الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

وزارة التعليم العالي والبحث العلمي

Ministry of Higher Education and Scientific Research
Directorate-General for Scientific Research and Technological Development (DGRSDT)

Ibn Khaldun University of Tiaret
Faculty of Applied Sciences (FSA)
Department of Mechanical Engineering (DGM)

In collaboration with the Research Laboratory of Industrial Technologies (RLIT)

Organize the

National Conference on Mechanical Engineering

NCoME25Tiaret

CONFERENCE DATE: 13 / 11 / 2025

Honorary Members

Pr BELGOUMENE Berrezoug (University Rector)
Dr BERKANI Abderrahmane (Dean of FSA)
Dr GUEMMOUR Mohamed Boutkhil (Head of DGM)
Pr HADDOUCHE Kamel (Director of RLIT)

Conference Chair: Dr ELGUERRI Mohamed
Conference Co-Chair: Dr ABO SHIGHIBA Hicham

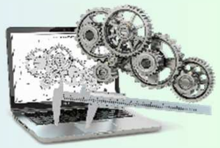
OBJECTIVES

The National Conference on Mechanical Engineering is a real intersection for scientific exchange allowing university researchers and private or public industrial collaborators to meet in order to share their knowledge and experience and to learn about the latest scientific and technical advances in the field of mechanical engineering.

This first edition of the NCoME'25 follows the seminars that have been held for many years at the Ibn Khaldoun University in Tiaret, aimed at further increasing scientific activities towards other horizons and strengthening partnership links with both Algerian and foreign academic researchers as well as those in the industrial and socio-economic sectors.

TOPICS

Topic 1: Mechanical Engineering



1. *Contact Mechanics & Mechanism*
2. *Elasticity*
3. *Machining & CNC Machines*
4. *Mechanical & Machine Design*

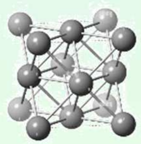
Topic 2: Energy

1. *Fluid Dynamics*
2. *Heat Transfer*
3. *Internal Combustion Engine & Turbomachinery*
4. *Renewable Energy*

Topic 3: Electromechanics & Industrial Maintenance

1. *Industrial Maintenance*
2. *Systems Reliability*
3. *Tribology*
4. *Vibration & Structures Dynamics*

Topic 4: Materials Science



1. *Composite Materials*
2. *Fatigue & Damage*
3. *Manufacturing Processes*
4. *Strength of Materials*

CONFERENCE DATE: 13 / 11 / 2025

INSCRIPTION AND MODALITIES

Authors are invited to submit their articles in English or French according to Templates to be download from the conference link:

fsa.univ-tiaret.dz/NCoME25/

The proposals selected by the Scientific Committee will be the subject of an oral presentation or a poster.

IMPORTANT DATES

Abstract submission:	*10 / 09 / 2025*
Abstract submission deadline:	*20 / 09 / 2025*
Paper submission:	*30 / 09 / 2025*
Paper submission deadline:	*10 / 10 / 2025*
Acceptance notification:	*20 / 10 / 2025*

NCoME

SCIENTIFIC COMMITTEE

President:	Pr BOUZIDANE Ahmed	U. Tiaret
	Pr AISSAT Sahraoui	U. Tiaret
	Pr AIT AMAR MEZIANE Mohamed	U. Tiaret
	Pr BALTACH Abdelghani	U. Tiaret
	Pr BENDAOUDI Seif-Eddine	U. Relizane
	Pr BEKKI Hadj	U. Tiaret
	Pr BELARBI Mostefa	U. Tiaret
	Pr BENSATTALAH Tayeb	U. Tiaret
	Pr BOUAFIA Hamza	U. Tiaret
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	Pr KARAS Abdelkader	U. Tiaret
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	Pr LEDJDEL Omar	U. Oran
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	Pr MEKROUSSI Said	U. Tiaret
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	Pr NEGADI Karim	U. Tiaret
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	Pr SAHLI Abderrahmene	U. Sidi-Bel-Abbes
	Pr ZEBBAR Djallel	U. Tissemsilt
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	Dr AKERMI Nasreddine	U. Tiaret
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	Dr MAHDJOUR Abdelkader	U. Oran
	Dr SI TAYEB Tayeb	U. Tissemsilt
	Dr ZAGANE Mohammed El Sallah	U. Tiaret
	Dr ZENGAH Sahnoun	U. Mascara

EXPOSITION

In order to make this conference a success, manufacturers are invited to participate in an exhibition that will be held at the heart of the proposed topics. This exhibition will be a real crossroads for exchanges between participants from university, research and industry, who will be expected in this unmissable event.

CONFERENCE OPPORTUNITY

The best articles selected by the Scientific Committee will be published in special or ordinary issues of journals as: "Recueil de mécanique", "MOMA Journal", and "Revue des Sciences et Sciences de l'Ingénieur".

Authors of the selected articles will be invited to submit extensive versions for publication.

		
Recueil de mécanique	Revue des Sciences et Sciences de l'Ingénieur	MOMA Journal

CONFERENCE SECRETARY

Conference secretary
Department of Mechanical Engineering
Faculty of Applied Sciences
B. P. 78 Zaâroura, 14000 Tiaret, Algérie
Tel / Fax: +213 (0) 46.25.93.14
Email: ncme@univ-tiaret.dz
Conference link: fsa.univ-tiaret.dz/NCoME25/

CONFERENCE DATE: 13 / 11 / 2025

ORGANIZING COMMITTEE

President:	Dr ELGUERRI Mohamed	
Co-President:	Dr ABO SHIGHIBA Hicham	
Members:	Dr ABED Belkacem	U. Tiaret
	Dr ARARIA Rabah	U. Tiaret
	Dr ASRI Aicha	U. Tiaret
	Dr BECHEIKH Mostefa	U. Tiaret
	Dr BELMILOUD Mohamed Amine	U. Tiaret
	Dr BENALOUACH Khaled	U. Tiaret
	Dr BENARBIA Djamila	U. Tiaret
	Dr BENARIBA Boubakeur	U. Tiaret
	Dr BENSATTALAH Aissa	U. Tiaret
	Dr BEY Mohamed	U. Tiaret
	Dr BEZZERROUK Med Amine	U. Tiaret
	Dr BOUMEDIENE Bachir	U. Tiaret
	Dr BOUREGUIG Kada	U. Tiaret
	Dr CHEDJARA Zakaria	U. Tiaret
	Dr CHEIKH Samra	U. Tiaret
	Dr HAMMOU Mahmoud	U. Tiaret
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	Dr SAAD Mohamed	U. Tiaret
	Dr SLIMANI Halima	U. Tiaret
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	Dr ZAITRI Mohamed	U. Tiaret
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	Mr ATHMANI Houari	U. Tiaret
	Mr BELFODIL Farid	U. Tiaret
	Mr BENAMAR Badr	U. Tiaret
	Mr BOUZOUINI Mohammed	U. Tiaret
	Mr DEBBIH Senouci	U. Tiaret
	Mr MADANI Ahmed	U. Tiaret
	Mr MAZARI Djamel	U. Tiaret

PARTICIPATION FEES

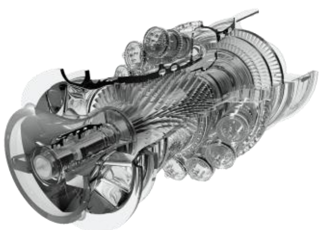
The participation fees cover the acts of the conference, the catering and the coffee breaks.

