UNIVERSITE PARIS X NANTERRE

POLE SCIENTIFIQUE ET TECHNOLOGIQUE

VILLE D'AVRAY – ST CLOUD

LABORATOIRE D'ENERGETIQUE ET D'ECONOMIE D'ENERGIE

8th INTERNATIONAL CONFERENCE ON MECHANICAL AND PHYSICAL BEHAVIOUR OF MATERIALS UNDER DYNAMIC LOADING

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Theoretical and numerical study of strain localization under high strain rate solicitation

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Introduction

Objectives of the study :

- Simulate the initiation and the propagation of adiabatic shear bands (ASB).
- To understand the effect of the roughness of the specimen on the band initiation and propagation

Case of the titanium alloy TA6V during dynamic torsion solicitation

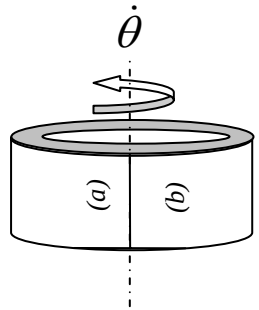
The presentation :

- Geometry of the problem and the thermomechanical model
- Choice of a behavior law and identification of the parameters
- Numerical simulation of ASB formation

Model of a torsion specimen

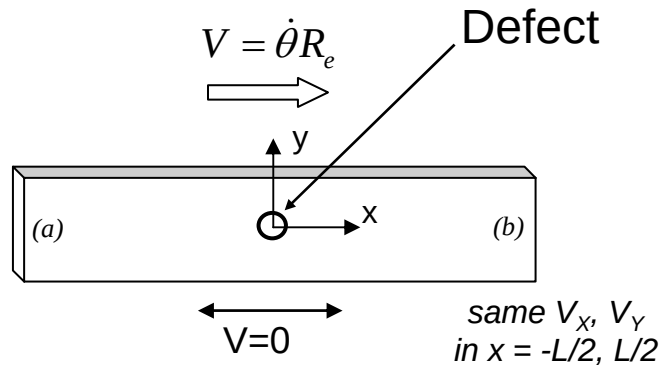
- Geometry

Classical thin wall tubular specimen



3D Problem

Wall thickness : 0.4mm
Diameter : 9mm
Length : 2mm



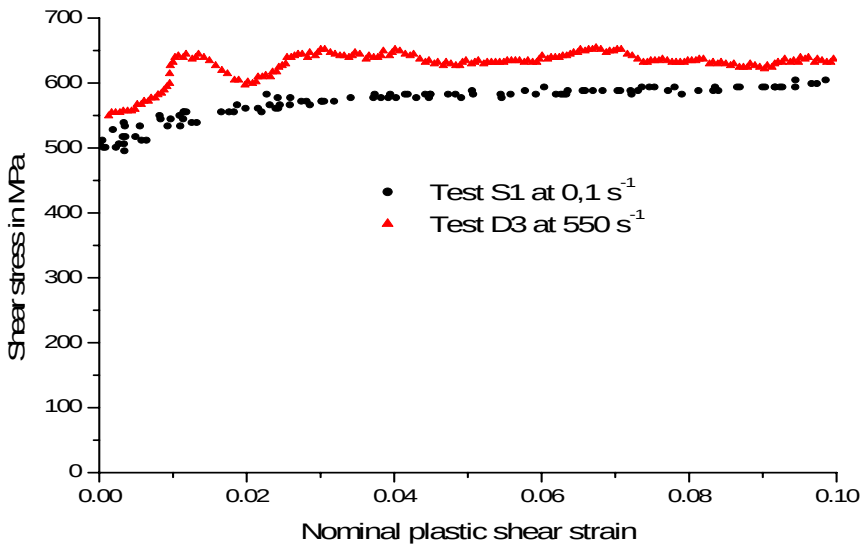
2D Problem

- Defect :
  - Small reduction of the specimen thickness on a circular zone
  - Defect diameter : between 20µm and 100µm
  - Defect amplitude $\Delta e/e$: between 1% and 5%

