FACULTY OF ENGINEERING AND ARCHITECTURE

FINITE ELEMENT MODELLING RESEARCH GROUP (FEMRG)

Laboratory Soete, Faculty of Engineering and Architecture, Ghent University

http://www.finiteelementresearch.ugent.be/

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FACULTY OF ENGINEERING AND ARCHITECTURE

Staff

Head of Research Group: Prof. dr. ir. Magd Abdel Wahab

Current Researchers: Dr. Yong Ling, Dr. Sutao Han, Chao Li, Nguyen Ngoc Lan, Muhammad Imran, Can Wang, Hussein Zahran, Kaifa Fan, Acar Kocabicak, Yanan Zhang, Jianfu Bai, Gaofang Wang, Usama Hamid, Mingpo Zheng, Zhikun Zhou, Yingjian Guo, Zhiyuan Xue, QiQi Xiao, Jianxin Liu, Dewen Zhou, Bilal Ahmed

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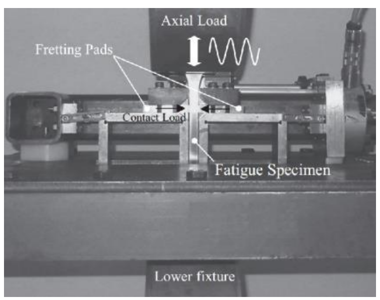
Numerical Modeling Of Fretting Fatigue In Heterogeneity Material

Keywords: fretting fatigue, heterogeneity, critical plane method, finite element method

Promoter: Prof. Magd Abdel Wahab

Student: Can Wang



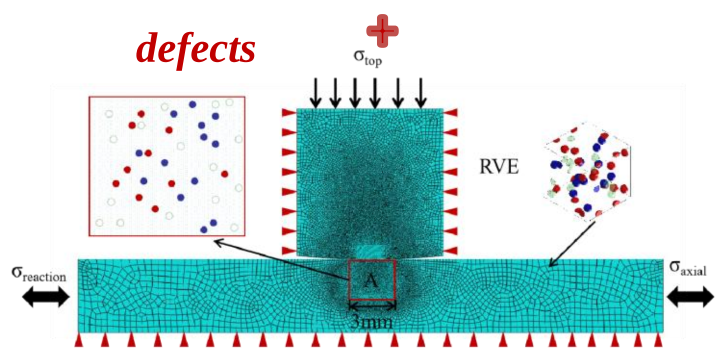
Sketch of Fretting Fatigue Experiment Setup

$$FP = \frac{\Delta\tau_{max}}{2} + k_1\sigma_n^{max}$$

$$FP = \tau_f^{'}\ (2N_i)^b$$

$$FS = \frac{\Delta\gamma_{max}}{2}\left(1 + k_2\frac{\sigma_n^{max}}{\sigma_y}\right) = \frac{\tau_f^{'}}{G}(2N_i)^{b^{'}} + \gamma_f^{'}\ (2N_i)^{c^{'}}$$

Critical Plane Method



***N_i* - Crack initiation lifetime**

$N_{i\text{-numerical}}$

?

$N_{i\text{-experimental}}$

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Numerical Simulation of Fretting Fatigue Behaviours of Titanium Alloy Treated by Ultrasonic Surface Rolling Process

Keywords: fretting fatigue, ultrasonic surface rolling, compressive residual stress, finite element Method

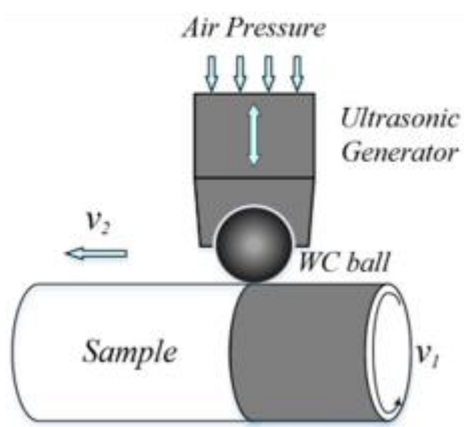
Promoter: Prof. Magd Abdel Wahab

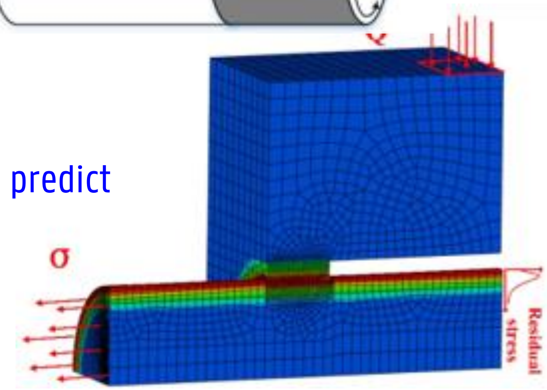
Student: Kaifa Fan

Objectives: USRP can introduce compressive residual stress (CRS), surface hardening, grain refinement to the surface of titanium alloy, which are beneficial to improve the fretting fatigue (FF) resistance.

Methods: Finite element methods are effective in predicting the FF life combined with critical plane model (CP) or continuum damage model (CDM).

Task: Investigate the effect of USRP on FF behaviors and predict the FF life under various working conditions.





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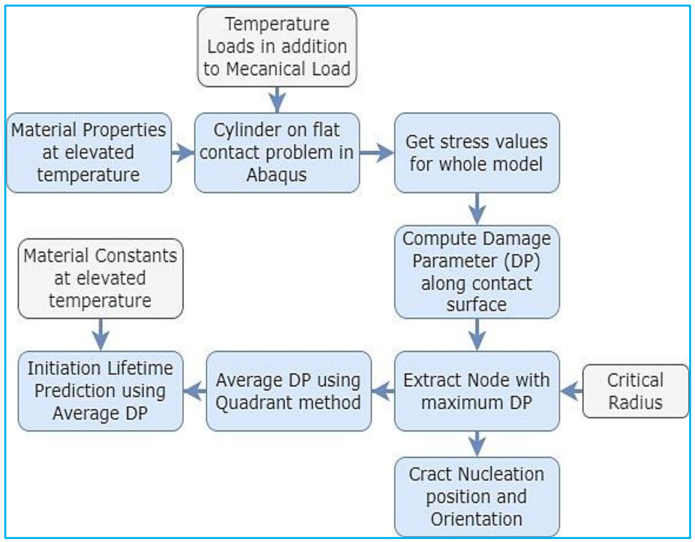
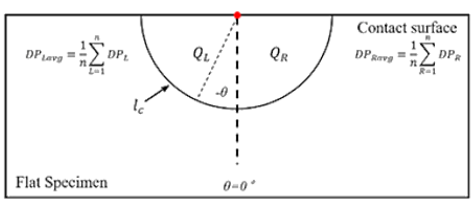
Numerical Modeling of Fretting Fatigue Behavior at Elevated Temperatures

Keywords: fretting fatigue, elevated temperatures, crack nucleation, critical plane

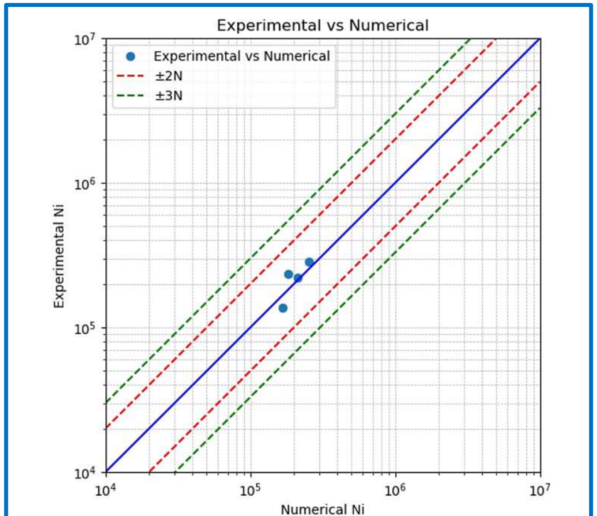
Promoter: Prof. Magd Abdel Wahab

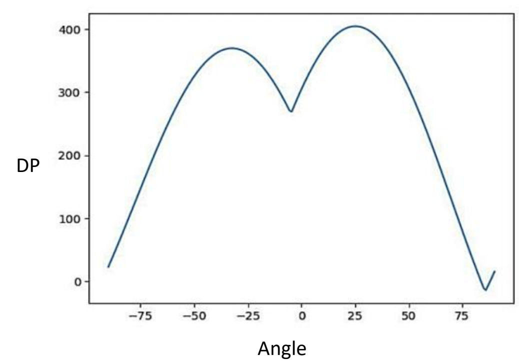
Student: Bilal Ahmed



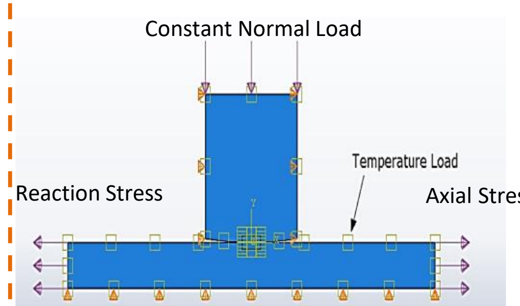


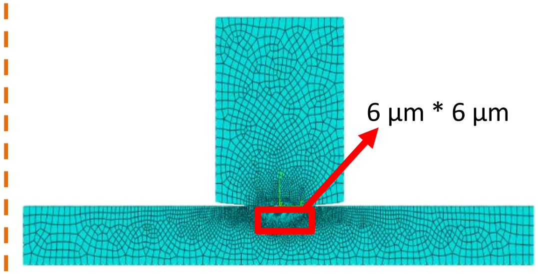
Quadrant Averaging Method





Fretting Fatigue Numerical Setup





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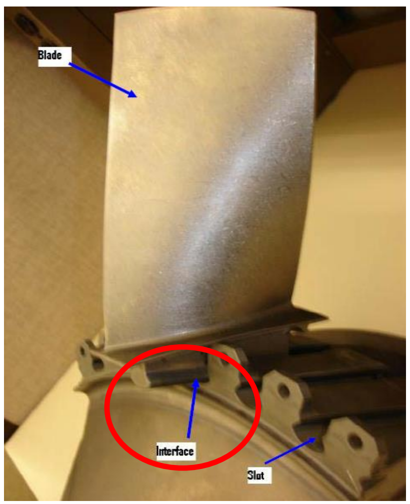
Finite Element Analysis Of Fretting Fatigue In Dovetail Joints

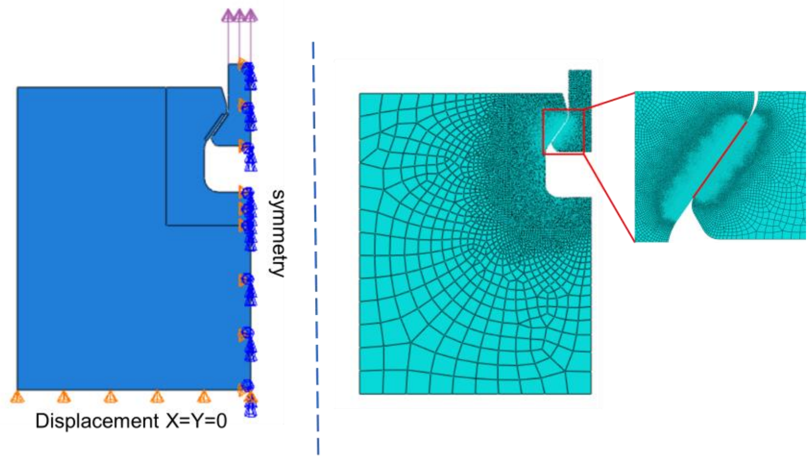
Keywords: fretting fatigue; dovetail joints; critical plane method; crack initiation

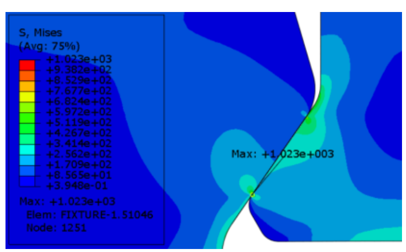
Promoter: Prof. Magd Abdel Wahab

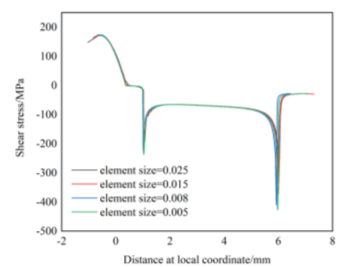
Student: Qiqi Xiao



Stress Analysis







Fatigue Analysis

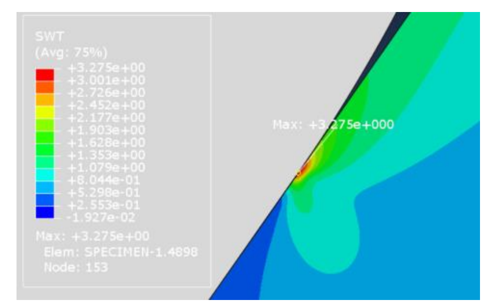
$$\sigma_n = \frac{\sigma_x+\sigma_y}{2} + \frac{\sigma_x-\sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau = -\frac{\sigma_x-\sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$$

$$\varepsilon_n = \frac{\varepsilon_x+\varepsilon_y}{2} + \frac{\varepsilon_x-\varepsilon_y}{2}\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

$$\gamma = -\frac{\varepsilon_x-\varepsilon_y}{2}\sin 2\theta + \frac{\gamma_{xy}}{2}\cos 2\theta$$

$$\sigma_n^{max}\frac{\Delta\varepsilon_n}{2} = \frac{\sigma_f'^2}{E}(2N_i)^{2b} + \sigma_f'\varepsilon_f'(2N_i)^{b+c}$$