Participation fees	Amount
Students	3000 DA
Teachers / Researchers	5000 DA
Professionals / Industrialists	7000 DA

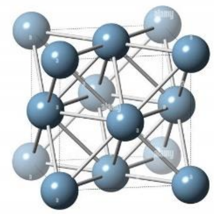
National Conference on Mechanical Engineering

“NCoME’25”

Tiaret, October 30, 2025



Registration Sheet



Name:	Assas	***Last name:***	Taqiyeddine
Quality:	Phd Student	***Grade:***	Phd Student
Affiliation:	Laboratory of Hydraulic Developments and Environment (LAHE), Civil Engineering and Hydraulic Department, University of Biskra	***Specialty:***	Public Works
Phone:	0670876131	***E-mail:***	taqiyeddine.assas@univ-biskra.dz

Theme:

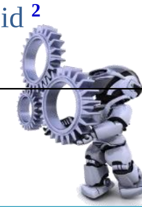
☐	***Topic 1:***	*1. Contact Mechanics & Mechanism* *3. Machining & CNC Machines*	*2. Elasticity* *4. Mechanical & Machine Design*
☐	***Topic 2:***	*1. Fluid Dynamics* *3. Internal Combustion Engine & Turbomachinery*	*2. Heat Transfer* *4. Renewable Energy*
☐	***Topic 3:***	*1. Industrial Maintenance* *3. Tribology*	*2. Systems Reliability* *4. Vibration & Structures Dynamics*
☒	***Topic 4:***	*1. Composite Materials* *3. Manufacturing Processes*	*2. Fatigue & Damage* *4. Strength of Materials*

(Double click to activate or deactivate the box)

Article title: **Analysis of laminated composite plates using higher-order shear deformation plate theory and strain based finite element formulation**

Co-auteurs: Taqiyeddine Assas [1*], Messaoud Bourezane [1], Madjda Chenafi [1] Seyfeddine Benabid [2]

(Semicolon between co-authors)



Wishes to participate in the NCoME’25 by a communication

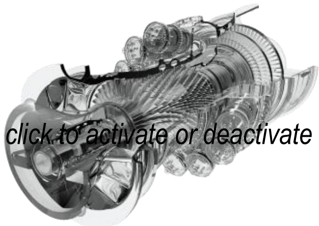
☒	***Oral***
☐	***Poster***

To be completed and send by e-mail to: ncme@univ-tiaret.dz

National Conference on Mechanical Engineering

“NCoME’25”

Tiaret, October 30, 2025



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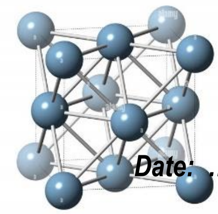

Date: ……/……/……

To be completed and send by e-mail to: ncme@univ-tiaret.dz

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Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
Direction Générale de la Recherche Scientifique et du Développement Technologique

Université Ibn Khaldoun - Tiaret
Faculté des Sciences Appliquées
Département de Génie Mécanique
Laboratoire de Recherche des Technologies Industrielles - LRTI

Conférence Nationale de Génie Mécanique

NCoME'25

Tiarat, 13 Novembre 2025

Lettre d'Acceptation

Réf. ID : **T4O02**

Monsieur : **ASSAS Taqiyeddine**

Co-auteurs : **BOUREZANE Messaoud**, **CHENAFI Madjda**, **BENABID Seyfeddine**

Nous avons le plaisir de vous informer que le comité scientifique a retenu votre contribution intitulée : **Analysis of laminated composite plates using higher-order shear deformation plate theory and strain based finite element formulation**,

pour une présentation en session : **Orale**

à la ***Conférence Nationale de Génie Mécanique*** de Tiaret « ***NCoME'25*** ».

Dans l'attente de vous voir à Tiaret, nous vous prions d'agréer, l'expression de nos meilleures salutations. N'hésitez pas à nous contacter pour de plus amples informations.

Fait à Tiaret le, 8 novembre 2025.
Président de la Conférence
Dr ELGUERRI Mohamed

جامعة ابن خلدون - تيارت
الملتقى الوطني في الهندسة الميكانيكية بتيارت
NCOME 25
كلية العلوم التطبيقية

رئيس الملتقى الوطني
في الهندسة الميكانيكية
د. القري محمد

People's Democratic Republic of Algeria
Ministry of higher education and scientific research
The General Directorate of Scientific Research and Technological Development

Ibn Khaldoun University of Tiaret
Applied Sciences Faculty
Department of Mechanical Engineering

In collaboration with the Research Laboratory of Industrial Technologies (RLIT)

National Conference on Mechanical Engineering (NCoME'25)

13 November 2025, Tiaret

Conference Link: *sites.google.com/view/ncome25-tiaret/*

Global Program of the Conference

8h00-9h00	***Reception and attendee's inscription***		
9h00-9h30	*Opening and address* ***Conference Moderator: Dr ABO SHIGHIBA Hichem***		
	Address by the Rector of Ibn Khaldoun University of Tiaret: ***Prof Ém. BELGOUMANE Berrezoug***		
	Address by the Dean of the Faculty of Applied Sciences: ***Dr BERKANI Abderrahmane***		
	Address by the Conference President: ***Dr ELGUERRI Mohamed***		
9h30-10h00	*Plenary Conference:* ***Dr ABO SHIGHIBA Hichem** – Ibn Khaldoun University - Tiaret, Algeria*		
10h00-10h30	***Coffee Break***		
10H30-11H00	***Morning Poster Workshop***	***Topic 1: Mechanical Engineering***	*ID: T1P01; T1P02; T1P03; T1P04*
		Topic 2: Energy	*ID: T2P01; T2P02; T2P03; T2P04; T2P05; T2P06*
		Topic 3: Electromechanics & Industrial Maintenance	*ID: T3P01; T3P02; T3P03; T3P04*
		Topic 4: Materials Sciences	*ID: T4P01; T4P02; T4P03; T4P04; T4P05; T4P06; T4P07; T4P08; T4P09; T4P10; T4P11; T4P12; T4P13; T4P14; T4P15; T4P16; T4P17; T4P18; T4P19; T4P20; T4P21*
11H00-12H30	***Morning Oral Workshop***	***Topic 1: Mechanical Engineering***	
		Topic 2: Energy	
		Topic 3: Electromechanics & Industrial Maintenance	
		Topic 4: Materials Sciences	
12H30-14H00	***Lunch Break***		
14H00-14H30	***Afternoon Poster Workshop***	***Topic 1: Mechanical Engineering***	*ID: T1P05; T1P06; T1P07*
		Topic 2: Energy	*ID: T2P07; T2P08; T2P09; T2P10; T2P11; T2P12*
		Topic 3: Electromechanics & Industrial Maintenance	*ID: T3P05; T3P06; T3P07; T3P08; T3P09*
		Topic 4: Materials Sciences	*ID: T4P22; T4P23; T4P24; T4P25; T4P26; T4P27; T4P28; T4P29; T4P30; T4P31*
14H30-16H00	***Afternoon Oral Workshop***	***Topic 1: Mechanical Engineering***	
		Topic 2: Energy	
		Topic 3: Electromechanics & Industrial Maintenance	
		Topic 4: Materials Sciences	
16H00-16H30	***Closing Ceremony***		