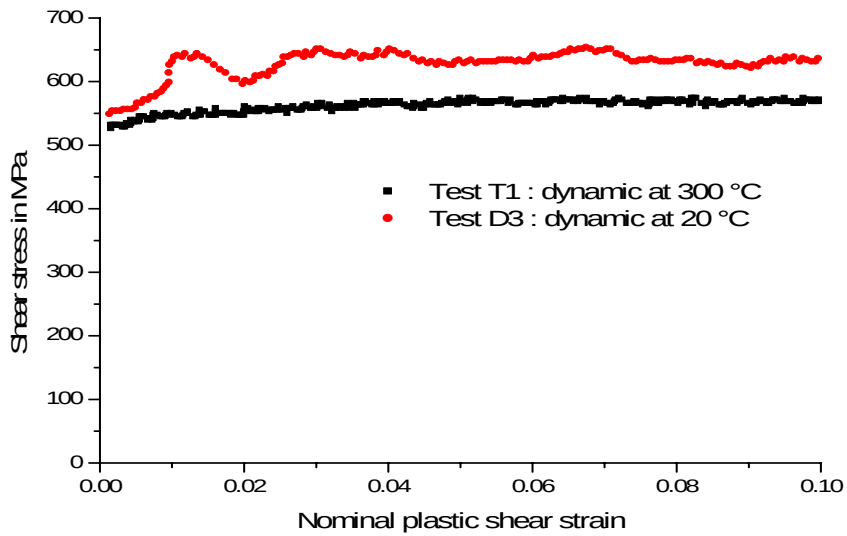
Behavior of the material

- A serie of torsion tests were performed

Test reference	S1	S2	S3	D1	D2	D3	D4	T1	T2	T3
Shear strain rate in s^{-1}	0.097	0.0104	0.101	776	571	565	406	365	222	301
Temperature in °C	20	20	20	20	20	20	20	300	300	230



Strain hardening, Strain rate hardening



Thermal softening

⇒ **We chose a Johnson Cook behavior law**

Identification of the parameters of behavior law

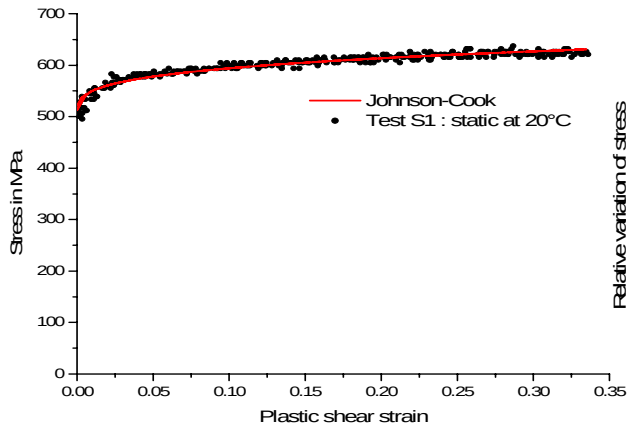
Johnson Cook plastic law :

$$\tau\left(\gamma,\dot{\gamma}_{eq},T\right)=\underbrace{\left(A+B\gamma^{n}\right)}_{\text{Strain hardening}}\underbrace{\left(1+C\ln\left(\frac{\dot{\gamma}}{\dot{\gamma}_{0}}\right)\right)}_{\text{Strain rate hardening}}\underbrace{\left(1-\left(\frac{T-T_{t}}{T_{f}-T_{t}}\right)^{m}\right)}_{\text{Thermal softening}}$$

We chose :

