Texas A&M Engineering Experiment Station

Arts et Métiers Institute of Technology

AM²
Synergetic Research Initiation Workshop

October 14

TEXAS A&M UNIVERSITY Engineering

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Agenda (CT Time)

Texas A&M Engineering Experiment Station

9:00 - 9:10 AM	**Introduction**	**-**	**10’**
	Welcome		S. Bukkapatnam, M. El Mansori
	Overview of AM^2 Partnership		E. Masad
	TEES vision for AM^2		D. Lagoudas
	Arts et Metiers vision for AM^2		I. Iordanoff
9:10 – 9:20 AM	**Educational Exchanges**	**-**	**10’**
	REEP and Dual Degree		M. Alves, R. Kubler
	IRES Projects		M. El Mansori ***Group picture**
9:25 – 10:55 AM	**Research activities Arts et Metiers – TEES**	**-**	**90’**
	See detailed program		
11:00 – 11:20 AM	**Discussions (Q&A)**	**-**	**20’**
11:20 – 11:30 AM	**Closings and next steps**	**-**	**10’**

AM^2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

Synergetic Research Initiation Workshop

Texas A&M Engineering Experiment Station

9:25 – 10:55 AM Research activities Arts et Metiers – TEES - 90’

1- M. Chao “Powder-bed additive manufacturing”

2- R. Knoblauch “Smart machining and sensors”

3- D. Sagapuram “Machining and deformation processing of metals”

4- H. Ramezani Dana “Analysis of the mechanical behavior of 3D Printed structures ”

5- B. Tai “Additive and subtractive processes”

6- A. Ktari “Digital twins for smart low-pressure casting process”

7- M. Kuttolamadom “AM of Pharmaceutical Printlets

8- F. Chegdani “Machining of biocomposites under extreme conditions”

10:05-10:10 Break

9- Q. Wang “Sustainable Manufacturing of Polymer Composites”

10- C. Eksin “Network science and distributed optimization”

11- M. Elhadrouz “Digital Twins For Additive Manufacturing”

12- S.J. Wolff “In situ monitoring of metal additive manufacturing”

13- S. Jegou “Thermochemical surface treatments and gradient properties”

14- C. Lee “Precision metrology”

15- R. Kubler “Mechanical behavior and gradient properties”

16- J.P. Goulmy “Development of DIC for the understanding of mechanisms at different scales”

17- J. Wilkerson “Processing - microstructure - ballistic performance relationships”

AM^2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

Texas A&M Engineering
Experiment Station

TEES – ENSAM Partnership

Eyad Masad
Executive Director for Global Partnerships
Texas A&M Engineering Experiment Station

Guiding Principles for Partnerships

- Create opportunities and engage in global programs that:
  - are consistent with TEES strategic areas
  - build on unique capabilities of TEES
  - offer added value for TEES and its partners
  - have potential for funding
- Encourage faculty/researcher-driven initiatives

Active Research Projects with International Partners

- Argentina
- Australia
- Bangladesh
- Belgium
- Brazil
- Canada
- China
- France
- Germany
- Greece
- Israel
- Japan
- Mexico
- Morocco
- Norway
- Netherlands
- Paraguay
- Peru
- Qatar
- Saudi Arabia
- Singapore
- South Korea
- Sweden
- Taiwan
- Turkey
- United Kingdom

Sub-awardees

- Australia
- Canada
- China
- Egypt
- France
- Greece
- Norway
- Qatar
- Spain
- Singapore
- South Korea
- Turkey
- United Kingdom

Arts et Métiers Institute of Technology (AMIT)

- Hybrid manufacturing
- Processing of extreme environment materials
- Manufacturing analytics and control

- An active advisory committee
- An agreement with Henri-Fabre technology center for internships
- Joint proposals in Europe and the US
- Support study abroad in Aix-en-Provence
- Joint workshops

Faculty Collaborations

- Joint PhD and Master students
  - 2 PhD completed and 2 are currently in AMIT
  - 1 PhD at TAMU
  - 2 MS committees completed in TAMU
  - 2 MS committees completed in AMIT?
- Joint appointments with AMIT
  - 5 TAMU faculty members are affiliated with AMIT
  - 9 assistant professors at AMIT supporting the partnership
- Invited visiting professor (Dr. JN Reddy)
- AMIT Faculty Visit to TAMU: Dr. El Hadrouz and his student Mr. Ejaz (Dr. Lagoudas)
- Fulbright-Tocqueville Distinguished Chair 2020-2021 (Dr. Bukkapatnam)

Academic Partnerships

- Dual master degree with AMIT (manufacturing focus)
- Study abroad programs
- REEP with AMIT
  - 2015-2019: 2 Arts et Metiers students each year in TAMU
  - 2018-2019: TAMU students for a full semester at Arts et Metiers
  - 2019: 4 ENSAM students participate remotely in Global Engineering Design
  - 2020: 4 Arts et Metiers students at TAMU and 2 TAMU st. at Arts et Metiers Aix
- Research internships for TAMU students at AMIT

Research Funding

- A project funded by STILL Company for development of AI-based methods for defect detection
- International Research Experience for Students -National Science Foundation Project
- Expected more research funding from companies in the next few months
- CPER Project supported by the southern region for common research facilities and staff

Short Courses, Workshops and Training- AM2 Cluster

- French American Innovation Day February 2020
- Workshops
  - 1st workshop 2018 in College Station together with SME
    - identified key smart manufacturing challenges for Industry 4.0
  - 2nd workshop 2019 in Aix en Provence with AM2 industrial partners
    - Discussed the needs for an industry consortium initiation and to implementation o industry 4.0 challenges
  - 3rd workshop 2019 in College Station with French Consulate
    - Initiating a consortium business model for AM2 Transatlan
  - 4th workshop 2021 (Online)

2020 FRENCH AMERICAN INNOVATION DAY HOUSTON/COLLEGE STATION

Deep Tech Talk Webinar Series

- https://tees.tamu.edu/global/deep-technology-webinar-series.html

Deep Technology Webinar Series

The Deep Tech Talk Webinar Series is a partnership with Texas A&M University at Qatar, Aristotle University of Thessaloniki in Greece and Arts et Métier in France. This webinar will present and discuss experiences from around the world about the path for commercialization of deep technologies that advance scientific frontiers. The webinar series will focus on:

Moving Forward

- Expand the collaborations to include broader topics and more faculty members
- Establish a joint research facility in Arts et Metier
- Hire a Senior Research Engineer to be located in France
  - Develop research opportunities (Industry and European Research Council)
  - Raise funds for joint research facilities
  - Identify research opportunities
  - Conduct research in collaborations with TEES researchers and collaborators in Europe

https://tamus.wd1.myworkdayjobs.com/en-US/TEES_External/job/College-Station-TEES/Senior-Research-Engineer-I_R-041469

Texas A&M Engineering Experiment Station

Arts et Métiers Institute of Technology

AM² Educational Exchanges

Regis Kubler, Maria Alves

TEXAS A&M UNIVERSITY Engineering

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Educational Exchanges

Texas A&M Engineering Experiment Station

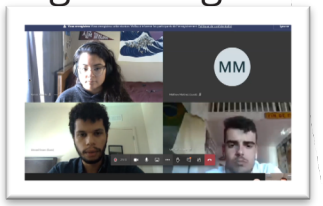
REEP (Reciprocal Educational Exchange Program) :

Mapping initiative between TAMU and Arts et Metiers curricula (Face Grant 2020-21)
MEEN-MSEN-ISEN-ITDE-ETID-MMET departments and Arts et Metiers Aix

ENGR410 projects: 2019-2021 -11 Arts et Metiers students

Hybrid REEP: AM² faculty-led program in manufacturing May-June 2022

TEXAS A&M UNIVERSITY Engineering

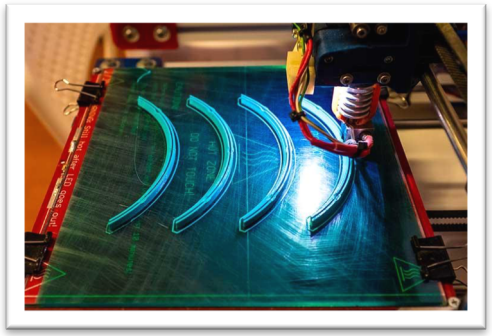


Dual Degree at Master level:

MTDE program : MSc/MEng in interdisciplinary engineering

MSc2 AM²S « Advanced Manufacturing and Materials Science » opened in Sep 2020

MSc1 AM²S to open in Sept 2022 – Aix en Provence campus



MASTER OF SCIENCE IN INTERDISCIPLINARY ENGINEERING
DUAL DEGREE PROGRAM

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

Texas A&M Engineering Experiment Station

Arts et Métiers Institute of Technology

Synergetic Research Initiation Workshop
Research activities

TEXAS A&M UNIVERSITY Engineering

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Synergetic Research Initiation Workshop

Texas A&M Engineering Experiment Station

Research activities Arts et Metiers – TEES - 90’

1- M. Chao “Powder-bed additive manufacturing”

2- R. Knoblauch “Smart machining and sensors”

3- D. Sagapuram “Machining and deformation processing of metals”

4- H. Ramezani Dana “Analysis of the mechanical behavior of 3D Printed structures ”

5- B. Tai “Additive and subtractive processes”

6- A. Ktari “Digital twins for smart low-pressure casting process”

7- M. Kuttolamadom “AM of Pharmaceutical Printlets

8- F. Chegdani “Machining of biocomposites under extreme conditions”

5’ Break

9- Q. Wang “Sustainable Manufacturing of Polymer Composites”

10- C. Eksin “Network science and distributed optimization”

11- M. Elhadrouz “Digital Twins For Additive Manufacturing”

12- S.J. Wolff “In situ monitoring of metal additive manufacturing”

13- S. Jegou “Thermochemical surface treatments and gradient properties”

14- C. Lee “Precision metrology”

15- R. Kubler “Mechanical behavior and gradient properties”

16- J.P. Goulmy “Development of DIC for the understanding of mechanisms at different scales”

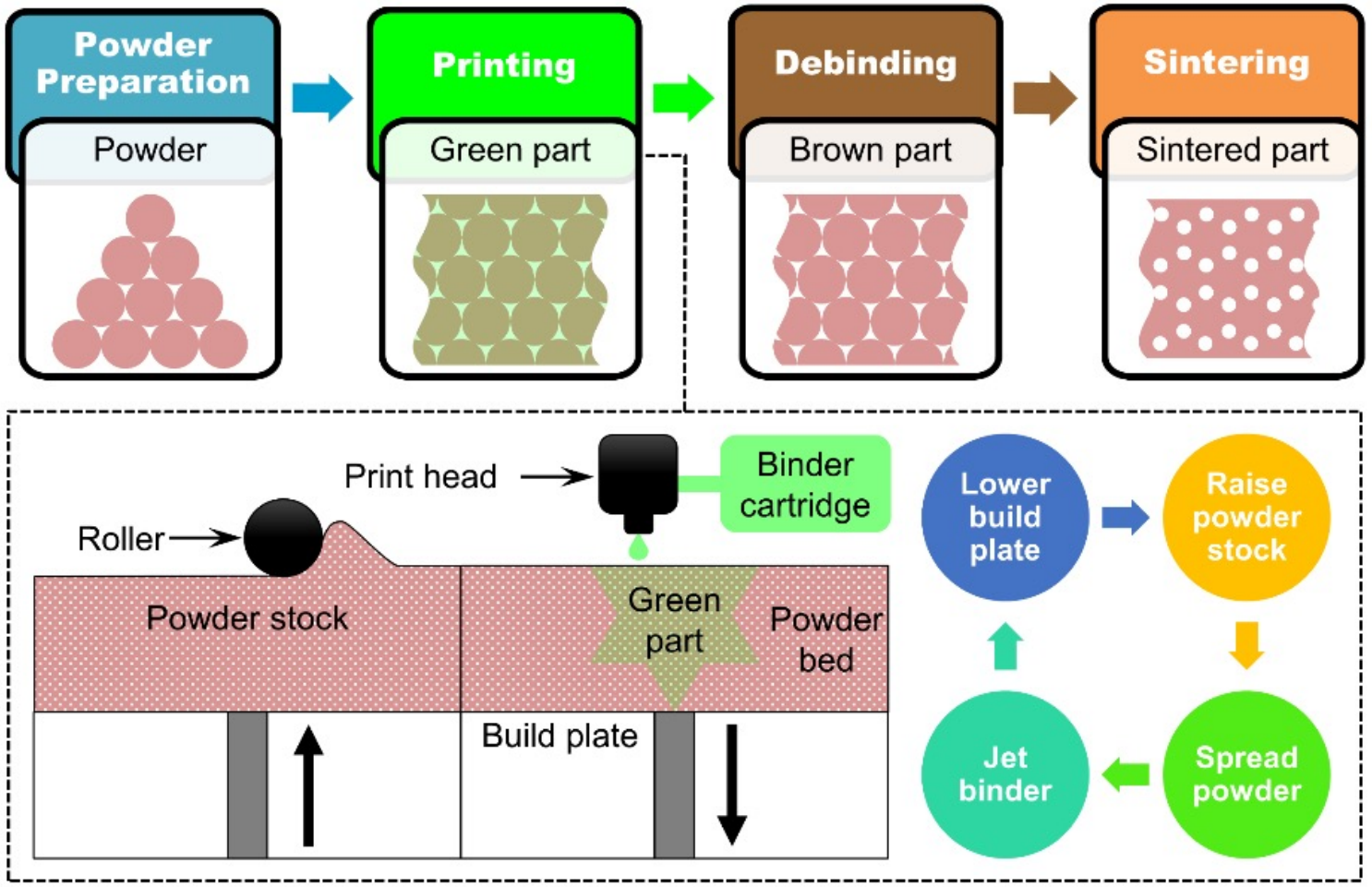
17- J. Wilkerson “Processing - microstructure - ballistic performance relationships”

AM2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

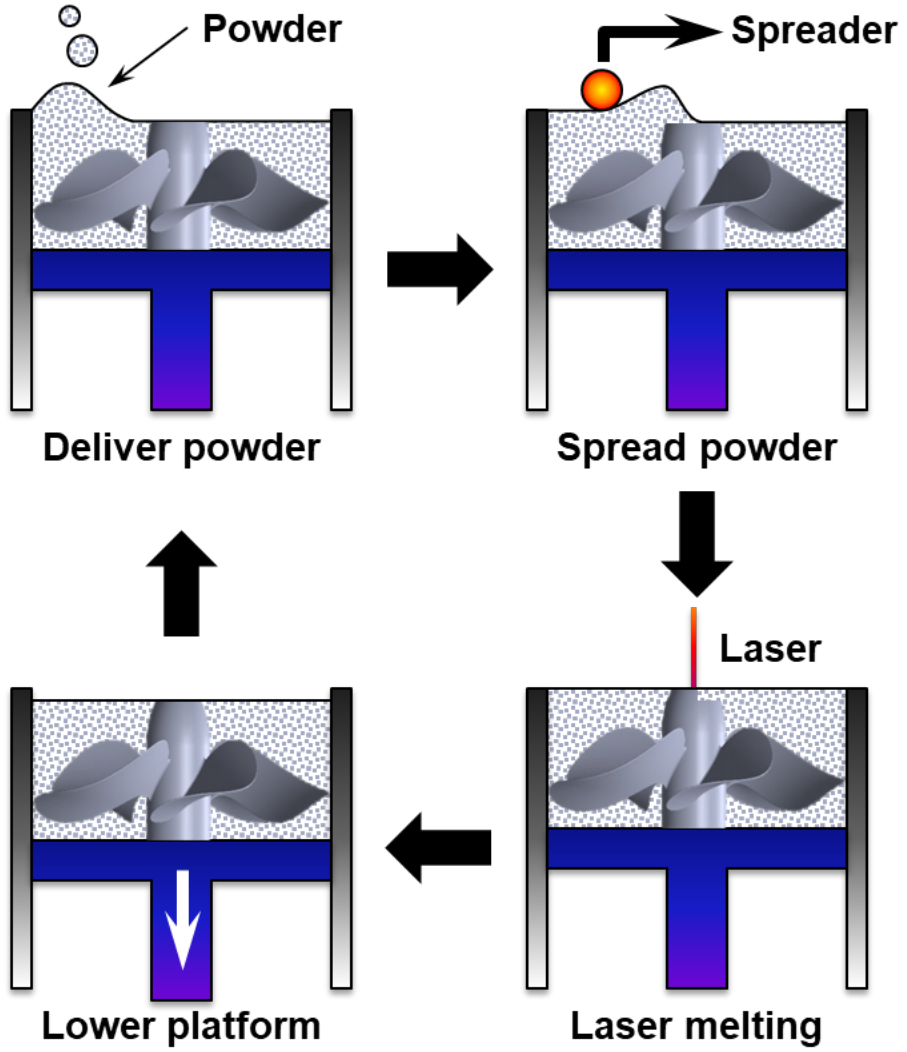
Binder Jetting Additive Manufacturing

- Projects
  - *Two NSF projects*
  - *Two industrial projects (sponsored by Fortune 500 companies)*
  - *One ANL project*
  - *One internal project*
- Applications
  - *High-quality **ceramic** and **metallic** components in various industries, such as energy, chemical, biomedical, aerospace, and defense*
- Publications
  - *12 journal papers, 7 conference papers, and 1 patent application*