Nationale Conference on Mechanical Engineering (NCoME'25)
30 Octobre 2025, Tiaret

Detailed Program of the Conference

8h00-9h00	Reception and attendee's inscription
9h00-9h30	Opening and address – **Conference Moderator:** **Dr ABO SHIGHIBA Hichem**
	Address by the Rector of Ibn Khaldoun University of Tiaret: **Pr Ém. BELGOUMANE Berrezoug**
	Address by the Dean of the Faculty of Applied Sciences: **Dr BERKANI Abderrahmane**
	Address by the Conference President: **Dr ELGUERRI Mohamed**
9h30-10h00	Plenary Conference: **Dr ABO SHIGHIBA Hichem** – Ibn Khaldoun University - Tiaret, Algeria
10h00-10h30	**Coffee Break**

10H30-11H00	**Morning Poster Workshop**			
Topic 1A: Mechanical Engineering – Moderators: Pr AISSAT Sahraoui				
	N°	Full name	ID	Thema
10H30-11H00	1	BACHIRI Abdessamad		Influence des propriétés adhésives sur les performances de la réparation active d'une sur une plaque d'aluminium fissurée
	2	HAROUNE Abdelhak		Impact of toothed belt geometry on the temperature of the transmission system
	3	MEDKOUR Mihoub		Calcul de la pression et le champ de vecteur de vitesse dans un milieu poreux pour un fluide non newtonien
	4	MAKHFI Souad		A Novel Approach to Machining Parameter Optimization
Topic 2B: Energy – Moderators: Pr MEKROUSSI Said				
10H30-11H00	1	BEKHADRA Samira		Numerical simulation of blood flow in the bifurcation of the carotid artery
	2	AZZAZEN Mohamed		Diffusion d'un mélange stœchiométrique H2 / O2
	3	SARIR Noureddine		Evaluating the Performance of the GA-FuzzyPI Fractional Controller on Power Quality in Smart Grids: Application to Three-Phase Faults

	4	BELMILOUD Mohamed Amine		Enhancing heat transfer in a lithium-ion battery cell through the use of cooling fins
	5	MAZARI Djamel		Investigation of Disk Friction Losses Effects on the Performance of mixed flow Turbine
	6	ZINE KHELOUFI Omar		Numerical study of a semi-axial turbine
Topic 3B: Electromechanics & Industrial Maintenance – Moderators: Pr MOULGADA Abdelmadjid				
10H30-11H30	1	HARKAT Yamina		Approches probabilistes pour la maîtrise du risque de rupture en fatigue des matériaux
	2	TAIBI Ahmed		Intelligent Bearing Fault Diagnosis Based on Dual-Tree Complex Wavelet Transform, AR Coefficients, and SVM
	3	DEBBAB Mohamed		Decentralized Data Integrity for Enhanced Reliability Analysis in Industrial Systems
	4	ABOURA Abderrahmane		Defect Path Reconstruction through 3D Signal Analysis in Eddy Current Array Testing
Topic 4A: Materials Sciences – Moderators: Pr HASSAINE DAOUADJI Tahar				
10H30-11H00	1	ADIM Belkacem		Contribution to the free vibration behavior study of laminated composite plates
	2	AKRICHE Ahmed		First-principal calculations of half-metallic properties of Ni2MnAl Heusler compounds
	3	BOUMEDIENE Hayet		Effet du collage sur la prédiction des contraintes de glissement dans une poutre mixte acier-béton connectée par adhésif
	4	BOUSSENA Ahmed		Mechanical Characterization of Recycled and Loaded Materials
	5	ATHMANE Sid Ahmed		Fatigue and follow of stiffness degradation in a composite material
	6	FEREDJ Bouabdellah 1		Durabilité chimique des blocs de terre comprimée stabilisés au ciment soumis à une attaque acide au H_2SO_4
	7	CHAMA Mourad		Using XFEM-CZM and fiber-matrix coupling laws to predict damage in notched plates reinforced with graded composite patches by USDFLD approach
	8	DJEBOUR Benali		Anisotropie élastique et propriétés mécaniques, dynamiques et électroniques du composé half-Heusler KScSn : Étude ab-initio
	9	MEFTAH Souad		Cold Forming Behavior and Compressibility Analysis of Copper–Alumina Powder Mixtures
	10	SAFA Ali 1		Recyclage des sables de la fonderie de Tiaret : un pas vers une fonderie durable
	11	LARBI Mhamed		First-Principles Investigation of Pressure Effects on the Electronic Properties of a Semiconductor
Topic 4C: Materials Sciences – Moderators: Pr BEKKI Hadj				
10H30-11H00	1	CHAMI Guermit		Porosity effect on fundamental frequencies of FGM sandwich beams
	2	KRALIFA Abderrahim Souffiane		Analyse du comportement mécanique des plaques composites hybrides stratifiées
	3	NASSAH Mohamed		A Stress and Deflection Analysis of a Functionally Graded Beam under Non-Uniform Loading
	4	DAIKH Abdelkader		Mechanical Behavior Analysis of Structures Damaged by Cracking
	5	GHOUL Sahraoui		Reliability of ANSYS-APDL for the Nonlinear Numerical Modeling of L-Shaped RC Shear Walls
	6	BOUAKKAZ Ahmed Ouadah		Modélisation micromécanique de l'endommagement du composite PP+talc
	7	DRAOUCHE Khayra		L'impact de la porosité et des conditions aux limites sur les caractéristiques dynamiques des plaques en matériau à gradient fonctionnel
	8	KHELIFI Halima		Influence of Boriding on The Fatigue Behavior of X70 Steel
	9	FEREDJ Bouabdellah 2		Influence de la microstructure des matières premières sur la durabilité hydrique des mortiers terre–ciment
	10	ASLI Imen		Modélisation des contraintes de cisaillement d'une poutre en béton armé renforcée par matériaux composites : effet de la précontrainte

