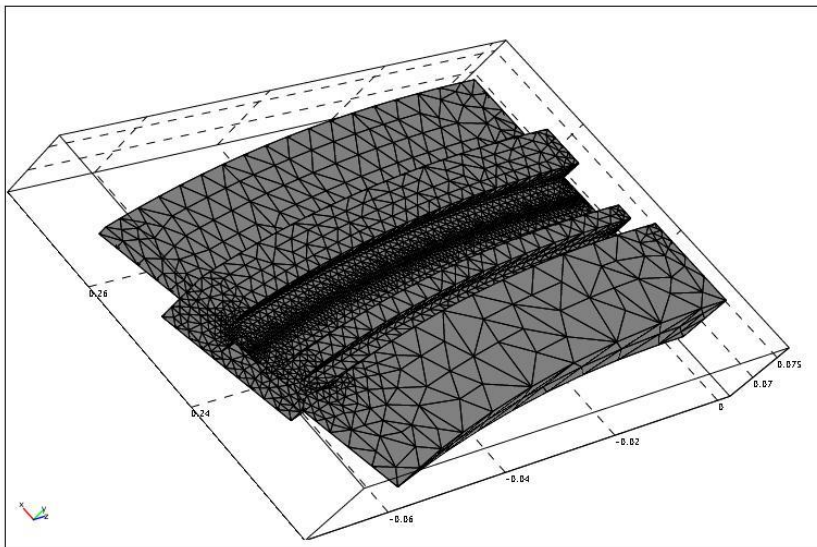


Etape 2: Modélisation du bain de fusion

Model the weld pool

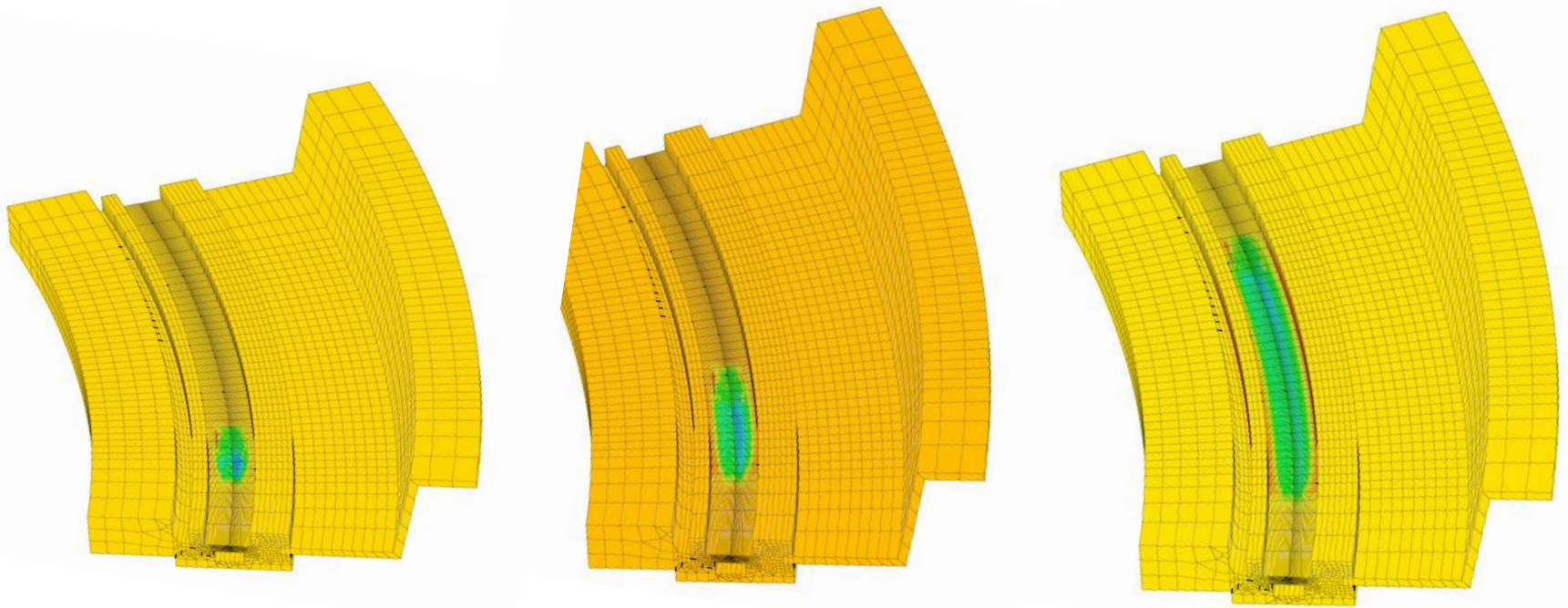
Difficulties :

