ArcelorMittal

Optimization of stamping tools to process very high strength steels ; comparison of cold work tool steels

Dominique Viale, Ravir Bhatnagar*,

Guy Baron, Perrine Jousserand*, M. Gomez

ArcelorMittal Global R&D*

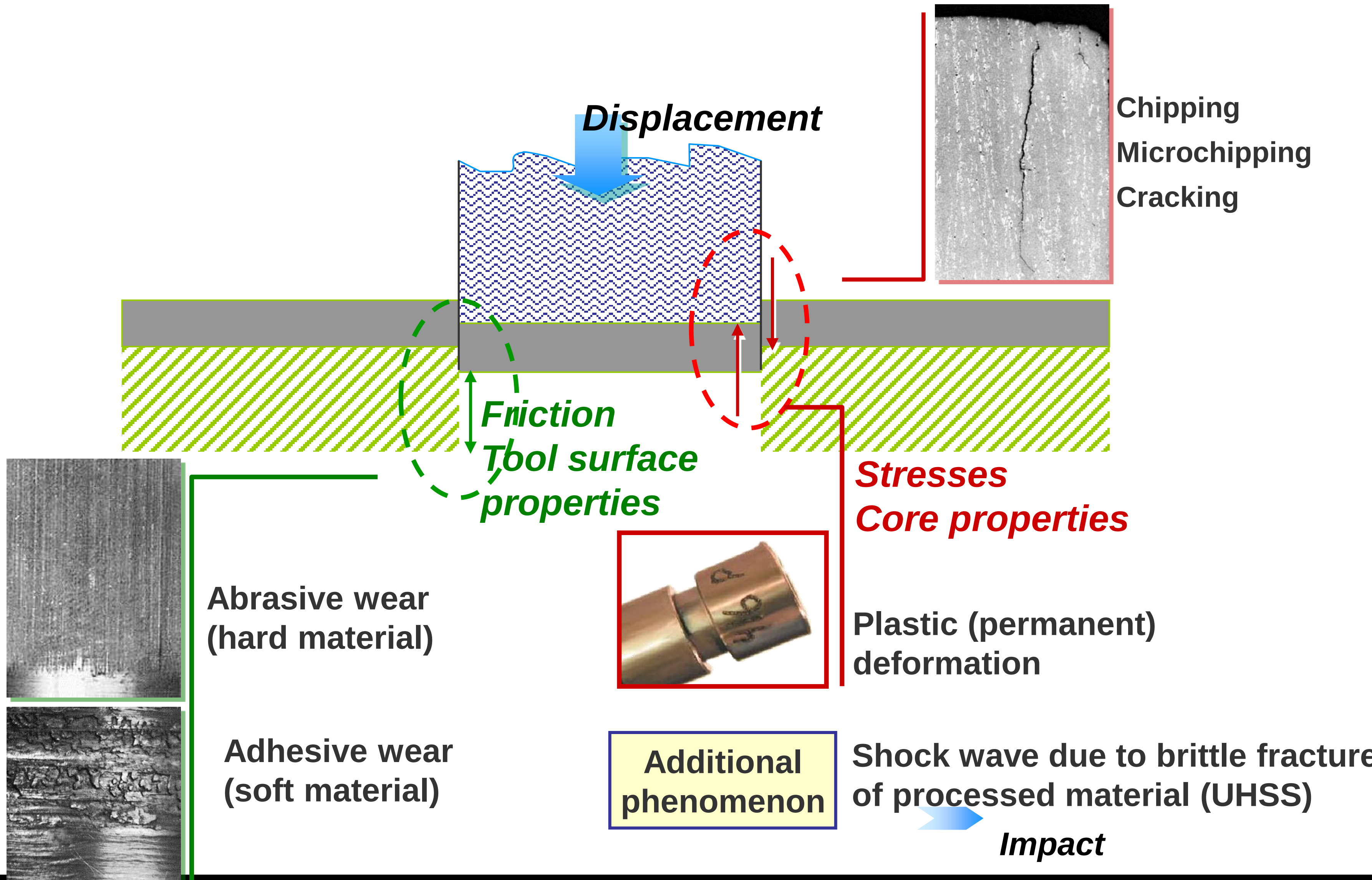
ArcelorMittal Industeel

Outline

- Background
  - Tool Wear Mechanisms - Failure Modes
- Tool Steel Formulation
  - Properties
- Experimental Work
  - Experimental Set up
  - Experimental Results
- Industrial Applications/Examples
- Conclusions

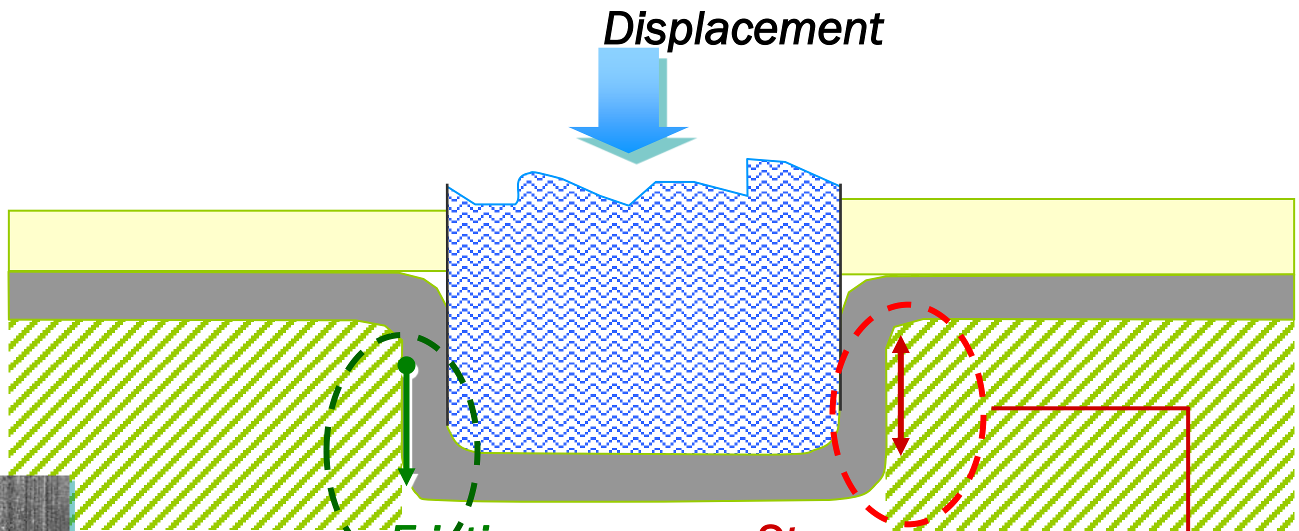
ArcelorMittal

Cutting/Trimming process



ArcelorMittal

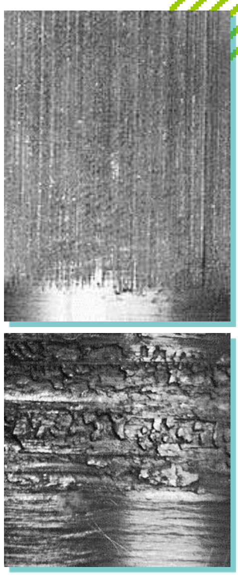
Forming/Trimming Process



Friction
Tool surface properties

Stresses
Tool core properties

Surface fatigue
Cracking/Chipping
Plastic deformation



Abrasive wear (hard material)

Adhesive wear (soft material)

+ *Peeling of coating*

Challenges for Tool Steels for processing VHSS/UHSS

Cutting/Trimming

① Microchipping → Chipping
→ cracking

② Plastic deformation

③ Abrasive wear

Choose tough substrate

Forming

① Abrasive wear

② Surface fatigue / chipping

Select appropriate substrate/coating

Substrate properties for processing VHSS/UHSS

- Toughness (Charpy)
- Compressive strength (Yield Strength)
- Compatibility with surface treatments of coating
- Repairability (welding)
- Hardness (Surface)
- Machinability
- Heat treatment

Properties addressed in the formulation of

TENASTEEL®℗

ArcelorMittal

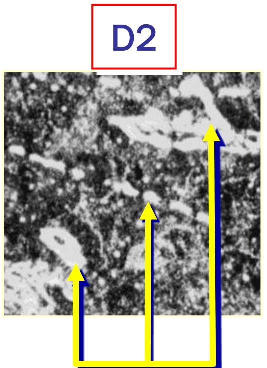
Characteristics/Properties of Tool steels

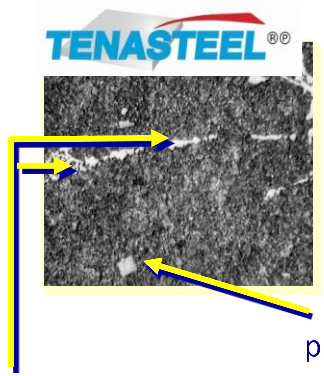
- Tool materials characteristics:

Product name	Type	Euronorm	Hardness		Compression strength (MPa)	Toughness* (J)
			As Delivered	Hardened condition		
Z160CDV12 (D2)	Cold work high chromium tool steel	X153 CrMoV12 *(W.Nr.: 1.2379)*	250 HB max	58 / 62 HRC	2200	18
Tenasteel	Cold work tool steel	X110 CrMoV8 family	250 HB max	58 / 62 HRC	2510	36

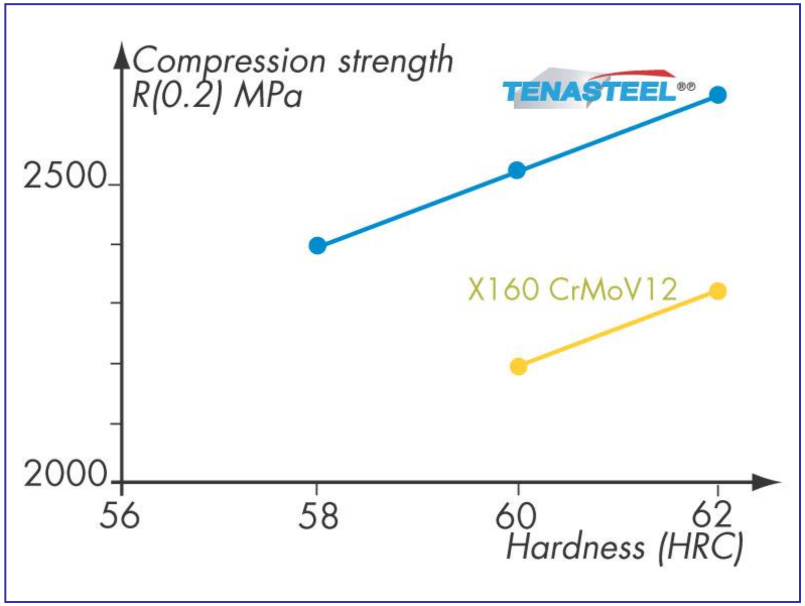
** Unnotched specimen*

Product name	Chemical analysis					
	C	Si	Mn	Cr	Mo	V
Z160CDV12 (D2)	1.55	0.30	0.35	11.75	0.75	0.75
Tenasteel	1.0		0.35	7.5	2.6	0.3





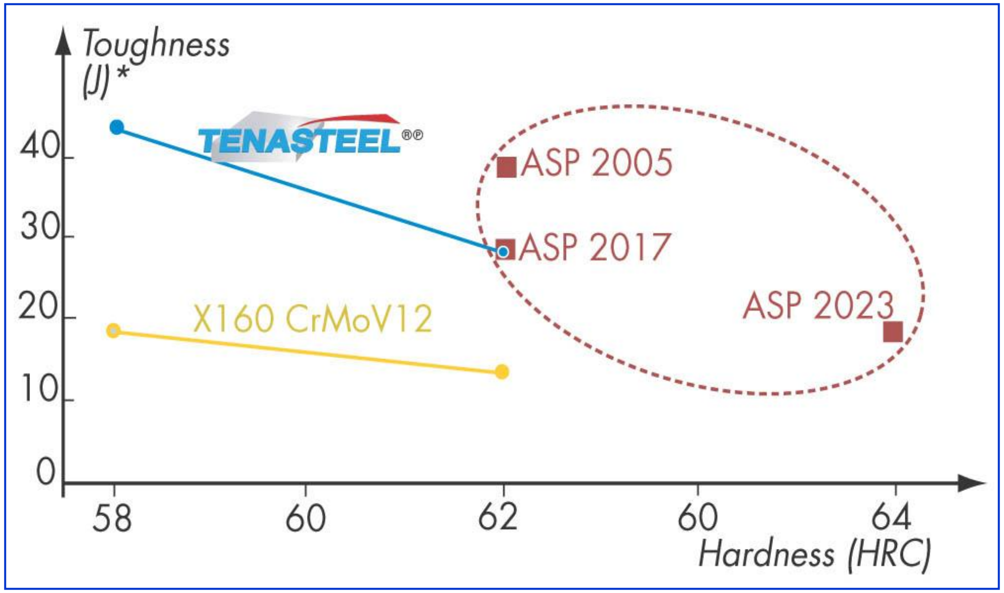
Properties of Tool Materials



Compression strength is necessary to avoid permanent deformation in high stressed area when processing VHSS/UHSS

- **Minimum 58 HRC necessary**
- **TENASTEEL provides better resistance than D2**

* Unnotched specimen



Powder Metal (PM) Grades

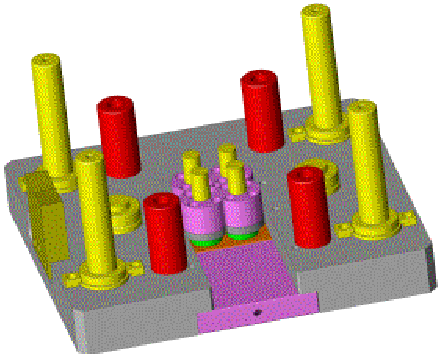
- **Most provide very high wear resistance**
- **Toughness not correspondingly high**

Experimental Work

Experimental Study - Objective

- **AIM:**
  - Provide guidelines to customers in terms of
    - tool material and coating,
    - Process parameters (cutting clearance)

- **PROCEDURE:**
  - In line cutting (total: 500 000 strokes per configuration)
  - Observations and measures during the campaign:
    - Detailed Examination of tools (observations, profiles, SEM analysis)
    - Detailed examination of parts (cut-edge quality (cf. Punching test), hole expansion test)
    - Data acquisition (force-displacement curves)

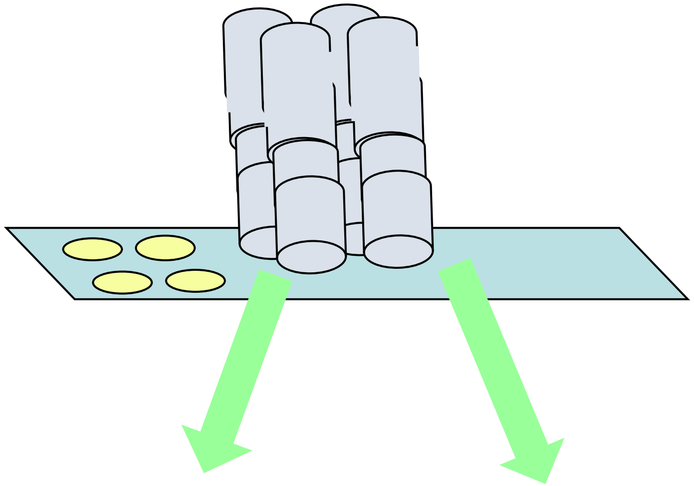


Experimental Set-up

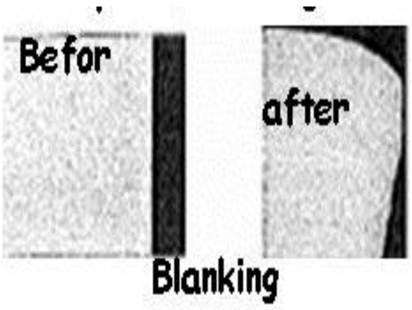
- **Steel sheet:** DP 980, 1.6mm
- **Part geometry:** 20mm diameter disc
- **Tool configurations (tested clearances)**

Tool material	Coating		
	Bare	TiN	AlCrN
D2 (Industeel)	7% 12%	12%	12%
Tenasteel (Industeel)	12%	12%	12%

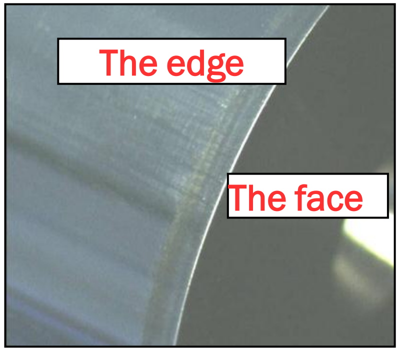
Product name	Requirement (HRC)	Hardness (HRC) (measured on tools)
(D2)	58/60	58
Tenasteel	58/60	59/60



Shape of cutting edge



Punch Body



Presentation of the study - Experimental schedule

- Investigation methodology for each tool configuration
  - Punch damage analysis through
    - 3D profile measurement
    - Bino and SEM observations
  - Influence of punch damage on sheet product
    - Cut-edge shape
    - Burr height
    - Stroke height through force/displacement curve
    - Cut-edge formability through hole expansion test
  - Frequency