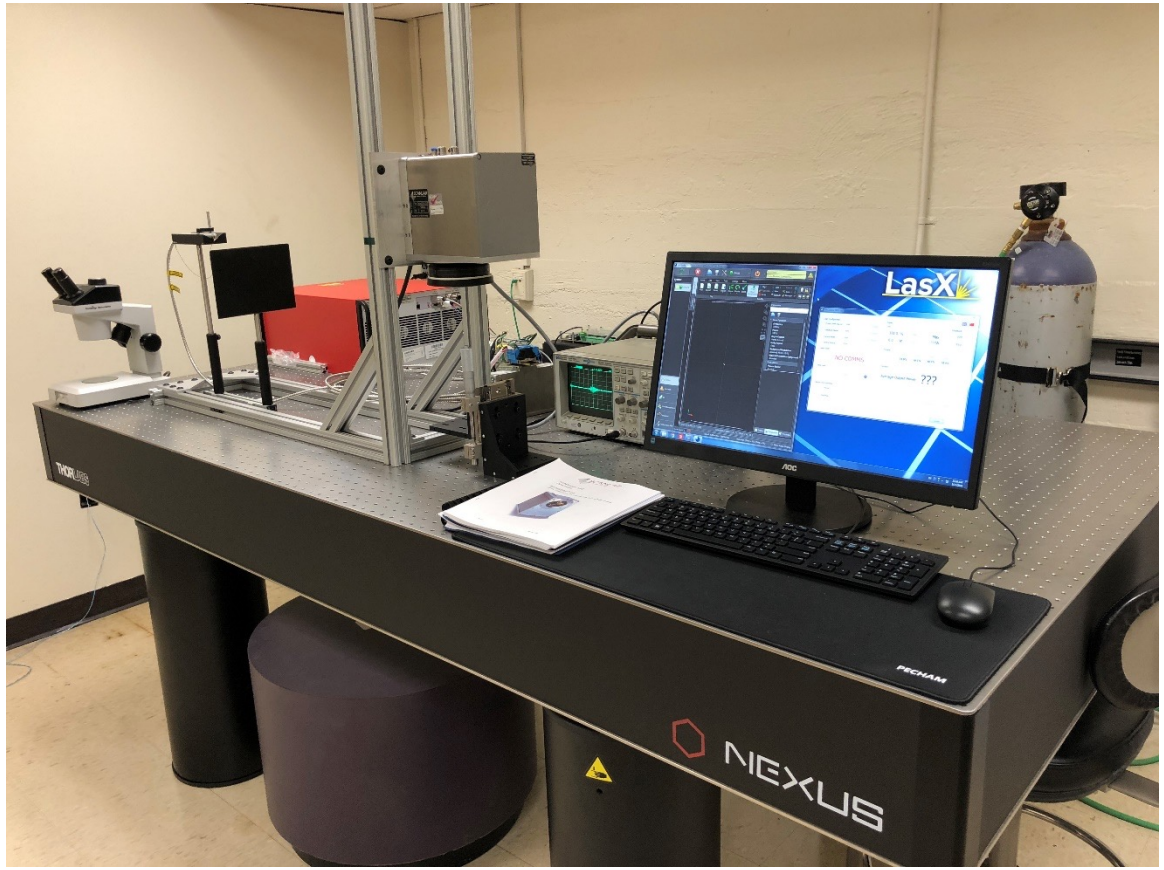
Powder Bed Fusion Additive Manufacturing

- Projects
  - *Two internal projects*
- Applications
  - *High-quality **metallic** components in various industries, such as energy, chemical, biomedical, aerospace, and defense*
- Publications
  - *10 journal papers and 4 conference papers*



Powder Bed Fusion Machines

- Renishaw AM 400 printer with high flexibility on parameter optimization
- Custom-built printer with high flexibility on material development and instrumentation



2- R. Knoblauch « Smart Manufacturing and sensors

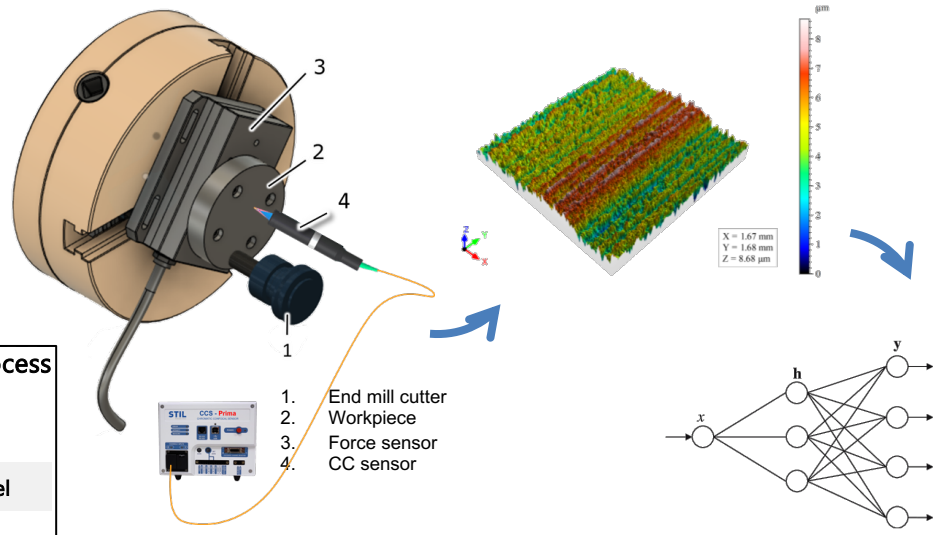
Texas A&M Engineering Experiment Station

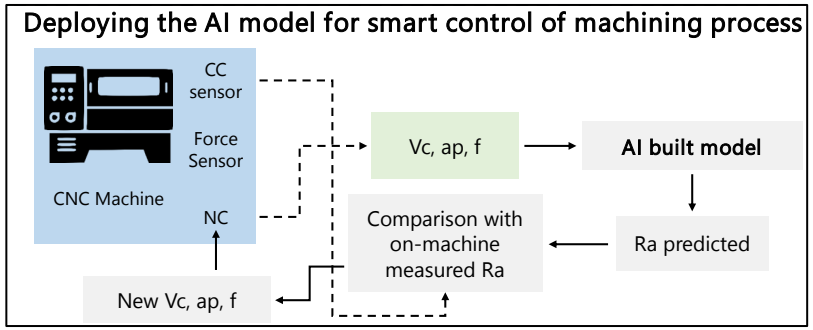
Smart manufacturing experimental setup on a 5-axis CNC machine-tool

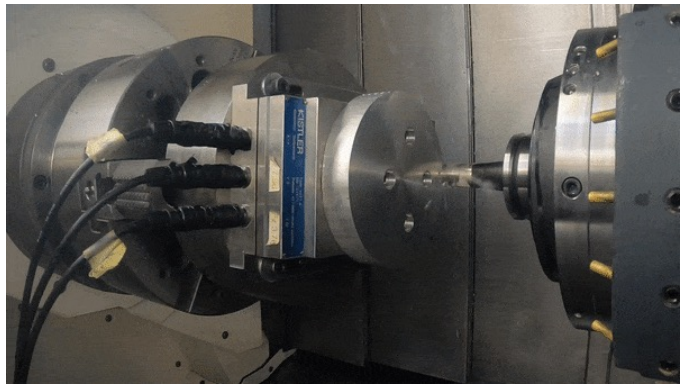
- Integration of the following sensors to the CNC machine:
  - Non-contact roughness sensor
  - Force sensor
- Development of AI models (off-line) that correlate input to output variables (model accuracy ≥ 90%)
- Machine Learning models being investigated:

- Random Forest
- Gradient Boosting
- Boosting
- ANN

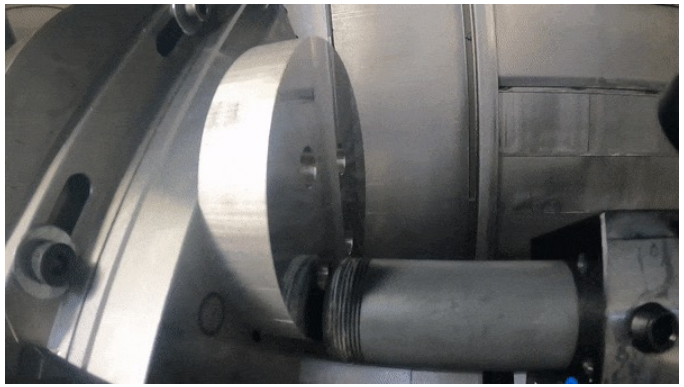
- Metrology analysis of chromatic confocal roughness measurement inside machine tool



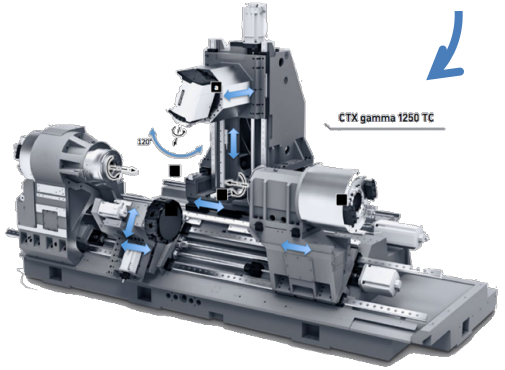




Milling of aluminum (dry cut)



Measurement of surface profiles with chromatic confocal sensor



AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

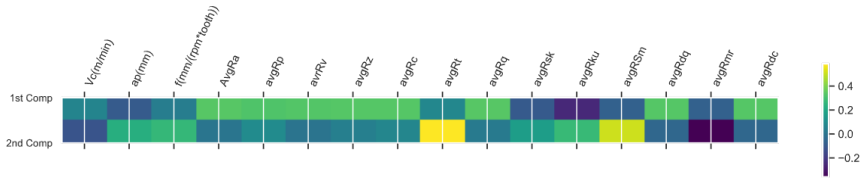
Arts et Métiers Institute of Technology

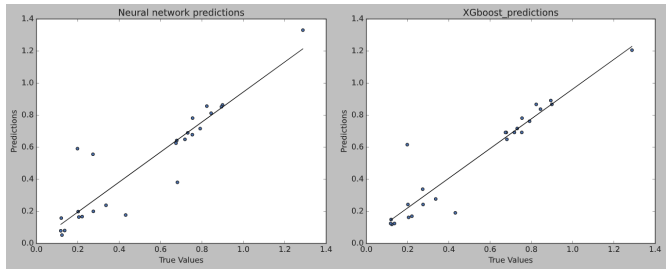
2- R. Knoblauch « Smart Manufacturing and sensors

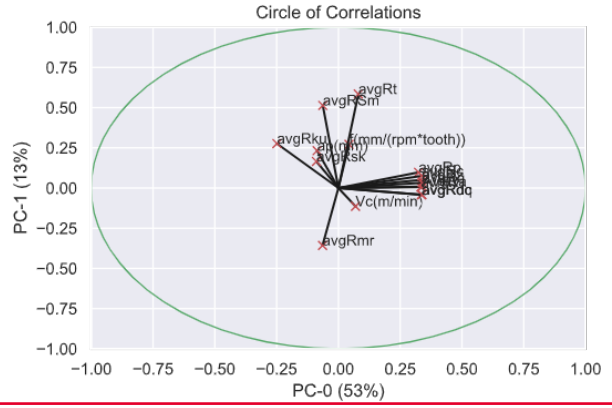
Texas A&M Engineering Experiment Station

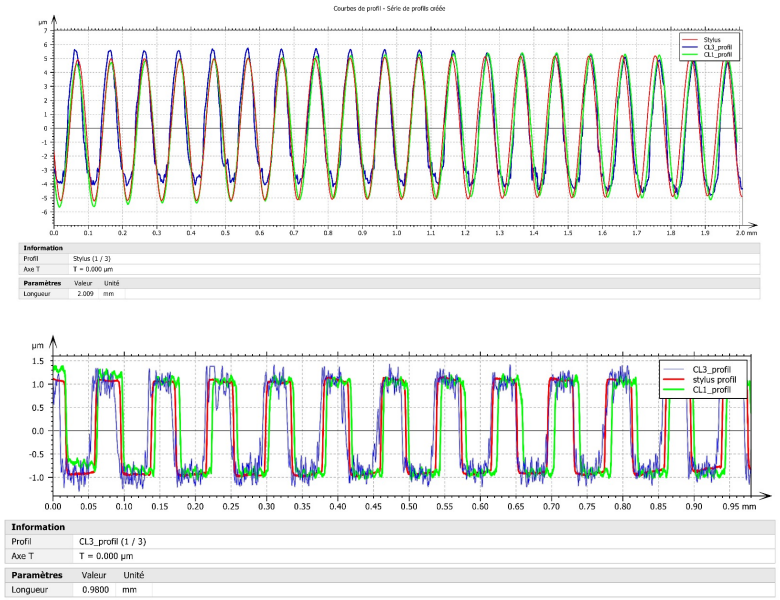
Next steps:

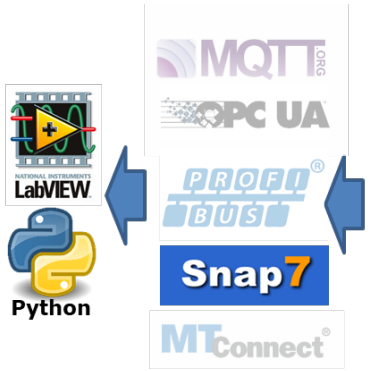
- Investigation on Machine Learning Control model for roughness
- Integration of AI-model to DAQ system and feedback method to **close the loop**

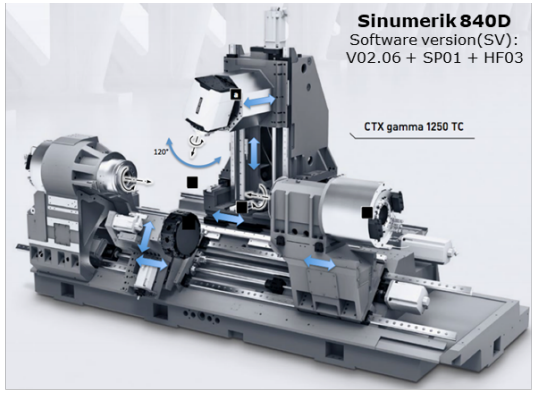








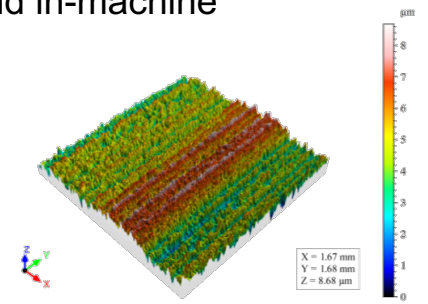




Connection of machine tool with external PC to close the loop

Next step:

- 3D comparison between metrology room and in-machine



AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

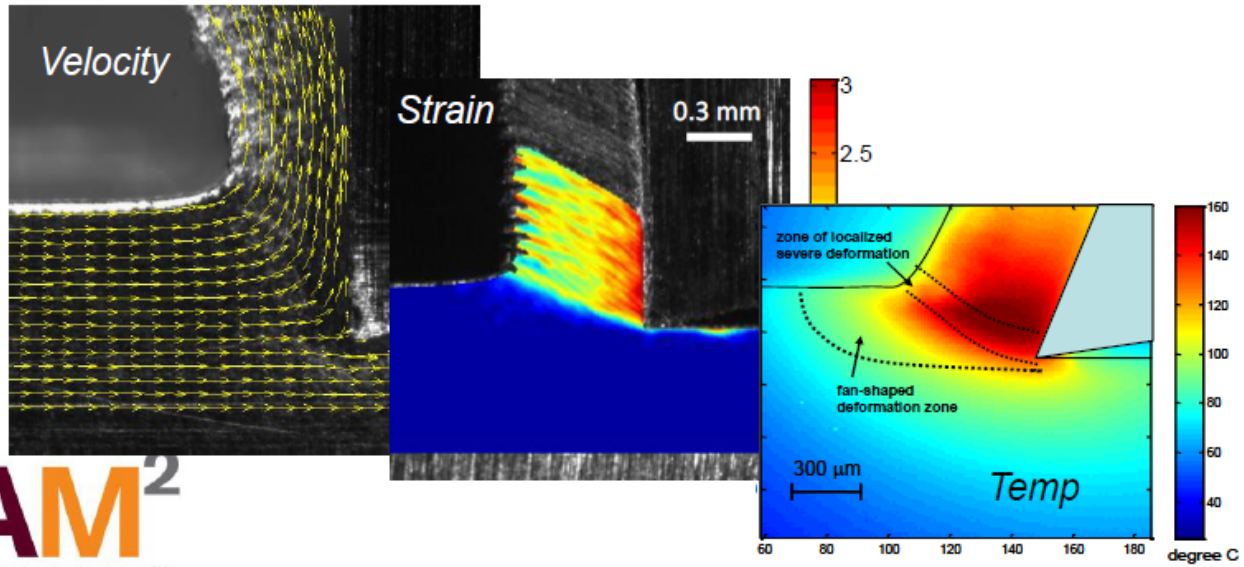
Texas A&M Engineering Experiment Station

Dinakar Sagapuram

ISEN Assistant Professor

Research Interests

- Physics of material behavior (deformation and failure) during processing
- Contact mechanics, friction, tribology
- High-speed imaging, *in-situ* experimental methods
- Synthesis of high-performance metallic materials

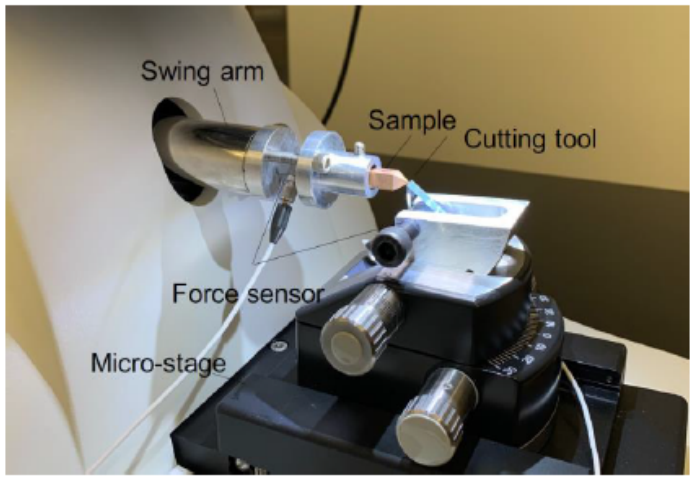


In Situ Analysis of Deformation Fields

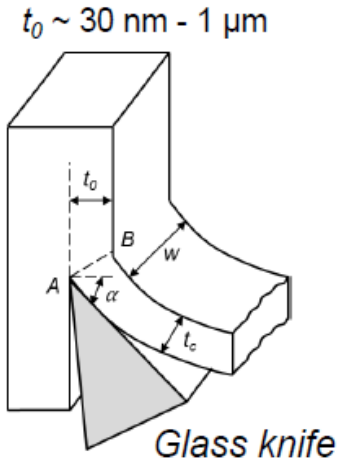
- Ultrahigh-speed photography (optical, infrared)
- Image correlation (PIV, DIC, etc.)
- Quantitative velocity, strain and temperature fields
- Validation of physics-based models (e.g., FE)
- Rapid material characterization under extreme conditions