-3D full penetrated weld pool



ETAPE 3: CALCUL THERMOMECANIQUE STATIONNAIRE ET TRANSITOIRE

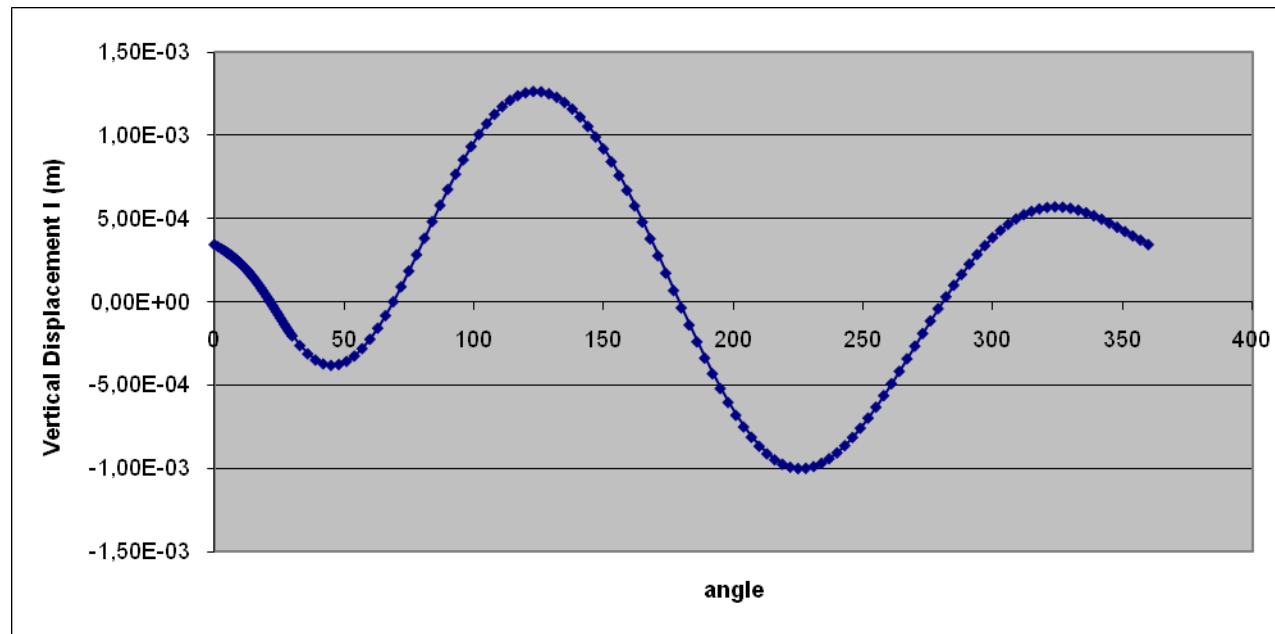
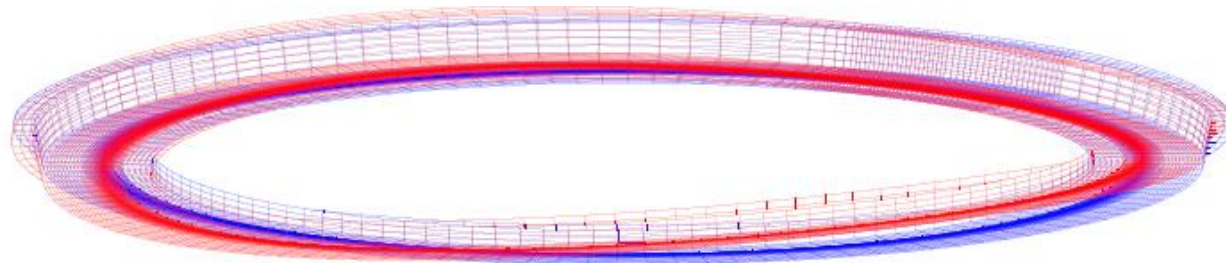
Model the steady mechanical state



Plastic strain evolution up to steady state

Prédiction des distorsions et des déplacements résiduels

Predict the distortions and the residual displacements



GLOBAL APPROACH

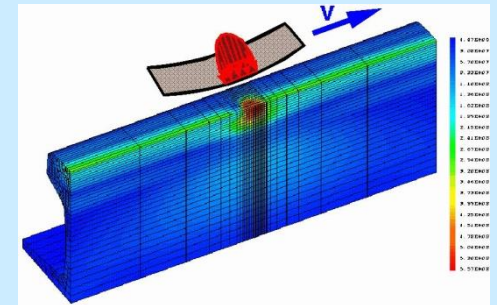
- **Dynamics of vehicle/track system**

Global forces

Contacts : localisations, pressures, ...