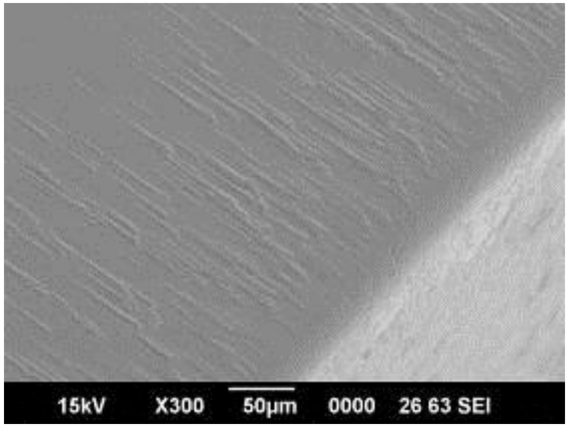
    Each configuration is totally characterized :
    - After 1, 30, 100, 500, 1000, 2500 strokes
    - From 5000 to 20000 strokes by 5000 steps
    - From 20000 to 100000 strokes by 20000 steps
    - From 100000 to 500000 strokes by 40000 steps

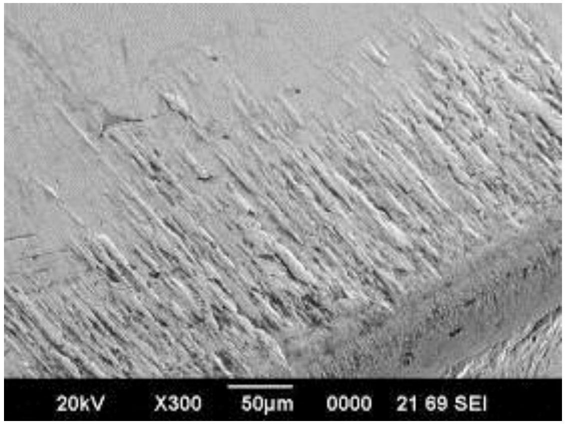
ArcelorMittal

Experimental Results

Definition of tool wear mechanisms
Substrate degradation

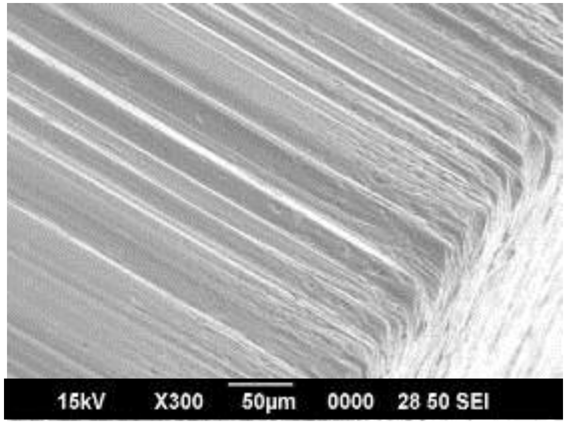
- **Adhesion / sticking**: Some sheet steel particles (debris) sticks on the tool

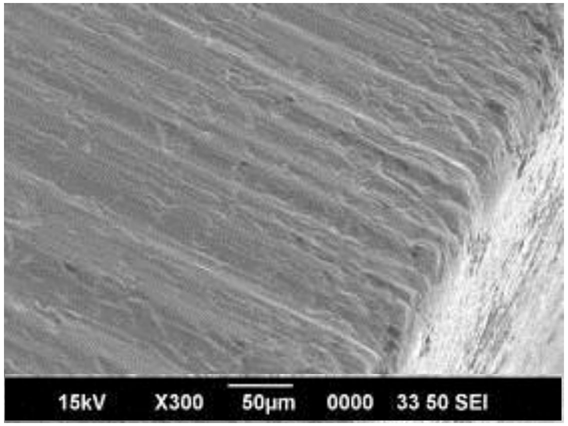


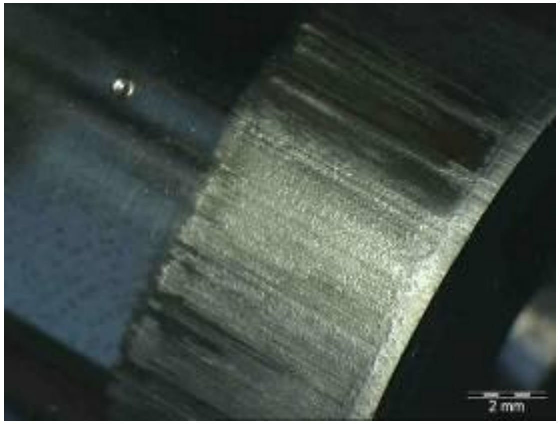


NB: In our case, this mechanism was microscopical ➔ not observed visually

- **Abrasive wear**: Friction scratches can clearly be identified in the punching direction



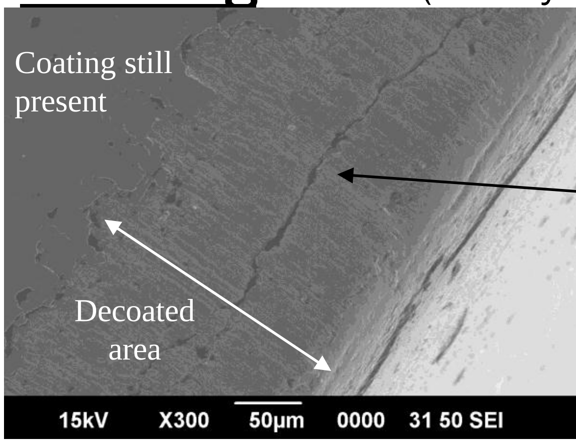




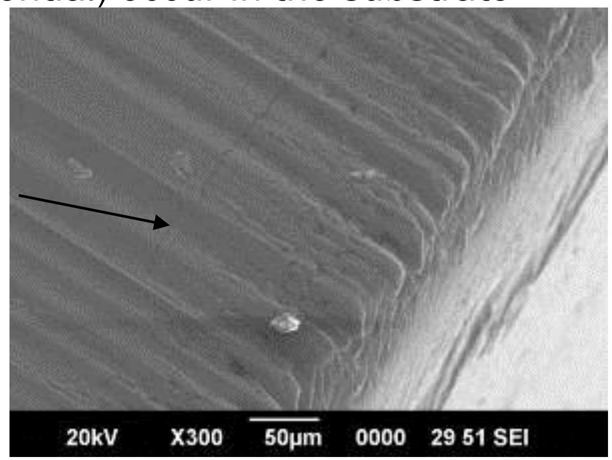
ArcelorMittal

Definition of tool wear mechanisms
Substrate degradation

- **Cracking:** Cracks (usually circumferential) occur in the substrate



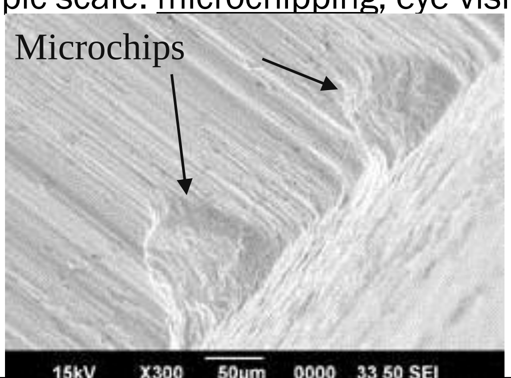
Substrate cracking

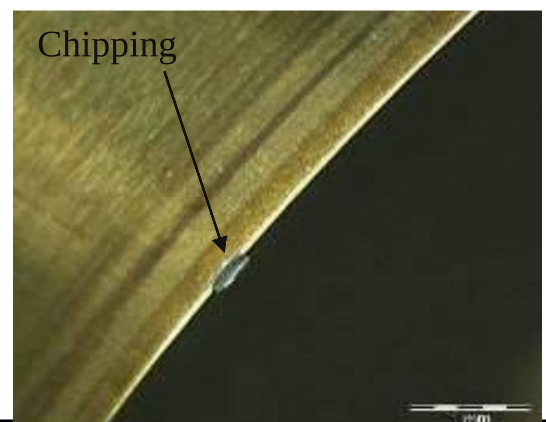


NB: Microscopic mechanism
➔Can not be observed visually

- **Chipping / Microchipping:** A small part of material breaks away from the tool

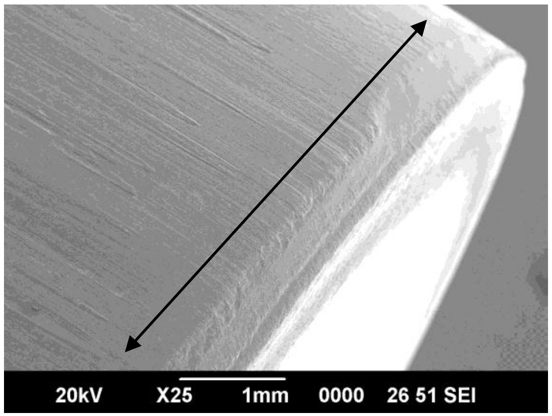
(microscopic scale: microchipping, eye visible: chipping)