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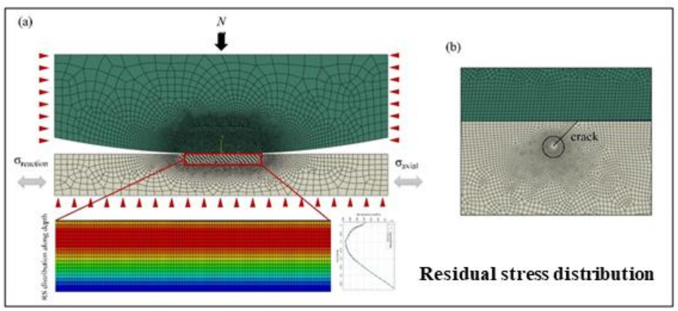
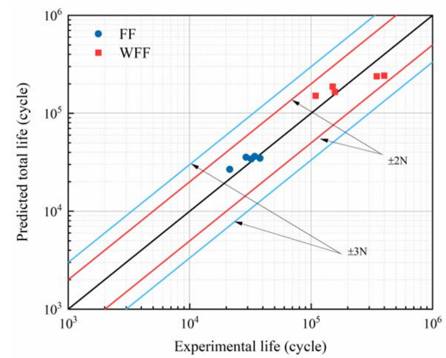
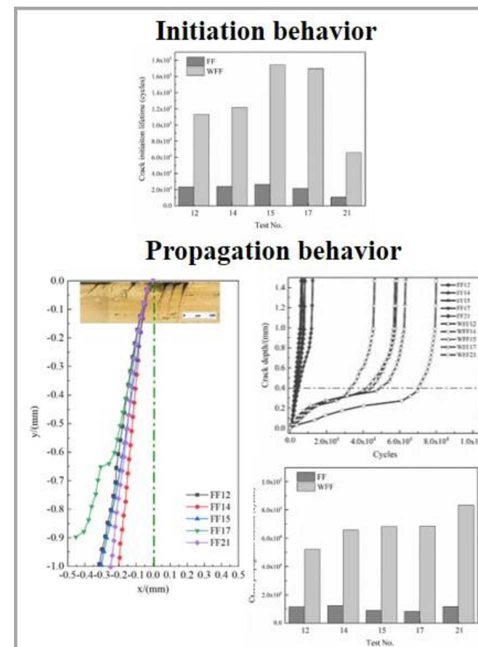
Effect Of Shot-peening On Fretting Fatigue Behavior

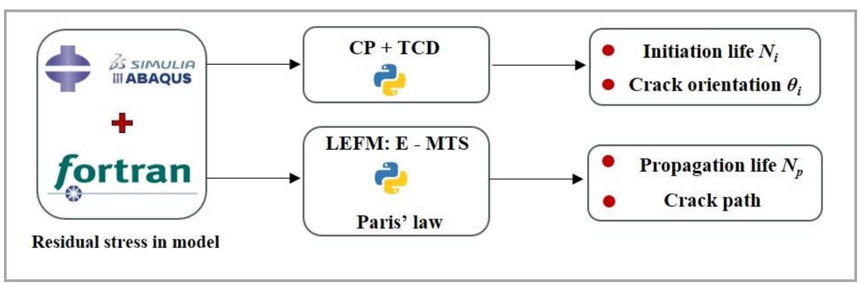
Keywords: fretting fatigue, crack initiation, crack propagation, shot-peening

Promotors: Prof Magd Abdel Wahab
Student: Can Wang







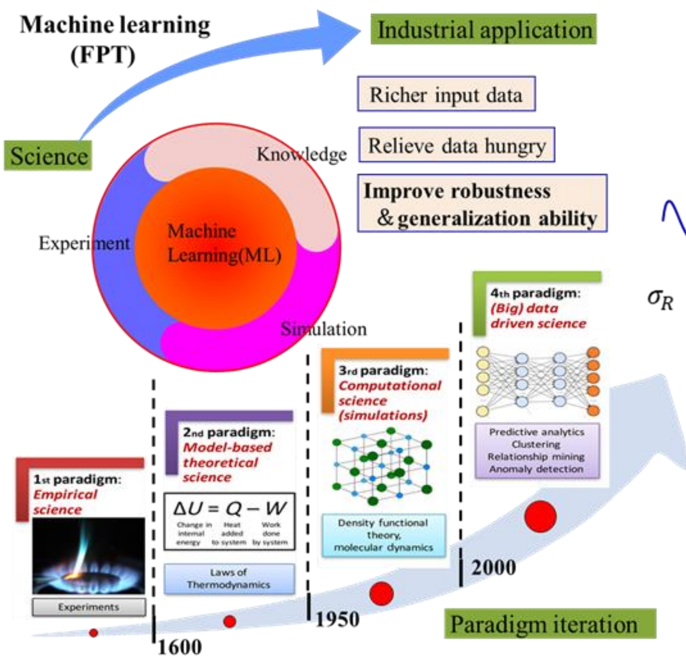


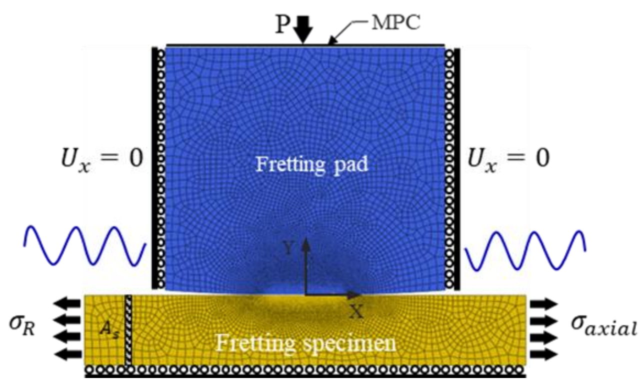
Investigate the fretting fatigue behavior combing with numerical modeling and deep learning

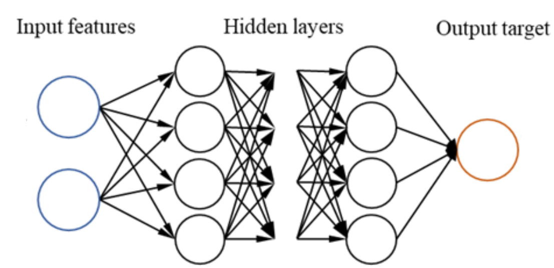
Keywords: fretting fatigue, deep learning, finite element model

Promoter: Prof. Magd Abdel Wahab

Post-doc: Sutao Han







Fretting fatigue behavior ?

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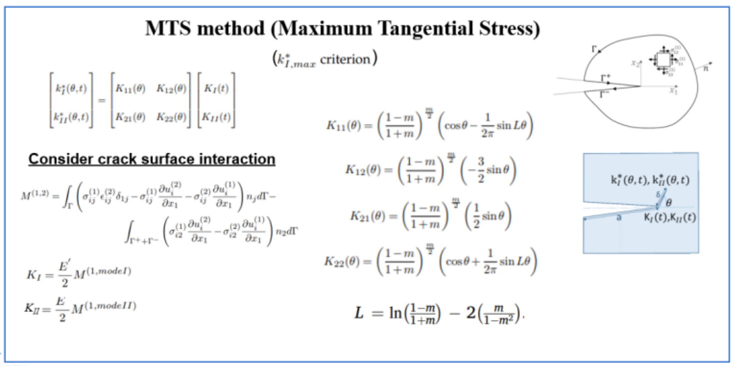
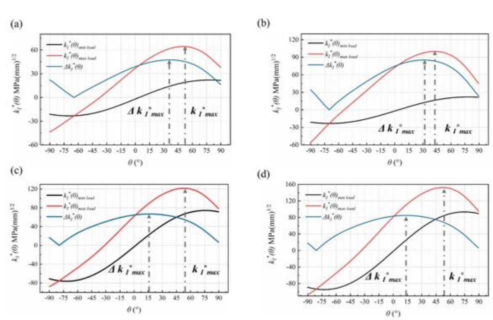
Fretting Fatigue Crack Propagation Analysis Under Non-Proportional Loading

Keywords: fretting fatigue, crack propagation, Linear elastic fracture mechanics, MTS

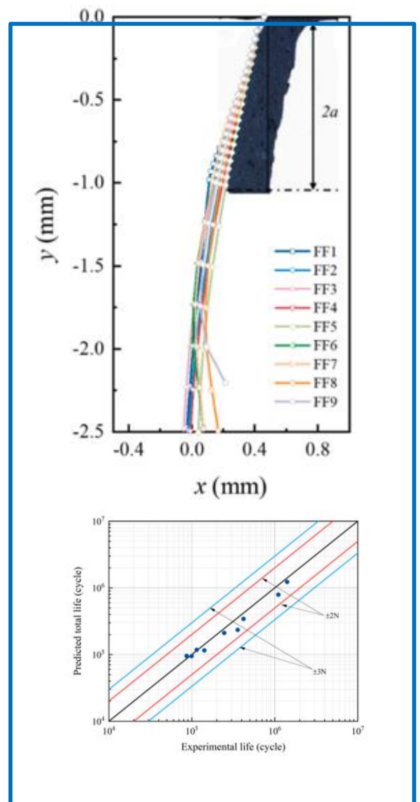
Promoter: Prof. Magd Abdel Wahab

Student: Can Wang

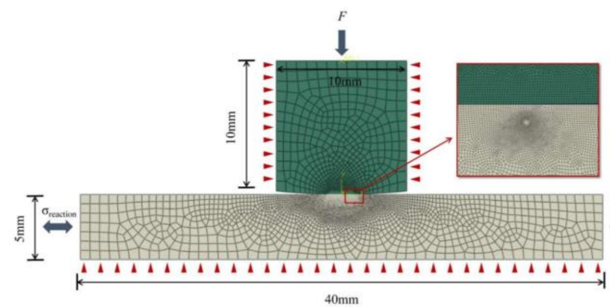


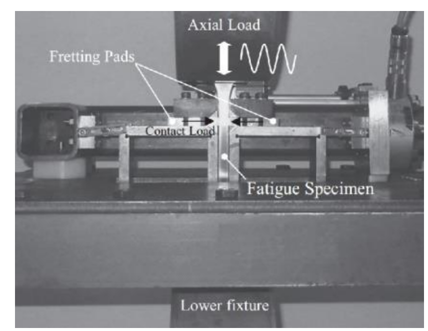


Predicted angle for crack propagation increments of test FF1: (a) on-set of crack propagation, (b) the 5th crack propagation increment, (c) the 10th crack propagation increment and (d) the 15th crack propagation increment.



Fretting Fatigue Experiment Setup and Model





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Finite Element Study Of Fretting Wear Of Steel Wires