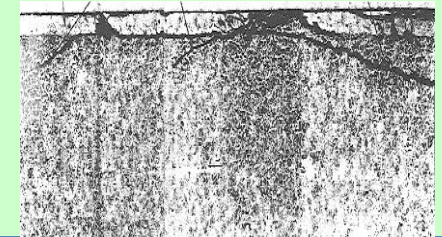


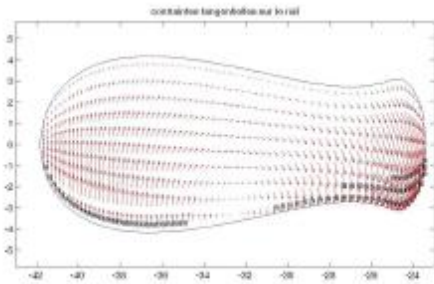
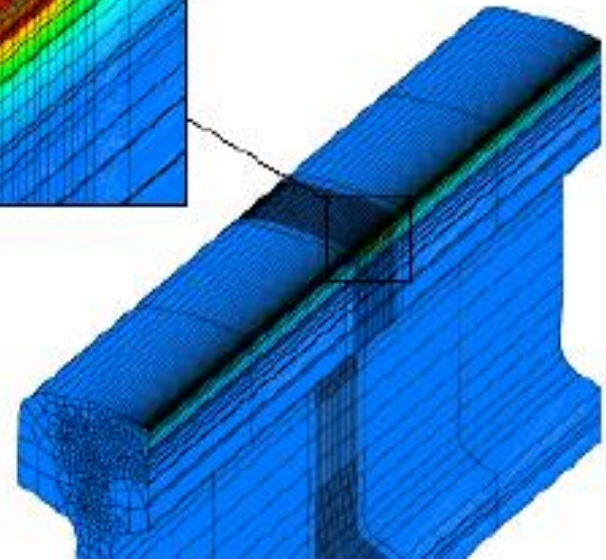
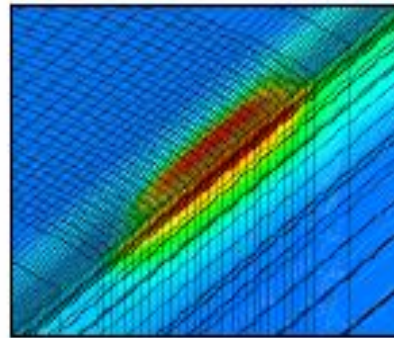
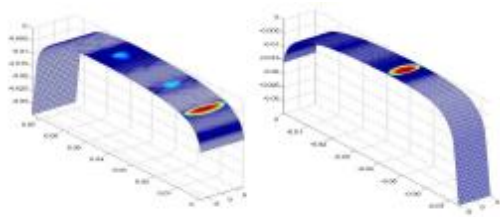
- **Evolution of the mechanical state
(stresses and strains)
under repeated moving contacts**



- **Rail defects damages**

Nature? Initiation, PROPAGATION





Déformations plastiques
Contraintes résiduelles



Besoin de Méthodes adaptés: METHODES STATIONNAIRES

I. Stationarity in the reference of the moving load

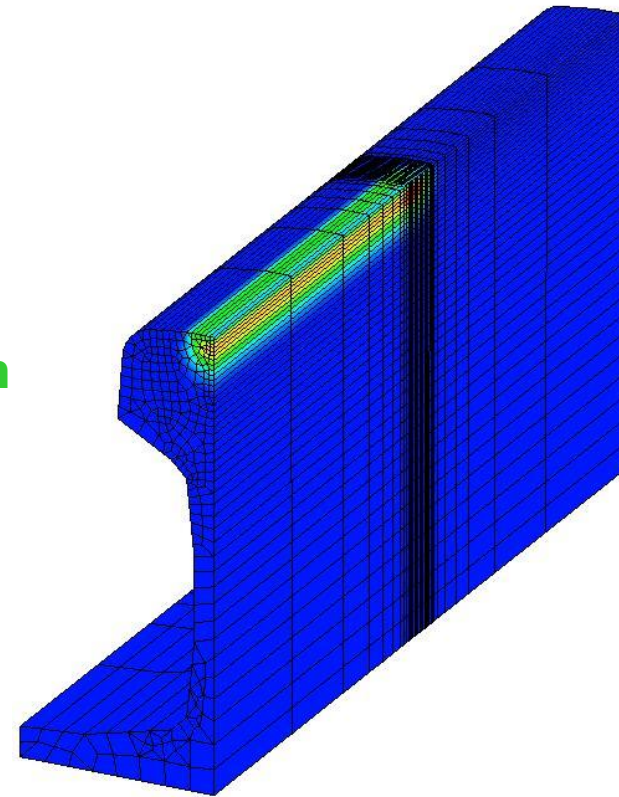
$$\dot{\mathbf{B}}(\mathbf{x}, t) = \frac{\partial \mathbf{B}}{\partial t}(\mathbf{x}, t) - \nabla_{\mathbf{x}} \mathbf{B}(\mathbf{x}, t) \cdot \mathbf{V}(\mathbf{x}, t) \quad + \mathbf{V} \text{ constante}$$