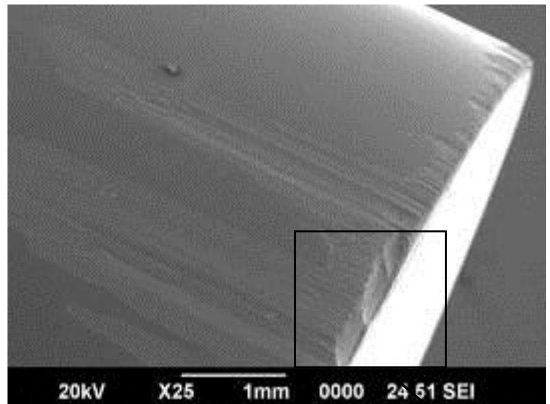


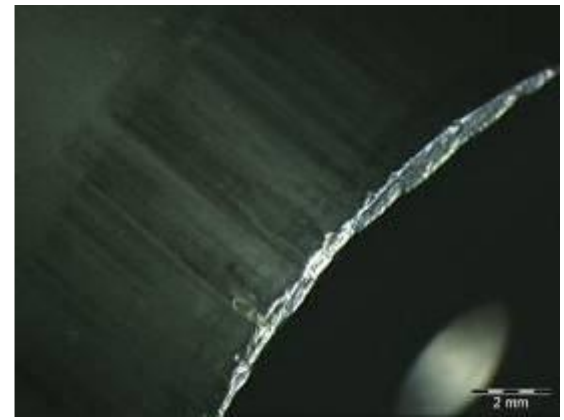


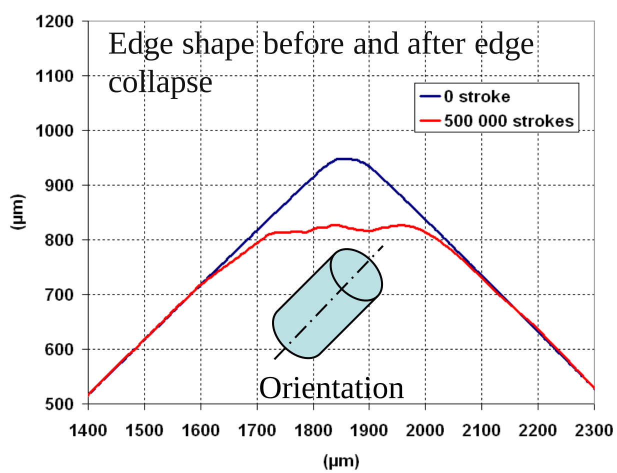
Definition of tool wear mechanisms
Substrate degradation

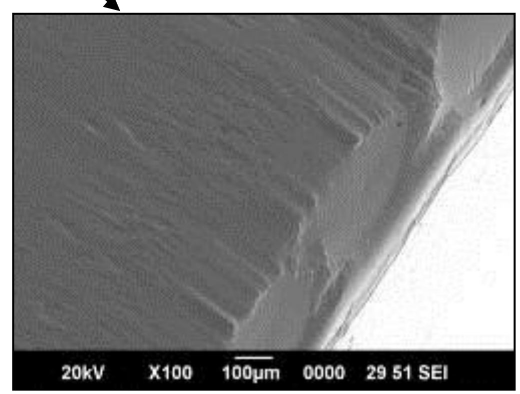
- **Edge collapse:** (often occurs as a consequence of chipping) A large amount of the edge is destroyed – the edge shape is then no longer triangular but flattened (see graph below)







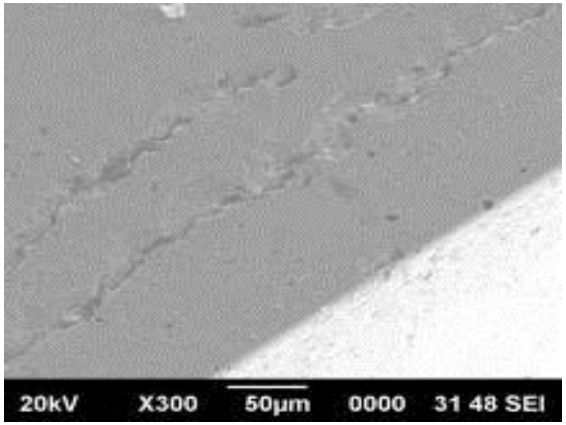


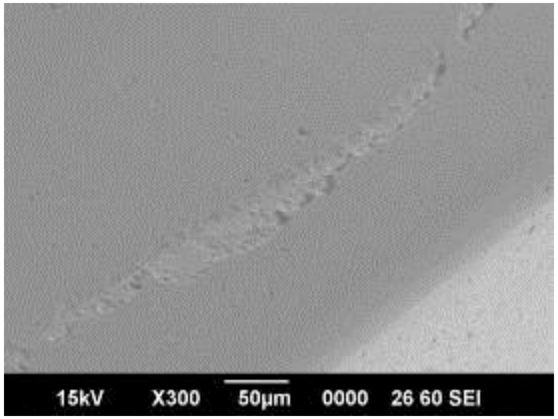


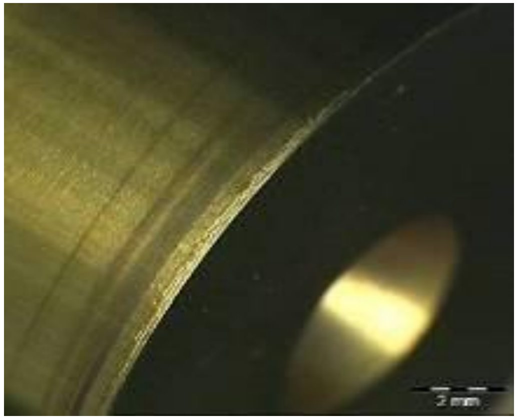
ArcelorMittal

Definition of tool wear mechanisms
Coating degradation

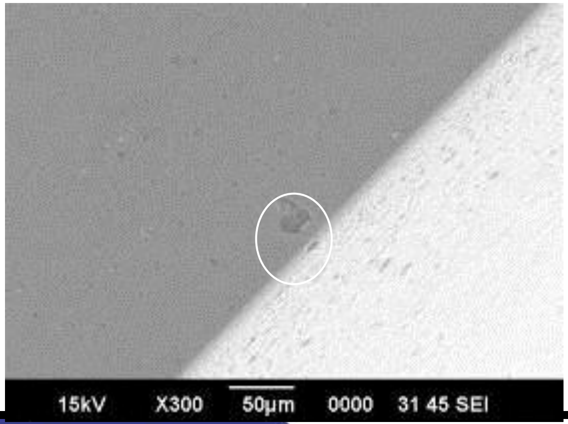
- **<u>Coating cracking</u>:** Cracks (usually circonferencial) in the coating

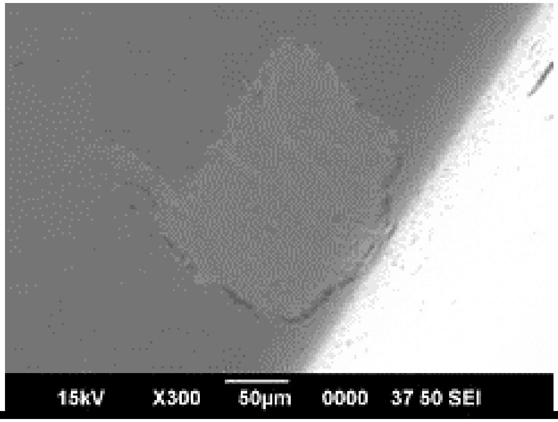


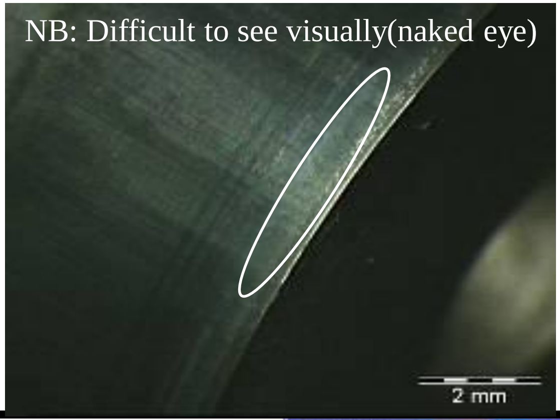




- **<u>Coating flaking</u>:** Coating delminates from the substrate and flakes off