11H00-12H30	Morning Oral Workshop		
Topic 1A: Mechanical Engineering – Moderator: Pr AISSAT Sahraoui			
Schedule	Full name	ID	Thema
	ABOSHIGHIBA & CHERCHEF		Discrete elements method for modeling granular media physics and tribology
	MIMOUN & HADDOUCHE		Prédiction de l'effort de coupe lors du tournage de l'acier A60 en utilisant les techniques d'apprentissage automatique
	SEBAA Mohamed Rida		Hybrid Artificial Intelligence Framework for Multi-Objective Optimization of Spur Gear Design Using Jaya Algorithm and Multi-Agent Systems
	BOUZIDANE Ahmed		Influence of three pad Hydrostatic Journal Bearing Characteristics on the Dynamic behaviour of a three-Disk Rotor
Topic 2B: Energy – Moderator: Pr MEKROUSSI Said			
	CHEIKH Samra		Analyse de la sensibilité paramétrique d'un thermo-transformateur à absorption destinée à la valorisation des puits de chaleurs de bas potentiel
	BORDJANE Mustapha		Investigation numérique de l'écoulement des fluides à travers l'intercooler d'un moteur thermique suralimenté
	AKERMI Nassreddine		Self-starting study of a variable pitch wind rotor exposed to turbulence intensity
	HAMMOU Mahmoud		Impact du Choix du Verre sur le Rendement Thermique d'un Distillateur Solaire Passif : Étude Numérique
	AYAD Fouad		Experiments at the mixing test facility ROCOM for benchmarking of CFD codes regarding Nuclear Reactor Safety (NRS) accident scenarios
Topic 3B: Electromechanics & Industrial Maintenance – Moderator: Pr MOULGADA Abdelmadjid			
	BENADDA Mohamed		Étude paramétrique des effets vibratoires d'un défaut d'engrenage en régime transitoire et permanent
	DAHMANE Sayda		Spectral Envelope Analysis-Random Forest based method for bearing fault detection
	BENMESSAOUD Tahar 1		Wind Farms Real Time Maintenance Based on SCADA Data and Fuzzy Logic: Real Case Study
	MAKHFI Souad		Smarter Bearing Fault Detection
Topic 4A: Materials Sciences – Moderator: Pr HASSAINE DAOUADJI Tahar			
	AOUDIA Hanane		Development and Characterization of Amphiphilic Nanocomposites Based on PCL-PEG-PCL Triblock Copolymer and Modified Maghnite
	ASSAS Taqiyeddine		Analysis of laminated composite plates using higher-order shear deformation plate theory and strain based finite element formulation
	RABAHI Abderrazak		A theoretical analysis for the static behavior of functionally graded porous plates: various models of distribution
	HOUARI Amin		Experimental vibration analysis of composite-patched plate
Topic 4B: Materials Sciences – Moderator: Pr BEKKI Hadj			
	MESSAAD Taieb		Effect of Prosthetic Liner Material on Residual Limb Stress Distribution During Normal walking
	TICHOUCHE Fatima Zohra		The Cantilever Beams Experimental Dynamic Investigation according to the Timoshenko Theory
	BENKOUACHI Narimane		Numerical modelling of a femoral prosthesis Following Lower limb amputation
	HADJI Lazreg		Free Vibration analysis of Functionally Graded Polymer Composite Plates Reinforced with Graphene Nanoplatelets
12H30-14H00	Lunch Break		

14H00-14H30	Afternoon Poster Workshop

Topic 1B: Mechanical Engineering – Moderators: Pr ZIDOUR Mohamed

	N°	Full name	ID	Thema
10H30-11H00	1	MERGHACHE Sidi Mohamed		Évaluation de la température sur une transmission par courroie dentée «Binder Magnetic»
	2	TAGHEZOUT Ali		Application de la méthode XFEM à la modélisation numérique de fissures dans des plaques en aluminium
	3	RABOUH Mustapha		Numerical analysis of hygrothermal effects on low-velocity impact contact force in s-glass/polyester composite plates

Topic 2A: Energy – Moderators: Pr SAD CHEMLOUL Nord Eddine

	N°	Full name	ID	Thema
14H00-14H30	1	KECHACHNI Mohamed 2		Réduction de la consommation énergétique dans les tunnels et infrastructures enterrées : approche globale par récupération de chaleur
	2	BOUZID Mohamed Amine		Adaptive Fuzzy Logic Control of Wind Standalone Conversion System with Storage
	3	BELFODIL Farid		Modélisation Numérique pour la Simulation du Refroidissement par Pulvérisation d'Eau Durant la Production des Métaux
	4	SEGHIER Djamal		Optimization of Renewable Energy Resources Using Machine Learning Algorithms
	5	KOUIDER Mostefa		Modélisation mathématique d'une butée hydrodynamique lubrifiée avec un fluide non newtonien
	6	KECHACHNI Mohamed 1		Influence de l'intégration BIM-BEM sur la prévision de la performance énergétique dans les bâtiments

Topic 3A: Electromechanics & Industrial Maintenance – Moderator: Pr KARAS Abdelkader

	N°	Full name	ID	Thema
14H00-14H30	1	DJELBANE Mohamed		Diagnostic de Défaillances d'un système d'énergie photovoltaïque avec une approche floue
	2	ZEMALI Zakaria		Robust Faut Diagnosis Strategy Based on Bnak Leunberger Observer for pitch System'Sonsor of wind Turbine Machine
	3	DJERBOUB Ahmed		An Integrated SVM-MPPT and Four-Leg SAPF Control Framework for Enhanced Power Quality in Grid-Connected Photovoltaic Systems
	4	KOULALI Mostefa		Efficient AC Load Management Through Multi-Source Energy Integration: PV, Fuel Cell, and Battery in Multi-Level Inverters
	5	MAASAKRI Moustafa		Optimisation des systèmes énergétiques mécaniques par apprentissage automatique : application à la maintenance prédictive et l'efficacité énergétique des installations CVCA

Topic 4C: Materials Sciences – Moderators: Pr BOUSMAHA Mohamed

	N°	Full name	ID	Thema
14H00-14H30	1	OULD LARBI Latifa		Modélisation micromécanique de l'endommagement du composite PP+talc
	2	LAKEL Adel		Analyse de la flexion d'une plaque sandwich poreuse multidirectionnelle à gradient fonctionnel
	3	ZOUATNIA Nafissa		Investigation of Dynamic Performance in Porous Sigmoid Functionally Graded Sandwich plates
	4	ZAGAAR Yamina		Investigation of the flexural response of porous FGM plates resting on elastic foundation
	5	HASSAINE DAOUADJI Maya		Renforcement des poutres isostatique en acier par collage externe des plaques composite en précontrainte
	6	NAOUS Mohamed		Engineering Dual-Charged Magnetite Nanoparticles for Broad-Spectrum Chromium (VI) Removal Across Diverse Water Conditions
	7	SAFA Abdelkader		Study on Thermal Vibration Response of Functionally Graded Material Beams
	8	TOUHAMI Belkacem Elhocine		Analysis of a wooden beam strengthened by external bonding of a composite materials: Effect of composite materials rigidity
	9	BABAKHALI Elmabrouk		La modification des propriétés mécaniques de l'acier sous l'effet de la galvanisation au zinc
	10	SAFA Ali 2		Analyse comparative des performances en fatigue de ressorts à lames : Cas des sections droites versus sections courbées