Consequences

1. Equilibrium equations : inertia terms
2. non local constitutive law
3. "Initial" conditions : up-stream condition

→ Global calculation of one pass

$\boldsymbol{\varepsilon}_p, \boldsymbol{\sigma}_{\text{res}}(M)$ complexes



AMORCAGE DE LA FISSURATION

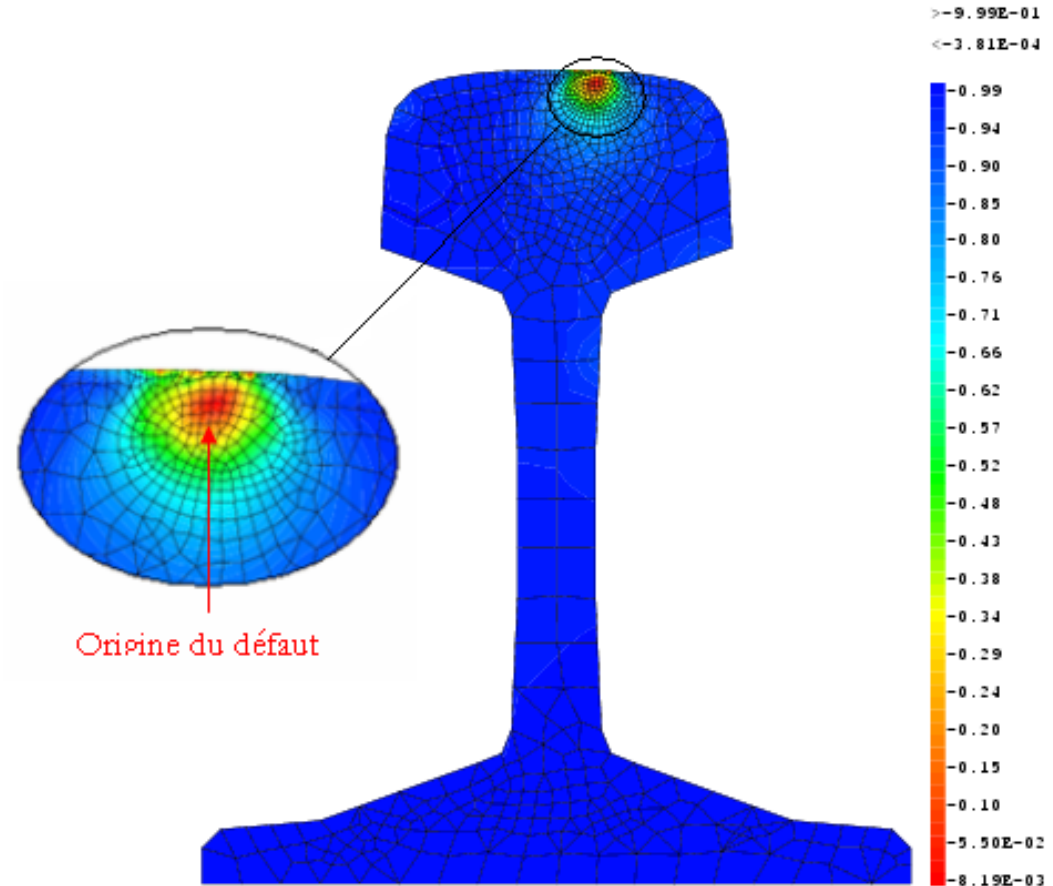
Application du critère de fatigue de D.V.



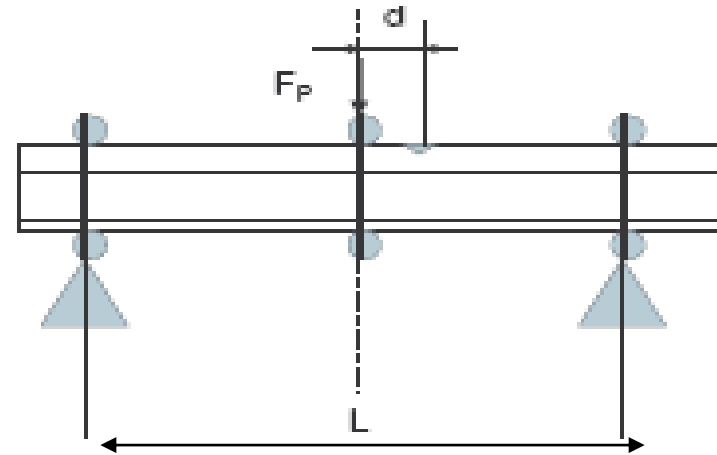
Localisation de l'amorçage



PROPAGATION?



ESSAIS B.A.M.