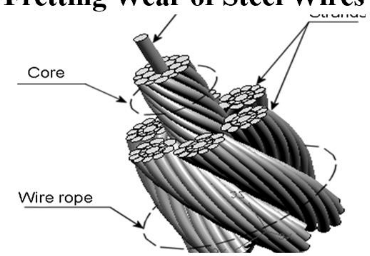
Keywords: fretting wear, wires, FEM

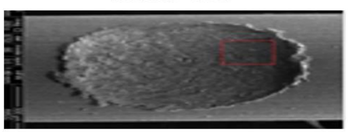
Promoter: Prof. Magd Abdel Wahab

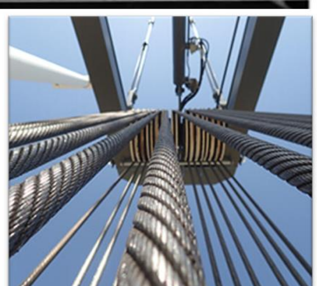
Student: Muhammad Imran

Objective

Fretting Wear of Steel Wires

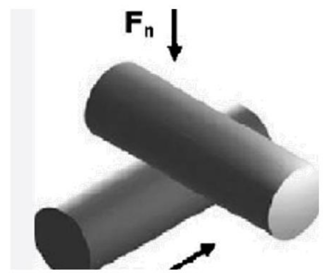


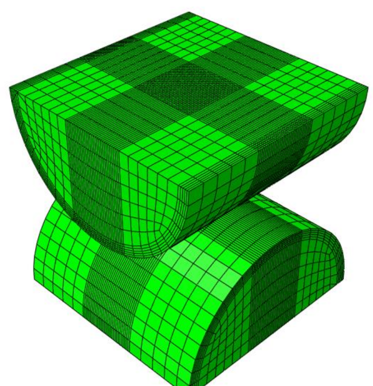




Applications

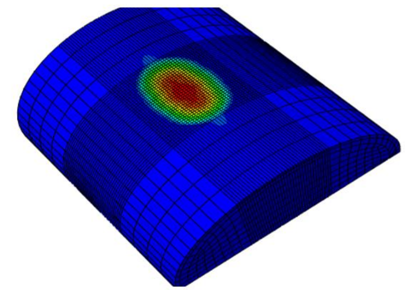
Methods

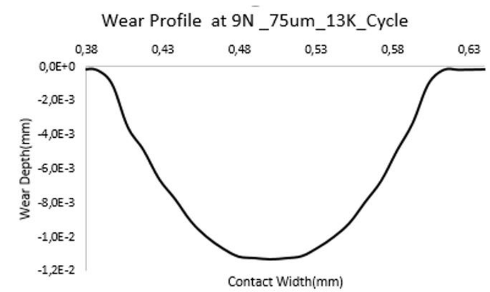




Numerical Modeling

Tasks





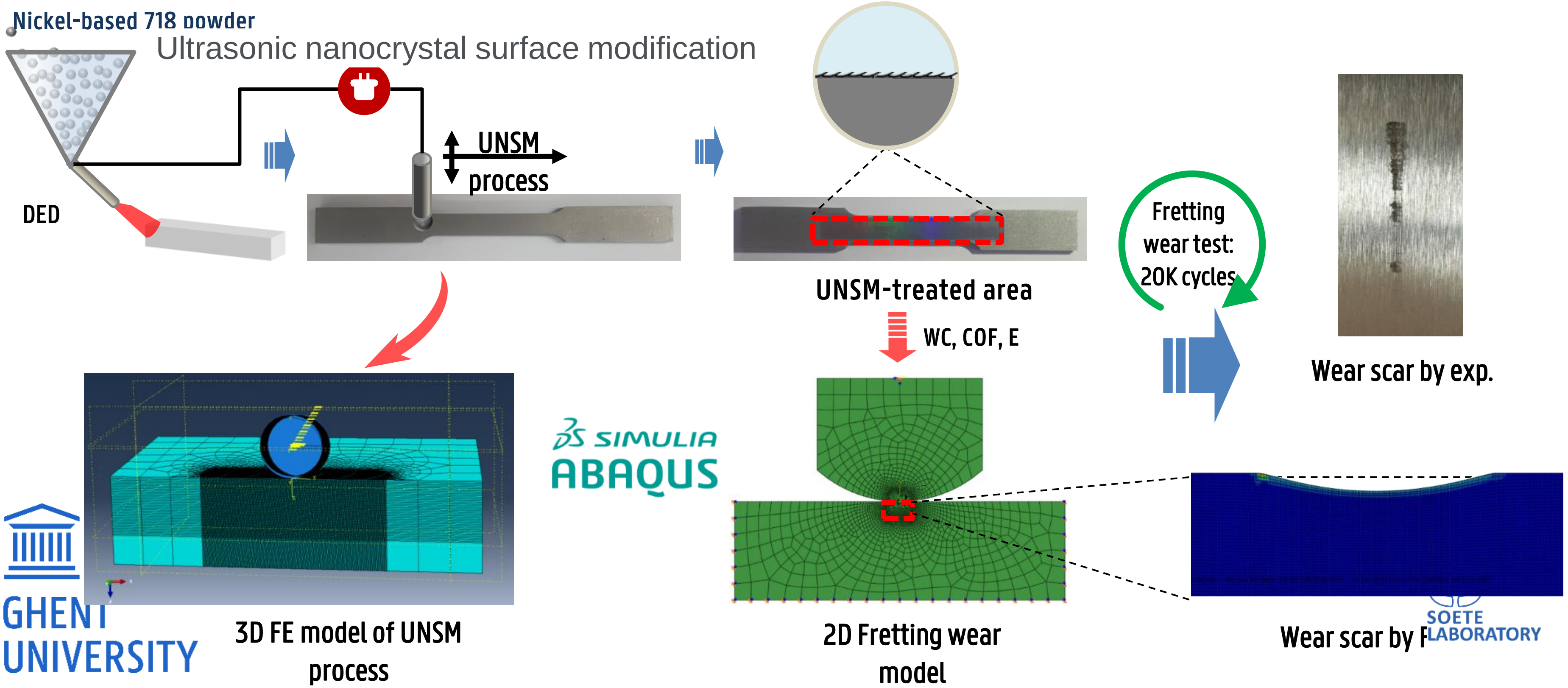
Parametric study to characterize fretting wear characteristics of steel wires

Finite Element Study Of Fretting Wear Properties Between UNSM-treated And As-printed Alloy 718

Keywords: UNSM process, FEM, fretting wear

Promoter: Prof. Magd Abdel Wahab

Student: Chao Li

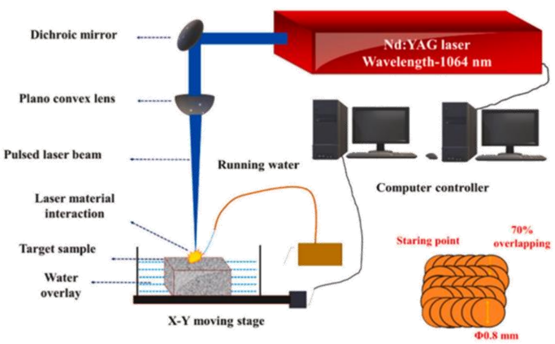


Finite Element Analysis Of The Influence Of Residual Stress Distribution On Fretting Wear

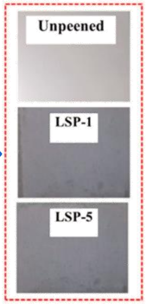
Keywords: fretting wear, finite element method (FEM), residual stress

Promotors: Professor Magd Abdel Wahab

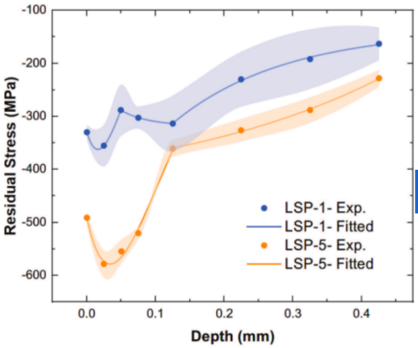
Student: Chao Li



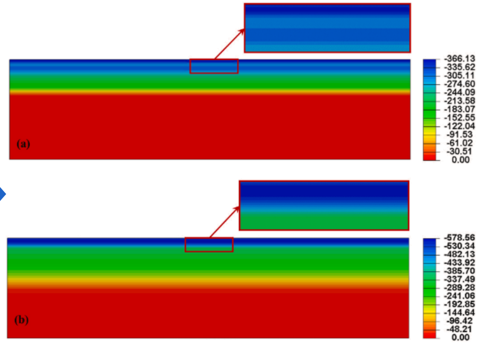
Laser shock peening (LSP)

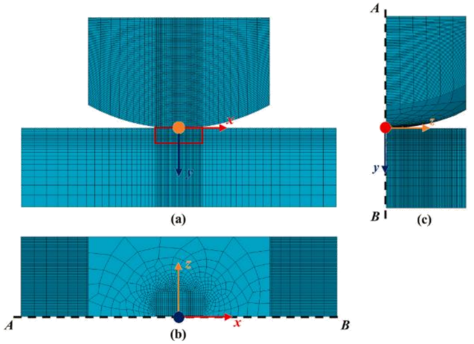


LSP-treated specimens



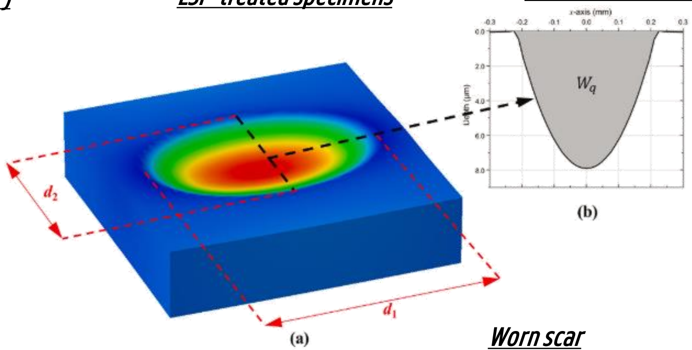
Residual stress induced by LSP





Fretting wear model with RS

Fretting wear process



Worn scar

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Effect Of Corrosion And Fretting On Wear Morphology And Mechanical Behavior Of Wire

Keywords: corrosion, fretting wear, wire

Promotors: Prof. Magd Abdel Wahab

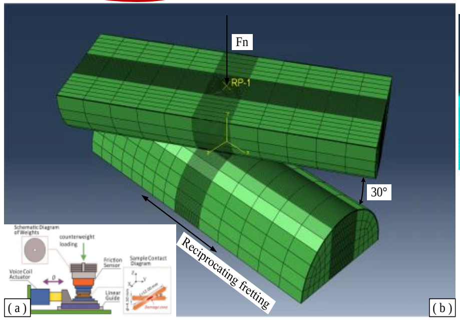
Student: Gaofang Wang

- Indicate tasks
- The influence of corrosion time (T) and the number of fretting cycles on steel wire wear was studied.
- The tribological properties of steel wire surface under different corrosion T values were evaluated by comparing the fretting wear simulation results and test results
- The surface mechanical properties of wire after fretting wear damage were analyzed.

- Indicate objectives

FIG. 1 Schematic diagram of cross-reciprocating fretting wear of steel wire (a) test diagram; (b) Simulation 3D modeling diagram

- Indicate method



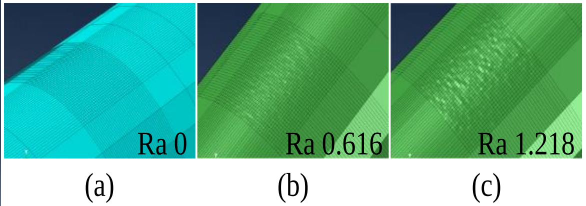


FIG. 2 Modeling diagram of steel wire surface under different corrosion time: (a) Corrosion time 0h; (b) Corrosion time 120h; (c) Corrosion time 480h

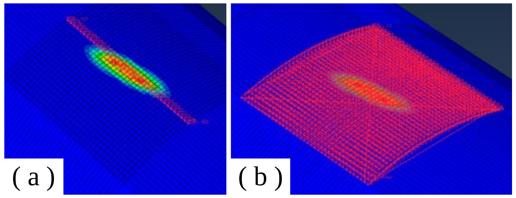


FIG. 3 Wear characteristics (a) and wear volume (b) extraction path

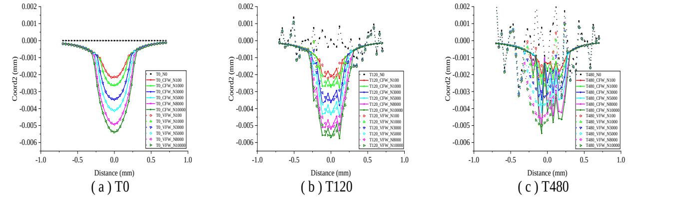


FIG. 4 Surface wear profile curve of steel wire under different corrosion time: (a) corrosion time is 0; (b) Corrosion time is 120h; (c) Corrosion time is 480h

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Experimental investigation and constitutive material modelling of low cycle fatigue of EUROFER97 for fusion applications

Keywords: asymmetric cyclic loading, fusion materials, Chaboche viscoplasticity model, strain memory effect

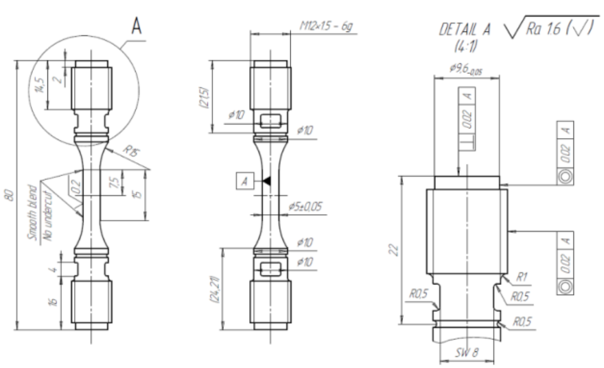
Promoter: Prof. Magd Abdel Wahab

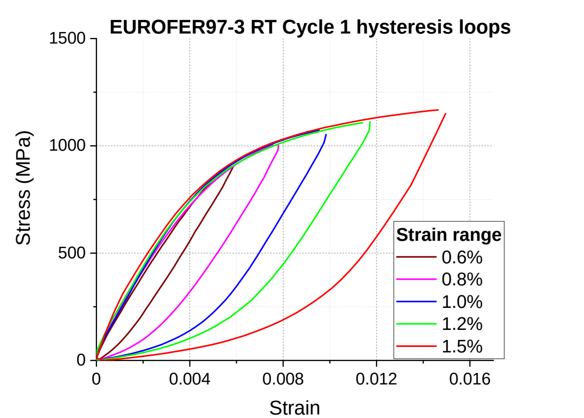
Student: Hussein Zahran

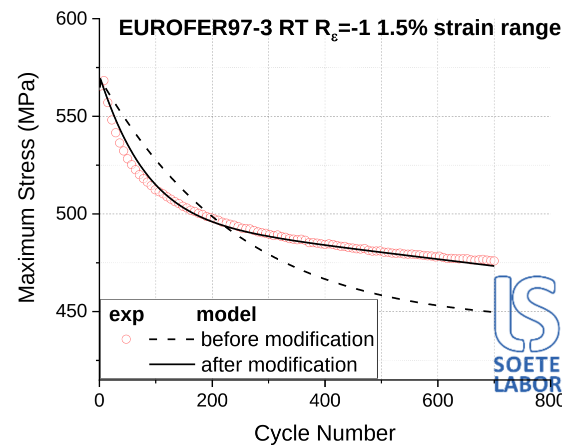
Objective
- Model the behaviour of EUROFER97-3 under LCF