14H30-16H00	Afternoon Oral Workshop		
Topic 1B: Mechanical Engineering – Moderator: Pr ZIDOUR Mohamed			
Schedule	Full name	ID	Thema
	ABOSHIGHIBA & HASSANI		New design of a porous aerostatic bearing with variable permeability
	GHEZAL & HADDOUCHE		Optimisation du processus de tournage dur par régulation numérique adaptative de l'effort de coupe
	BACHA Mohamed		Impact of Advanced Lubrication Modes on Cutting Forces and Surface Quality during hard Turning
	MAZOUZI Abdelmadjid		Stress Analysis in the Indentation Phase of Fretting Contact with a Flat-Rounded Edge Punch
Topic 1C: Mechanical Engineering – Moderator: Pr AISSAT Sahraoui			
	GUERCHOUH Nawel		Dynamic Finite Element Investigation of Contact Stresses in Transfemoral Prosthetic Interfaces
	ELGUERRI Mohamed		Study project by simulation of the design of an elliptical tank turning device
	BENARIBA Aboubakeur		Influence of micropolar lubricant on the dynamic behavior of a rigid rotor mounted on four-pad hydrostatic squeeze film dampers
	BEKHADDA Ahmed		Analyse des vibrations et du flambage des poutres FGM par une nouvelle théorie de déformation au cisaillement de premier ordre (NFSDT)
Topic 2A: Energy – Moderator: Pr SAD CHEMLOUL Nord Eddine			
	KHALDI Sabrina		Improving the performance of a photovoltaic panel using phase change materials enhanced with metal foams
	CHELABI Mohamed Amine		Analyse énergétique d'un rotor semi-axial en fonction de l'angle d'entrée d'aube
	BEKHADRA Mokhtar		Heat Transfer in Magnetorheological Fluids Under Variable Magnetic Fields
	SAHEL Djamila		CFD study of solar air heater thermal efficiency enhancement by using an innovative spiral configuration
	TRARI Benaissa		Étude numérique de l'effet du sens d'écoulement sur le transport de solutés dans une machine d'hémodialyse à fibres creuses
Topic 3A: Electromechanics & Industrial Maintenance – Moderator: Pr KARAS Abdelkader			
	GOISMI Mohamed		Smart Contracts for Industrial Maintenance: Toward Autonomous and Reliable Systems Using Blockchain Technology
	BENMESSAOUD Tahar 2		Optimization of wind turbines maintenance using the PSO method
	DJAAD Fethi		Enhanced PCM Melting in Triplex Tubes for Thermal Energy Storage with Optimized Configuration of Fin Design and Nanofluid Integration
Topic 4C: Materials Sciences – Moderator: Pr BOUSMAHA Mohamed			
	BENGHARBI Omar Abdelaziz		Fault Detection of Induction Motor Sensor Faults Using Machine Learning
	AICHOUBA Adda Cherif		Comparative Evaluation of Gel and Silicone Prosthetic Liners under Varying Thickness: Focus on Contact Pressure
	HAMMOUDI Maram		L'Optimisation en Mécanique des Structures par Les méta-heuristique
	BALTACH Abdelghani		Numerical Analysis of the Effect of Cold-Expanded Plate Thickness on Residual Stresses Around Cold-Expanded Fasteners Hole 7075-T6 Aluminum Alloy
16H00-16H30	Closing Ceremony		

Analysis of laminated composite plates using higher-order shear deformation plate theory and strain based finite element formulation

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Abstract

This paper presents the development of a novel four-node quadrilateral finite element for analyzing the free vibration behavior of composite plates, based on high-order shear deformation theory and a strain-based formulation. The element features five degrees of freedom per node, with displacement functions incorporating higher-order terms that ensure rigid body mode representation and are derived from assumed strains satisfying compatibility conditions. The performance of the proposed element is validated through its application to sandwich and laminated composite plates—both symmetric and antisymmetric—with varying geometries, boundary conditions, thickness ratios, stacking sequences, fiber orientations, and loading types. Comparative analysis with existing analytical and numerical solutions confirms the element's high accuracy, and computational efficiency .

Keywords : *Free vibration ; high-order shear deformation theory; Composite plates ; Strain-based.*

1 Introduction

The mechanical behavior analysis of laminated composite plates has received considerable attention over the past decades due to their extensive applications in aerospace, marine, automotive, and civil engineering structures [1]. These materials are characterized by high stiffness-to-weight and strength-to-weight ratios, as well as customizable mechanical properties, making them ideal for lightweight and high-performance structures. Accurate modeling of their bending, vibration, and stability behaviors remains crucial for the reliability and efficiency of engineering designs.

The Classical Plate Theory (CPT) neglects transverse shear effects, resulting in inaccurate predictions for moderately thick plates [2]. To overcome this limitation, the First-Order Shear Deformation Theory (FSDT) was introduced, incorporating constant transverse shear deformation through the plate thickness. However, this approach requires shear correction factors, which reduce its accuracy. To eliminate these drawbacks, Higher-Order Shear Deformation Theories (HSDT) have been developed, providing more realistic shear stress distributions without using correction factors. These include the third (TSDT)[3-6], trigonometric (TrSDT)[7-10], exponential (ESDT)[11-13], and hyperbolic shear deformation theory (HSDT) [14-17], plate theories (RPT)[18,19]. demonstrated that HSDT yields highly accurate results for laminated and sandwichs plats.

In parallel, the strain-based approach offers several advantages, notably the direct satisfaction of the two fundamental convergence criteria associated with constant strain states and rigid body motion. Moreover, it enables the enrichment of the displacement field with higher-order terms without introducing additional nodes or degrees of freedom. This approach effectively mitigates common numerical issues such as parasitic shear errors, mesh distortion, and various locking phenomena [20]. Strain-based finite element formulations were first introduced in the early 1970s as an alternative to displacement-based models. The initial developments focused on curved elements [21,22], and the method was subsequently extended to plane elasticity [23-25], three-dimensional elasticity [26-28], and plate bending problems [29-34]. These advancements provided a more directe and efficient means to capture structural deformation behavior.

It is important to note that all previously developed plate elements employing the strain-based approach were restricted to isotropic materials modeled with the First-Order Shear Deformation Theory (FSDT). In contrast, the present study introduces, for the first time, a novel strain-based finite element formulated within the framework of a Higher-Order Shear Deformation Theory (HSDT) for laminated composite plate analysis, thereby addressing this significant research gap.