AM2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

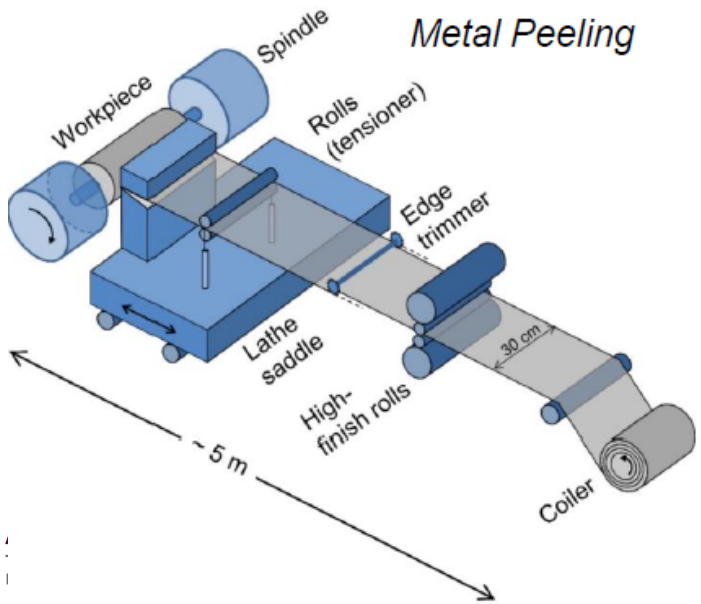


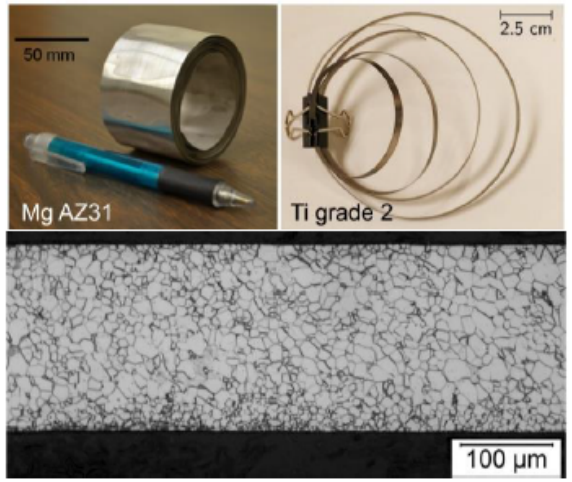
Instrumented ultramicrotomy



Length-Scale Effects in Cutting and Deformation Processes

- "Size effect" on energy and forces
- Brittle fracture to ductile flow transition
- Role of friction, adhesion and surface energy
- New applications of cutting for small-scale mechanical behavior and nanotribology studies





Energy Efficient Routes for Sheet Metal Production

- Microstructure and texture design for high performance
- Physics-based process modeling
- Process scale-up for large-scale sheet production
- Analysis of energy usage and emission reductions

Arts et Métiers Institute of Technology

4-H. Ramezani Dana
Analysis of the mechanical behavior of 3D Printed structures

Texas A&M Engineering Experiment Station

My research areas of interest are:

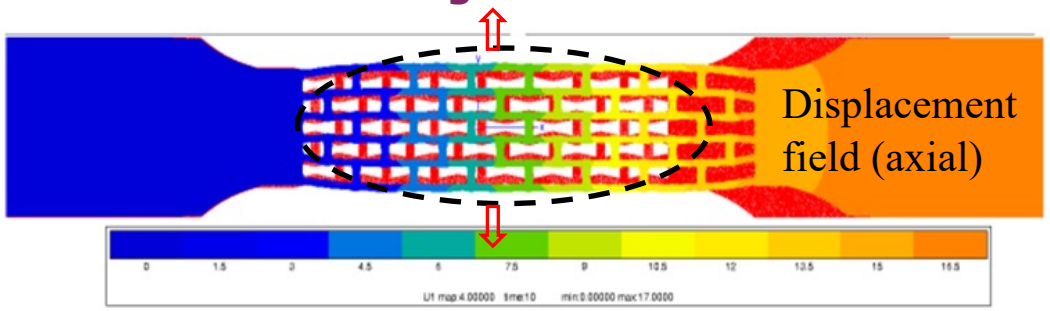
- ✓ Additive manufacturing processes
- ✓ Manufacturing process optimization
- ✓ Numerical simulation of mechanical behavior

Additive Manufacturing experiences:

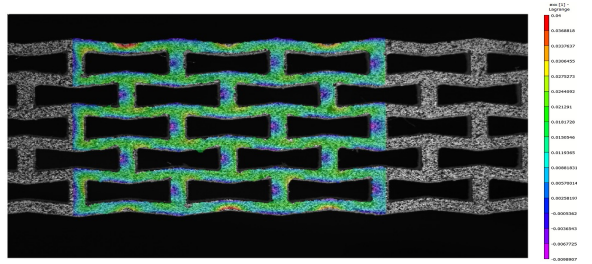
- ➢ 1st axis : Composite Additive Manufacturing – APF (PLA/Flax) – FDM (PA6/Carbon)
- ➢ 2nd axis : Ceramic Additive Manufacturing – ExOne sand 3D Printing (Binder jetting)
- ➢ 3rd axis : Metallic Additive Manufacturing – SLM (316L Stainless steel)

✓ **Development of auxetic structures via FDM process**

Auxetic materials exhibit a negative Poisson's ratio effect.



Numerical simulation of the mechanical behavior



Longitudinal displacement field derived from Digital Image Correlation (DIC)

- ✓ Polymeric auxetic structure (PLA)
- ➢ Composite auxetic structure (PLA/Flax fiber)

Aim: Evaluate the influence of natural fiber on the auxeticity of the structure

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

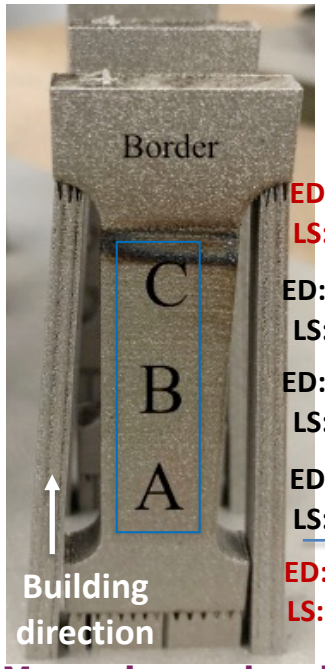
Arts et Métiers Institute of Technology

4-H. Ramezani Dana
Analysis of the mechanical behavior of 3D Printed structures

Texas A&M Engineering Experiment Station

Purposes: - Realisation of the Functionally Graded metallic Materials (SLM)
- Establish a relationship between the mechanical properties and the microstructures

Energy density change (Laser speed) ➡ **Microstructure change (grain size)** ➡ **Mechanical property change (elasticity, deformability)**



ED: 57 J/mm3
LS: 700 mm/s

ED: 180 J/mm3
LS: 222 mm/s

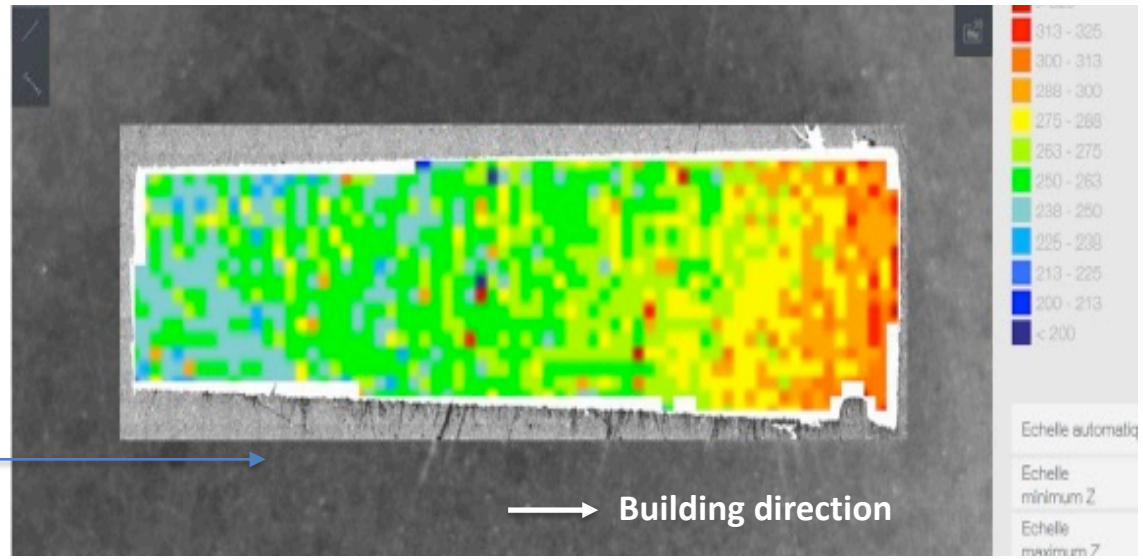
ED: 130 J/mm3
LS: 308 mm/s

ED: 80 J/mm3
LS: 500 mm/s

ED: 57 J/mm3
LS: 700 mm/s

FGM specimen showing the different energy level

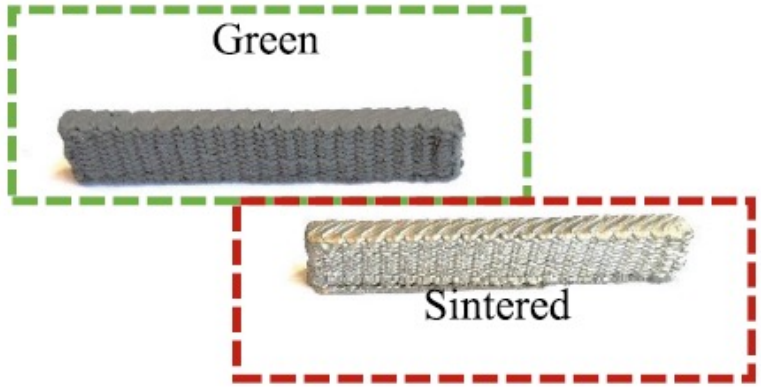
Energy density increase => hardness increase



A graph of each indentation and its respective hardness for the FGM sample, using a color-coded scale

The work in progress :

Additive Manufacturing of Metallic part via FDM technique (Printing - Debinding - Sintering)



Metallic part printed at the green and sintered state

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

As a part of Luca FREITAS internship (TAMU student)

Hossein RAMEZANI DANA

5- B. Tai« Additive and Subtractive Processes»

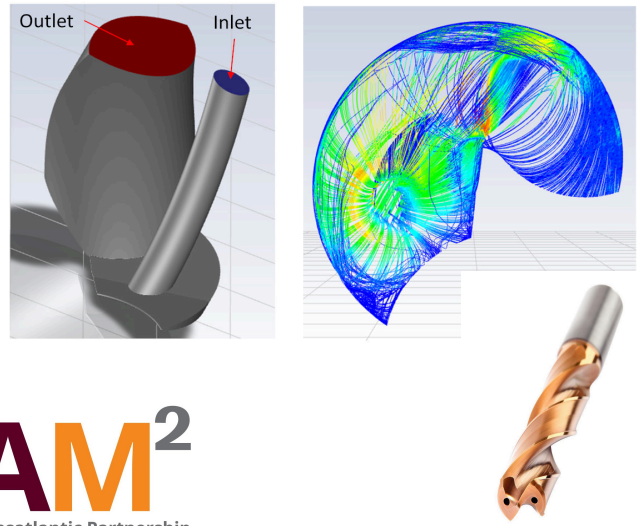
Texas A&M Engineering Experiment Station

Research Focus: Machining processes (metals, composites, ceramics)

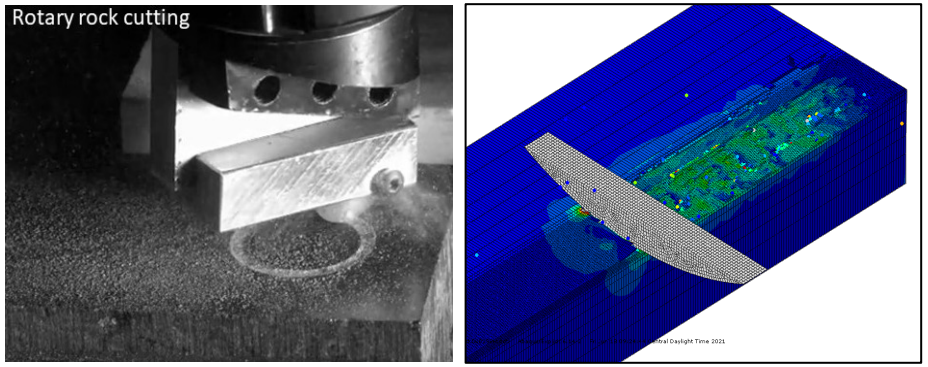
Strengths: Process characterization (custom-design, high-speed imaging, force sensing, vibration, temperature, etc.), and numerical modeling (thermo-mechanical FEA, meshfree SPH, CFD)

Feature projects:

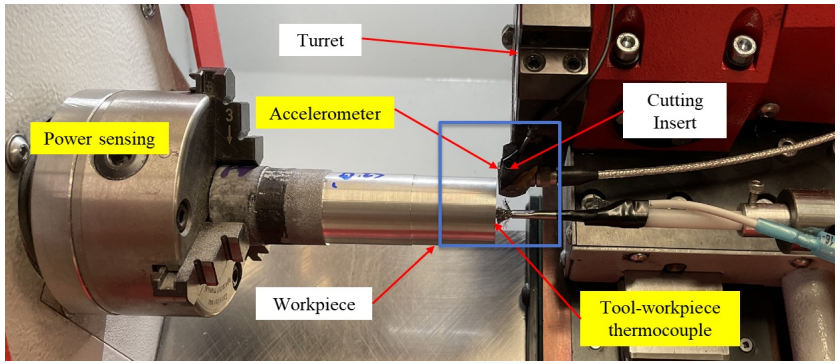
Drilling with through-tool oil mist (NSF)



Fracture-accelerated rock drilling (DOE)



Precision machining of AM metals (DOE)



AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

5- B. Tai« Additive and Subtractive Processes»

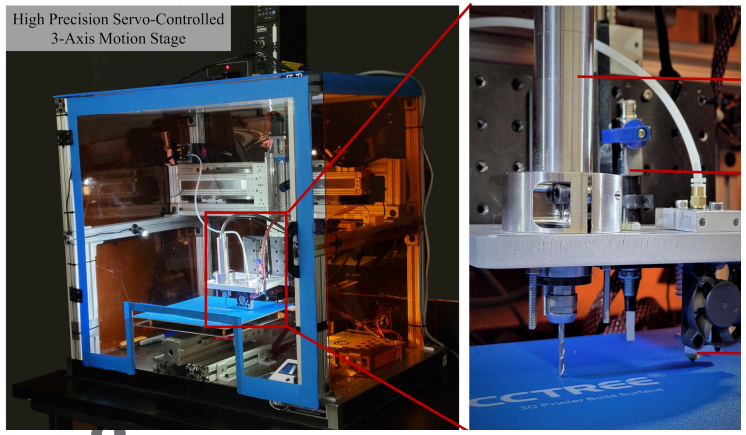
Texas A&M Engineering Experiment Station

Research Focus: 3D printing processes (thermoplastics, polymer composites, photopolymers)

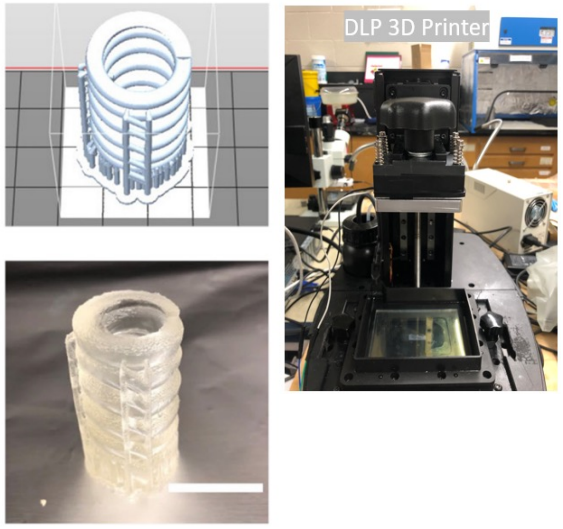
Strengths: Process development (machine design, fabrication, or integration), in-situ and post process characterization

Featured projects:

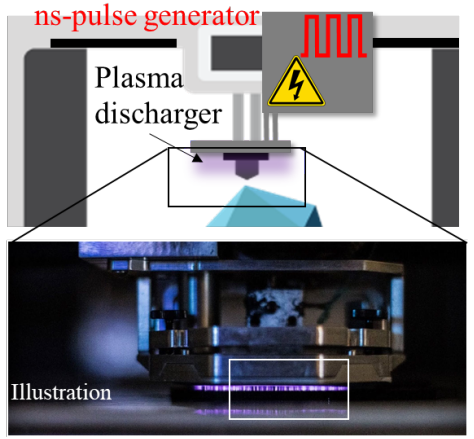
Hybrid manufacturing of polymer composites



Vat photopolymerization with soft materials (XYZ Printing)



Interlayer strengthening mechanism



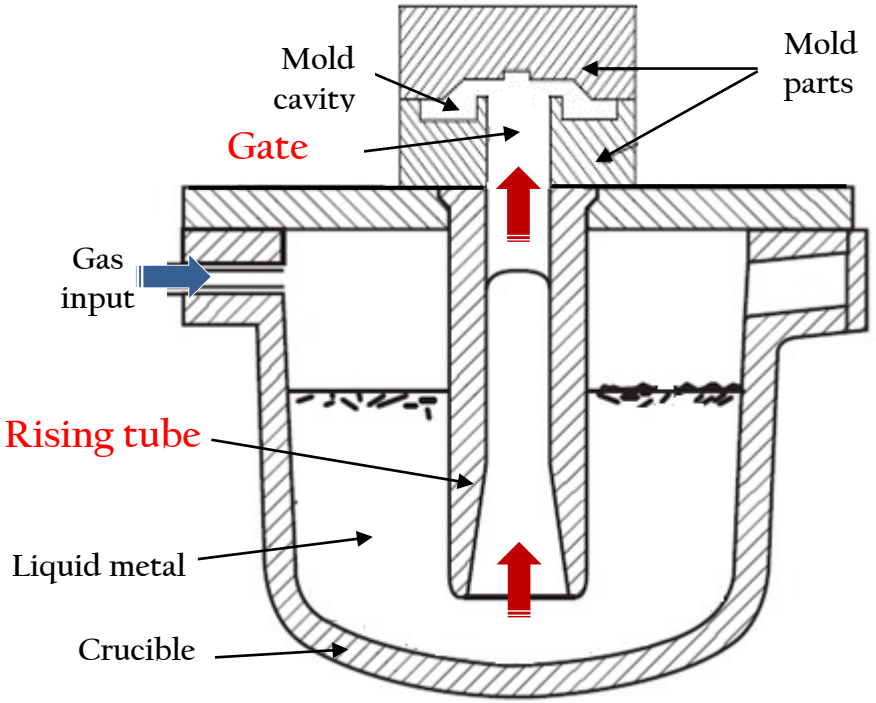
AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

6- A. KTARI
« Digital twins for smart low-pressure casting process »

Texas A&M Engineering Experiment Station

Research project - LPC process



- Gas is used to pressurize an enclosure furnace
- The melt is forced to rise through the rising tube towards the mold

Low-Pressure Casting Process

It is possible to maintain the velocity of the melt bellow the critical value ($V < 0.5$ m/s)

LPC parts (typical defects)

Filling defects

Local section change

$V_{liquid\ metal} > V_{critical}$
(Oscillation phenomena)

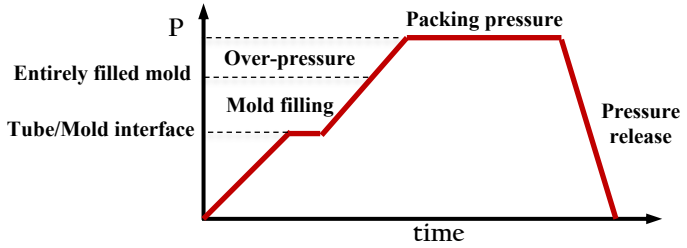
Oxide inclusions, bubbles, bifilms...