Method
- Chaboche viscoplasticity model with strain memory effect

Tasks
- Conduct LCF experiments on EUROFER97-3 at RT and 350 °C
- Modify Chaboche viscoplasticity model to account for different strain ranges
- Verify model with experimental results







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Prediction of low cycle fatigue life for neutron-irradiated and nonirradiated RAFM steels using their tensile properties

Keywords: EUROFER97, F82H, JLF-1, ARAA, In-RAFM, CLAM, Universal slope equation, ANOVA

Promoter: Prof. Magd Abdel Wahab

Student: Hussein Zahran

Objective

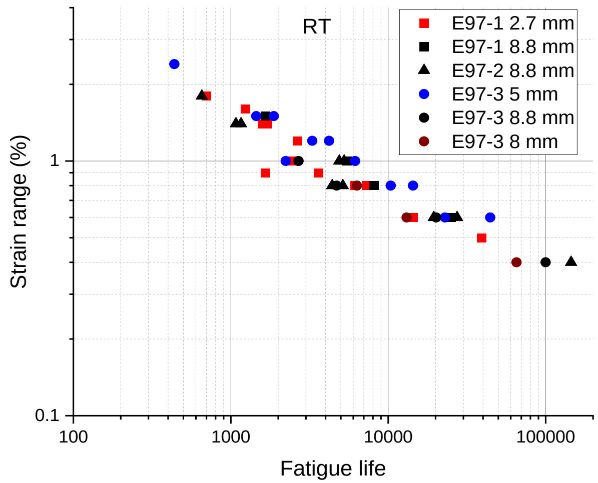
- propose a prediction of fatigue life of irradiated RAFM steels including EUROFER97 at irradiation conditions for which the LCF tests have not been done yet

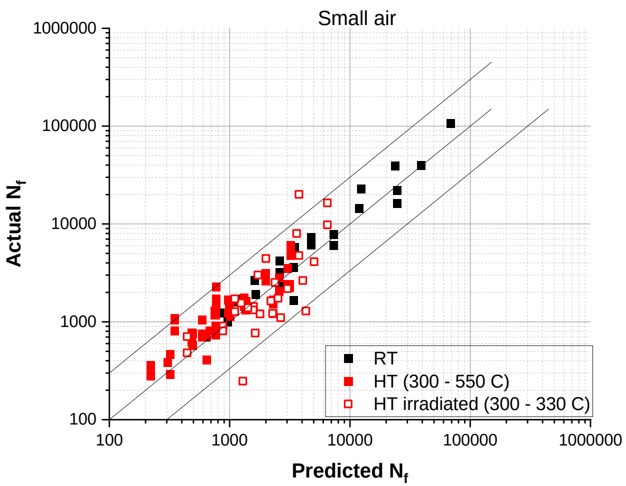
Method

- Calculating Manson-Coffin-Basquin equation parameters using tensile data

Tasks

- Gather LCF database from literature
- Find the best method to calculate the equation parameters
- Apply scaling factors to account for the effect of specimen size and test medium





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Simulation Of Mechanical Behavior Of Nuclear Materials In Irradiated Environment

Keywords: viscoplasticity, crystal plasticity, irradiation, nuclear materials, low cycle fatigue

Promoter: Prof. Magd Abdel Wahab

Student: Jianxin Liu

I. Unified viscoplastic model

$$\varepsilon_{ij}^{total} = \varepsilon_{ij}^{e} + \varepsilon_{ij}^{p}$$

$$\varepsilon^{e} = \mathbf{D}^{-1} : \boldsymbol{\sigma}$$

$$\dot{\varepsilon}^{p} = \sqrt{\frac{3}{2}}\dot{p}\frac{s-\beta}{\|s-\beta\|}$$

$$\dot{p} = \langle \frac{f_y}{Z} \rangle^{n}$$

$$f_y = \sqrt{\frac{3}{2}(s-\beta):(s-\beta)} - R - \sigma_{y0}$$

Non-linear Kinematic Hardening Equation

$$\dot{\beta}_1 = \xi_1\left(\frac{2}{3}\gamma_1\dot{\varepsilon}^{p} - \beta_1\dot{p}\right)$$

$$\dot{\beta}_2 = \xi_2\left[\frac{2}{3}\gamma_2\dot{\varepsilon}^{p} - \mu(p)\beta_2\dot{p}\right] - \tau(p)\left[\sqrt{\frac{3}{2}(\beta_2):(\beta_2)}\right]^{m-1}\beta_2$$

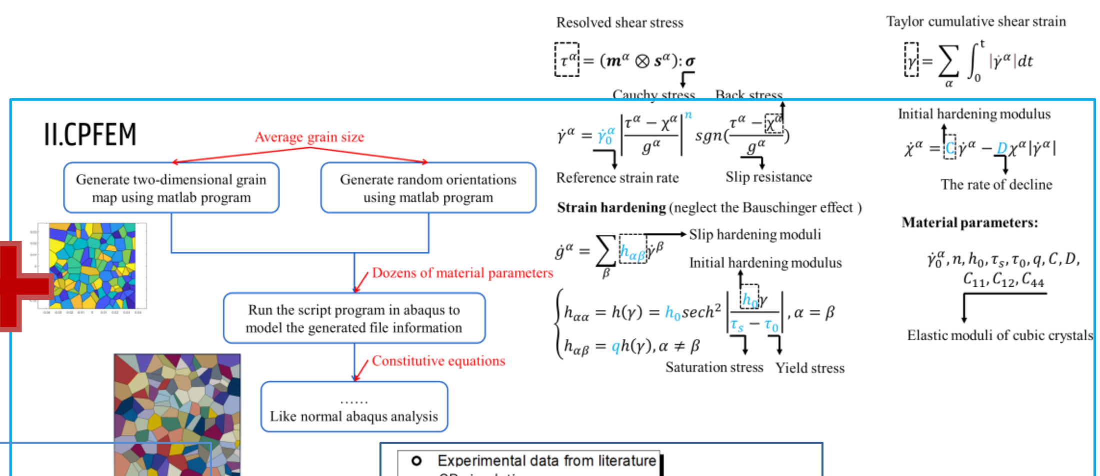
$$\mu(p) = 1 + \lambda(1 - e^{-\delta p}) \qquad \tau(p) = \tau_0[\phi + (1-\phi)e^{-\omega p}]$$

Isotropic Hardening Equation

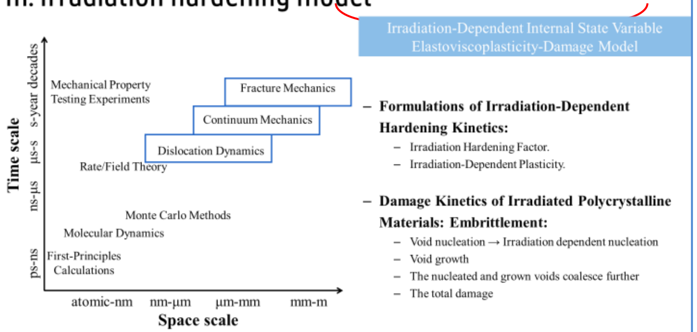
$$\dot{R} = b(Q(T) - R)\dot{p}$$

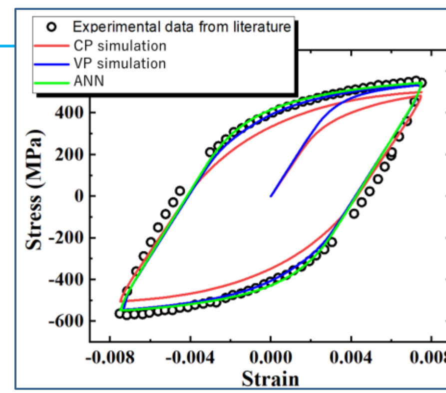
$$Q(T) = A\left[1 + B(1 - e^{-CT})\right]$$

II.CPFEM



III. Irradiation hardening model





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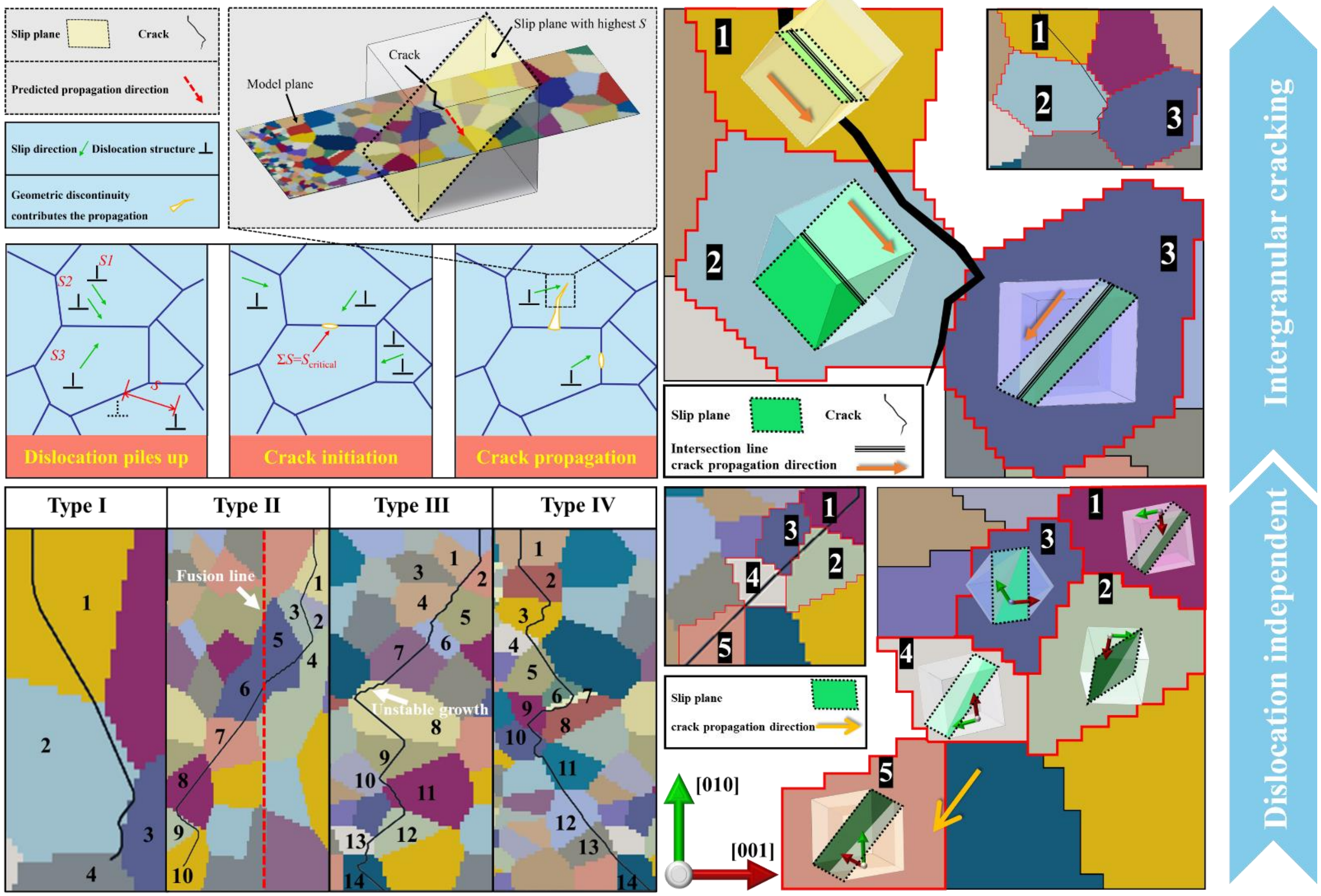
Microstructural Fatigue Crack Propagation Analysis

Keywords: crystal plasticity, crack propagation, extended finite element, MTS

Promoter: Prof. Magd Abdel Wahab/ Prof. Xiaowei Wang/ Prof. Jianming Gong

Student: Dewen Zhou

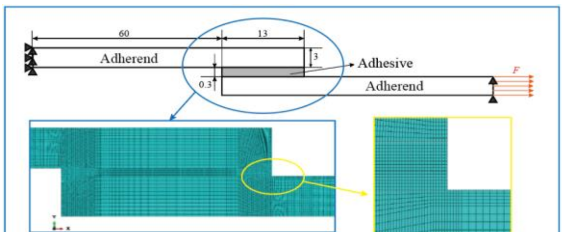


Finite element ANALYSIS OF functionally graded adhesive joint

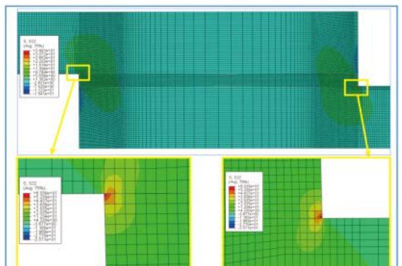
Keywords: adhesive bonding, single lap joint , FEM, functionally graded adhesive joints