This study introduces a four-node quadrilateral finite element, **HSDT-SBQMLP20**, developed using a strain-based equivalent single-layer (ESL) formulation within the framework of the Higher-Order Shear Deformation Theory (HSDT). The element has five degrees of freedom per node (u, v, w, βx, βy) and employs a quadratic shear strain distribution that satisfies the zero transverse shear stress conditions at the top and bottom surfaces. The polynomial displacement field, expressed through 20 strain parameters, accurately represents both rigid-body motion and deformation behavior. The model is applied to analyze the bending and free vibration responses of laminated composite plates with various geometries, layer configurations, and boundary conditions. The obtained results demonstrate high accuracy and strong agreement with established numerical and analytical references, confirming the efficiency and reliability of the proposed formulation

2 Materials and methods

2.1 Composite Laminated Plates

A laminated composite plate consists of multiple orthotropic layers bonded together to act as a single structural element. Each lamina has distinct mechanical properties and fiber orientations, enabling tailored stiffness and strength characteristics. The stacking sequence, fiber angle, and thickness of each ply significantly influence the overall mechanical behavior of the laminate.

In the present formulation, each layer is assumed to be linearly elastic and orthotropic, with its material axes aligned according to the local coordinate system (1,2,3), where direction 1 corresponds to the fiber orientation, 2 lies in the plane perpendicular to the fibers, and 3 is normal to the plate mid-surface. The global coordinate system (x,y,z) is related to the local system by a rotation angle θ_k for the k_{th} layer as shown in Figure 01[35].

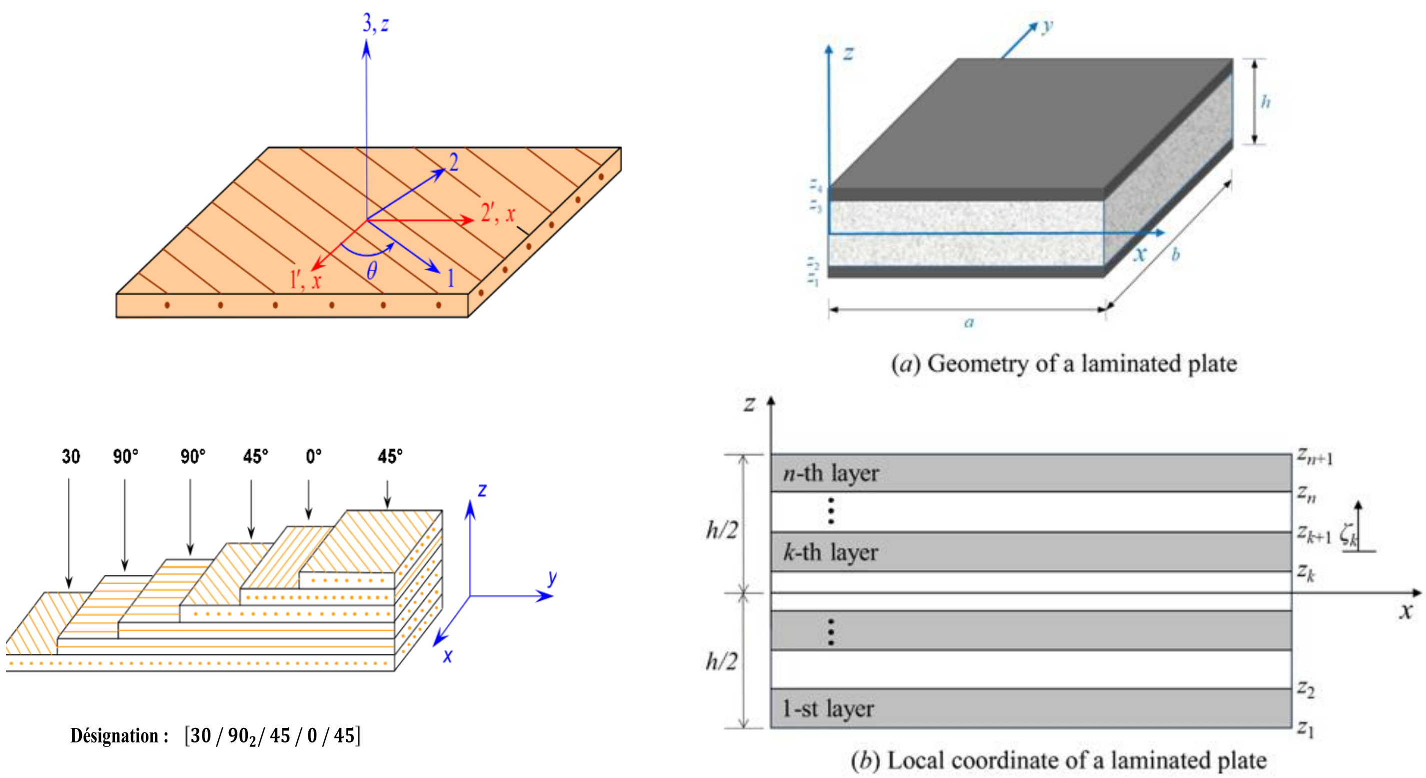

Figure 1. *Schematic diagram of a laminated plate*[35].

2.2 Kinematics and constitutive relations

2.2.1 Displacement functions and strains

Based on the higher-order formulation proposed by Tati[36], the displacement field at any point (x,y,z) of the plate can be expressed as:

$$
\begin{aligned}
u(x,y,z) &= u_0(x,y,z) + z\beta_x(x,y) \\
v(x,y,z) &= v_0(x,y,z) + z\beta_y(x,y) \\
w(x,y,z) &= f(z)w_0(x,y) + (f(z)-1)S(x,y)
\end{aligned} \tag{1}
$$

Where $S(x,y)$ is a function defiend by:

$$\beta_x(x,y) = \frac{\partial S(x,y)}{\partial x} \quad \beta_y(x,y) = \frac{\partial S(x,y)}{\partial y} \tag{2}$$

The strain vectors are expressed in the form of a matrix as follows :

$$\{\varepsilon\} = \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \{\varepsilon^0\} + z\{\kappa\} = \begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{Bmatrix} + z\begin{Bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix} \tag{3}$$

$$\{\gamma\} = \begin{Bmatrix} \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix} = f(z)\begin{Bmatrix} \gamma_{xz}^0 \\ \gamma_{yz}^0 \end{Bmatrix} \tag{4}$$