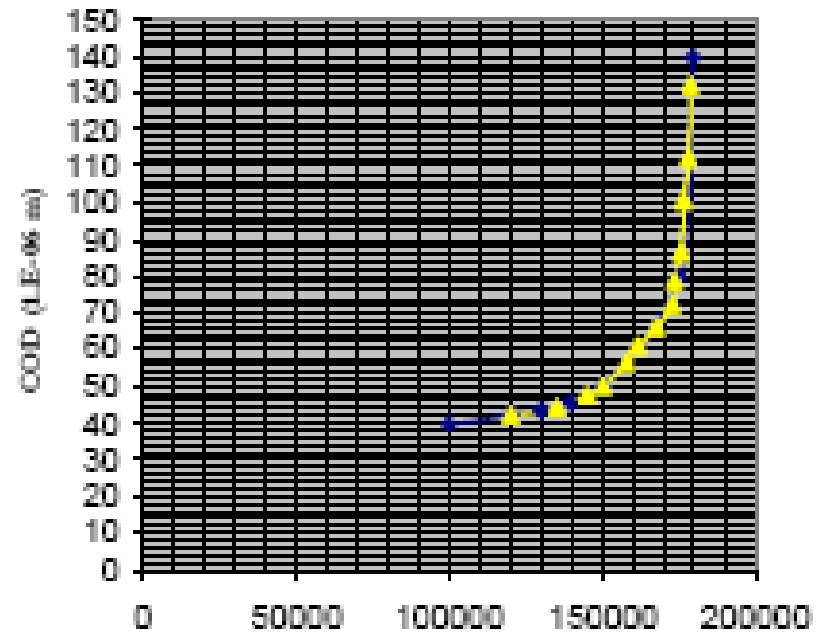


- Experimental COD

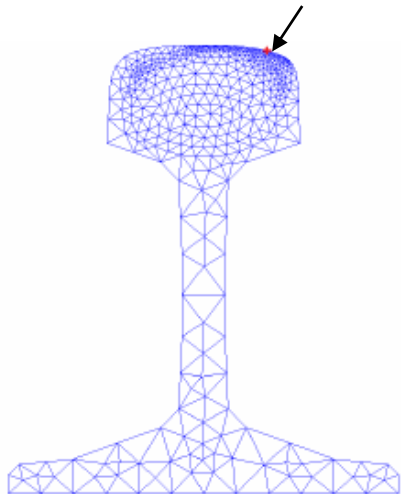
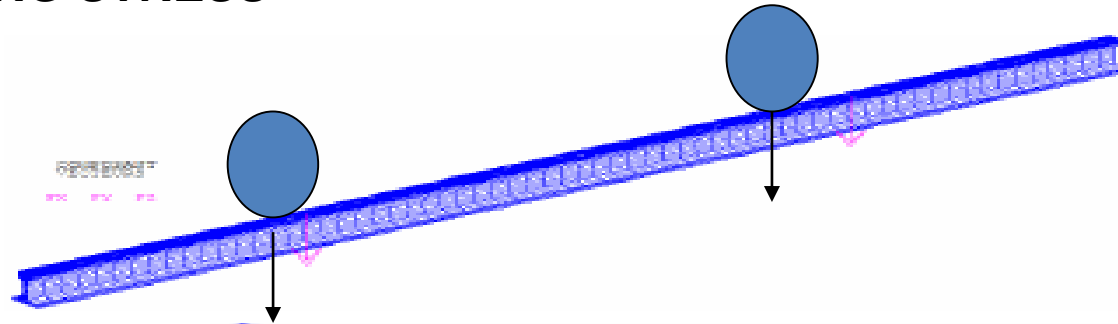
- Calculated COD

- Unknown: $a-N$?