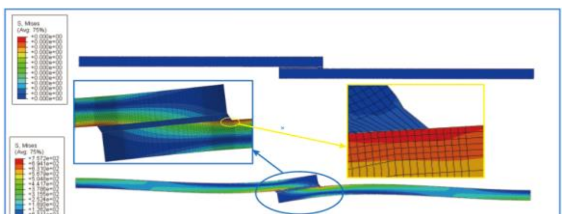
Promotors: Prof Magd Abdel Wahab

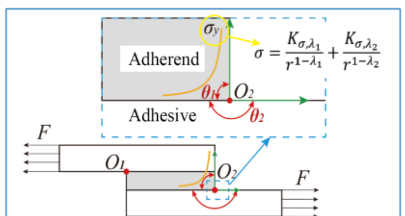
Student: Yanan Zhang



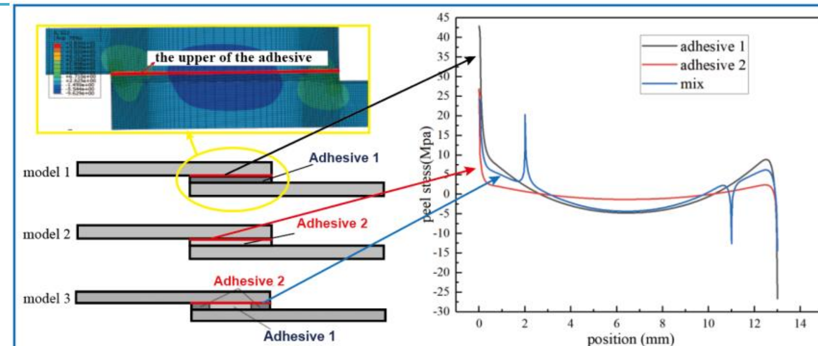
Single Lap Joint Model


the peel stress distributions of single lap joint

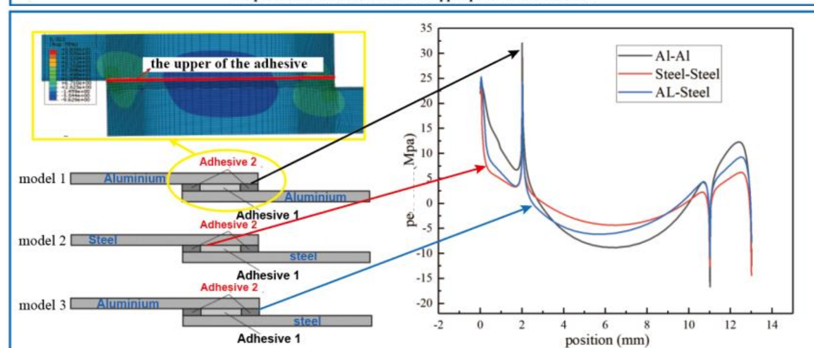

The deformation of single lap joint under tensile load



the stress singularity at the end of the overlap



the peel stress distributions in the upper plane of the adhesive



the peel stress distributions in bondings used different adherends

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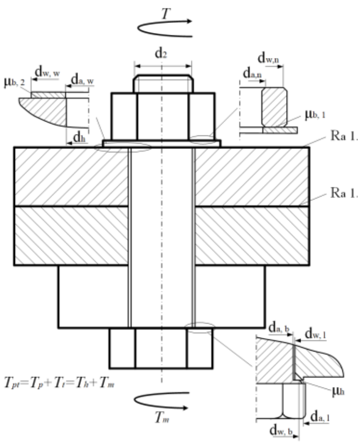
Degradation And Failure Analysis Of Bolted Joints

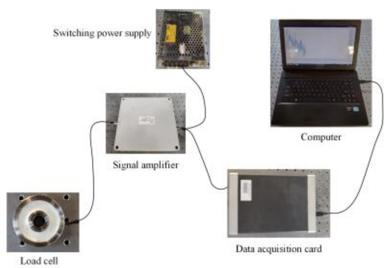
Keywords: tightening process; Initial loss; Force-displacement curve; Evolution of dynamic performance

Promoter: Prof. Magd Abdel Wahab

Student: Mingpo Zheng

Evaluation on friction coefficient of threaded fastener





$$\vec{\mu}_t = \left(\frac{\vec{T}_m}{\vec{F}} + \mu_h r_h - \frac{p}{2\pi}\right)\frac{\cos\beta}{r_t}$$

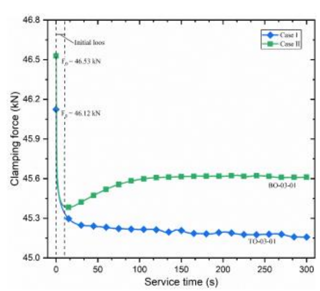
$$\vec{\mu}_b = \left(\frac{\vec{T}-\vec{T}_m}{\vec{F}} - \mu_h r_h\right)\frac{1}{r_b}$$

⇩ tightening finished

$$F = \begin{cases} F_0 & ; t=0 \\ F_0 - F_i^l(t) & ; t \le t_0 \\ F_0 - F_i^l(t_0) - F_c^l(t) - F_s^l(t) & ; t > t_0 \end{cases}$$

$$F_c^l(t_s) = F(t_0) - F(t_s)$$

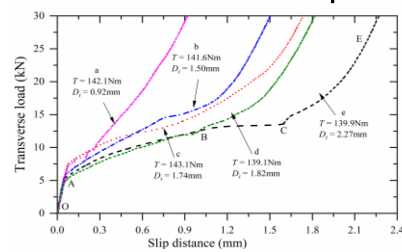
$$P_s = \frac{F_c^l(t_s)}{F_0}$$

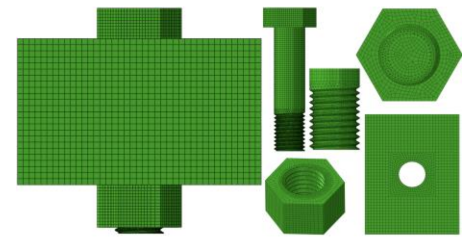


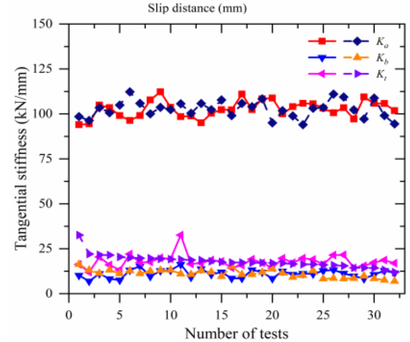
Initial loss stage (before service)

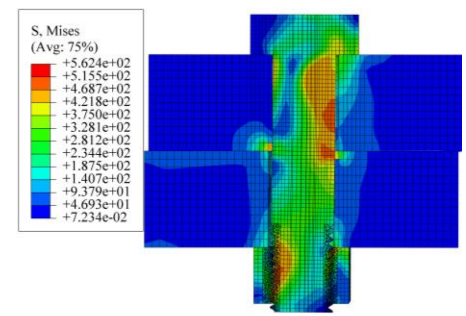
⇨ Service

Mechanical performance of bolted joint

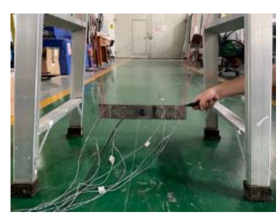


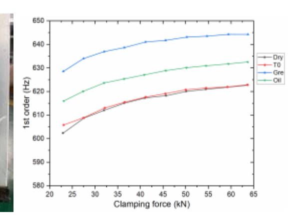


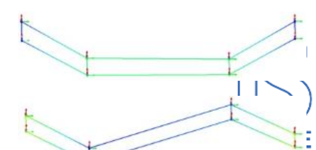




Frequency and mode shape of bolted joint







$$\omega_i = f(F(t)) = me^{pF(t)} + ne^{qF(t)}$$

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Development Of The Simulation Platform For WAAM Processing

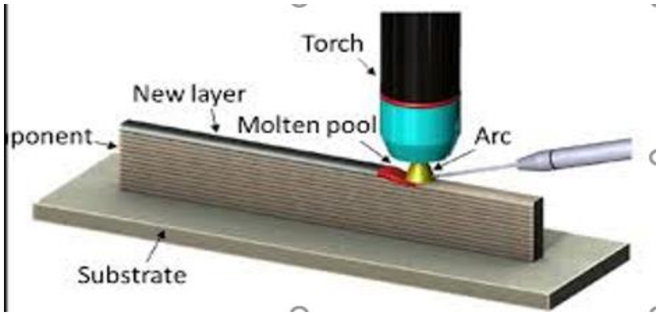
Keywords: simulation, WAAM, FEM

Promoter: Prof. Magd Abdel Wahab

Post-doc: Yong Ling

Objective:

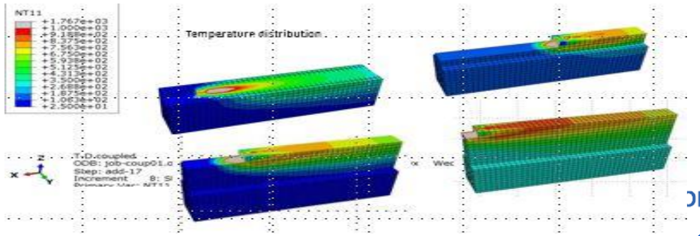
- Build the platform is for WAAM parameters inputs.
- Connect Abaqus, Matlab, Python and Fortran subroutines



Method: T-M-M FEA by Abaqus, Matlab and subroutines.

Tasks:

* develop the platform by using **.NET**.
* simulate WAAM process for the experiment part
* validate the thermo- mechanical modelling.



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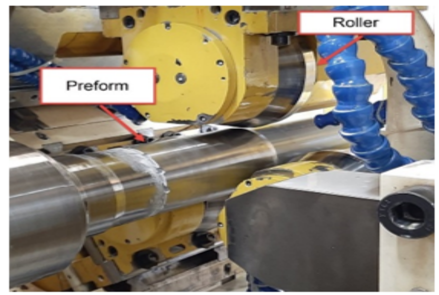
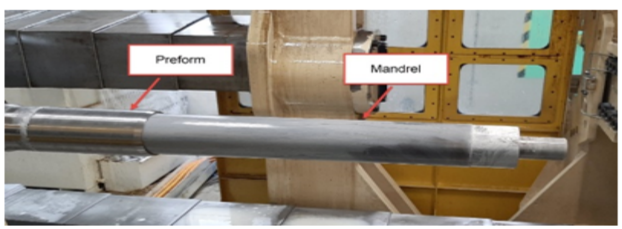
Experimental And Finite Element Analyses Of Backward Flow Forming Process Of AISI 5140 Steel

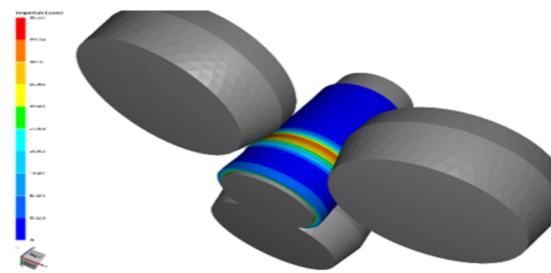
Keywords: flowforming, metal forming, FEA

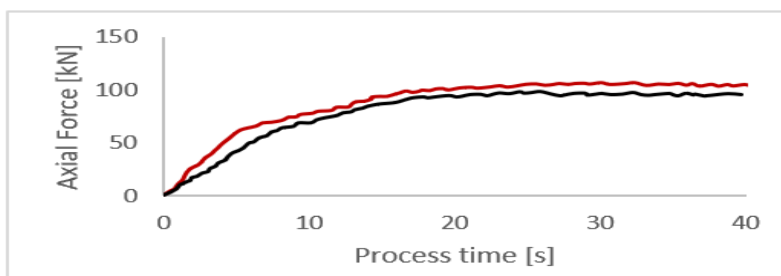
Promotor: Prof. Magd Abdel Wahab

Student: Acar Can. Kocabicak









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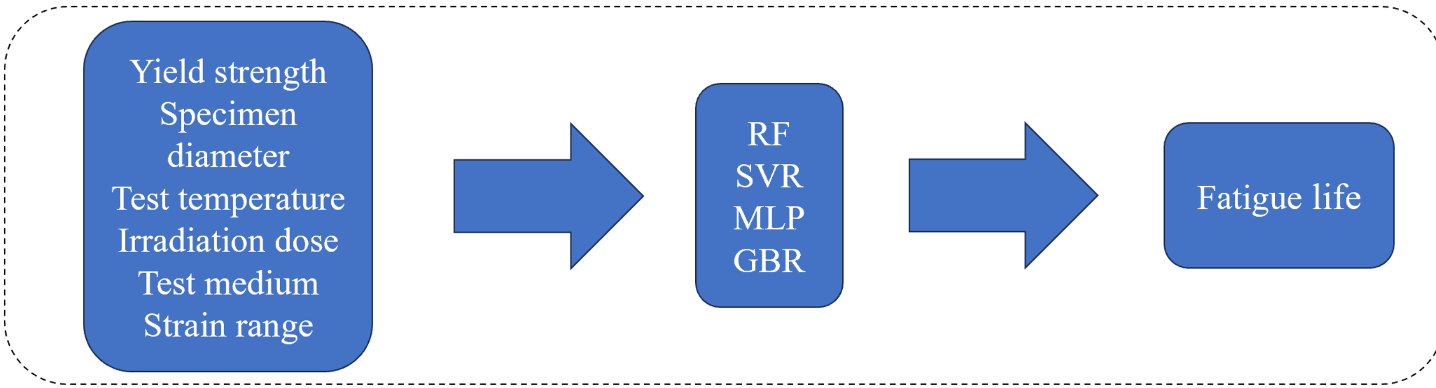
Predict the fatigue life of irradiated RAFM steels as candidates for structural materials in fusion reactors