Solidification Defects

Solidification shrinkage
(zones of last solidification)

Shrinkage porosity

Optimize the input pressure ramp sequence



How to Integrate new technologies to bridge the gap between physical and digital domains in LPC processes ?

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Industry 4.0

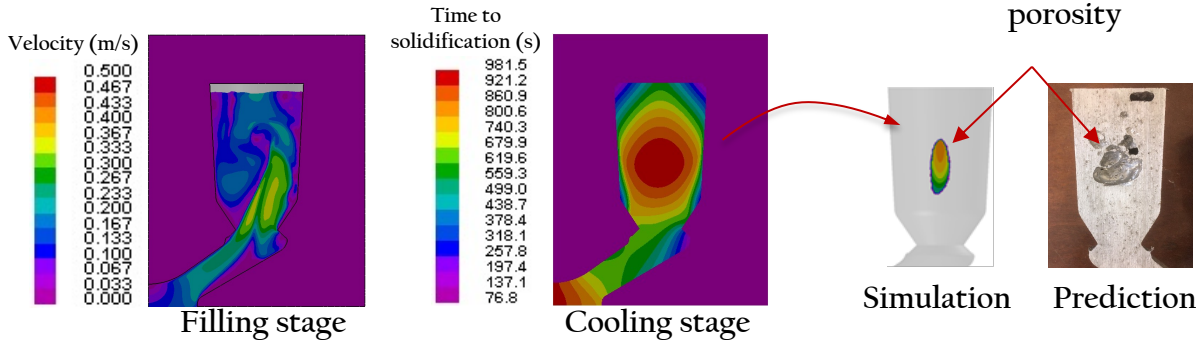
Arts et Métiers Institute of Technology

Research project - current work and future direction (2021 - 2024)

Build a digital twin for smart filling of 3D printed sand mold in LPC process

❑ High fidelity FE computations of LPC process

- ➡ Make accurate predictions (V, T, shrinkage,…)
- ➡ Generate data for machine learning



❑ Integration of smart contactless sensors (Printed 3D sand molds)

- ➡ On-line monitoring of the process parameters (V,T, P, …)
- ➡ Select the appropriate sensors (Extreme operating conditions !)

Dialog IoT Sensor

MEMS accelerometers, etc.

❑ Integration of a machine learning models

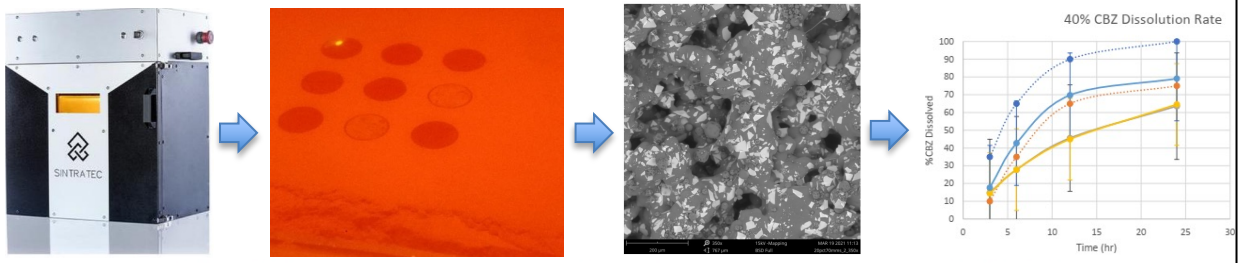
- ➡ ML based digital twin for online monitoring, inspection and adjustment of the process parameters

7- M. Kuttolamadom « AM of Pharmaceutical Printlets »

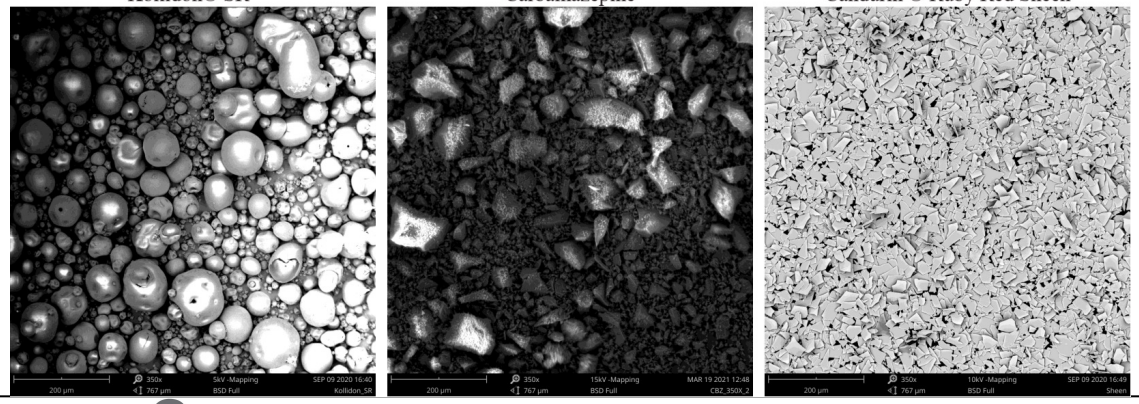
Texas A&M Engineering Experiment Station

SLS of Pharmaceutical Printlet Formulations

- To investigate SLS of tailored pediatric dosages without drug degradation
  - Liquid-phase sintering; Balancing structural integrity vs. degradation vs. performance

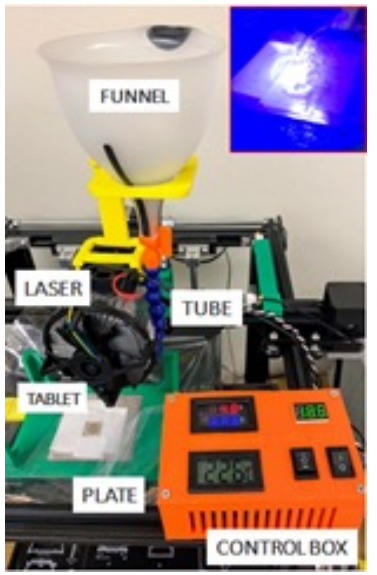


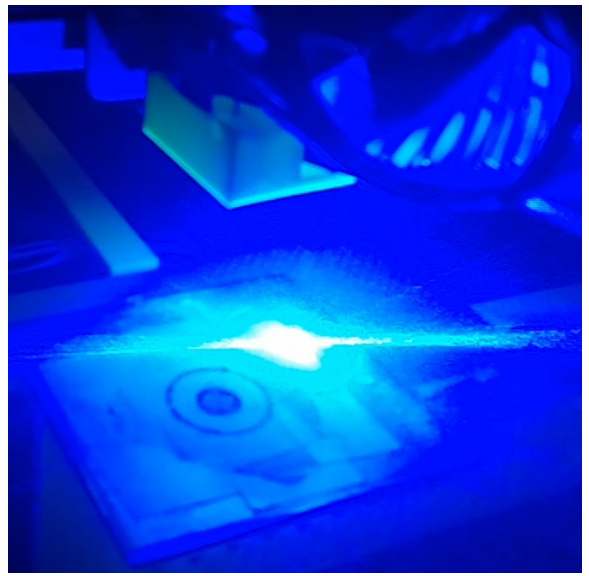
Kollidon® SR | Carbamazepine | Candurin ® Ruby Red Sheen



DED of Personalized Printlets

- Developing a prototype DED system for tailored multi-drug/dose manufacture
  - Supplementary heating vs. single-step
  - Order & grade compositions, rates, etc.
  - Process mechanics, monitoring & control





AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

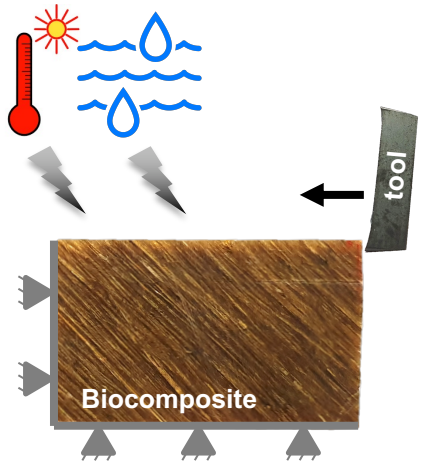
- Additive Manufacturing
  - PBF/DED of metallic alloys & ceramics/oxides
  - SLS/DED/SLA/FDM of pharmaceuticals & dental implants
  - Bioinspired functionally-graded material systems
- Surface Modification & Tribology
  - Laser surface texturing
  - Laser-based surface coating/alloying
- Machining (metallic alloys, rock-bit tribosystems)
- Engineering Education

Theme: Processing-Structure-Property-Performance interplays

8- F. Chegdani « Machining of biocomposites under extreme conditions »

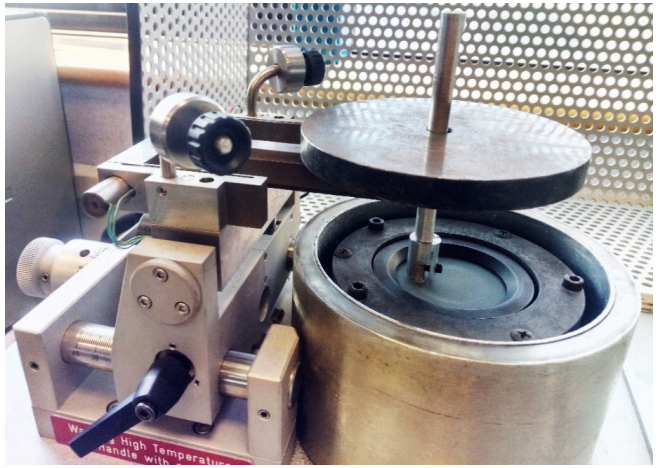
Texas A&M Engineering Experiment Station

Traditional machining



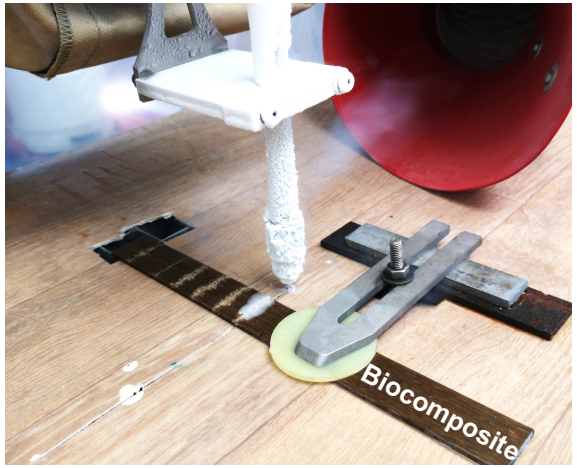
Effect of hygrothermal conditioning on the cutting behavior of biocomposites

Mechanical polishing



Effect of lubrication conditions on surface finish and damages of biocomposites

Cryogenic machining



Development of cryogenic nitrogen jet as sustainable machining process for biocomposites

Laser machining

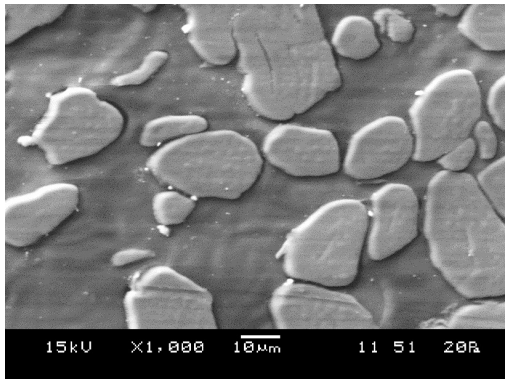
Optimization of the laser cutting process to avoid thermal degradation of biocomposites

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

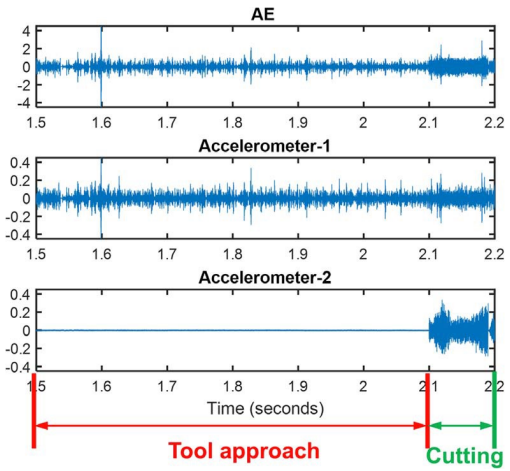
Arts et Métiers Institute of Technology

8- F. Chegdani « Machining of biocomposites under extreme conditions »

Texas A&M Engineering Experiment Station



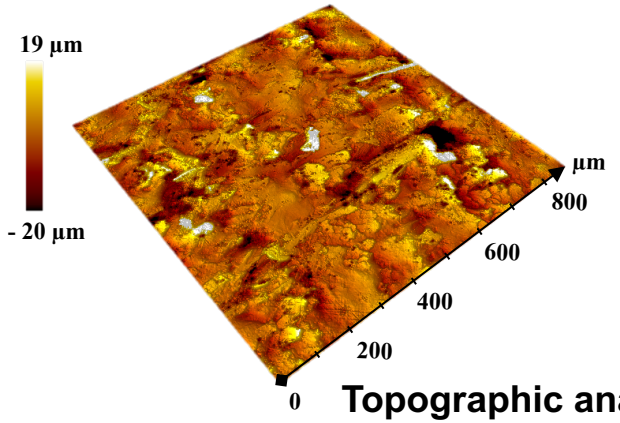
SEM analysis



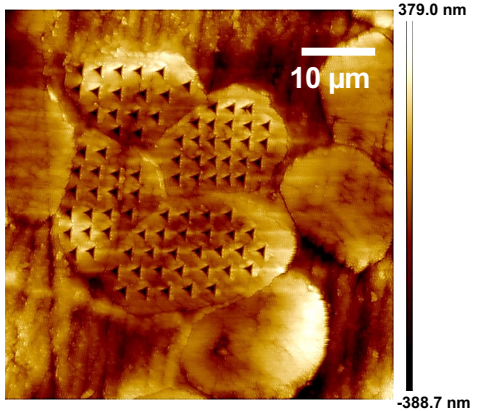
Acoustic Emission analysis

Machining forces analysis

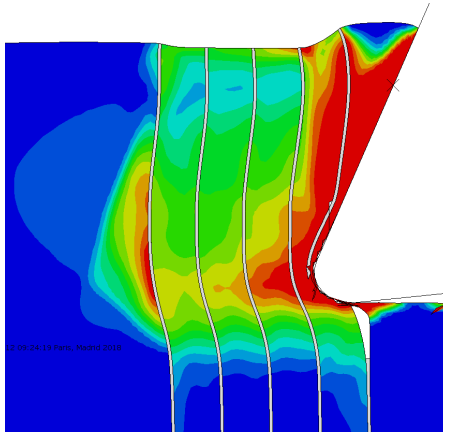
Machining analysis of biocomposites



Topographic analysis



AFM analysis



Finite Element analysis

AM2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

Synergetic Research Initiation Workshop

Texas A&M Engineering Experiment Station

Research activities Arts et Metiers – TEES - 90’

1- M. Chao “Powder-bed additive manufacturing”

2- R. Knoblauch “Smart machining and sensors”

3- D. Sagapuram “Machining and deformation processing of metals”

4- H. Ramezani Dana “Analysis of the mechanical behavior of 3D Printed structures ”

5- B. Tai “Additive and subtractive processes”

6- A. Ktari “Digital twins for smart low-pressure casting process”

7- M. Kuttolamadom “AM of Pharmaceutical Printlets

8- F. Chegdani “Machining of biocomposites under extreme conditions”

5’ Break

9- Q. Wang “Sustainable Manufacturing of Polymer Composites”

10- C. Eksin “Network science and distributed optimization”

11- M. Elhadrouz “Digital Twins For Additive Manufacturing”

12- S.J. Wolff “In situ monitoring of metal additive manufacturing”

13- S. Jegou “Thermochemical surface treatments and gradient properties”

14- C. Lee “Precision metrology”

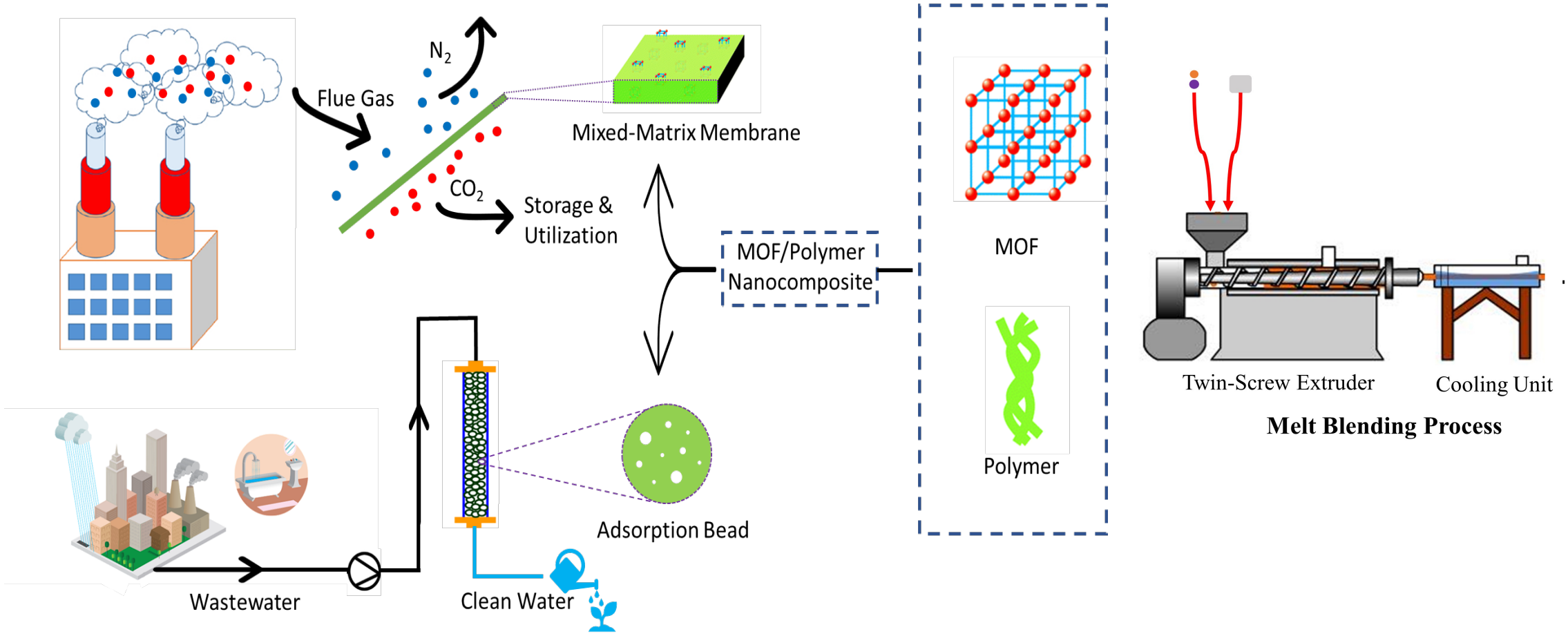
15- R. Kubler “Mechanical behavior and gradient properties”