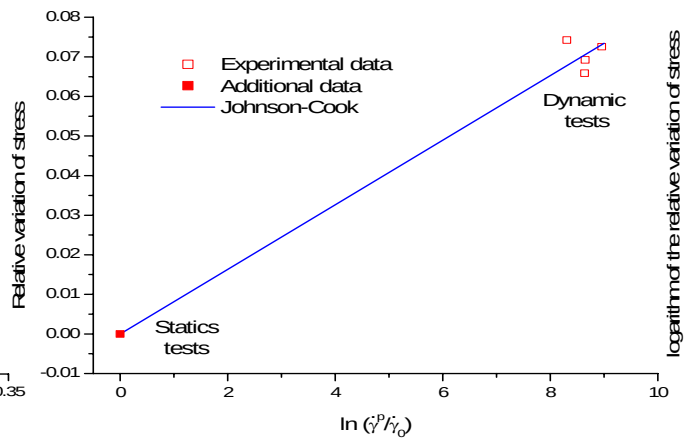
- a reference strain rate ($\dot{\gamma}_0$)of 0.1 s^{-1}.
- a transition temperature (T_t) of 20°C.

The melting point of TA6V is 1650°C

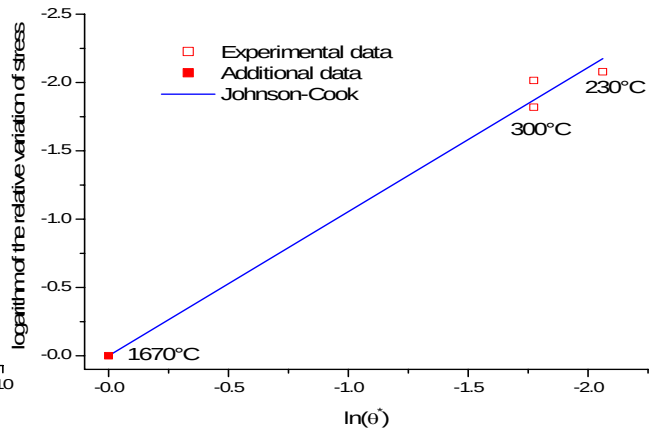


A = 500 MPa; B = 160 MPa

n = 0.25



C = 0.008



$$\theta^{*}=\frac{T-T_{t}}{T_{f}-T_{t}}$$

m = 1.055

Resolution of the problem

- Finit Elements Method :
  - Abaqus® Explicit
  - Fully coupled thermomechanical model taking into account of inertia and heat conductivity.

Heat equation : $$\rho C \frac{\partial T}{\partial t} = \underbrace{\beta \sigma : \dot{\varepsilon}_p}_{\textit{Dissipation}} + \underbrace{\lambda \Delta T}_{\textit{Conduction}}$$