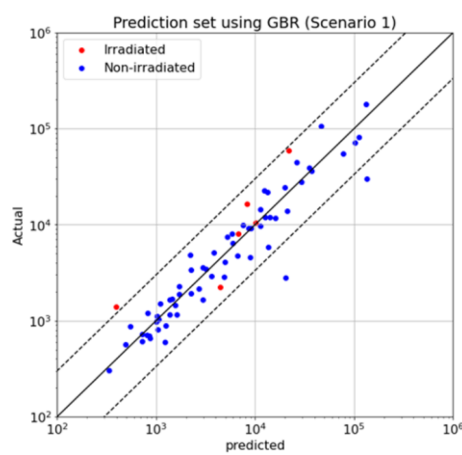
Keywords: fatigue, FEM, nuclear materials

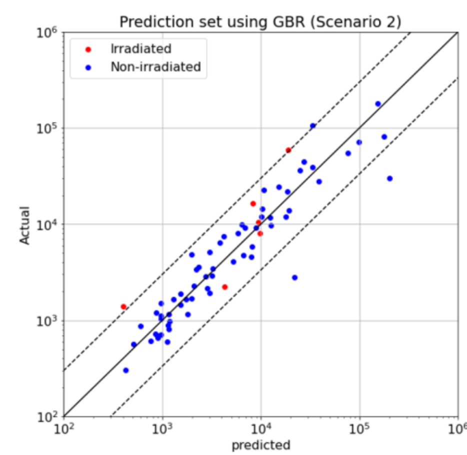
Promoter: Prof. Magd Abdel Wahab

Student: Hussein Zahran



Different ML models to predict fatigue life of RAFM steels





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Numerical and Deep Neural Network Method for Flowforming Process

Keywords: flowforming, metal forming, deep neural network

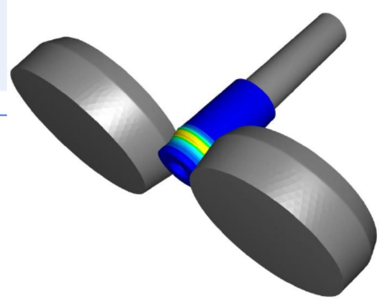
Promotor: Prof. Magd Abdel Wahab

Student: Acar Can. Kocabicak

Objective

Finite element analysis (FEA) and deep neural network (DNN) model to simulate flowforming with defining input parameters

✓Creating 3D Flowforming FE model



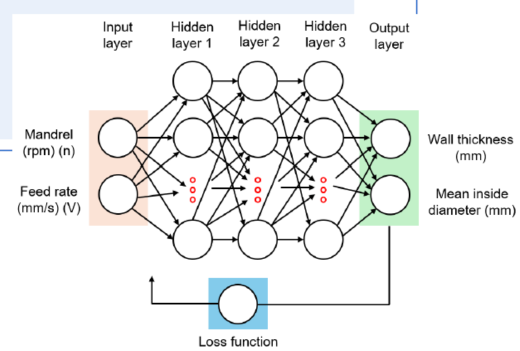
Method

FORGE NxT Finite Element Software

JMAT Pro software

DNN Model with Python coding

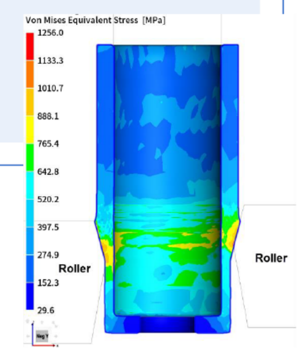
✓DNN Model



Task

Validating the FEA and DNN results with experimental results

✓Validation with experimental trials



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Numerical Simulation And Neural Network To Predict Cylindrical Cup Thickness In Deep Drawing Process

Keywords: deep drawing, finite element method, thinning

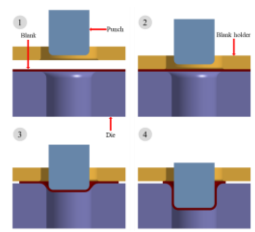
Promotors: Prof. Magd Abdel Wahab

Student: Yingjian Guo

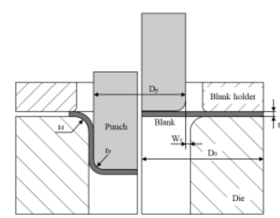
Objectives: This study aims to investigate the thickness distribution of cylindrical cups during the deep drawing process.

Methods: Finite element method and neural network are used to obtain the thickness distribution.

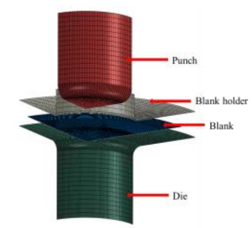
Tasks: Validate the accuracy of prediction methods, and explore the effects of punch radius, temperature and blank holder force on thickness.



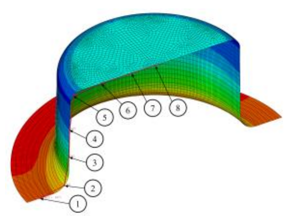
Deep drawing process



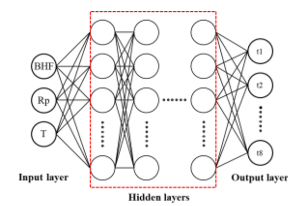
Geometry of deep drawing assembly



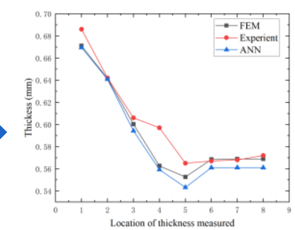
FE model



Thickness measurement locations for simulation results



Construction of the artificial neural network



Thickness comparison

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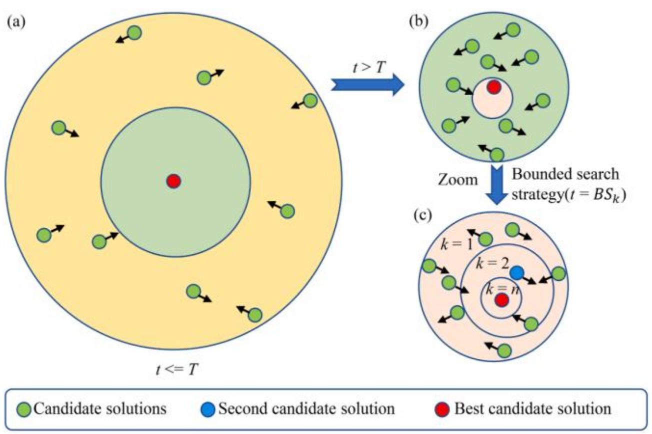
A Sinh Cosh Optimizer

Keywords: Meta-heuristic, Sinh Cosh Optimizer (SCHO), Engineering design problems

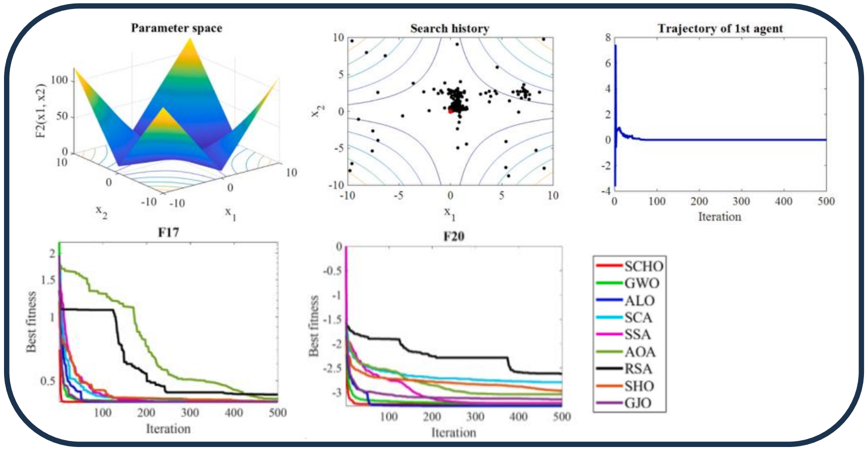
Promoter: Prof. Magd Abdel Wahab

Student: Jianfu Bai

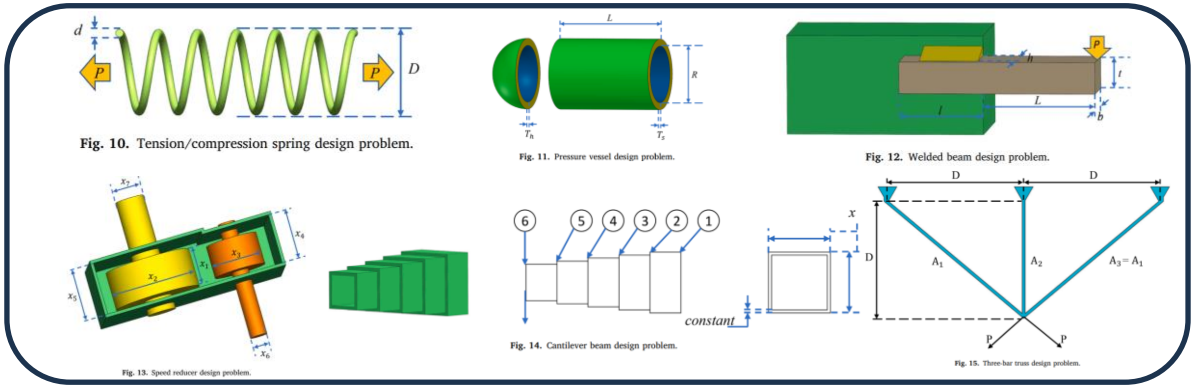


Sinh Cosh Optimizer

Numerical experiment



Engineering design



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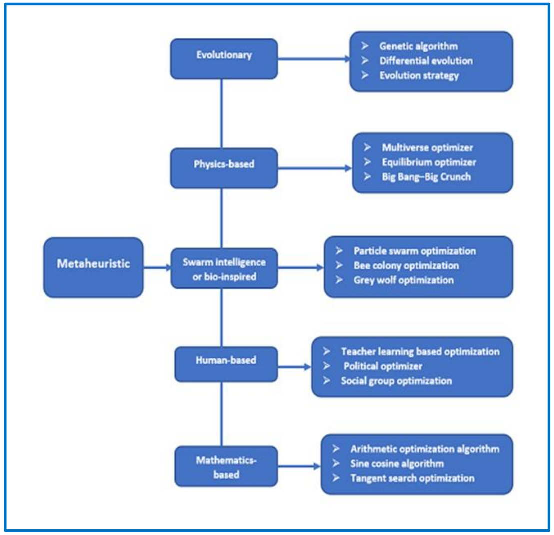
A Gradient Spiral Mathematical Optimization Algorithm (GSMOA)

Keywords: meta-heuristic; exploration; exploitation; spiral and gradient search; mathematics-based optimizer, structural design; speed reducer

Promoter: Prof. Magd Abdel Wahab

Student: Usama Hamid



Categories of meta-heuristic algorithms

Mathematical model of GSMOA

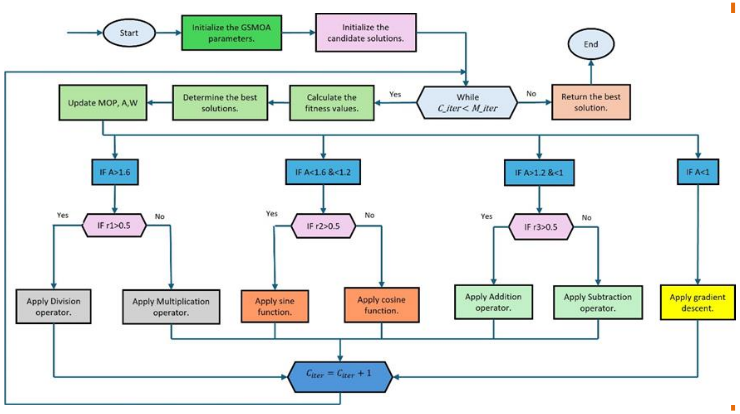
$$X_i^{t+1} = \begin{cases} X_i^t \times MOP \times (2 \times e^{0.5 r_5}) \times (UB - LB) \times \mu + LB, & r_1 > 0.5 \\ X_i^t \div MOP \times (2 \times e^{-r_5}) \times (UB - LB) \times \mu + LB, & otherwise \end{cases}$$

$$X_i^{t+1} = \begin{cases} X_i^t + W \times cos\Theta \times | X_i^{t+1} - X_i^t |, & r_2 > 0.5 \\ X_i^t - W \times sin\Theta \times | X_i^{t+1} - X_i^t |,, & otherwise \end{cases}$$

$$X_i^{t+1} = \begin{cases} X_i^t - MOP \times (UB - LB) \times \mu + LB, & r_3 > 0.5 \\ X_i^t + MOP \times (UB - LB) \times \mu + LB, & otherwise \end{cases}$$