Where $f(z) = \frac{5}{4}\left(1 - \frac{4z^2}{h^2}\right)$

2.2.2 Stress–Strain Relationships

Each lamina of the laminated composite plate is orthotropic and defined in its local coordinate system (1,2,3), as shown in Fig. 1(a). Direction 1 corresponds to the fiber orientation, 2 lies in-plane perpendicular to the fibers, and 3 is normal to the plate. Under the plane stress assumption (σ3=0), the constitutive relation is expressed as [37] :

$$\{\sigma_1\} = [D_1]\{\varepsilon_1\};\{\tau_1\} = [G_1]\{\gamma_1\} \tag{5}$$

$$\{\sigma_1\} = \begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{12} \end{Bmatrix} = \begin{bmatrix} D_{11} & D_{12} & 0 \\ D_{21} & D_{22} & 0 \\ 0 & 0 & D_{66} \end{bmatrix}\begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \gamma_{12} \end{Bmatrix};\{\tau_1\} = \begin{Bmatrix} \tau_{13} \\ \tau_{23} \end{Bmatrix} = \begin{bmatrix} G_{13} & 0 \\ 0 & G_{23} \end{bmatrix}\begin{Bmatrix} \gamma_{13} \\ \gamma_{23} \end{Bmatrix} \tag{6}$$

$$D_{11} = \frac{E_1}{1-\nu_{12}\nu_{21}};D_{12} = \frac{\nu_{12}E_1}{1-\nu_{12}\nu_{21}};D_{22} = \frac{E_2}{1-\nu_{12}\nu_{21}} \tag{7}$$

$\mathbf{E_1}$ and $\mathbf{E_2}$ represent the Young's moduli along the 1 and 2 material directions, respectively. $\mathbf{G_{12}}$, $\mathbf{G_{23}}$, and $\mathbf{G_{13}}$ denote the shear moduli corresponding to the 1–2, 2–3, and 3–1 planes, respectively, while $\boldsymbol{\nu_{12}}$ and $\boldsymbol{\nu_{21}}$ are the major and minor Poisson's ratios.

The matrix transformation from the local material coordinate system (1–2–3) to the global Cartesian coordinate system (x–y–z) can be expressed as :

$$\left[T_1\right]=\begin{bmatrix} \cos^2\theta_k & \sin^2\theta_k & \cos\theta_k\sin\theta_k \\ \sin^2\theta_k & \cos^2\theta_k & -\cos\theta_k\sin\theta_k \\ -2\cos\theta_k\sin\theta_k & 2\cos\theta_k\sin\theta_k & \cos^2\theta_k-\sin^2\theta_k \end{bmatrix};\ \left[T_2\right]=\begin{bmatrix} \cos\theta_k & \sin\theta_k \\ -\sin\theta_k & \cos\theta_k \end{bmatrix} \tag{8}$$

Finally, the stress–strain relationship in the global Cartesian coordinate system (X–Y) can be expressed as[37] :

$$\{\sigma\}=\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix}=[H]\{\varepsilon\};\{\tau\}=\begin{Bmatrix}\tau_{xz}\\ \tau_{yz}\end{Bmatrix}=[G]\{\gamma\}$$
$$[H]=[T_1]^T[D_1][T_1];[G]=[T_2]^T[G_1][T_2] \tag{9}$$

2.2.3 Stress resultants

The stress resultants are determined by integrating the stress components σ_x, σ_y, τ_{xy}, τ_{xz}, and τ_{yz} through the plate thickness h as follows [38]:

$$\begin{Bmatrix}N_x\\ N_y\\ N_{xy}\end{Bmatrix}=\int_{-\frac{h}{2}}^{\frac{h}{2}}\begin{Bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{Bmatrix}dz=\sum_{k=1}^{n}\int_{z_k}^{z_{k+1}}\begin{Bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{Bmatrix}dz;$$
$$\begin{Bmatrix}M_x\\ M_y\\ M_{xy}\end{Bmatrix}=\int_{-\frac{h}{2}}^{\frac{h}{2}}\begin{Bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{Bmatrix}(z)\,dz=\sum_{k=1}^{n}\int_{z_k}^{z_{k+1}}\begin{Bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{Bmatrix}(z)\,dz; \tag{10}$$
$$\begin{Bmatrix}Q_x\\ Q_y\end{Bmatrix}=\int_{-\frac{h}{2}}^{\frac{h}{2}}f(z)\begin{Bmatrix}\tau_{xz}\\ \tau_{yz}\end{Bmatrix}dz=\sum_{k=1}^{n}\int_{z_k}^{z_{k+1}}f(z)\begin{Bmatrix}\tau_{xz}\\ \tau_{yz}\end{Bmatrix}dz$$

Or, in terms of strains, by using Eqs. (3)-(4) and (9), we get :

$$\begin{Bmatrix}N_x\\ N_y\\ N_{xy}\end{Bmatrix}=\sum_{k=1}^{n}\left\{\int_{z_k}^{z_{k+1}}[H]\begin{Bmatrix}\varepsilon_x^0\\ \varepsilon_y^0\\ \gamma_{xy}^0\end{Bmatrix}dz+\int_{z_k}^{z_{k+1}}[H]\begin{Bmatrix}\kappa_x\\ \kappa_y\\ \kappa_{xy}\end{Bmatrix}(z)\,dz\right\}$$
$$\begin{Bmatrix}M_x\\ M_y\\ M_{xy}\end{Bmatrix}=\sum_{k=1}^{n}\left\{\int_{z_k}^{z_{k+1}}[H]\begin{Bmatrix}\varepsilon_x^0\\ \varepsilon_y^0\\ \gamma_{xy}^0\end{Bmatrix}(z)\,dz+\int_{z_k}^{z_{k+1}}[H]\begin{Bmatrix}\kappa_x\\ \kappa_y\\ \gamma_{xy}\end{Bmatrix}(z^2)\,dz\right\} \tag{11}$$
$$\begin{Bmatrix}Q_x\\ Q_y\end{Bmatrix}=\sum_{k=1}^{n}\left\{\int_{z_k}^{z_{k+1}}[G]\begin{Bmatrix}\gamma_{xz}\\ \gamma_{yz}\end{Bmatrix}f(z)\,dz\right\}=\sum_{k=1}^{n}\left\{\int_{z_k}^{z_{k+1}}[G]f^2(z)\begin{Bmatrix}\gamma_{xz}^0\\ \gamma_{yz}^0\end{Bmatrix}dz\right\}$$

In matrix form, the relationship between the stress resultants and the corresponding strain components can be expressed as:

$$\begin{Bmatrix} N \\ M \\ Q \end{Bmatrix} = \begin{bmatrix} D_m & D_{mb} & 0 \\ D_{bm} & D_b & 0 \\ 0 & 0 & D_s \end{bmatrix} \begin{Bmatrix} \varepsilon^0 \\ \kappa \\ \gamma^0 \end{Bmatrix} \tag{12}$$

Where

- D_m, D_{mb}, and D_b are the membrane, coupling, and bending stiffness matrices, respectively,
- D_s represents the transverse shear stiffness matrix.

$$\begin{aligned} \left(D_m \quad D_{mb} \quad D_b\right) &= \int_{-h/2}^{h/2} [H](1, z, z^2)dz \\ D_s &= \int_{-h/2}^{h/2} [G]\left[f(z)\right]^2 dz \end{aligned} \tag{13}$$

2.3 Formulate finite element

The proposed element, **HSDT-SBQMLP20**, is developed using the strain-based approach together with the high order shear deformation plate theory (HSDT). As illustrated in Figure.2, the four-node quadrilateral element has five DOFs per node: three translational displacements u,v,w along the x, y and z axes, and two rotations (β_x, β_y) corresponding to rotations of the normal in the y-z and x-z planes, respectively.