16- J.P. Goulmy “Development of DIC for the understanding of mechanisms at different scales”

17- J. Wilkerson “Processing - microstructure - ballistic performance relationships”

9- Q. Wang «Sustainable Manufacturing of Polymer Composites

Texas A&M Engineering Experiment Station

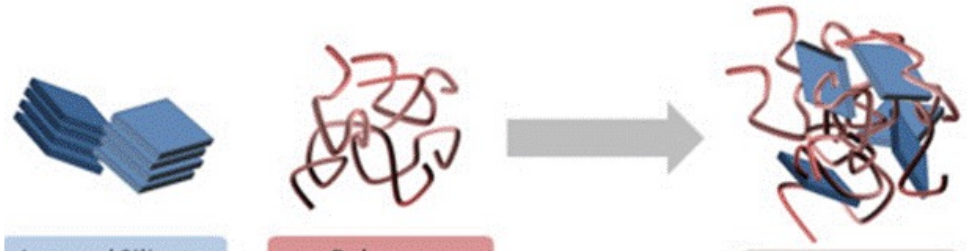


9- Q. Wang «Sustainable Manufacturing of Polymer Composites

Texas A&M Engineering Experiment Station

Flame Retardant Plastics Manufacturing

Surface Treatment → Extrusion Compounding → Characterization SEM/XRD/XPS/TGA → Fire Testing

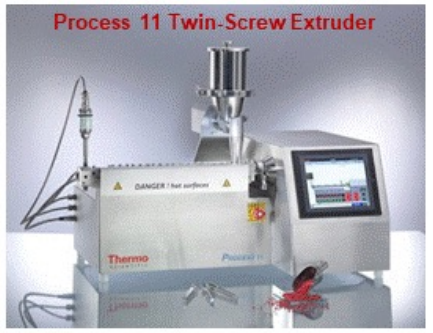


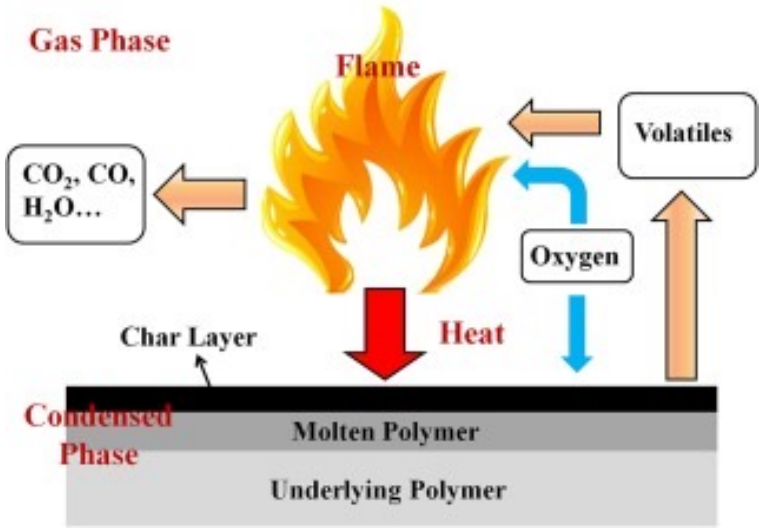
Layered Silicate

Polymer

Nanoparticle
Nanotubes
2D Materials
- Graphene
- Mxene
- ZrP

LDPE, HDPE
PP, PC
PET, PBT
ABS, ASA, PS
PA 6, PA 66
PC/ABS





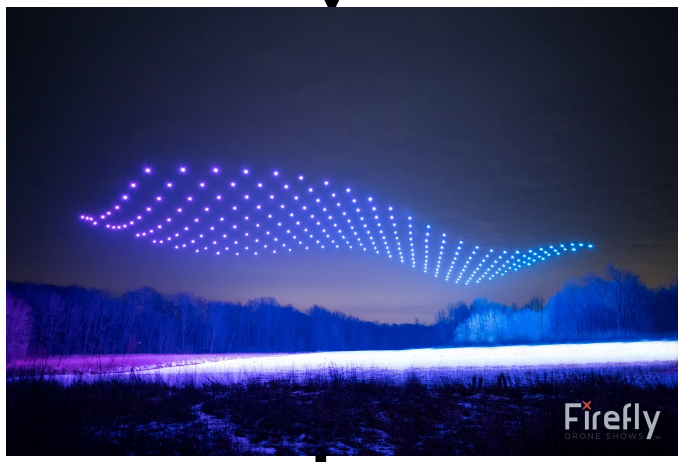
Wang Research Lab @ Texas A&M Chemical Engineering; Contact: QWANG@tamu.edu

10 - C. Eksin « Network science and distributed optimization»

Texas A&M Engineering Experiment Station

Autonomous teams

Distributed algorithms



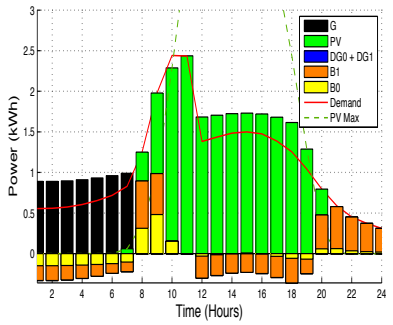
Environment

(consensus, shape formation)

Vision: Plan, learn and coordinate in novel environments

Smart Grid

Operator (Supply)



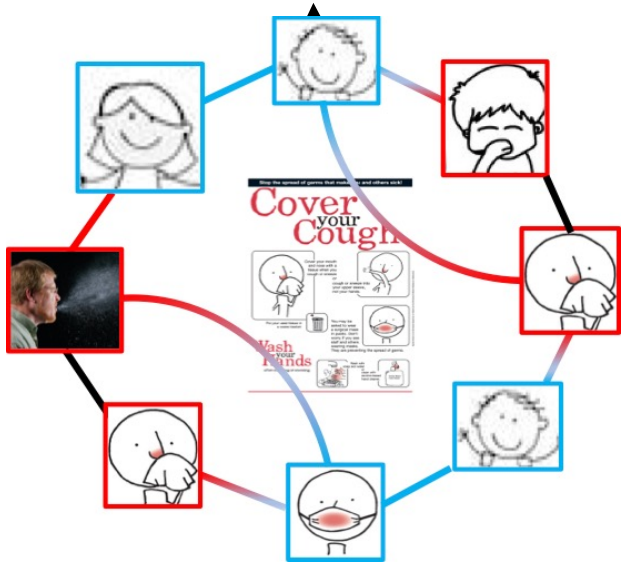
Consumer (Demand)

(unknown, incentives)

Vision: Digital, active consumers, flexible, scalable, and secure

Epidemics

Individual behavior



Disease dynamics

(co-evolution)

Vision: Standardized accurate forecasts and control policies

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

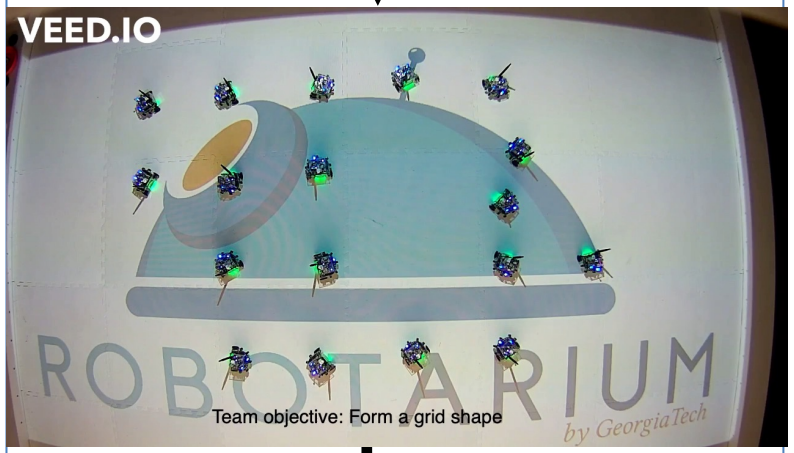
Arts et Métiers Institute of Technology

10 - C. Eksin « Network science and distributed optimization»

Texas A&M Engineering Experiment Station

Autonomous teams

Distributed algorithms



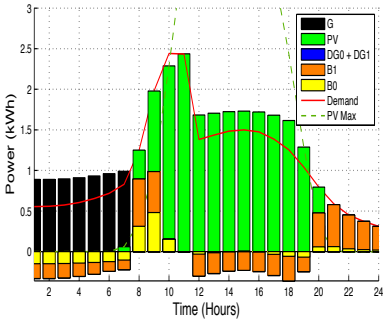
Environment

(consensus, shape formation)

Vision: Plan, learn and coordinate in novel environments

Smart Grid

Operator (Supply)



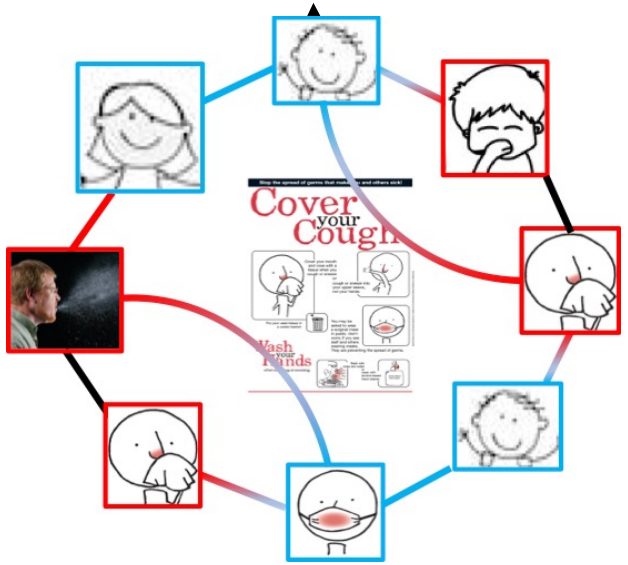
Consumer (Demand)

(unknown, incentives)

Vision: Digital, active consumers, flexible, scalable, and secure

Epidemics

Individual behavior



Disease dynamics

(co-evolution)

Vision: Standardized accurate forecasts and control policies

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

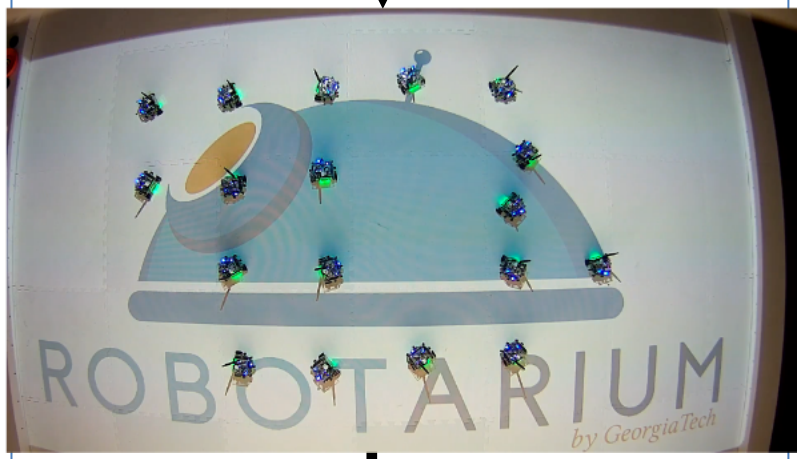
Arts et Métiers Institute of Technology

10 - C. Eksin « Network science and distributed optimization»

Texas A&M Engineering Experiment Station

Autonomous teams

Distributed algorithms



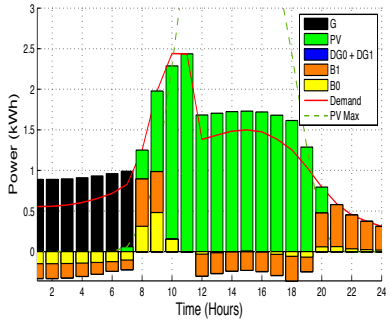
Environment

(consensus, shape formation)

Vision: Plan, learn and coordinate in novel environments

Smart Grid

Operator (Supply)



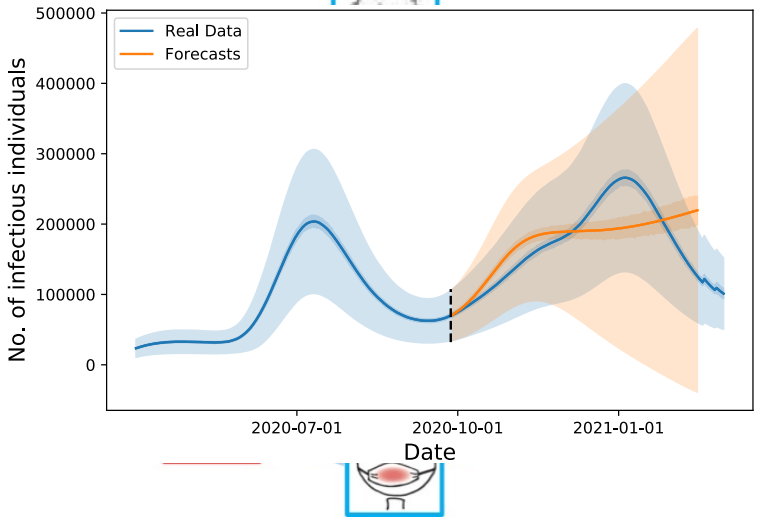
Consumer (Demand)

(unknown, incentives)

Vision: Digital, active consumers, flexible, scalable, and secure

Epidemics

Individual behavior



Disease dynamics

(co-evolution)

Vision: Standardized accurate forecasts and control policies

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

11-M. EL HADROUZ « Digital Twins For Additive Manufacturing »

Texas A&M Engineering Experiment Station

Education

- Phd in Mechanics of Materials
- Master of Research in Mechanics, Materials, Structures and Manufacturing Processes
- MSc in Mathematical Sciences
- MSc in Mechanical Engineering
- BSc in Physics and Chemistry

Current Position

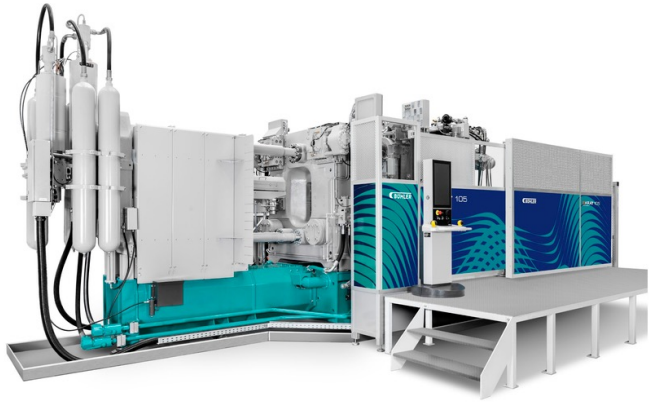
- Associate Professor (Campus of Châlons en Champagne)
- Teaching : Mechanics, Mechanical Design, CAD, Finite element method
- Research : Advanced Numerical Simulation Methods for Digital Twin for Additive Manufacturing

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

Research Project

Industrial project (ENSAM Châlons-en-Champagne: Learning Factory): **High pressure die casting (1300T)**

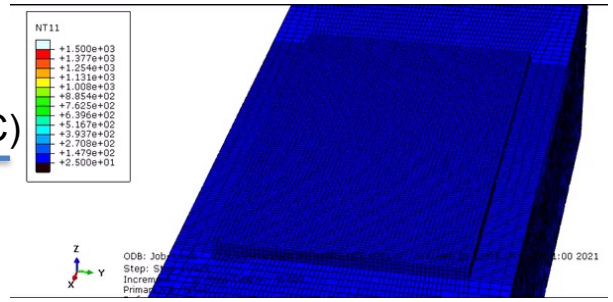


Additive Manufacturing + conformal cooling

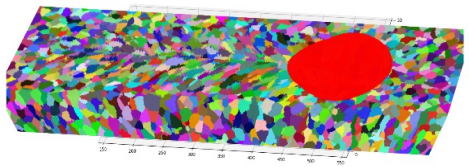
Tooling steel

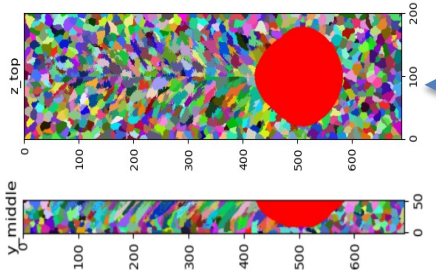
- High wear resistance
- High hardness at high temperature
- High toughness
- ……

Simulation of Laser heating (Thermal field)



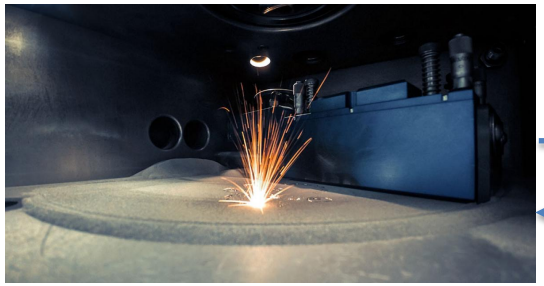
T(°C)