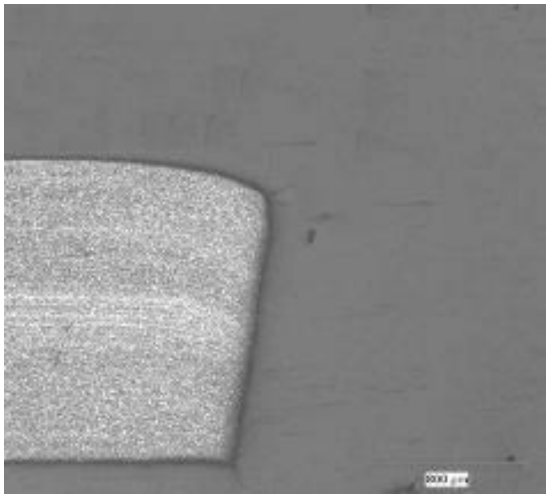


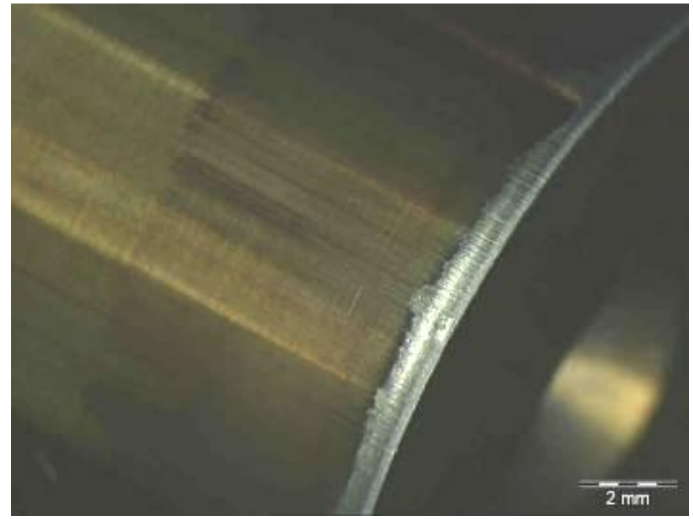


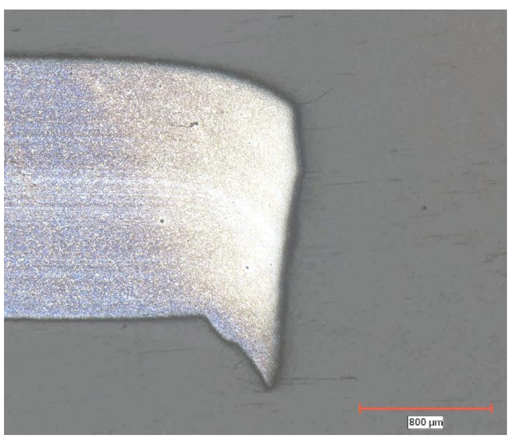
ArcelorMittal

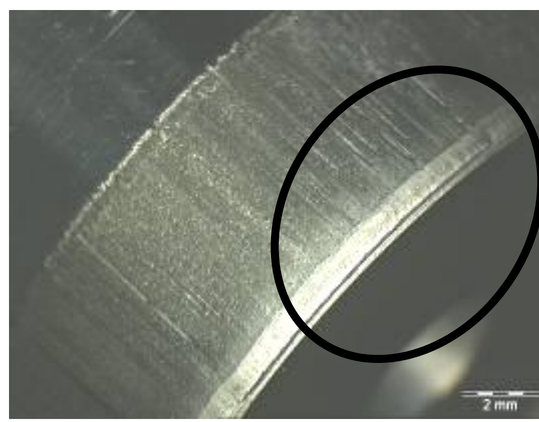
Definition of tool wear mechanisms
Effect of Worn Took on Sheet Steel Edge

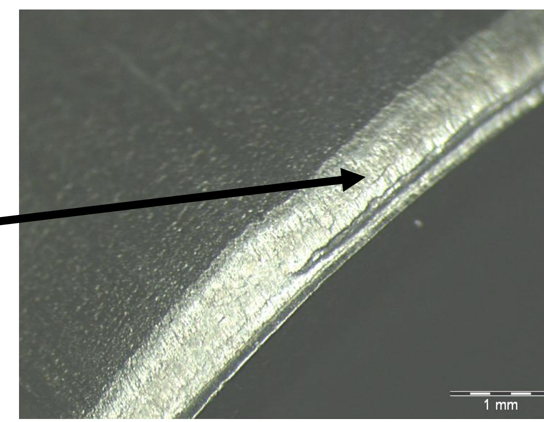
Co-relation between Cut-edge Burr and Tool wear