ρ : density

C : heat capacity

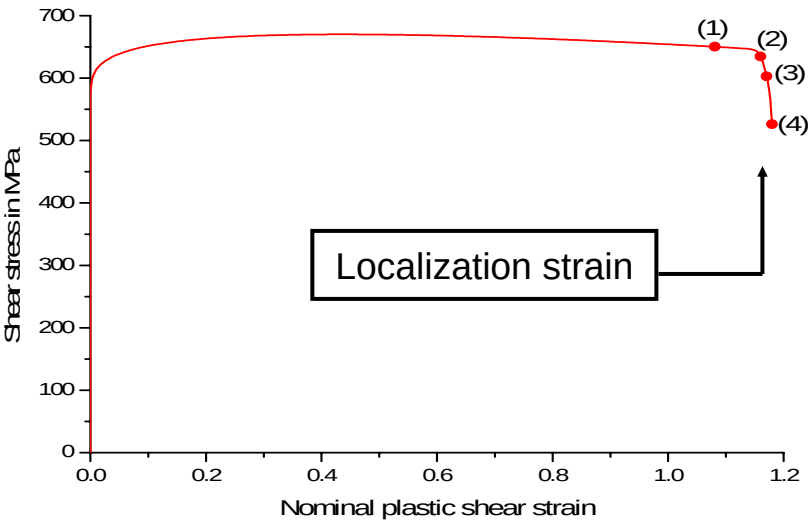
β : Taylor Quinney coefficient

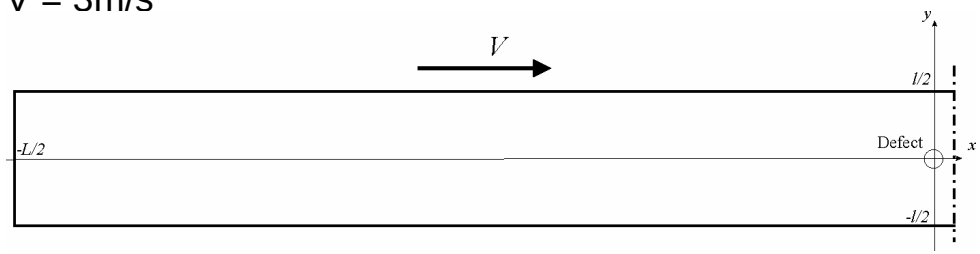
λ : thermal conductivity

- Mesh characteristics
  - Size of the elements located in the area of the ASB propagation : 10µm ;
  - Number of elements : around 4000
  - Same mesh for the different defects diameter

Results of the model

- ASB initiation and propagation : V = 3m/s





(1) γ = 1,08; t = 746µs

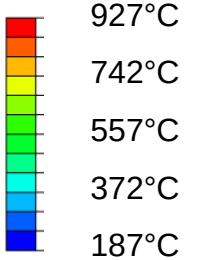
(2) γ = 1,16; t = 804µs

(3) γ = 1,17; t = 816µs

(4) γ = 1,18; t = 840µs

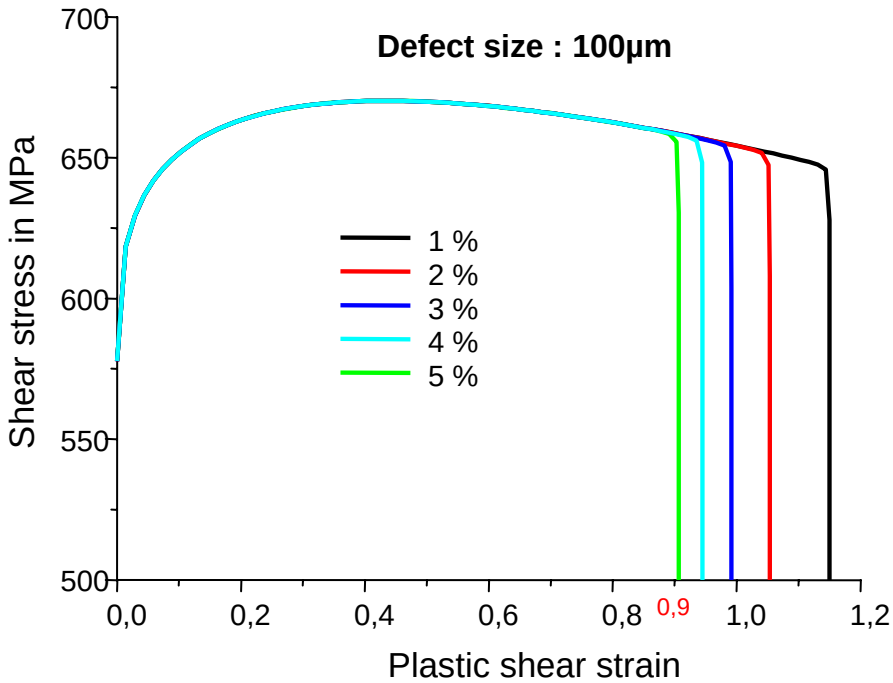
Defect :