170 MPA en flexion sont nécessaires pour faire propager la fissure !!!



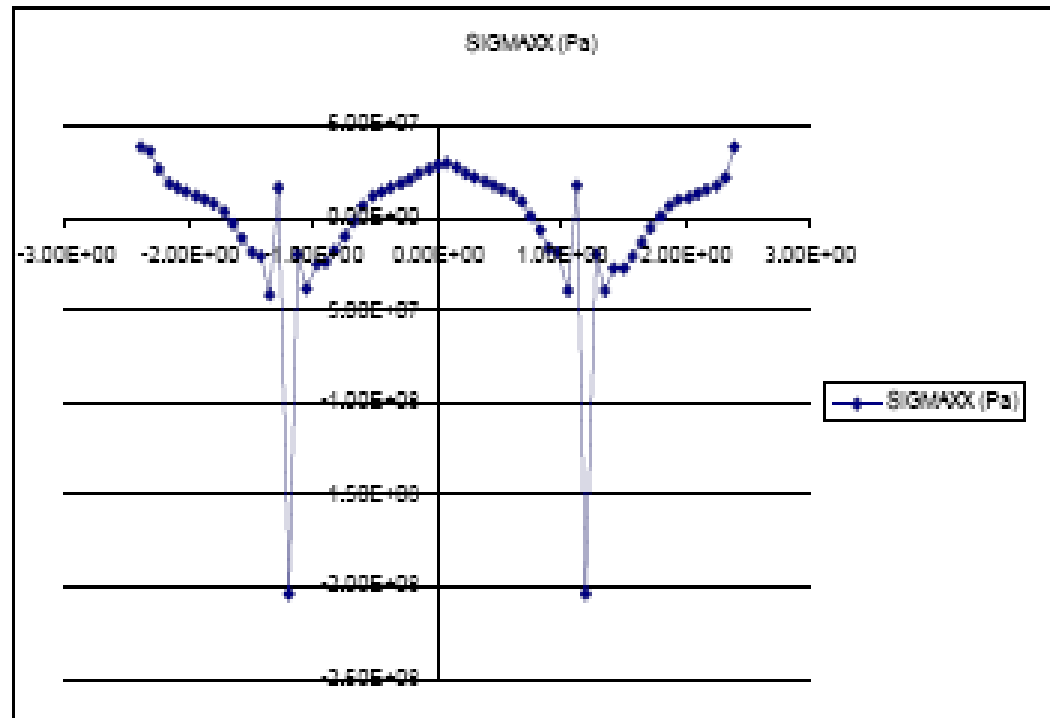
BENDING STRESS



$F_x = -24348\text{N}$

$F_y = -3541\text{N}$

$F_z = -108851\text{N}$



SCENARIO DE LA MODELISATION DE LA PROPAGATION DES FISSURES DE FATIGUE

1- LA FISSURE EST FERMEE SOUS LA ROUE (COMPRESSION
GENeree PAR LES CONTRAINTES DE CONTACT ET DE FLEXION)

2- LA FISSURE S'OUVRE PROGRESSIVEMENT DUE A L' ACTION DE:

-CONTRAINTe DE FLEXION POSITIVE

-CONTRAINTe THERMIQUE

-CONTRAINTES RESIDUELLES

3- LE MAXIMUM DE L'OUVERTURE CORRESPOND AU
MAXIMUM DES CONTRAINTES DE FLEXION POSITIVE

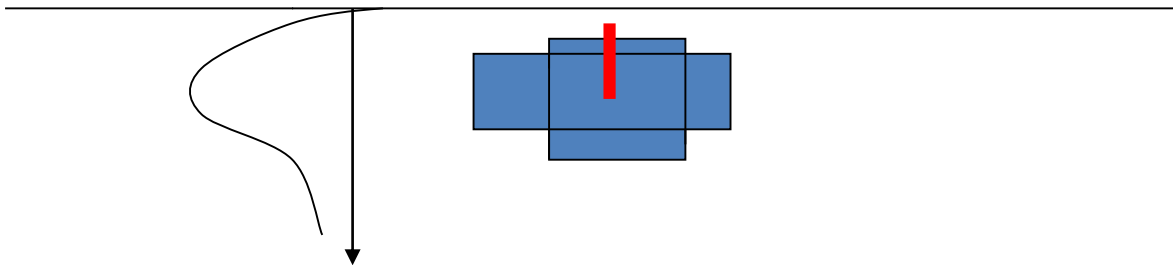
CALCUL DES FACTEURS D'INTENSITE: 2 DIFFICULTES:

1- MODES COMPLEXES : (K_I , K_{II} , K_{III}) EXISTENT SIMULTANEMENT

-**LA METHODE DES DISCONTINUITES DES DEPLACEMENTS** permet de séparer les modes

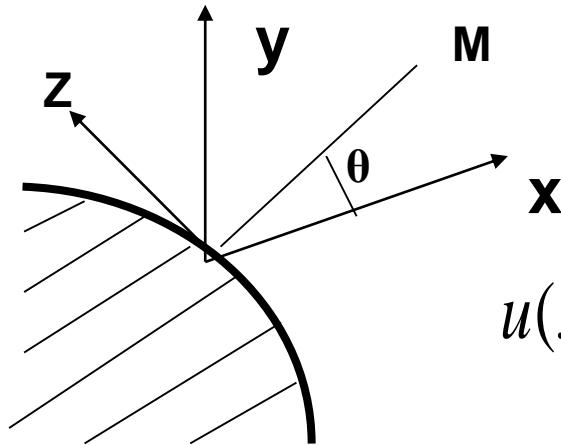
2-L'EVALUATION DES FACTEURS D'INTENSITE EN PRESENCE DE CHAMPS RESIDUELLES : CONTRAINTES OU DEFORMATIONS?

LES CONTRAINTES RESIDUELLES SONT MODIFIEES PAR LA PRESENCE DE LA FISSURE, CE QUI N'EST PAS LE CAS DU CHAMP DE **DEFORMATION PLASTIQUE**

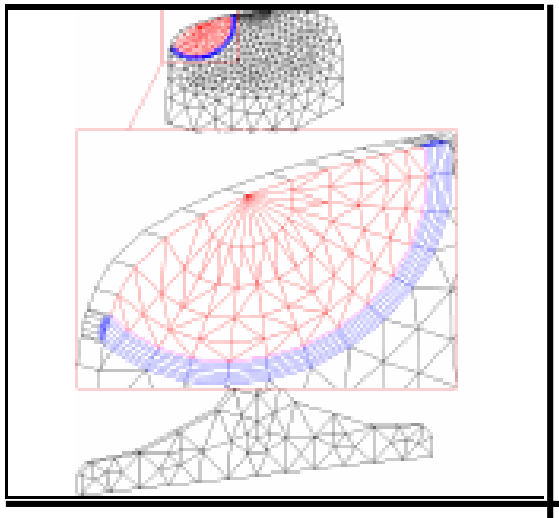


La fissure peut être ouverte alors que le champ des σ résiduelles sont des compressions!!!