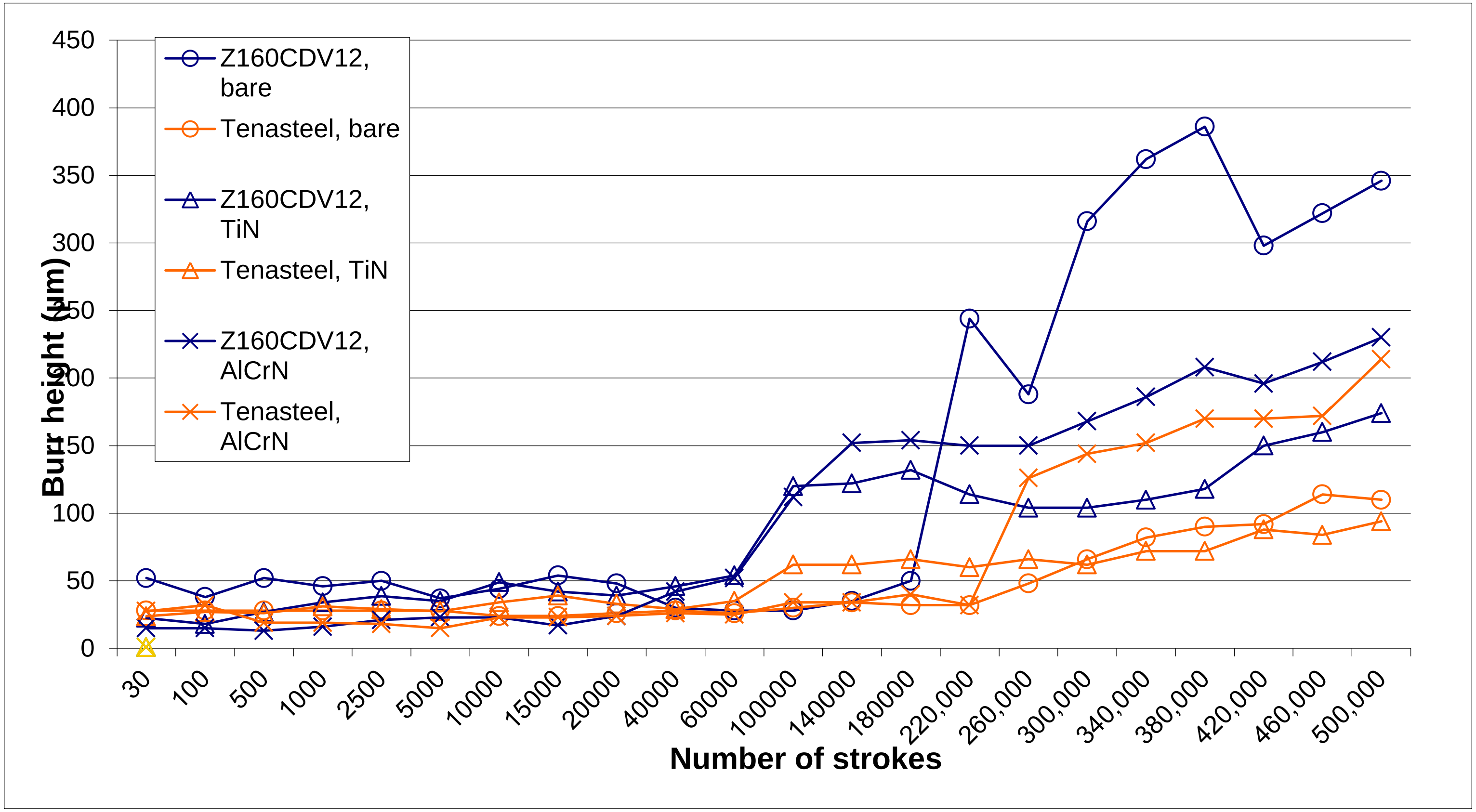








Experimental Results
Burr height evolution

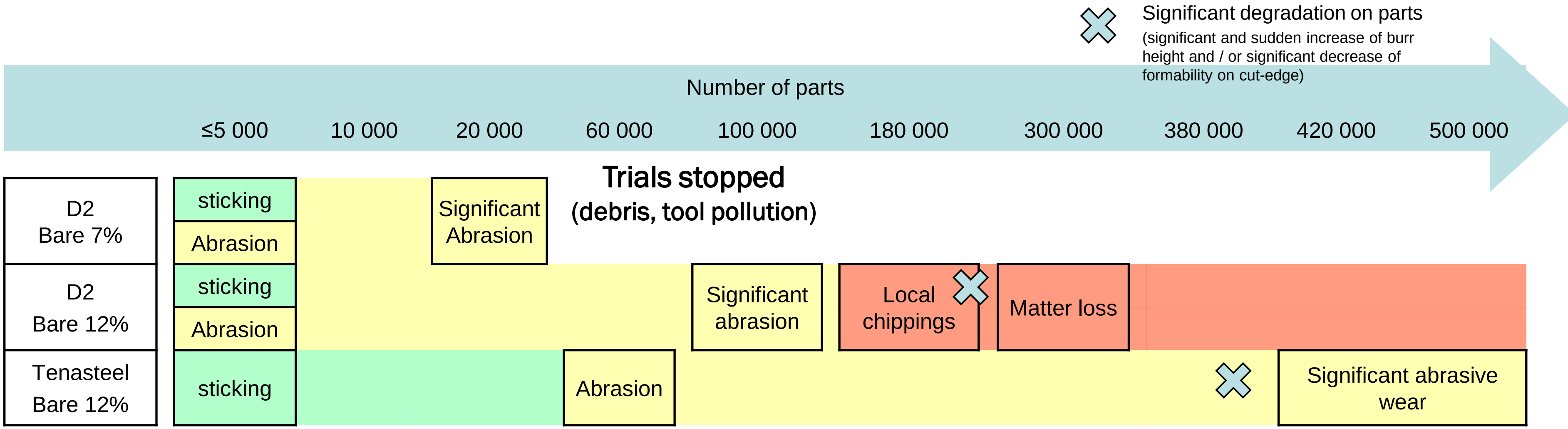


- Significant and early increase of burr height for **D2 tools** (180 000 strokes for bare tool and even less than 100 000 strokes for coated tools) – final height is more than 10% of the sheet thickness

ArcelorMittal

Major degradation modes
Tools – Uncoated (Bare)

- Adhesive wear
- Abrasive wear
- Damage on substrate
- Significant degradation on parts (significant and sudden increase of burr height and / or significant decrease of formability on cut-edge)



- **Cutting clearance:**
  - Low cutting clearance (7%): problems at the early stages of the campaign
- **Until 180 000 strokes:**
  - Good resistance of both **D2** and **Tenasteel**
- **After 180 000 strokes:**
  - **D2:** localized chipping leads to significant loss of matter at the cutting edge (part quality is impacted)
  - **Tenasteel:** abrasive wear until 500 000 strokes, slow degradation of the tool – After 400 000 strokes, the matter loss due to abrasive wear is significant.

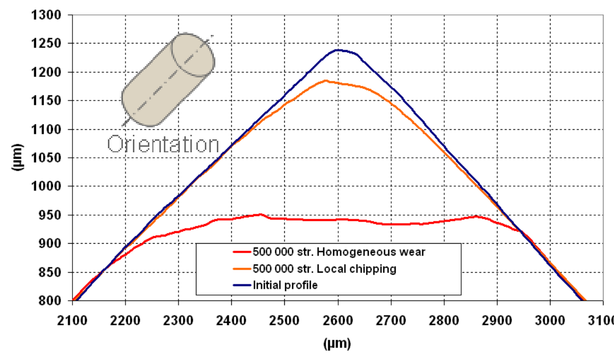
ArcelorMittal

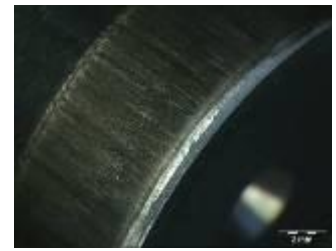
Tool Wear Analysis
Non-coated (bare), 12%-clearance

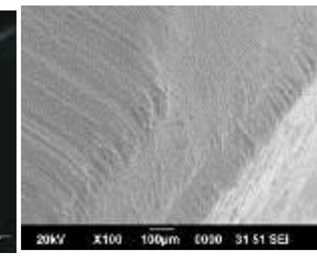
D2	Hardness: 58HRC (58-60HRC required) Roughness: 0.04	Punch diameter: 20mm Punch edge radius: 10-20µm

Tool evolution:

- Homogeneous abrasive wear
- Chipping observed after 180 000 strokes then significant edge collapse at 380 000 strokes (~ ¼ of the tool affected)



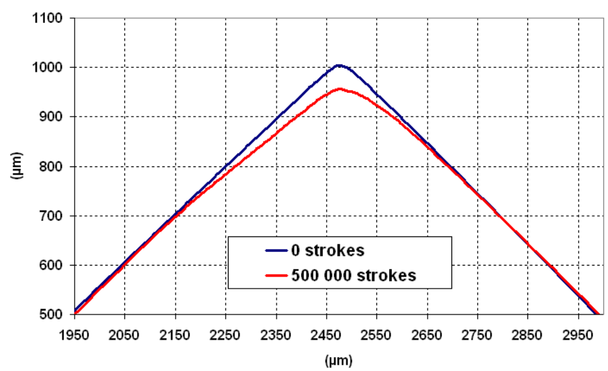


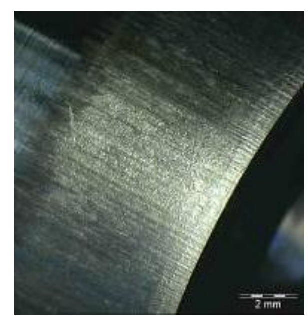


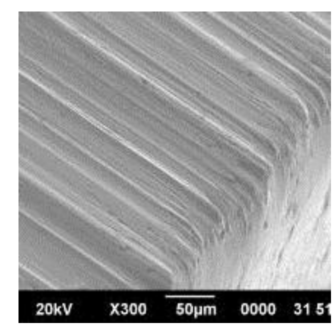
TENASTEEL®®	Hardness: 59HRC (58-60HRC required) Roughness: 0.04	Punch diameter: 20mm Punch radius: 20-25µm

Tool evolution:

- Important homogeneous abrasive wear
- No chipping ➔ good resistance of the material



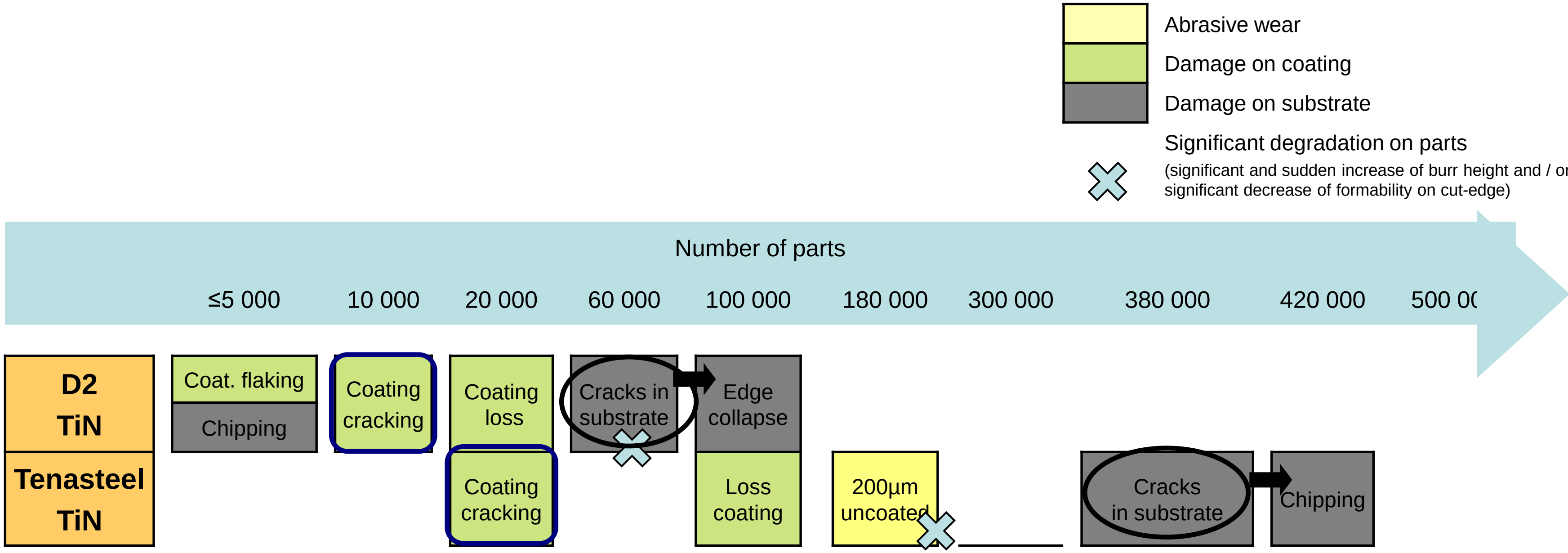




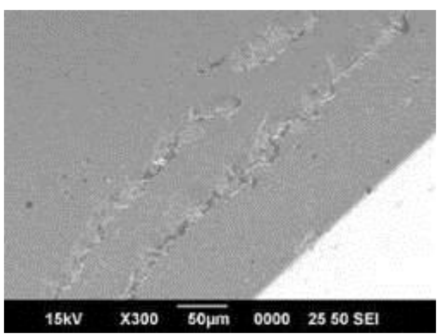
preferential area for cracks initiation

ArcelorMittal

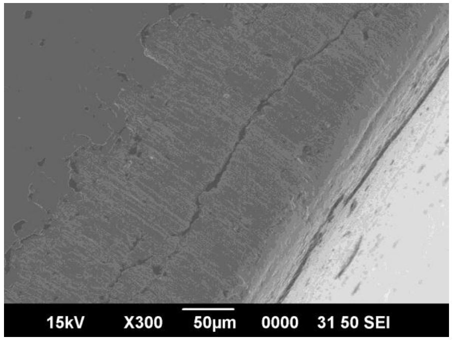
Major degradation modes
TiN-coated tools