- Diameter of 40µm
- Amplitude of 5%

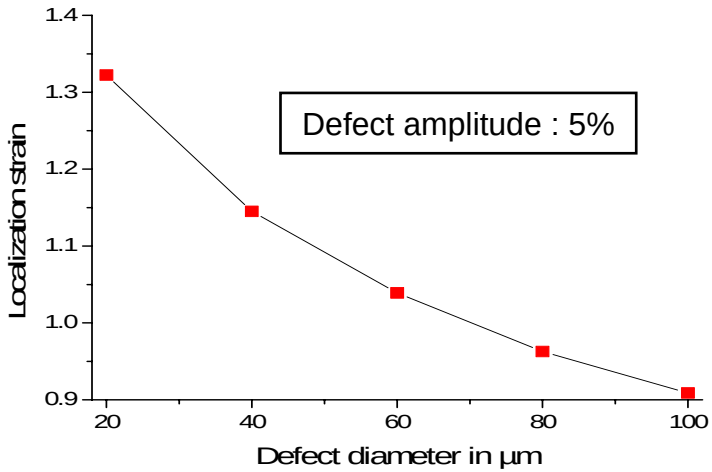


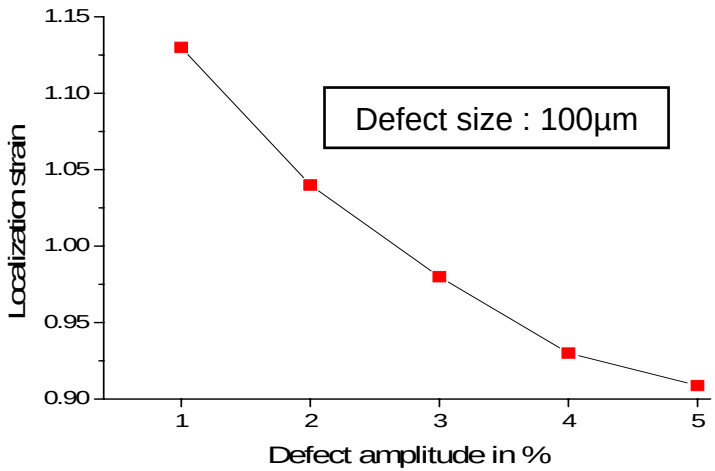
Results of the model : effect of the defect size

- Release of the shear stress



- Effect of the defect size on the strain localization





Increase of the size and the amplitude of the defect

⇩

Decrease of the strain localization

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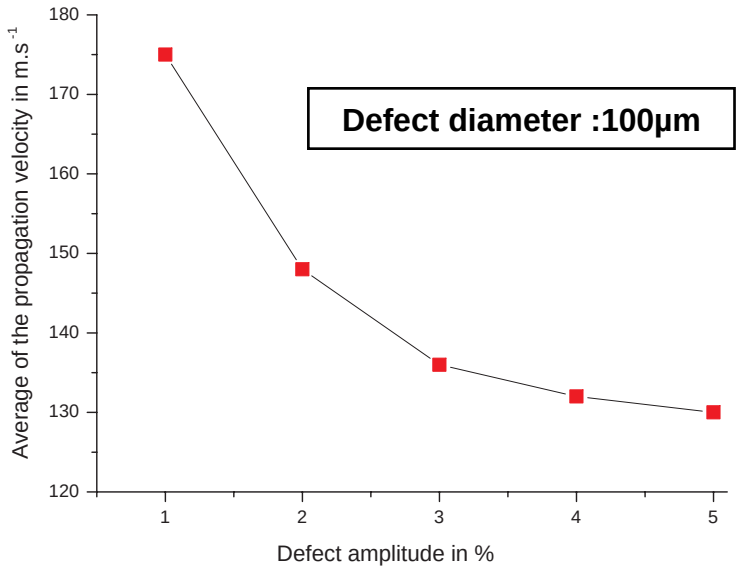
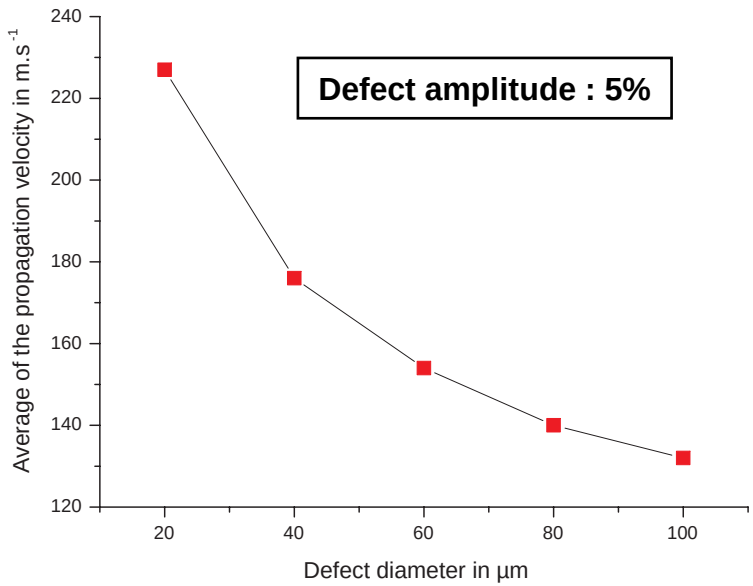
Results of the model : effect of the defect size