ETAT DE CONTRAINTE COMPLEXE → K_I, K_{II}, K_{III} COEXISTENT Simultanément



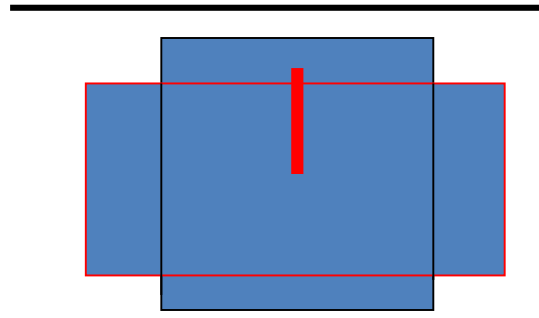
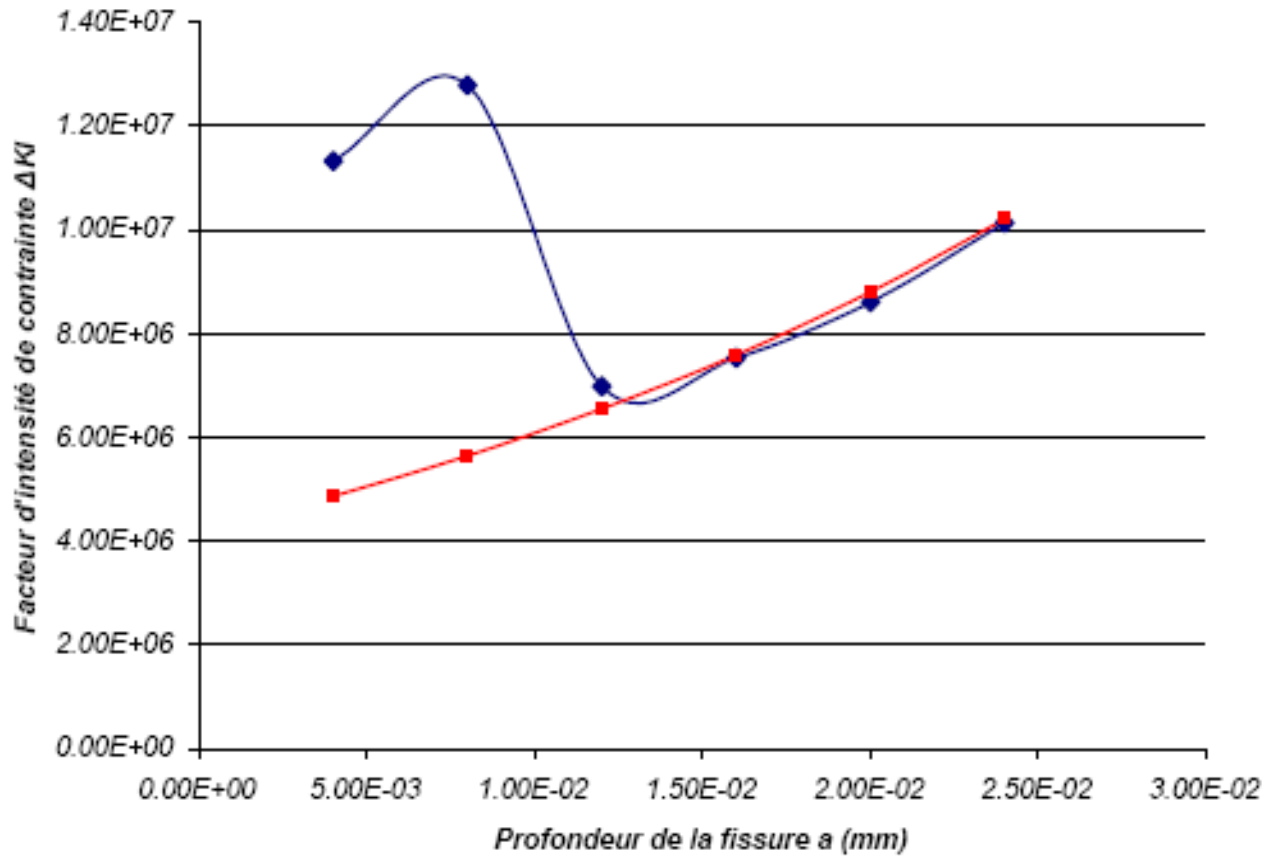
$$u(x, \pi) - u(x, -\pi) = \sqrt{\frac{x}{2\pi}} \left(\frac{\kappa+1}{\mu}\right) K_{II}$$