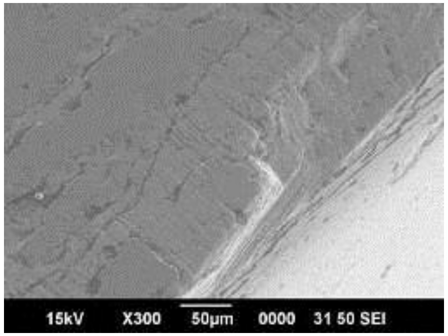
- No sticking phenomena and delayed abrasive wear with PVD-coating



For D2 and Tenasteel, cracks in the coating are clearly identified as the first damaging mode

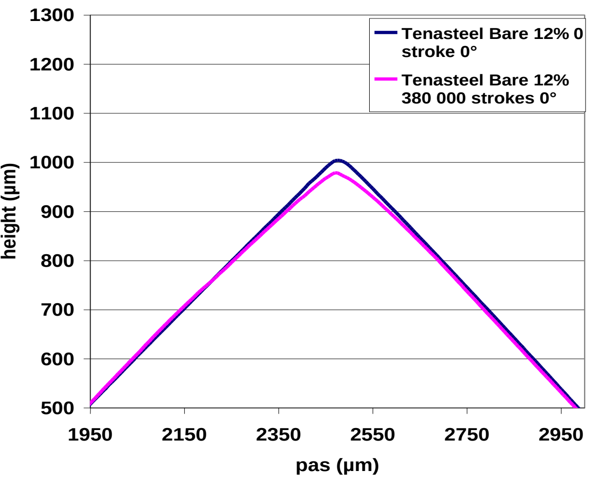


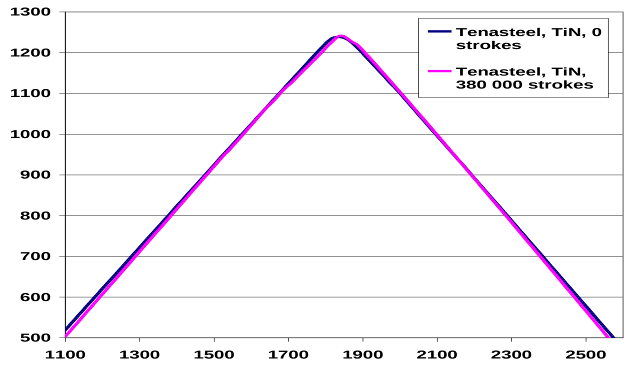
Then the coating flakes along the cracks
On uncoated areas, cracks in the substrate are visible (on every punch)

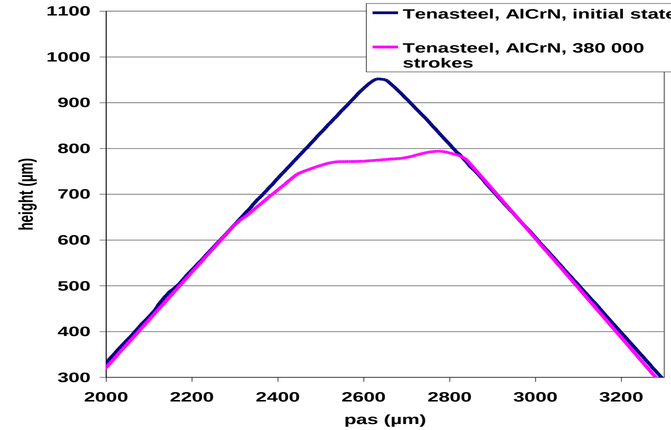


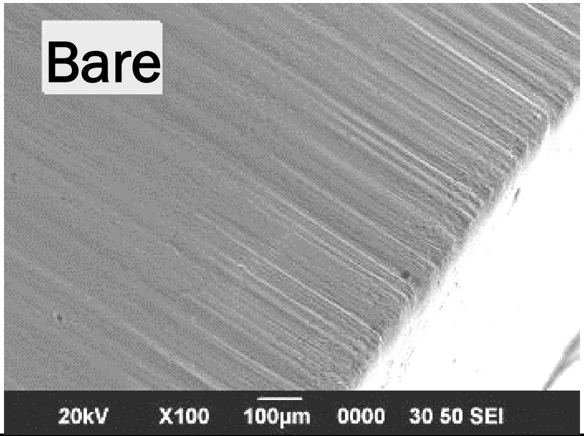
Chipping always follow the cracks initiated in the substrate then matter loss at punching edge ➔ Significant degradation of parts quality

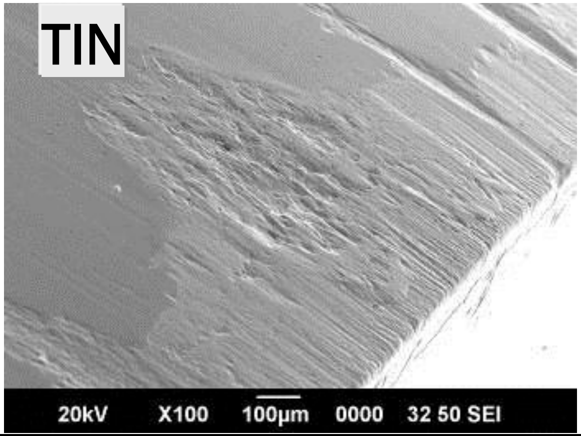
Tool Analysis – Influence of Coatings
Punch: Tenasteel, bare, 12%-clearance

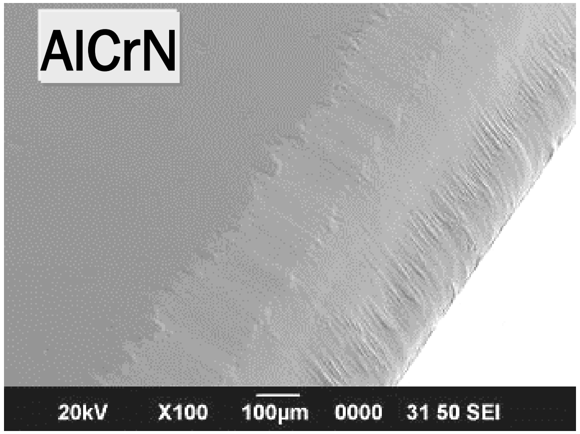












ArcelorMittal

Summary of Experimental Work

- <u>Forces</u>:
  - No significant effect of tool wear on cutting forces
- <u>PVD-coating</u>:
  - Suppresses / decreases adhesive wear,
  - TiN coating enables a longer resistance than AlCrN coating
- <u>Substrate influence</u>:
  - Tenasteel lasts significantly longer than D2 tools (with the same coating configuration)
- <u>Burr height evolution</u>:
  - Early and high increase of burr height with Z160CDV12 tools
  - Important / sudden increases of burr height often linked to local chippings / edge collapse
  - No important increase of burr height for every other configurations until 200 000 strokes
- <u>Formability</u>:
  - Formability loss is linked to any local heterogeneity on cut-edge