The average of the propagation velocity of the ASB between the defect and the quarter of the specimen :





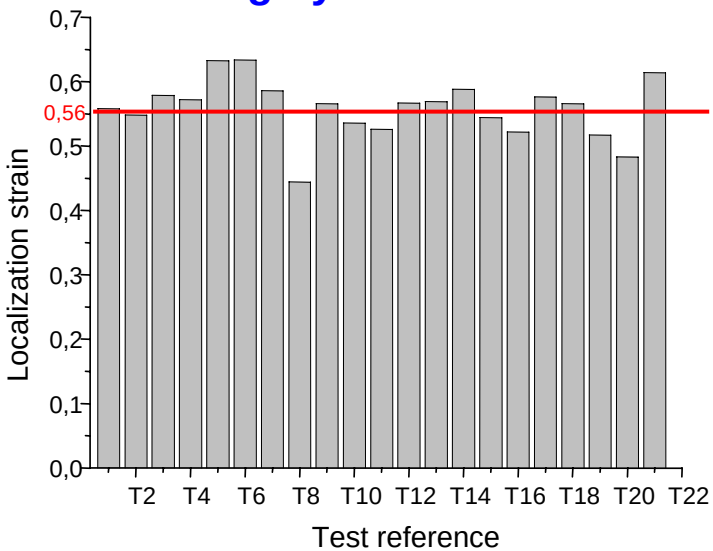
Increase of the size and the amplitude of the defect

⇩

Decrease of the average propagation velocity

Comparison with experimental data

Experimental determination of localization strain during dynamic torsion tests



Mean of the localization strain : 0.56

Measure of the roughness :

Defect amplitude : 0,6%

Characteristic size : 10µm to 100µm

Prediction of the localization strain :

Localization strain higher than 0.9 (defect : 5%;100µm)

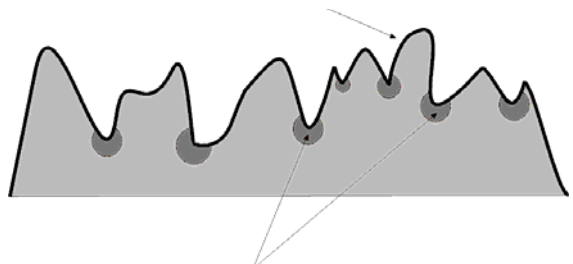
Overestimation of the localization strain

Conclusion :

- Underestimation of the plastic strain concentration (3D strain distribution)

- multiple initiation site? Interaction between defects

Surface roughness



Zone of plastic strain concentration

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Conclusion

- The model allows :
  - to simulate the initiation and the propagation of ASB
  - Determination of the effect of the defect on the strain localization
- The magnitude of the localization strain is higher than those found in experiments
  - (several defects, 3D simulation)