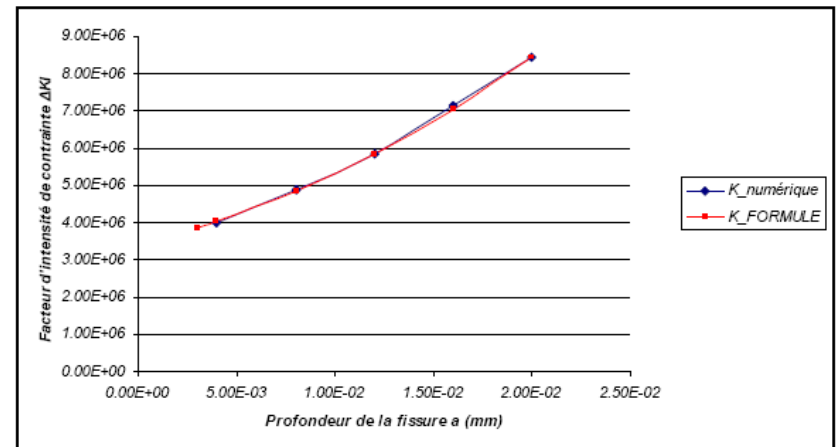
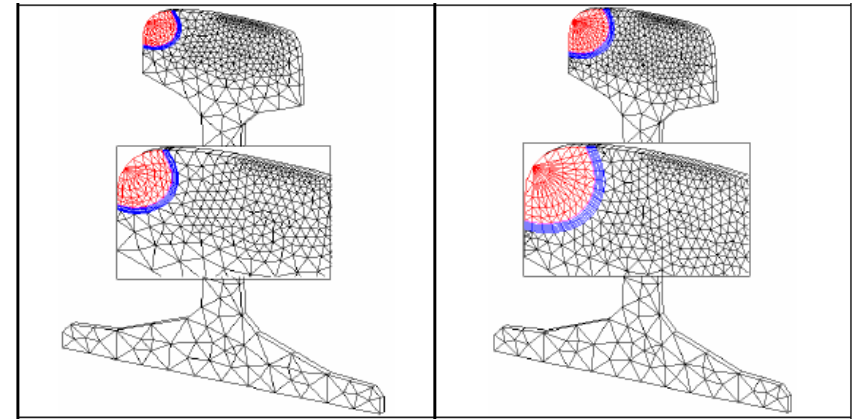
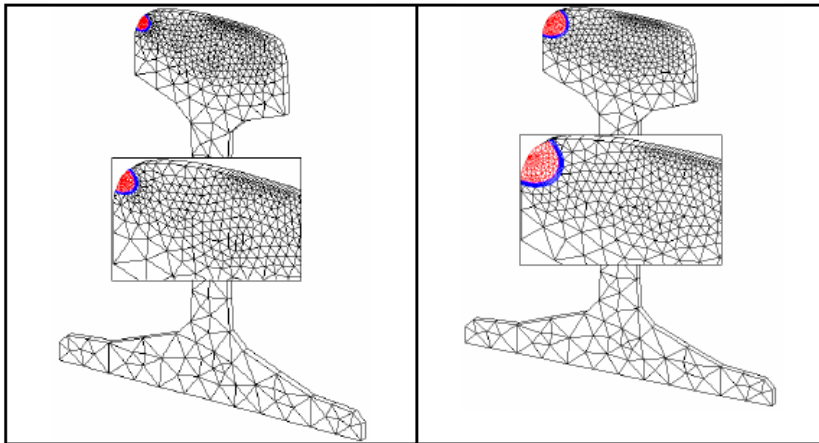
$$\rightarrow v(x, \pi) - v(x, -\pi) = \sqrt{\frac{x}{2\pi}} \left(\frac{\kappa+1}{\mu}\right) K_I$$

$$w(x, \pi) - w(x, -\pi) = 4 \sqrt{\frac{x}{2\pi}} \frac{K_{III}}{\mu}$$

a	K _f	K _r	new K _t	K numérique
3.00E-03				
4.00E-03	1.31E+06	8.79E+06	1.23E+06	1.13E+07
8.00E-03	2.23E+06	8.58E+06	1.98E+06	1.28E+07
1.20E-02	2.77E+06	1.64E+06	2.58E+06	6.98E+06
1.60E-02	3.25E+06	1.28E+06	3.00E+06	7.53E+06
2.00E-02	3.80E+06	1.03E+06	3.78E+06	8.61E+06
2.40E-02	4.46E+06	1.31E+06	4.36E+06	1.01E+07



Simulation de la propagation d'une fissure d'angle



- CONCLUSIONS:

En **présence de champ de contraintes résiduelles à fort gradient spatial** (cas des contraintes induites par le roulement, mais également de celles générées par le soudage), il est inexact de les considérer comme des champs lointains dans le calcul de propagation de fissure.

Ce sont les **déformations anelastiques** qui doivent être introduites, déformations qui ne sont pas directement mesurables.

MERCI POUR VOTRE ATTENTION