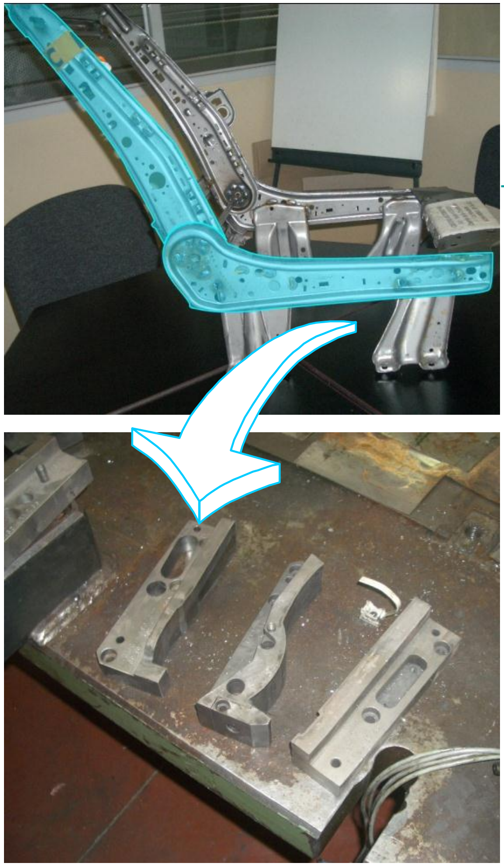
Guidelines for Tool Materials Selection

When cutting DP980

- Very small clearances must be avoided ➔ ~ 12% of the thickness is recommended
- Traditional Z160CDV12 (D2) bare, clearance 12% is a good solution:
  - For small series [equivalent to less than 100 000 parts (20mm-discs)]
  - CAUTION: Ensure steel cleanliness
  - But major risk: failure/chipping
- Tenasteel (or a material from X110 CrMoV8 family) bare,
  - Clearance of12% material thickness Clearance is optimal configuration:
  - For longer series or for less frequent reworking (at least twice the life time of D2)
  - Major risk (Failure / chipping) decreased with the higher toughness
- PVD-coating (TiN/AlCrN) does not offer any benefit:
  - Only has an effect on adhesive and abrasive wear
  - Do not decrease the chipping/failure risk

Industrial Applications of TENASTEEL®℗

Industrial Application – Seats Side member



Component Seat Side-members

Sheet Material S420 MC (YS 420 MPa, TS 550 MPa)

Thickness 1.5 mm

Tools Trimming blade Tenasteel replacing D2
Hardness 58 HRC ; Bare

Results

- Less re-sharpening
- Maintenance every 100 000 strokes instead of 20 000 with D2.
- Welding without preheating

Tool Life + 500 % Improvement

Industrial Application – Hot Stamped B-pillar

Component B.Pillar (1.6 mm)
Bumper beam (1.8 mm)

Sheet Material USIBOR 1500MPa

Thickness 1.6 mm & 1.8 mm

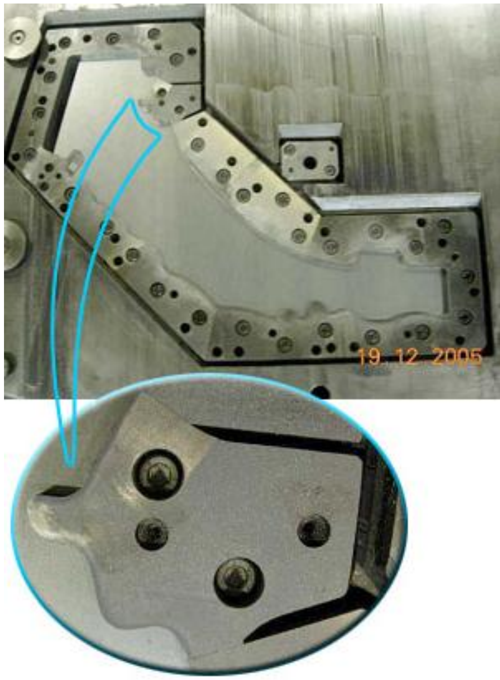
Tools Trimming blades after hardening

Results

- 1.6 mm → ~80 000/90 000 hits (D2 do not work at all)
- 1.8 mm → ~40 000 hits

TENASTEEL®® *Approved for USIBOR Trimming*

Industrial Application – Laser welded Blank



Component Laser Welded Blank

Sheet Material FB 400
YS~450MPa; TS 600MPa (min)

Thickness 3.0 mm

Tools Cutting blade Substituted for PM tool
Hardness 58/60 HRC ; Bare
Blade thickness 60 mm

Results

- Less chipping, easier maintenance (welding)
- Re-sharpening every 150 000 strokes

Significant Cost Savings

Automotive Examples

Component : Welded blank for a front rail
Worked steel : FB600
Thickness : 3 mm

Uncoated TENASTEEL® blades (60 mm) -Hardness 58/60 HRC

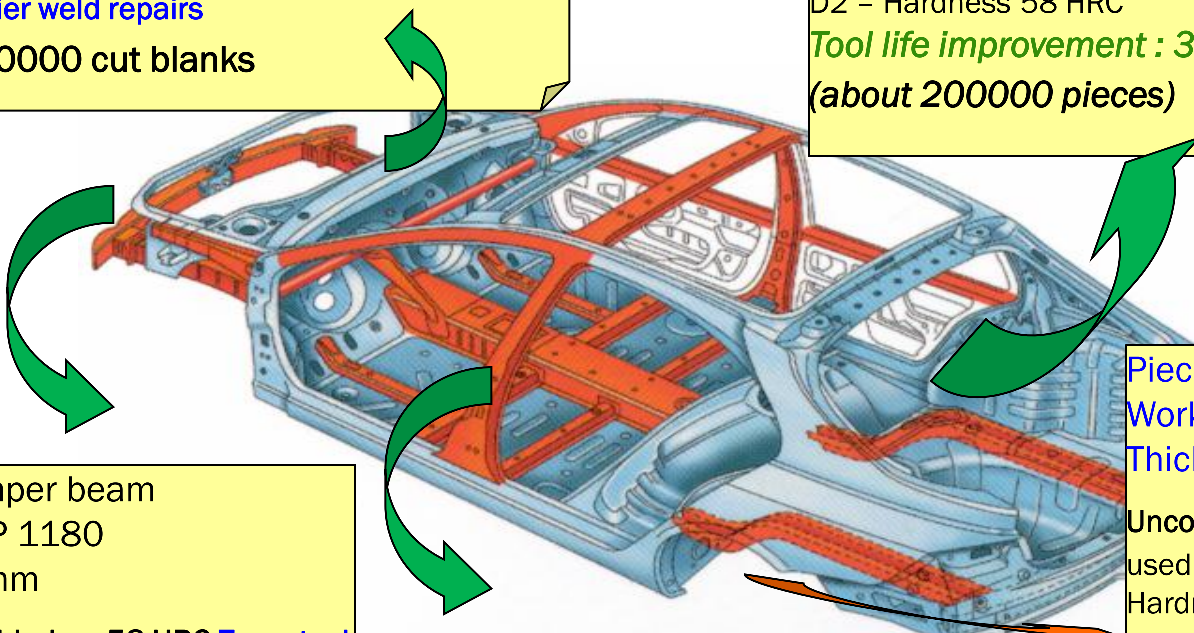
- **Tenasteel used in substitution to PM - less chipping problems and easier weld repairs**
- **More than 300000 cut blanks**

Piece : Closed plate members
Worked steel : DP 600
Thickness : 1.6 mm

Uncoated cutting blade - **Tenasteel** used in substitution to D2 – Hardness 58 HRC

Tool life improvement : 300 %

(about 200000 pieces)



Piece : Front bumper beam
Worked steel : DP 1180
Thickness : 1.6 mm

Uncoated trimming blade – 58 HRC Tenasteel used in substitution to D2 58 HRC

Tool life improvement : 400 to 500 %
(about 12000 parts)

Piece : B Pillar ; bumper beam
Worked steel : USIBOR 1500
Thickness : 1.6 mm
Uncoated trimming blade
Hardness 58 HRC

Piece : Suspension arm
Worked steel : FB600
Thickness : 4 mm

Uncoated cutting blade - **Tenasteel** used in substitution to D2 – Hardness 58/60 HRC

Tool life improvement : 200 %
with about 100000 pieces

Next Steps

Planned Activities in North AmericaVHSS/UHSS cutting tools

Non-Automotive

- ArcelorMittal Indiana Harbor CAL Line – Entry Shear Knives
- IN-TEK/IN-KOTE - Slitting knives for Pickling unit
- ArcelorMittal Cleveland Plant – Slitting knives for Pickle unit
- Flat Rock Processing – Scrap Chopper Knives

Automotive Trials

- Trimming tool for Hot-stamped USIBOR
- Trimming tool for DP980 CR
- Other..........

Experimental Work

- Phase II – USIBOR?

Acknowledgements

- Benoit Cesar (ArcelorMittal Global R&D, Maizières)
- Rob Esling (ArcelorMittal Industeel)
- Fred Fletcher (ArcelorMittal Global R&D, Coatesville)
- Stephanie Fonlupt (ArcelorMittal Industeel)
- Richard Garvin (ArcelorMittal Industeel)
- Mike Groyza (ArcelorMittal USA LLC)
- Martin Munier (ArcelorMittal Global R&D, Maizières)
- Zofia Niemczura (ArcelorMittal Global R&D, East Chicago)

Thank you

Questions