Grain growth and solidification Cellular Automaton

Process optimization

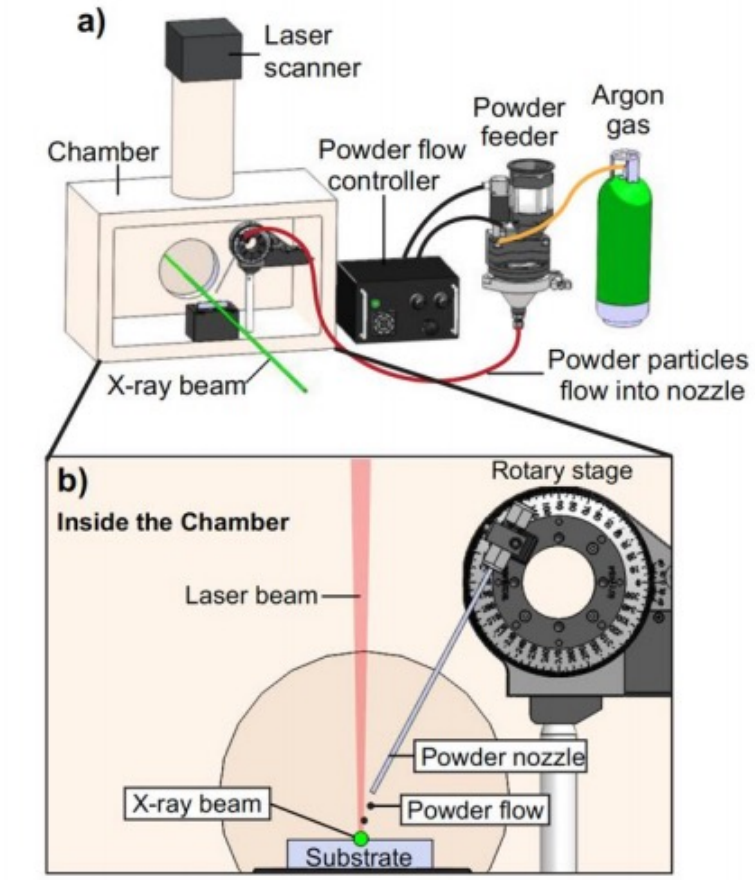


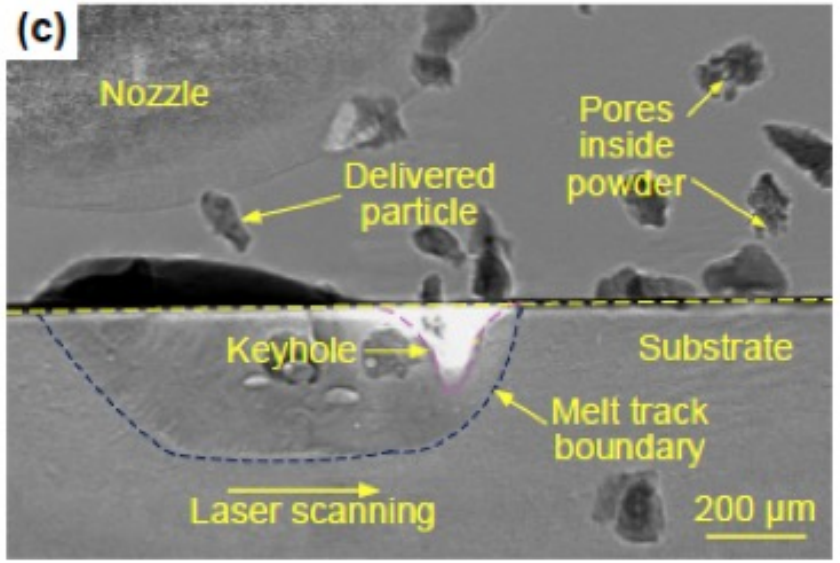
Powder Bed Fusion Manufacturing

12- S. Wolff« In situ monitoring of metal additive manufacturing »

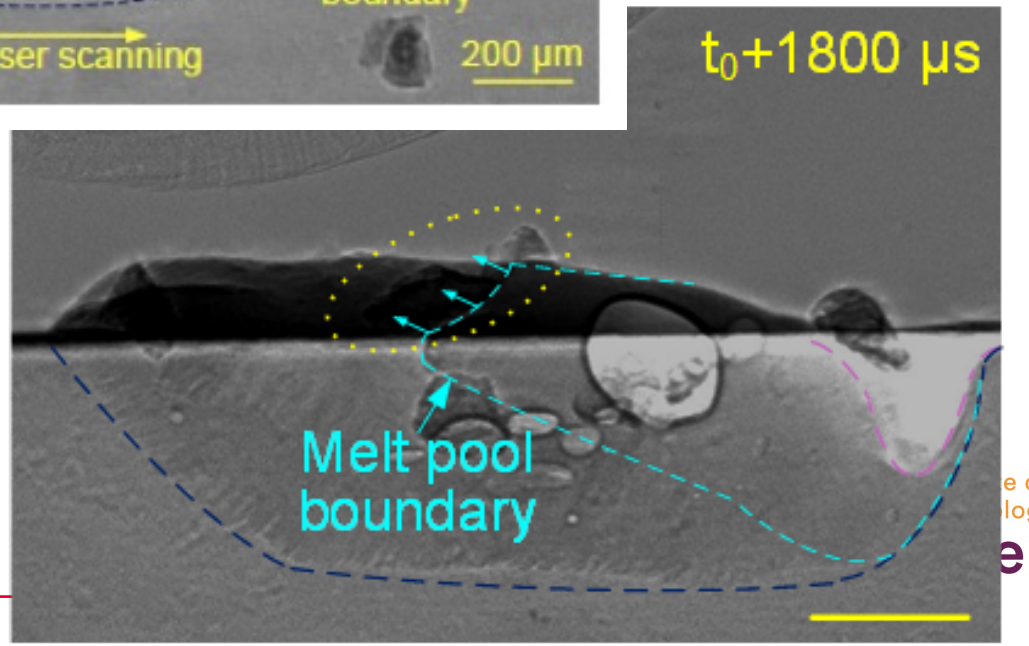
Texas A&M Engineering Experiment Station

Custom operando directed energy deposition system at synchrotron for in situ high-speed X-ray imaging at up to 1 MHz





X-ray images show porosity formation, melting, and solidification



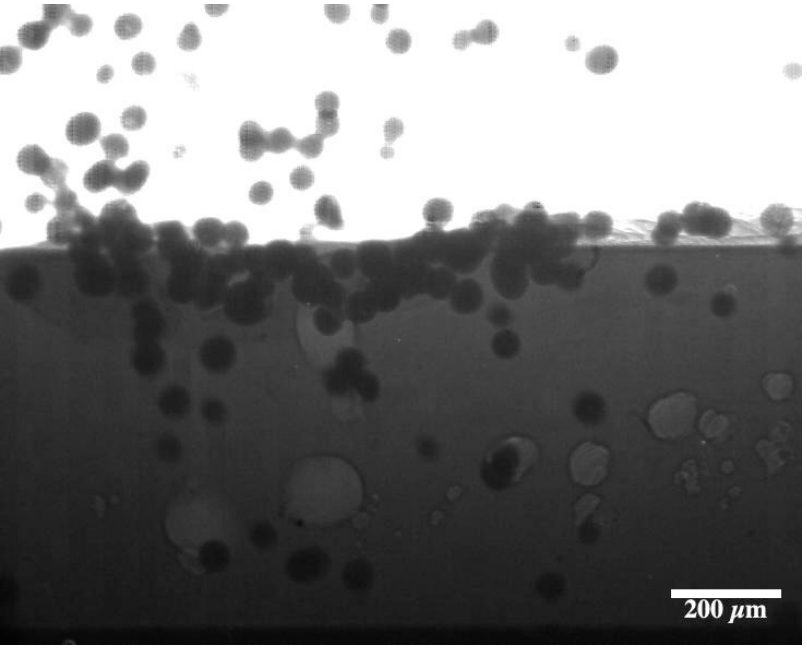
Transatlantic Par
FOR INDUSTRY OF THE FUTURE

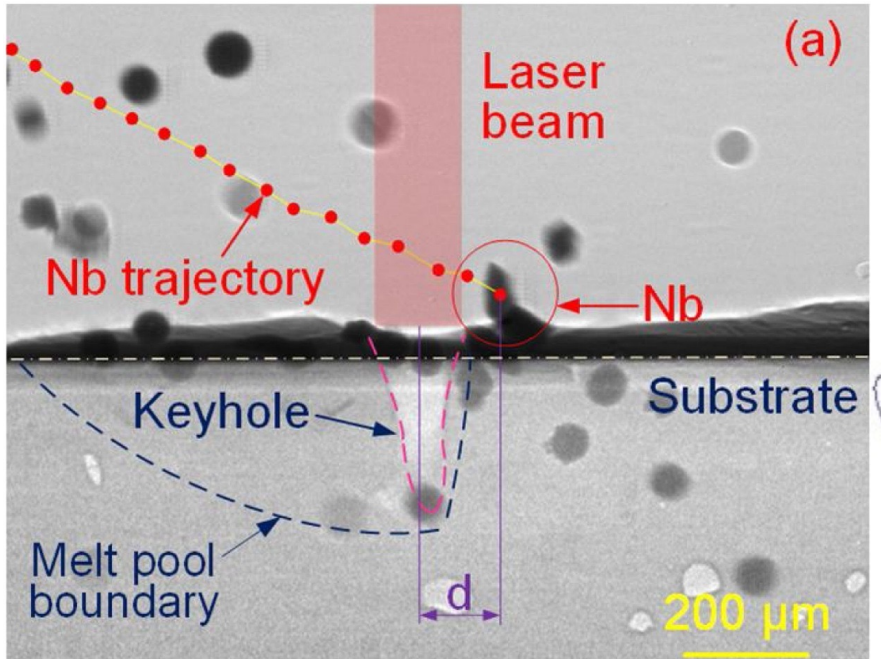
12- S. Wolff« In situ monitoring of metal additive manufacturing »

Texas A&M Engineering Experiment Station

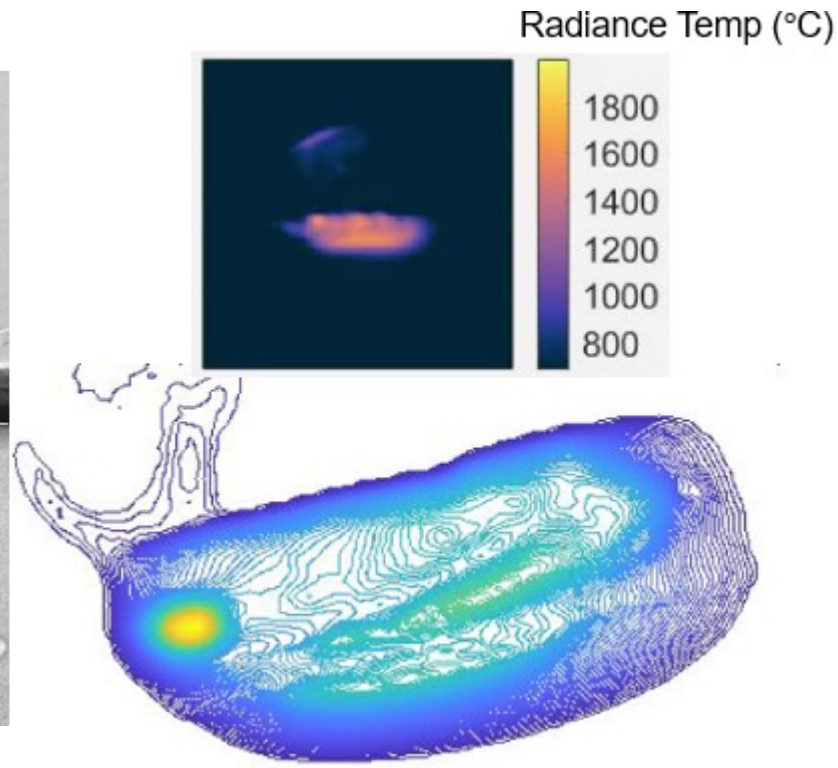
Observations of dissimilar material printing:

Flowability, miscibility, melting, and solidification





Synchronized X-ray imaging with infrared thermal imaging



AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

13- S. Jégou « Thermochemical surface treatments and gradient properties»

Texas A&M Engineering Experiment Station

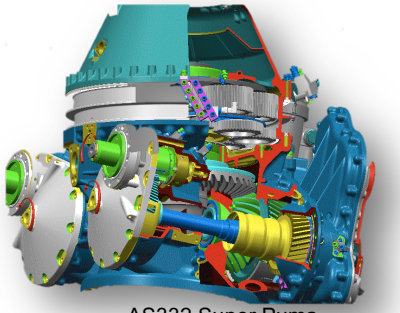
- Associate Professor since 2011
  - **Material Science**
  - **Surface Engineering**

- Research activities:
  - Relation : microstructure / properties / process

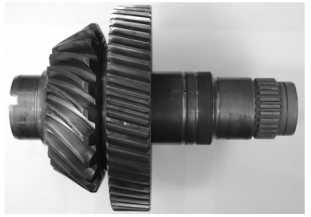
  - Microstructure design of metallic alloys
  - Thermo-chemical treatments and optimisations

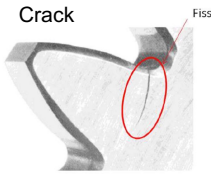
  - ***Kinetics of diffusion and phase transformations***
    - Control of microstructure during treatments and in operations
    - Effect of initial microstructure
    - Effect of applied or induced gradients
      - Ex.: driving forces due to applied/residual stress
    - Modelling of diffusion and thermodynamic calculations

  - Example : Nitriding of
    - Bearing and Tool steels
    - Electrical steels

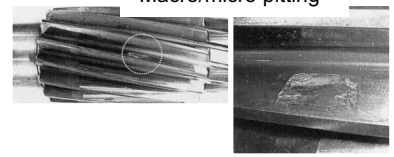

AS332 Super Puma
Airbus Helicopters

33CrMoV12-9 steel-made gear



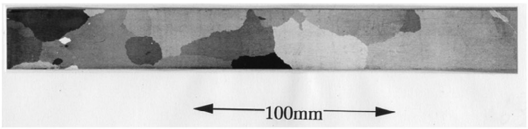


Macro/micro pitting

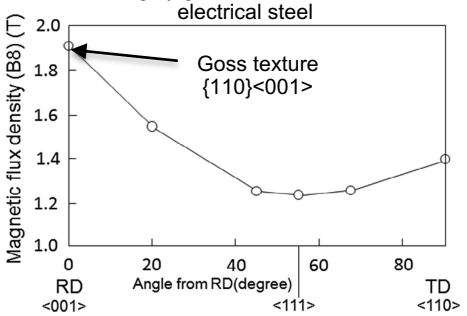



Electrical transformers

Fe-Si electrical steel-made sheet metal



Highly grain-oriented Fe-Si electrical steel



AM2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

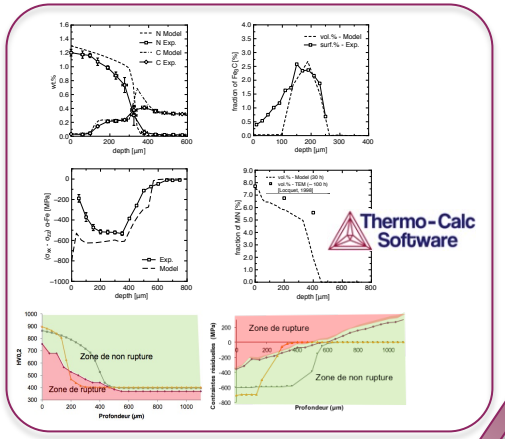
13- S. Jégou « Thermochemical surface treatments and gradient properties»

Texas A&M Engineering Experiment Station

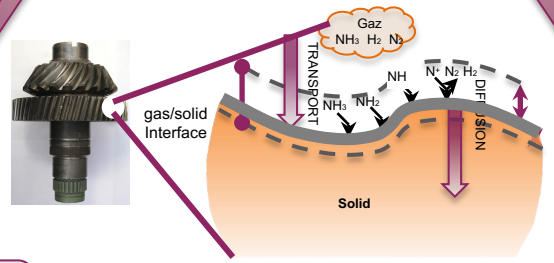
Transversal approach

12 Ph.D.:
1992 – Barrallier L.
1998 – Locquet J-N.
2000 – Chaussumier M.
2006 – Goret V.
2009 – Jégou S.
2015 – Fallot G.
2016 – Guillot B.
2017 – Weil H.
2018 – Godet F.
2022 – Germain L.
2023 – Zhang Y.
2024 – Delarbre F.

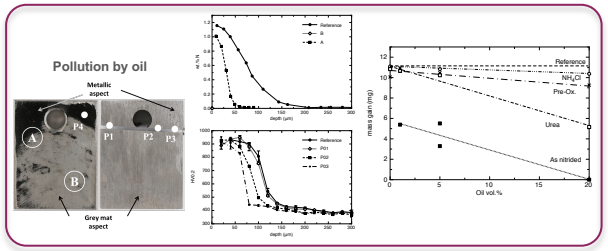
MODELLING the gradients



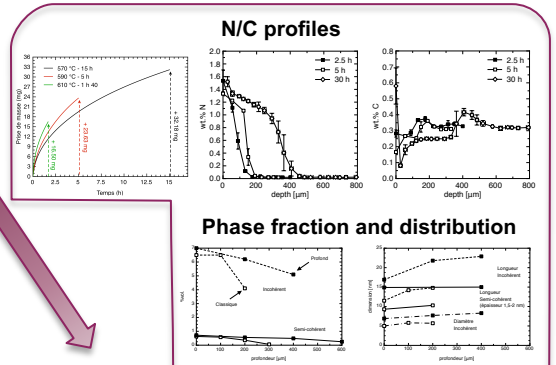
PROCESS



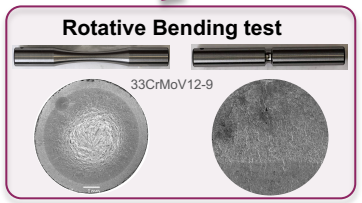
SURFACE CLEANING



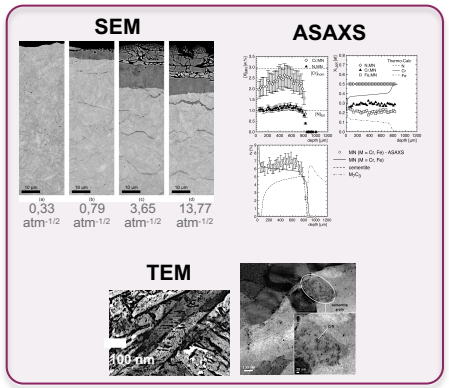
KINETICS OF DIFFUSION AND PRECIPITATION



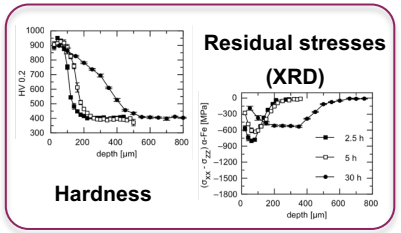
FATIGUE PROPERTIES



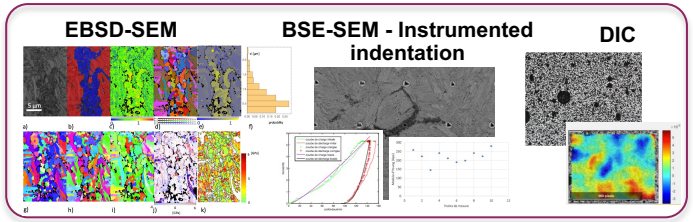
MICROSTRUCTURE



MECHANICAL PROPERTIES

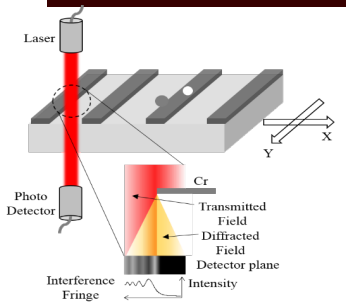


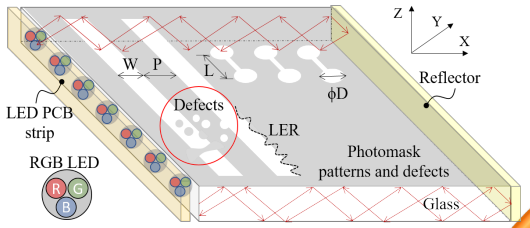
LOCAL MECHANICAL PROPERTIES

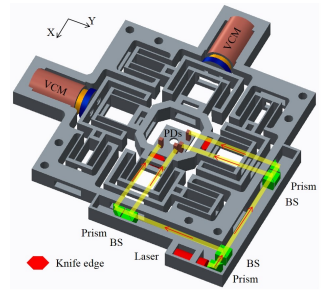


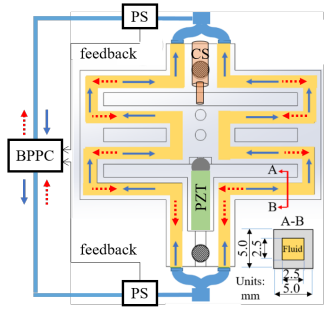
14- ChaBum Lee « Precision Metrology »