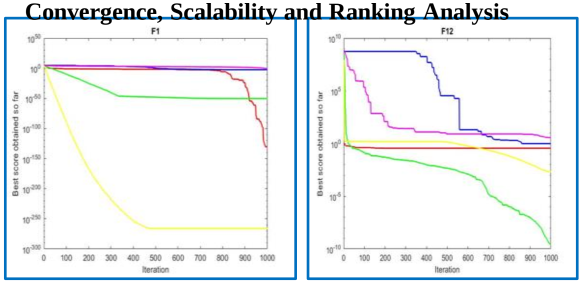
$$X_i^{t+1} = \begin{cases} X_i^t + W \times grad(F) \times | X_i^{t+1} - X_i^t |, & r_4 > 0.5 \\ X_i^t - W \times grad(F) \times | X_i^{t+1} - X_i^t |,, & otherwise \end{cases}$$

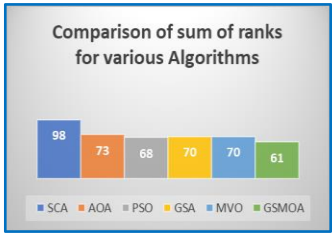
$$A = u \times \left(\frac{\gamma}{\beta} \times \frac{C_{iter}}{M_{iter}}\right) + r_8 \times e^{-\left(\frac{C_{iter}}{M_{iter}}\right)}$$



Flow chart of GSMOA

Convergence, Scalability and Ranking Analysis





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Damage Assessment in Laminated Composite Plates using Model Strain Energy and YUKI-ANN algorithm

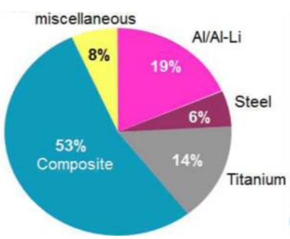
Keywords: artificial neural network, modal strain energy, yuki algorithm, damage in laminated composite plates

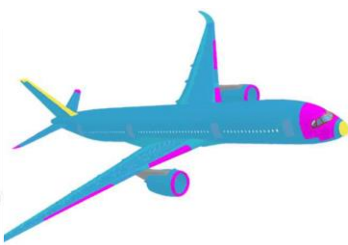
Promoter: Prof. Magd Abdel Wahab

Student: Irfan Shirazi

Composite plates are now widely used in aerospace, naval and military applications

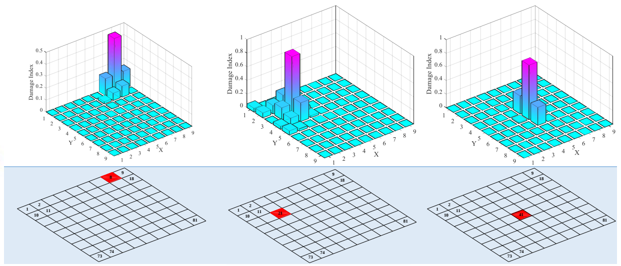
Structural health monitoring of these structures is crucial to detect presence and location of damage and compute damage severity



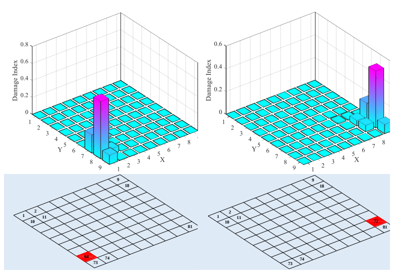


Source: Bachmann et al. Science China Technological Sciences. 60, 2017

Damage Location



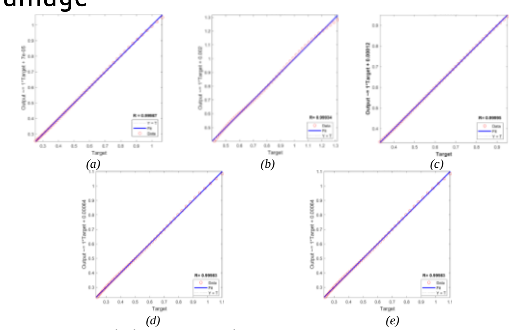
Scenario 1 *Scenario 2* *Scenario 3*



Scenario 4 *Scenario 5*

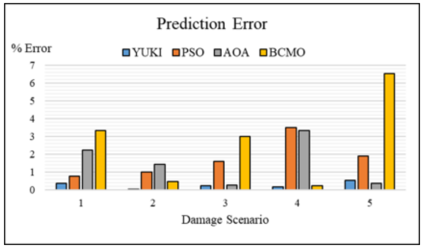
Identification of damage location for different damage scenarios using FEM-MSEcr.

Damage Quantification



Regression fits for YUKI algorithm for (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, (d) Scenario 4 and (e) Scenario 5

Damage indices for different optimization techniques compared with YUKI algorithm



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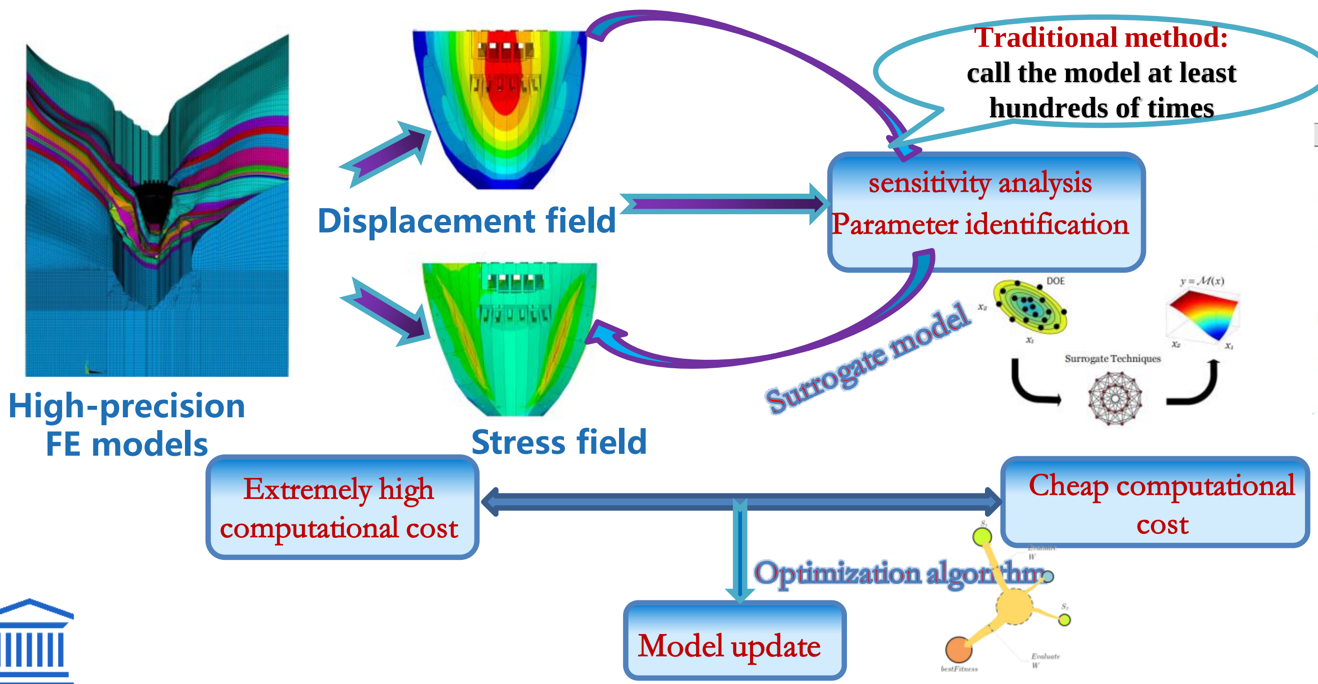
A Surrogate-assisted Stochastic Optimization Inversion Algorithm For Parameter Identification Of Dams

Keywords: Concrete dams, Surrogate model, Stochastic optimization algorithm, Model update

Promoter: Prof. Magd Abdel Wahab

Student: Yifei. Li



Surrogate modelling vs. machine learning [1]

Features	Supervised learning	Surrogate modelling
Computational model $\mathcal{M}$	✗	✔
Probabilistic model of the input $X \sim f_X$	✗	✔
Training data: $\mathcal{X} = \{(\boldsymbol{x}_i, y_i), i = 1, \ldots, n\}$	✔ Training data set (big data)	✔ Experimental design (small data)
Prediction goal: for a new $\boldsymbol{x} \notin \mathcal{X}$, $y(\boldsymbol{x})$?	$\sum_{i=1}^{m} y_i K(\boldsymbol{x}_i, \boldsymbol{x}) + b$	$\sum_{\boldsymbol{\alpha} \in \mathcal{A}} y_{\boldsymbol{\alpha}} \Psi_{\boldsymbol{\alpha}}(\boldsymbol{x})$
Validation (resp. cross-validation)	✔ Validation set	✔ Leave-one-out CV

$$Err_{LOO} = \frac{\sum_{i=1}^{N}\left(\mathcal{M}\left(\boldsymbol{x}^{(i)}\right) - \mathcal{M}^{meta\setminus i}\left(\boldsymbol{x}^{(i)}\right)\right)^2}{\sum_{i=1}^{N}\left(\mathcal{M}\left(\boldsymbol{x}^{(i)}\right) - \hat{\mu}_Y\right)^2}$$

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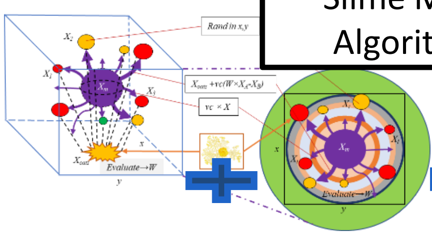
Applications Of Novel Bio-inspired Metaheuristic Algorithms On Damage Assessment Of A Truss Bridge

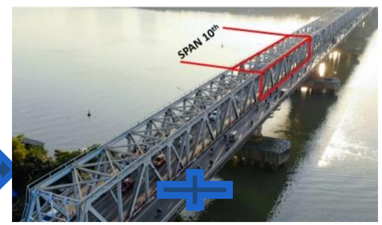
Keywords: structural health monitoring, optimization, damage assessment

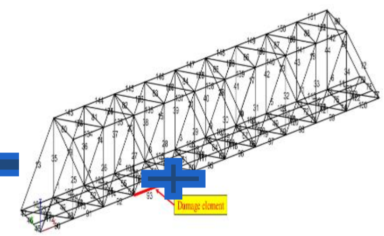
Promoter: Prof. Magd Abdel Wahab

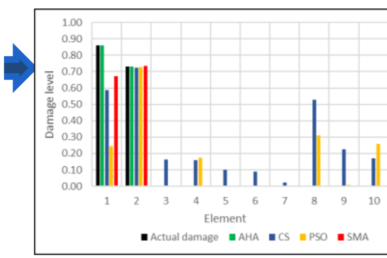
Student: Nguyen Ngoc Lan

Slime Mold Algorithm

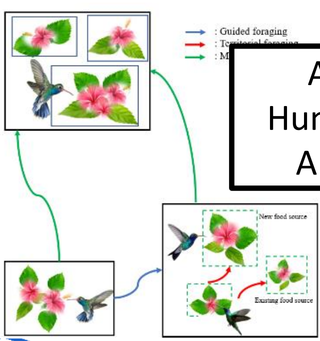


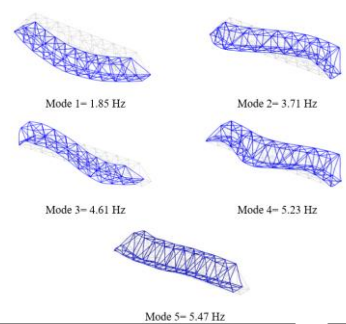


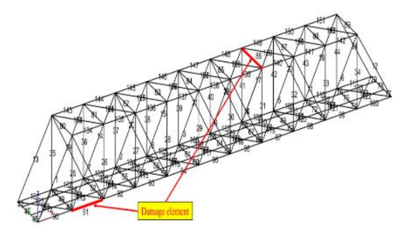




Artificial Hummingbird Algorithm







Application of novel Bio-inspired metaheuristic algorithms

Vibration Measurement + Model updating of Chuong Duong truss bridge

Single and multiple damage scenarios to validate damage detection method

Optimal damage detection capability of proposed methods are proven versus traditional optimization algorithms

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Damage Detection Of Bridges Using Neural Networks And Optimization Algorithm