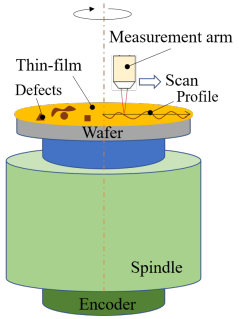
Texas A&M Engineering Experiment Station











- Positioning/Posture control
- Signal processing
- Electric circuit design

- Wafer inspection
- Photomask inspection
- Optic surface inspection
- R2R pattern inspection

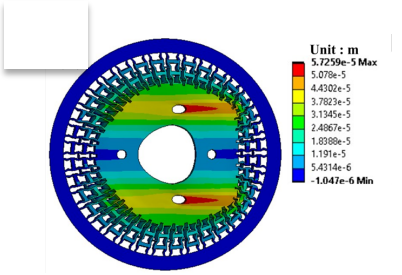
Mechatronics

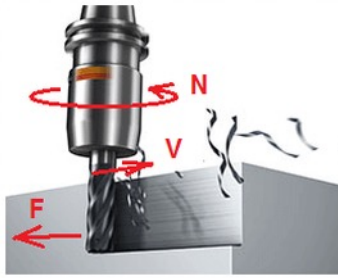
Semiconductor Metrology

Precision Metrology

Dynamic Systems

- Machine dynamics
- Solid mechanics
- Finite element analysis
- Impedance modeling
- Dual-mode stage
- Fast tool servo
- Auxetics



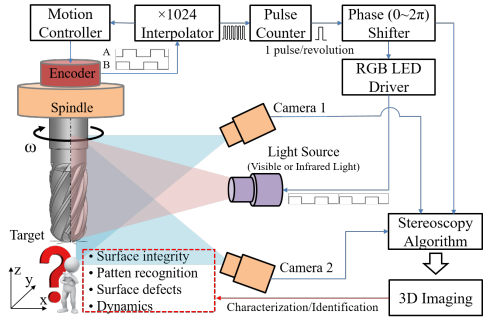


- Spindle metrology
- Cutting force metrology
- Cutting tool metrology.
- OMM surface metrology
- Cutting temperature metrology

Machine Tool Metrology

Sensors & Instrument.

- Interferometers
- Microscopy
- Fluorescence strobo-stereoscopy
- Strobo-spectroscopy
- Knife-edge interferometer
- Curved-edge interferometer
- Magneto-eddy NDT



*NDT: Non-Destructive Testing
*R2R: Roll-to-Roll

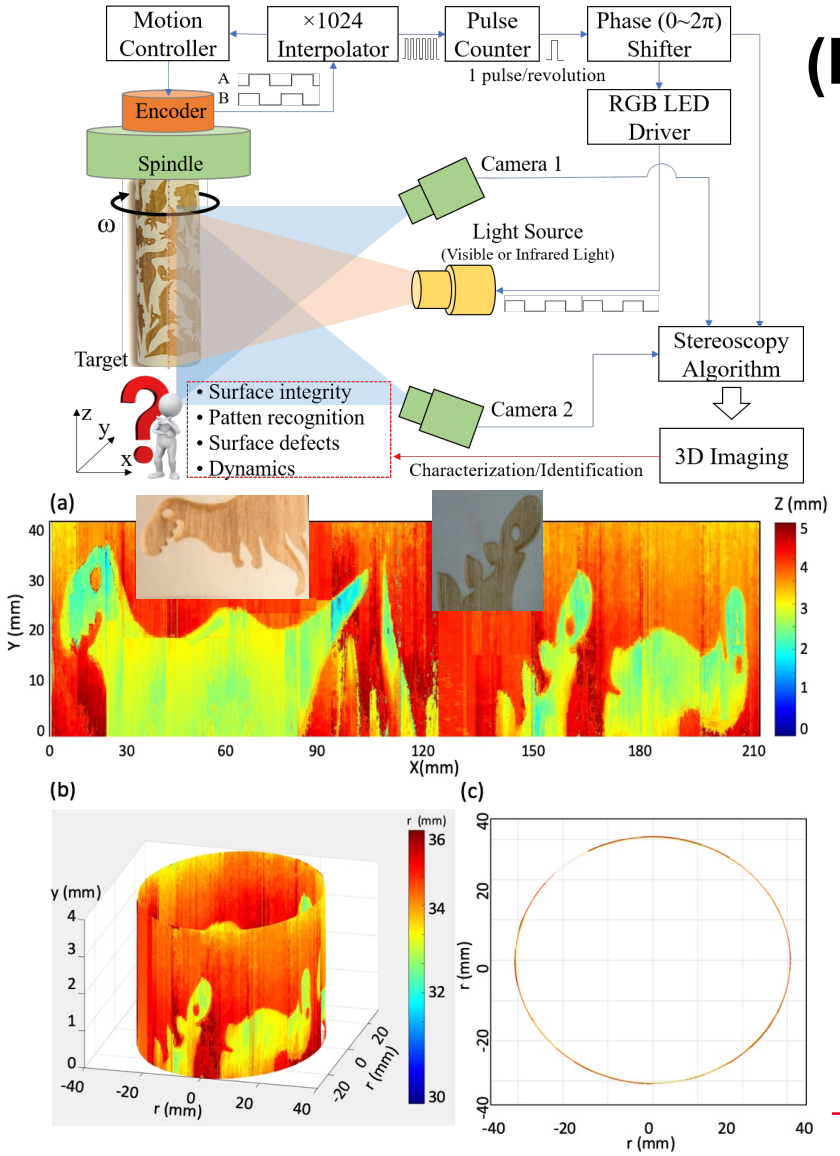
AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

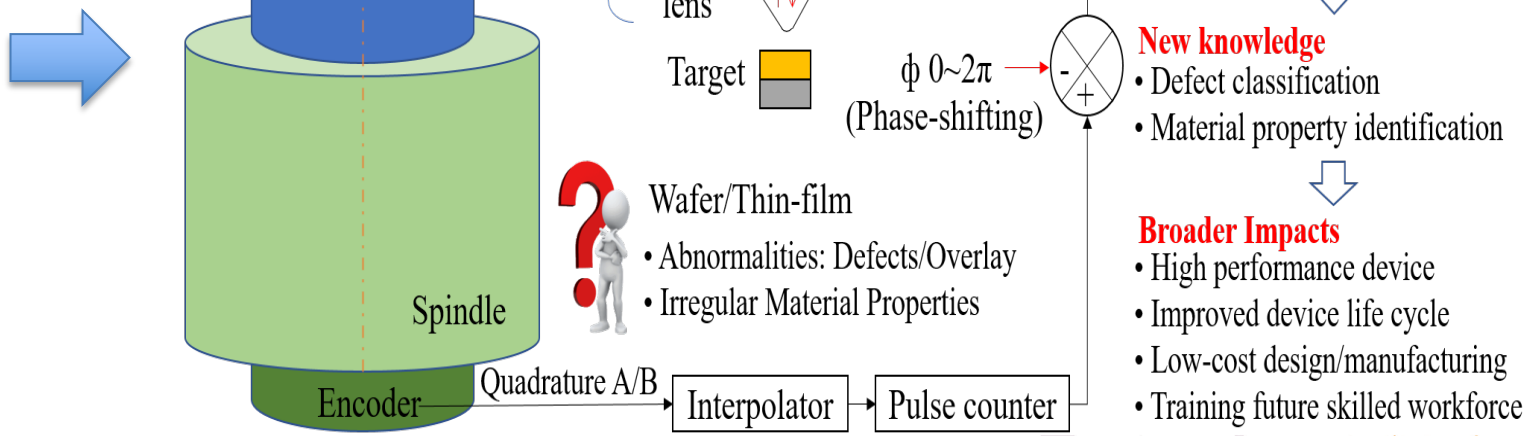
Arts et Métiers Institute of Technology

14- ChaBum Lee « Precision Metrology »

Texas A&M Engineering Experiment Station

(Fluorescence) Strobo-Stereoscopy and -Spectroscopy





Arts et Métiers Institute of Technology

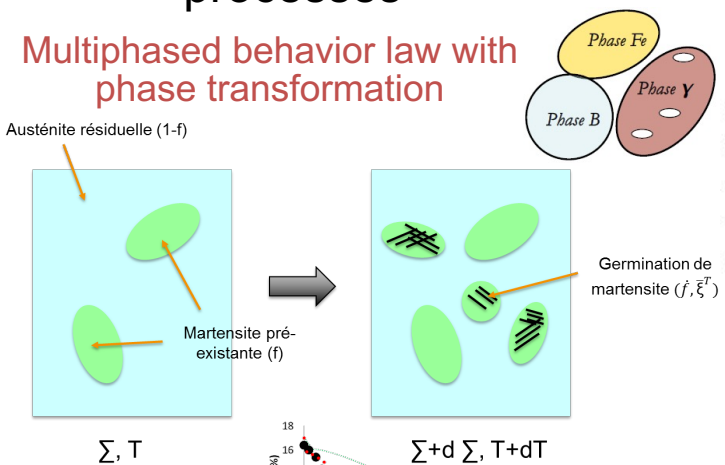
15- R. Kubler « Mechanical behavior and gradient properties »

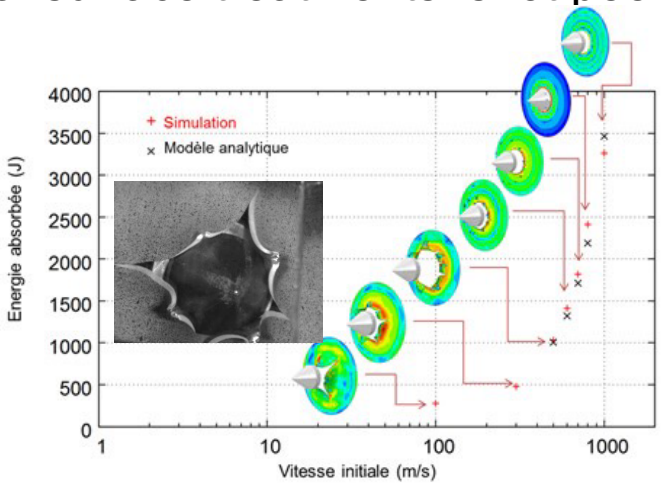
Texas A&M Engineering Experiment Station

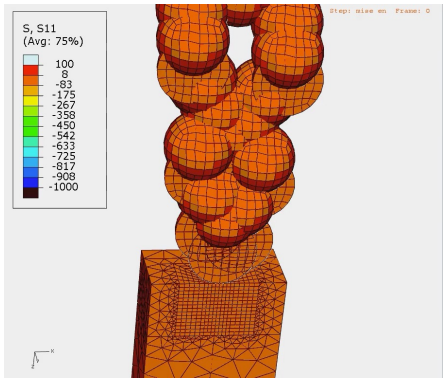
Research Focus :

- Material behavior of metals and ceramics
- Numerical modeling of the thermomechanical behavior implemented in a FE code applied to processing
- Residual stress field prediction vs experimental data
- Impact analysis from the material to the structure
- Applications to mechanical surface treatments: shot peening, deep rolling, burnishing, compaction processes

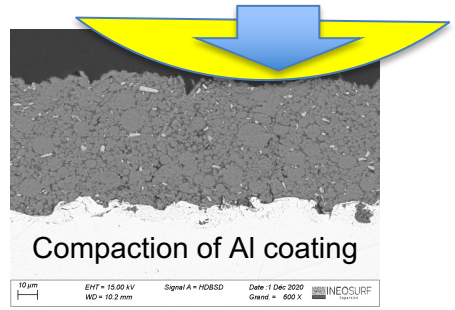
Multiphased behavior law with phase transformation

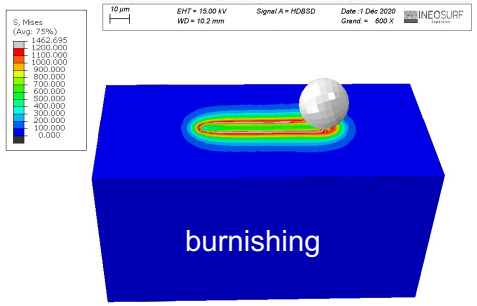


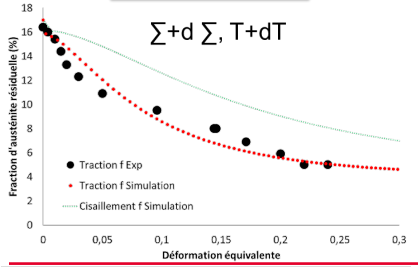


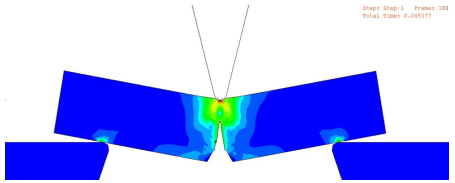


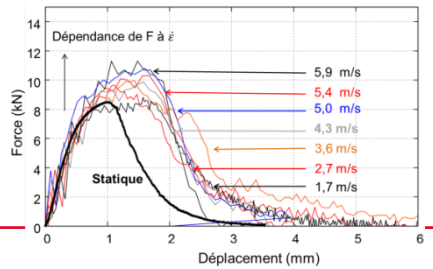
Shot peening











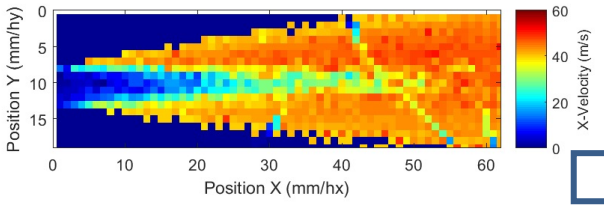
AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

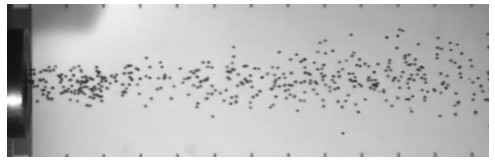
Arts et Métiers Institute of Technology

15- R. Kubler « Mechanical behavior and gradient properties »

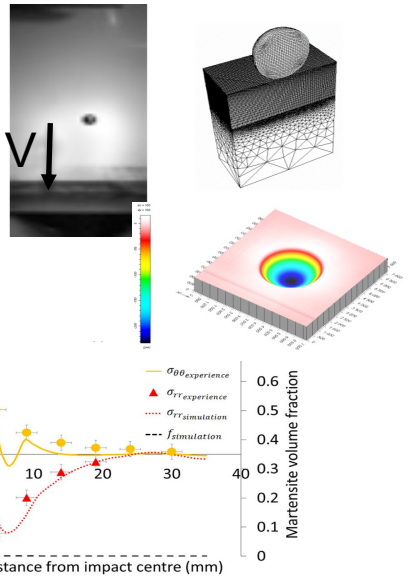
Texas A&M Engineering Experiment Station

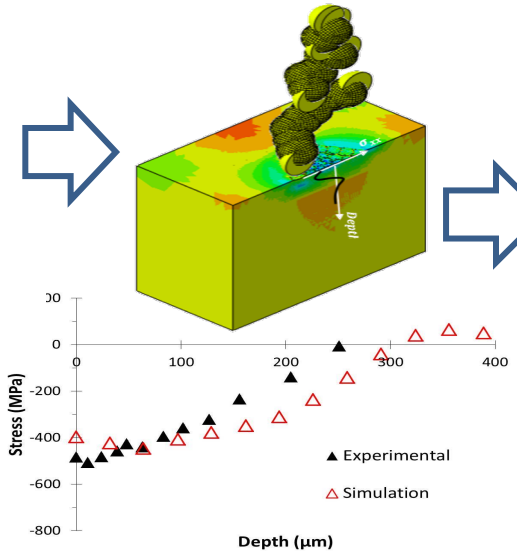
Process Parameters | **Material behavior and Single impact** | **Multiple Impacts and residual fields** | **Durability of mechanical fields and fatigue**



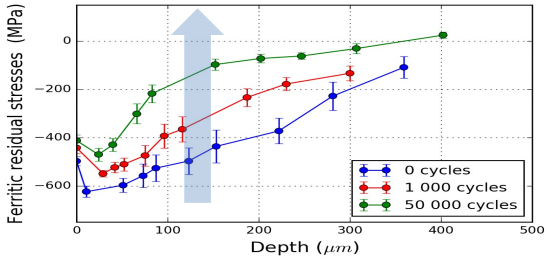


nozzle

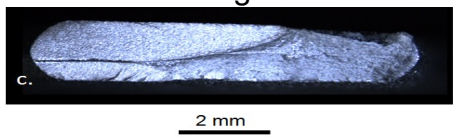




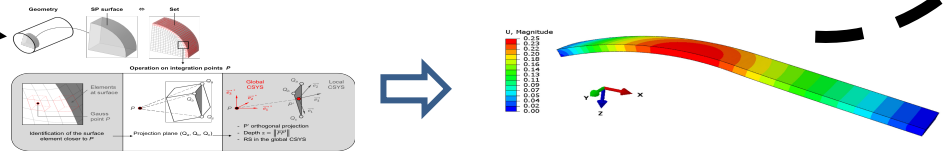
Mechanical stress relaxation

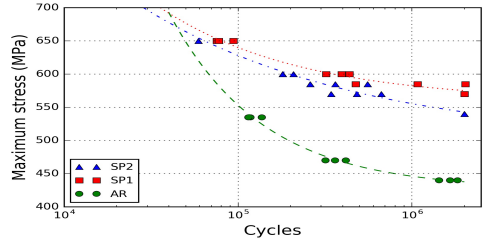


Fatigue fracture surface



Eingenstrain method implemented on complex parts

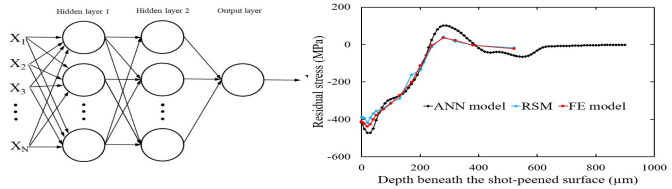


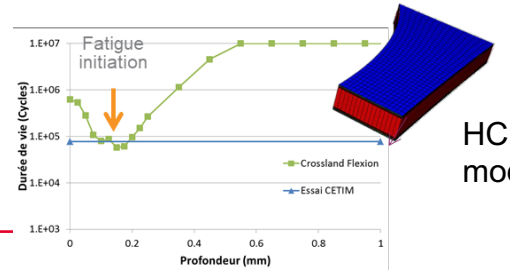


Fatigue curve

[Condor Project 2014-2018]