Keywords: damage detection, machine learning, optimization algorithm

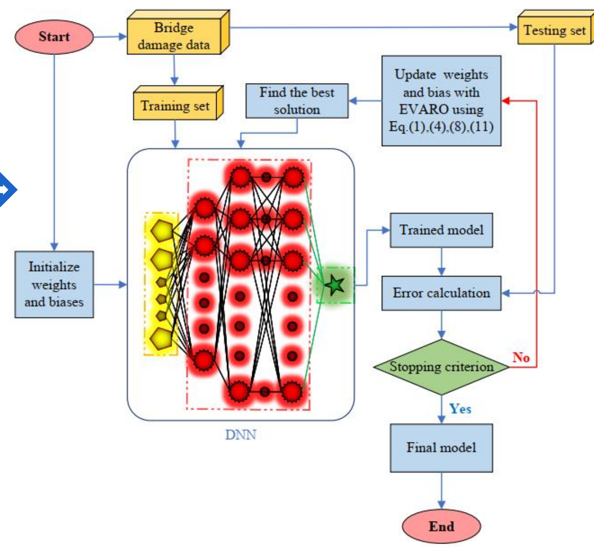
Promotors: Prof. Magd Abdel Wahab

Student: Nguyen Ngoc Lan

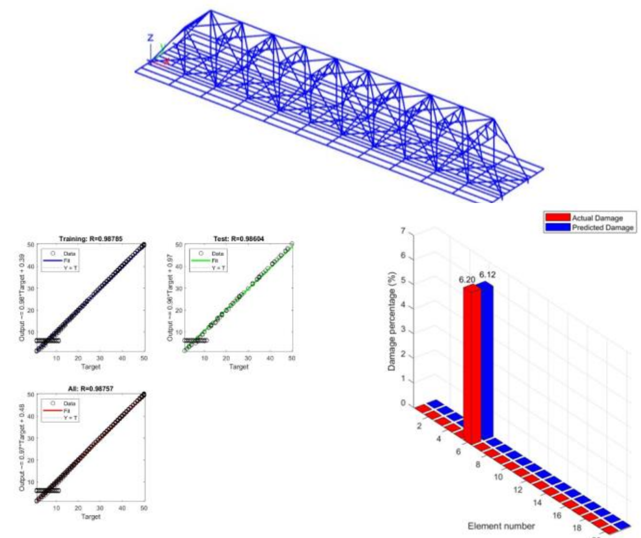
Objectives

- Design bridge structure using Finite Element
- Design Enhanced neural networks using optimization algorithms
- Detect location & severity of structural damages of bridge using proposed method

Methodology



Tasks-results



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Optimization Of Auxetic Honeycomb Cell Parameters In Sandwich Nanoplates For High Energy Absorption

Keywords: auxetic honeycomb cell, sandwich nanoplates, negative poisson's ratio, energy absorption, optimization

Promoter: Prof. Magd Abdel Wahab

Student: Usama Hamid

Elastic Properties of Honeycomb core layer

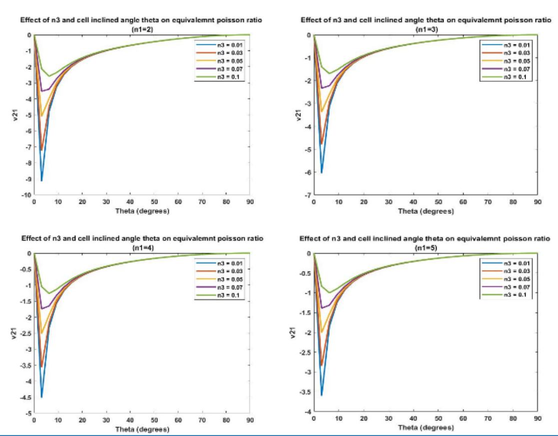
$$E_{11}^{c}=\frac{E^{s}\eta_3^3(\eta_1-\sin\theta)}{\cos^3\theta\left[1+\left(\tan^2\theta+\eta_1\sec^2\theta\right)\eta_3^2\right]}\ ;\ E_{22}^{c}=\frac{E^{s}\eta_3^3}{\cos\theta(\eta_1-\sin\theta)\left(\tan^2\theta+\eta_3^2\right)}$$

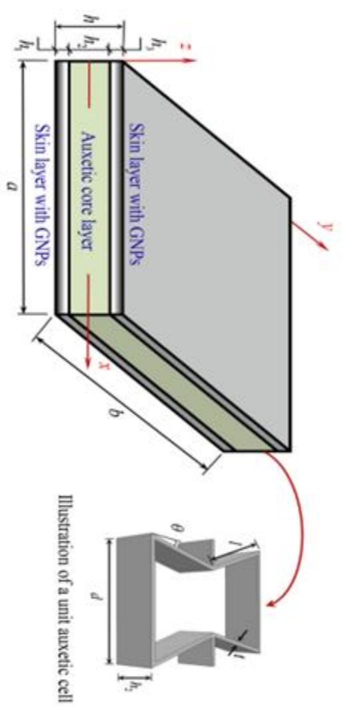
$$G_{12}^{c}=\frac{E^{s}\eta_3^3}{\eta_1(1+2\eta_1)\cos\theta}\ ;\ G_{23}^{c}=\frac{G^{s}\eta_3\cos\theta}{\eta_1-\sin\theta}\ ;\ G_{31}^{c}=\frac{G^{s}\eta_3}{2\cos\theta}\left[\frac{\eta_1-\sin\theta}{1+2\eta_1}+\frac{\eta_1+2\sin^2\theta}{2(\eta_1-\sin\theta)}\right]$$

$$\nu_{12}^{c}=\frac{-\sin\theta\left(1-\eta_3^2\right)(\eta_1-\sin\theta)}{\cos^2\theta\left[1+\left(\tan^2\theta+\eta_1\sec^2\theta\right)\eta_3^2\right]}\ ;\ \nu_{21}^{c}=\frac{-\sin\theta\left(1-\eta_3^2\right)}{(\eta_1-\sin\theta)\left(\tan^2\theta+\eta_3^2\right)}$$

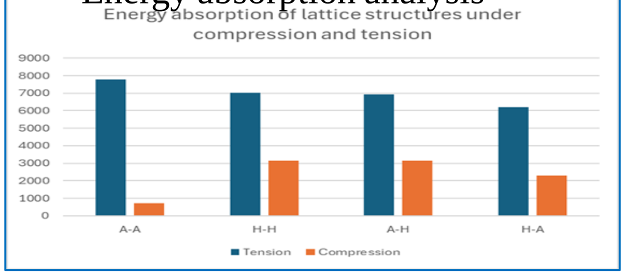
$$\rho^{c}=\frac{\rho^{s}\eta_3(\eta_1+2)}{2\cos\theta(\eta_1-\sin\theta)}\ ;\ G^{s}=\frac{E^{s}}{2(1+\nu^{s})}$$

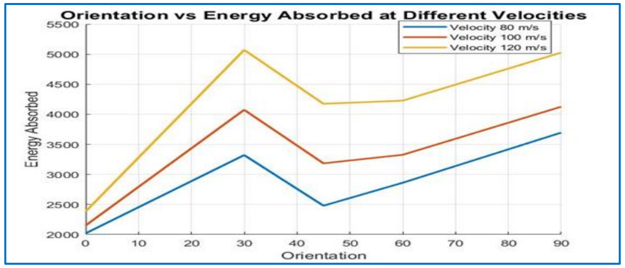
Thickness and angle effect on Equivalent Poisson's Ratio

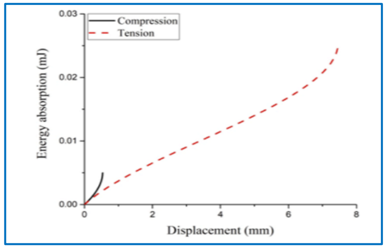




Energy absorption analysis







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Numerical Analysis Of Korteweg-de Vries (Kdv) Equations

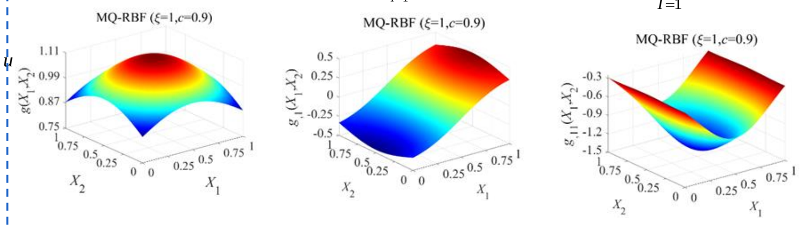
Keywords: radial basis collocation method, kdv equations, high accuracy, super-convergence

Promoter: Prof. Magd Abdel Wahab

Student: Zhiyuan Xue

Radial basis function approximations and its derivatives

$$u^h_{,i}(X)=\sum_{I=1}^{N_s} g_{I,i}(X)d_I \qquad u^h_{,ij}(X)=\sum_{I=1}^{N_s} g_{I,ij}(X)d_I$$



Discrete format

$$\mathbf{K}_n\mathbf{a}_{n+1}=\mathbf{F}_{n+1}$$

$$\mathbf{K}_n=\begin{bmatrix}\mathbf{K}_n^1\\ \mathbf{K}_n^2\\ \mathbf{K}_n^3\end{bmatrix},\quad \mathbf{F}_{n+1}=\begin{bmatrix}\mathbf{F}_{n+1}^1\\ \mathbf{F}_{n+1}^2\\ \mathbf{F}_{n+1}^3\end{bmatrix}$$

$$\mathbf{K}_n^1=\sum_{i=1}^{N_i}\xi_i E_1\mathbf{\Phi}(\bar{\mathbf{p}}_i)\mathbf{a}_{n+1}+\sum_{i=1}^{N_i}\xi_i E_2\mathbf{\Phi}_{,x}(\bar{\mathbf{p}}_i)\mathbf{a}_{n+1}$$

$$+\sum_{i=1}^{N_i}\xi_i E_3\mathbf{\Phi}_{,xxx}(\bar{\mathbf{p}}_i)\mathbf{a}_{n+1}+\sum_{i=1}^{N_i}\xi_i E_4\mathbf{\Phi}_{,xyy}(\bar{\mathbf{p}}_i)\mathbf{a}_{n+1}+\sum_{i=1}^{N_i}\xi_i E_5\mathbf{\Phi}_{,xzz}(\bar{\mathbf{p}}_i)\mathbf{a}_{n+1}$$

$$\mathbf{K}_n^2=\sum_{i=1}^{N_i}\xi_i\mathbf{A}^{\tau}\mathbf{\Phi}^{\mathrm{T}}(\bar{\mathbf{q}}_i),\quad \mathbf{K}_n^3=\sum_{i=1}^{N_i}\xi_i\mathbf{A}^{g}\mathbf{\Phi}^{\mathrm{T}}(\bar{\mathbf{r}}_i),$$

$$\mathbf{F}_{n+1}^1=\sum_{i=1}^{N_i}\xi_i E_6-\sum_{i=1}^{N_i}\xi_i E_7-\sum_{i=1}^{N_i}\xi_i E_8-\sum_{i=1}^{N_i}\xi_i E_9,$$

$$\mathbf{F}_{n+1}^2=\sum_{i=1}^{N_i}\xi_i\boldsymbol{\tau}_{n+1}(\bar{\mathbf{q}}_i),\quad \mathbf{F}_{n+1}^3=\sum_{i=1}^{N_i}\xi_i\mathbf{g}_{n+1}(\bar{\mathbf{r}}_i)$$

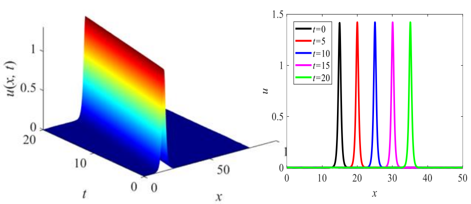
Generalized third order nonlinear KdV

$$u_t+\varepsilon u^2u_x+\kappa u_{xxx}+\alpha u_{xyy}+\beta u_{xzz}=0 \quad \text{in } \Omega$$

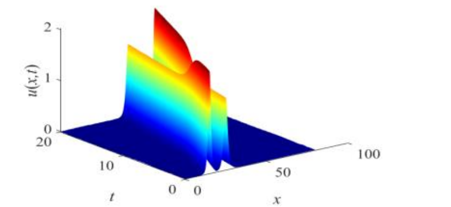
$$\begin{cases}\mathrm{A}^{\tau}u(x,y,z,t)=\tau(x,y,z,t) & \text{on } \Gamma\\ \mathrm{A}^{g}u(x,y,z,t)=g(x,y,z,t) & \text{on } \Pi\end{cases}$$

$$u(x,y,z,t)=u_0(x,y,z,t),\quad t=0 \ \text{in } \Omega$$

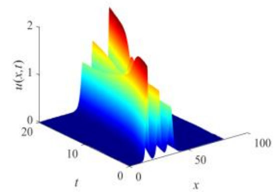
The single wave propagation



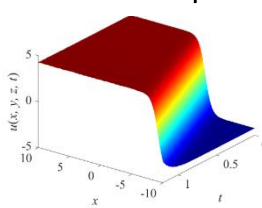
Two solitary waves



Three solitary waves



The 3D modified KdV-ZK equation



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