Hybrid model coupling FEM/AI





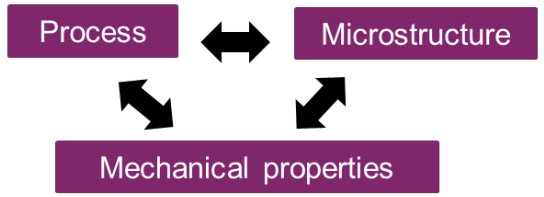
HCF Fatigue model

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

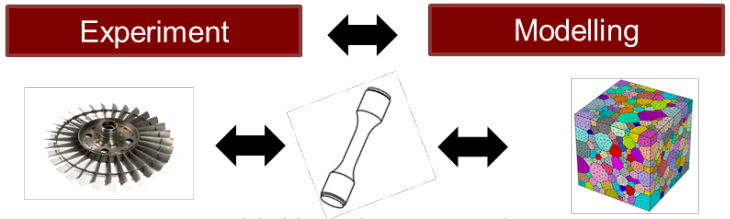
16- J.P. GOULMY « Development of DIC for the understanding of mechanisms at different scales »

Texas A&M Engineering Experiment Station

Challenge



Tools



Multi-scale approach

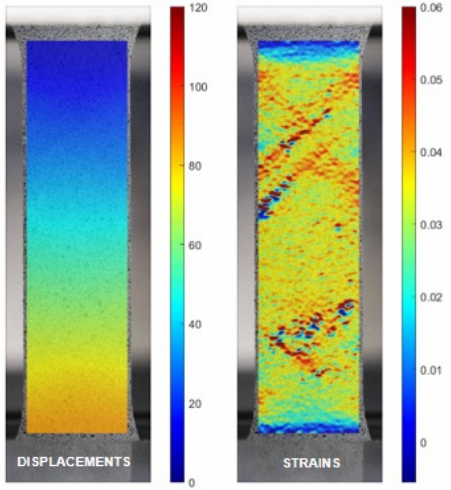
Objective:

Development of experimental mechanics and test-calculation dialogue

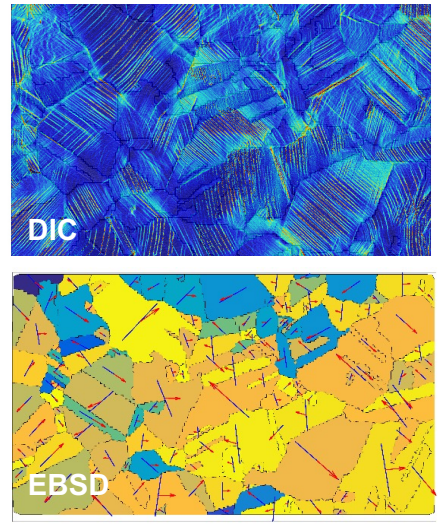
→ DIC measurements for the understanding of mechanisms

Method:

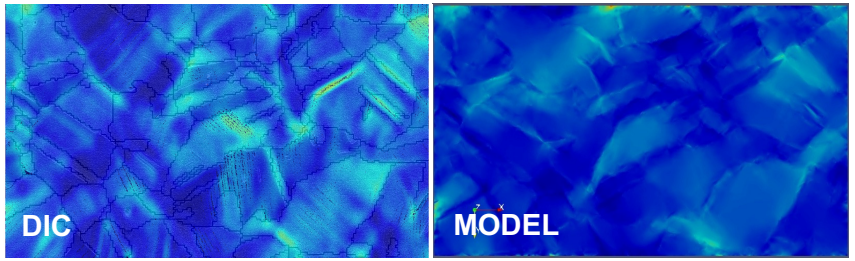
- Development of tools to improve the quality of experiments
- Use of different tools (Optical camera, SEM)
- Coupling of different characterization techniques
- Development of the test-calculation dialogue (macroscopic and polycristal models)



DIC apply on steel using optical camera



Example of EBSD and DIC coupled test



Comparison between DIC and modeling. Tensile test on pure copper.

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

16- J.P. GOULMY « Development of DIC for the understanding of mechanisms at different scales »

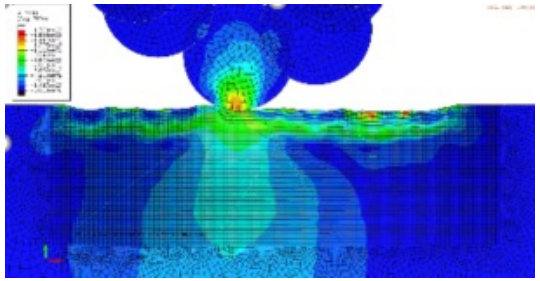
Texas A&M Engineering Experiment Station

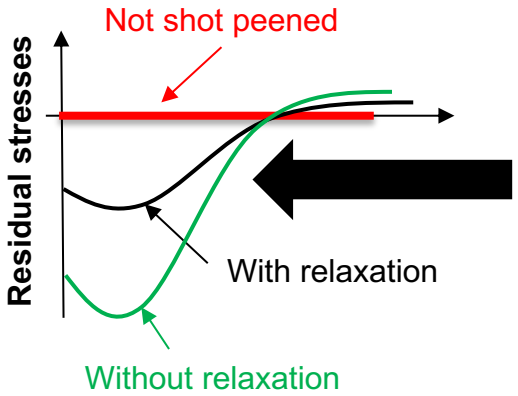
An example of future research project : understand residual stress relaxation mechanisms

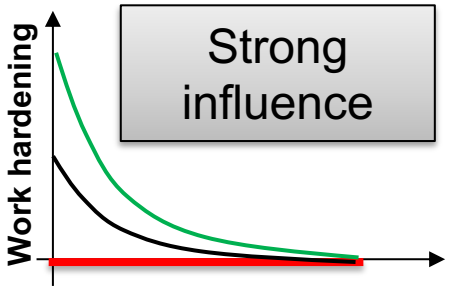
Shot peening → Residual stresses Work hardening → Residual stress and work hardening relaxation during thermal or cyclic loading → Decrease in fatigue lifetime gain

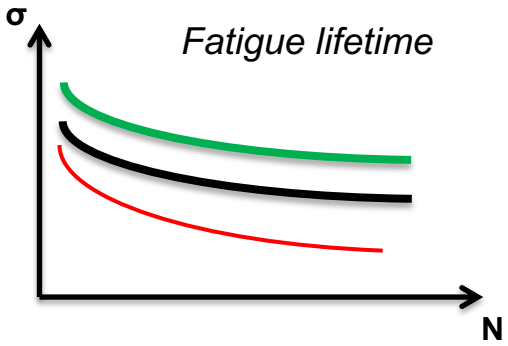
Turbine disk

Connecting rods









Structural effect or physical mechanism?

- Plasticity
- Recrystallization
- …

Explanation of the physical mechanisms involved

- Couple measurements techniques (surface or volume information) at different scales
- Develop in-situ test like DIC at high temperature
- Develop ex-situ test
- Use of test-calculation dialogue : development of multi-scale and multi-physic modelling

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

et Métiers

17-J. Wilkerson « Processing – Ballistic Performance

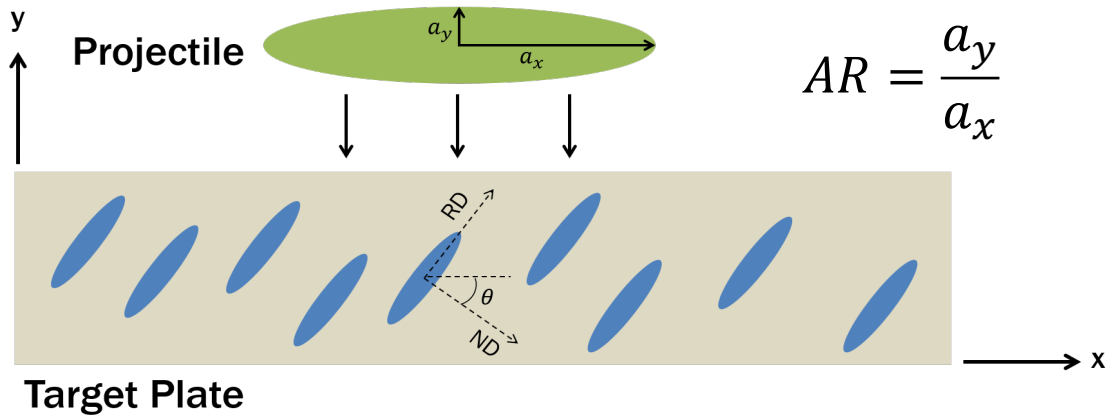
Texas A&M Engineering Experiment Station

- Failure often nucleated from Mn-rich particles in AZ31B.
- These particles are preferentially aligned along the rolling direction (RD) in rolled AZ31B.
- We studied effect of particle orientation on ballistic performance.

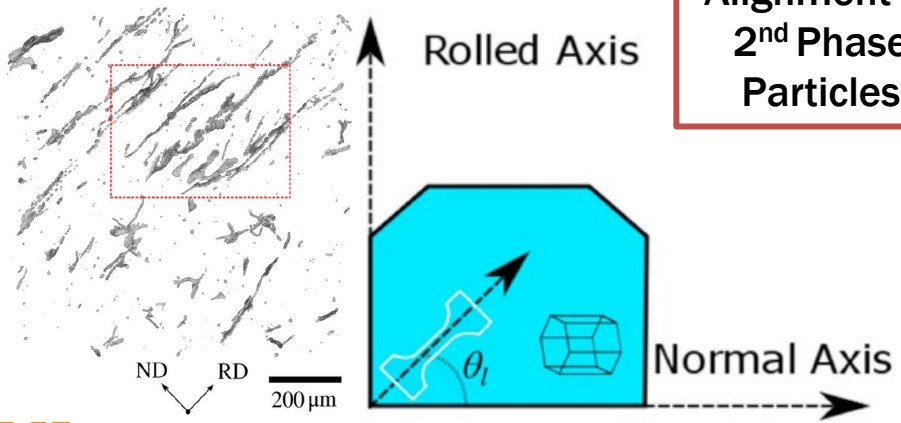
Conclusions

- The alignment of the second-phase particles affects the ballistic performance of sphere-like projectiles, but not plate-like projectiles.
- Projectile geometry affects stress state, which affects failure mode.
- Regardless of orientation and projectile shape, reducing Mn-rich particles improves ductility, spall strength, & ballistic performance.

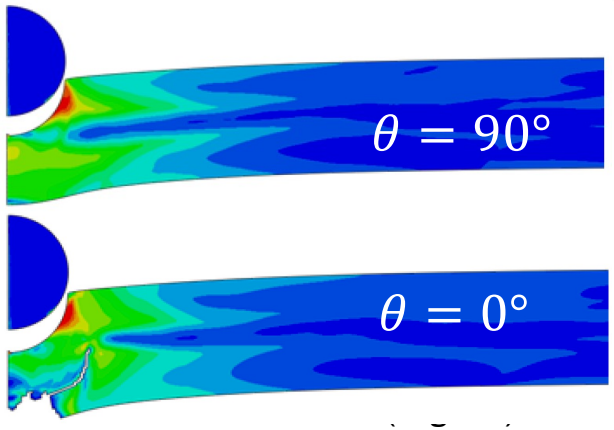
Problem Setup



Alignment of 2nd Phase Particles



Critical Velocity vs. Particle Alignment



- For plate, $AR \ll 1$.
- For sphere, $AR = 1$.

v_{cr} is the minimum projectile velocity to induce damage, spall, fracture, or penetration.

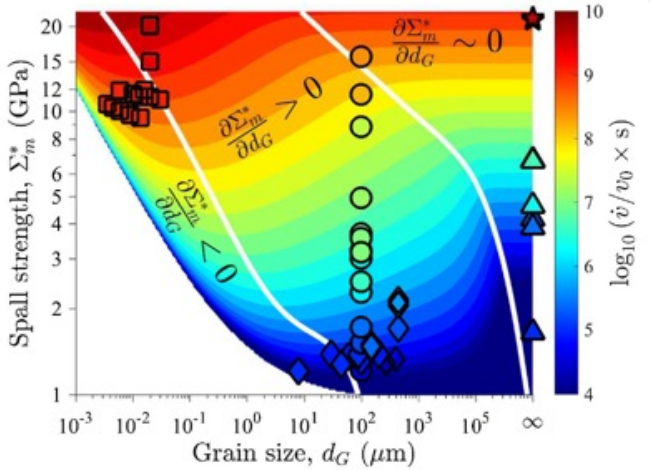
Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers Institute of Technology

17-J. Wilkerson « µstructure – Ballistic Performance »

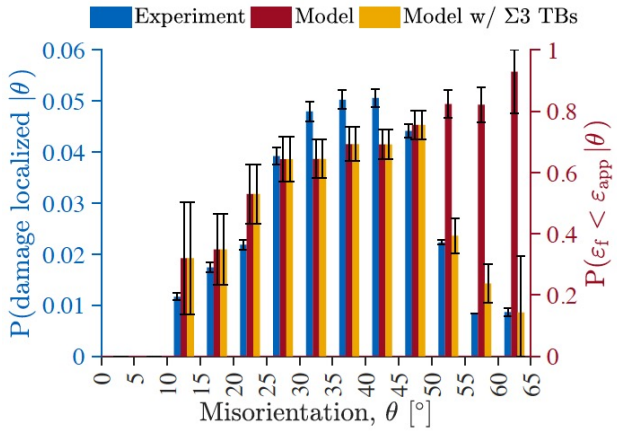
Texas A&M Engineering Experiment Station

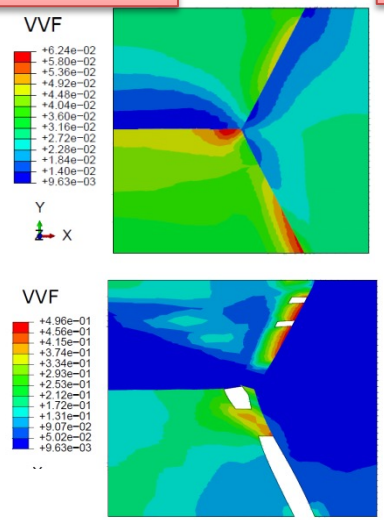
Modeled anomalous size effects

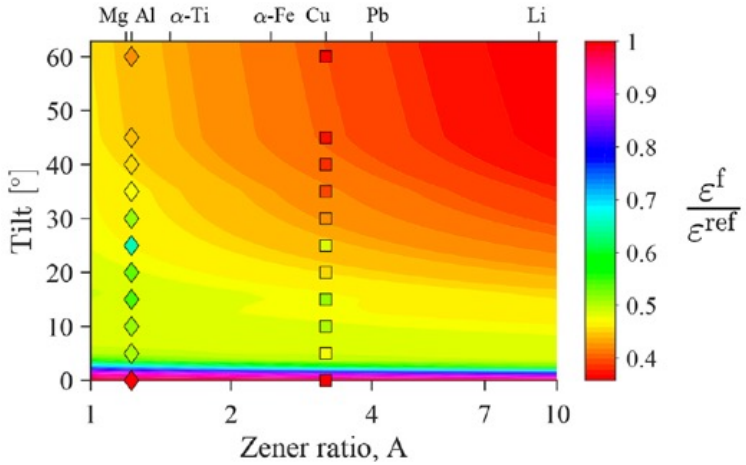


Wilkerson & Ramesh, PRL (2016); Mallick, Williams, Wilkerson, JDMB (2020); Mallick, Parker, Wilkerson, Ramesh, JDBM (2020); Williams, Mallick, Wilkerson, JDBM (2020).

Modeled effect of GB misorientation

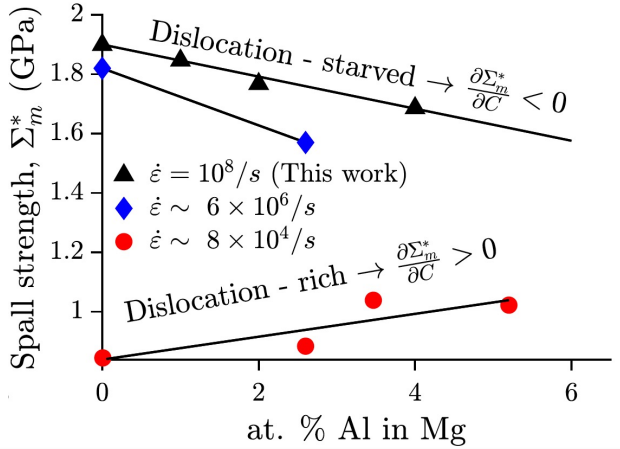




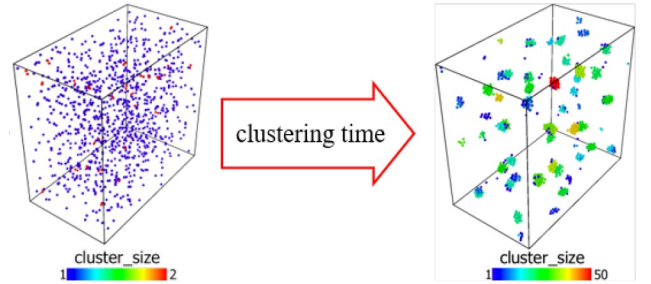


Nguyen, Luscher, Wilkerson, JMPS (2017, 2020, 2021); Acta Mat (2020).

Modeled deleterious effect of point defects



Nitol, Adibi, Barrett, & Wilkerson, MOM (2020).



Mg with vacancies

Final microstructure a function of
- Temperature
- Clustering time

Adibi & Wilkerson, EML (2021); JAP (2020).

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Arts et Métiers

Texas A&M Engineering Experiment Station

Arts et Métiers Institute of Technology

Synergetic Research Initiation Workshop Discussions

TEXAS A&M UNIVERSITY Engineering

AM² Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Texas A&M Engineering Experiment Station

Arts et Métiers Institute of Technology

Synergetic Research Initiation Workshop
Closing and next steps

TEXAS A&M UNIVERSITY Engineering

AM2 Transatlantic Partnership FOR INDUSTRY OF THE FUTURE

Texas A&M Engineering Experiment Station

Thank you - Merci

Arts et Métiers Institute of Technology

AM²
Transatlantic Partnership
FOR INDUSTRY OF THE FUTURE