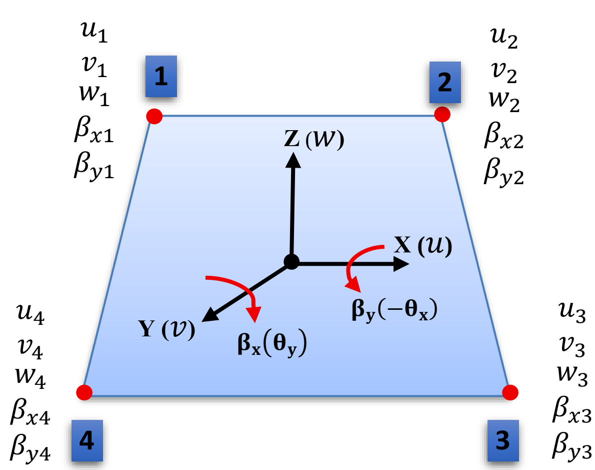

Figure 2. *Quadrilateral FG plate element (HSDT-SBQMLP20).*

2.3.1 Displacements field of the (HSDT-SBQMLP20) element

To determine the displacement filed for the current element (***HSDT-SBQMLP20***), we combined the displacement fields acquired from both the plate element (SBQMP) introduced by Bellounar et al[39]. and the membrane element (SBRIE) suggested by Sabir and Sfendji[40]

First,the displacement fields obtained for the membrane component (SBRIE) are[40]:

$$\begin{Bmatrix} u \\ v \end{Bmatrix} = [F_m]\{\alpha_m\} \tag{14}$$

Where $\{\alpha_m\} = \{\alpha_1, \alpha_2, \ldots, \alpha_8\}^T$

$$[F_m] = \begin{bmatrix} 1 & 0 & -y & x & xy & 0 & -\frac{y^2}{2} & \frac{y}{2} \\ 0 & 1 & x & 0 & -\frac{x^2}{2} & y & xy & \frac{x}{2} \end{bmatrix} \tag{15}$$

Whereas for the plate bending component (SBQMP), the displacement functions provided by Bellounar et al are[39]:

$$\begin{Bmatrix} w \\ \beta_x \\ \beta_y \end{Bmatrix} = [F_b]\{\alpha_b\} \tag{16}$$

Where $\{\alpha_b\} = \{\alpha_9, \alpha_{10}, \ldots, \alpha_{20}\}^T$

$$[F_b] = \begin{bmatrix} 1 & -x & -y & -\frac{x^2}{2} & -\left(\frac{x^2 y}{2} + \frac{y^3}{12}\right) & -\frac{y^2}{2} & -\left(\frac{xy^2}{2} + \frac{x^3}{12}\right) & -\frac{xy}{2} & \frac{x}{2} & \frac{xy}{2} & \frac{y}{2} & \frac{xy}{2} \\ 0 & 1 & 0 & x & xy & 0 & \left(\frac{x^2}{4} + \frac{y^2}{2}\right) & \frac{y}{2} & \frac{1}{2} & \frac{y}{2} & 0 & -\frac{y}{2} \\ 0 & 0 & 1 & 0 & \left(\frac{y^2}{4} + \frac{x^2}{2}\right) & y & xy & \frac{x}{2} & 0 & -\frac{x}{2} & \frac{1}{2} & \frac{x}{2} \end{bmatrix} \tag{17}$$

The displacement functions from Eqs. (15) and (17) are formulated using the strain approach, satisfying constant strain, rigid body, and compatibility conditions. Their combination yields the interpolation functions for the HSDT-SBQMLP20 element as follows[41]:

$$\{\mathrm{U_e}\} = \begin{Bmatrix} u \\ v \\ w \\ \beta_x \\ \beta_y \end{Bmatrix} = \begin{bmatrix} [F_m] & [0] \\ [0] & [F_b] \end{bmatrix} \begin{Bmatrix} \{\alpha_m\} \\ \{\alpha_b\} \end{Bmatrix} = [\mathrm{F}]\{\alpha\} \tag{18}$$

Where $\{\alpha\}^T = \{\{\alpha_m\}\,\{\alpha_b\}\}^T = \{\alpha_1, \ldots \alpha_{20}\}^T$

$$[\mathrm{F}] = \begin{bmatrix} [F_m] & [0] \\ [0] & [F_b] \end{bmatrix} \tag{19}$$

The transformation matrix [C] linking the elemental nodal displacement vector $\{\delta^e\}^{\mathrm{T}} = \left\{ u_{\mathrm{i}}, v_{\mathrm{i}}, w_{\mathrm{i}}, \beta_{x_{\mathrm{i}}}, \beta_{y_{\mathrm{i}}} \right\}_{i=1,2,3,4}$ to the vector of constants $\{\alpha\}$ is defined as follows:

$$\{\delta^e\} = [C]\,\{\alpha\} \tag{20}$$

Where

$$[C]=\{[F_1(x_i,y_i)]\ [F_2(x_i,y_i)]\ [F_3(x_i,y_i)]\ [F_4(x_i,y_i)]\}^{\mathrm{T}} \tag{21}$$

And (x_i, y_i) are the coordinates of the four node i (i = 1, 2, 3, 4)

The constant parameter vector $\{\alpha\}$ is determined from Eq. (37) as follows:

$$\{\alpha\} = [C]^{-1}\{\delta^e\} \tag{22}$$

Substituting Eq. (22) into Eq. (18) yields:

$$\{\mathrm{U_e}\} = \begin{Bmatrix} u \\ v \\ w \\ \beta_x \\ \beta_y \end{Bmatrix} = [F][C]^{-1}\{\delta^e\} = [N]\,\{\delta^e\} \tag{23}$$

Where

$$[N] = [F][C]^{-1} \tag{24}$$

2.3.2 Strain-displacement relation

The strain-displacement relationship for membrane, curvatures and shear strains, respectively are calculated[41]:

$$\{\varepsilon^0\} = \begin{bmatrix} \partial/\partial x & 0 \\ 0 & \partial/\partial y \\ \partial/\partial y & \partial/\partial x \end{bmatrix} \big[[F_m] \quad [0]\big]_{3\times 20}\{\alpha\} = [R_m]\,\{\alpha\} \tag{25}$$

$$\{\kappa\} = \begin{bmatrix} 0 & \partial/\partial x & 0 \\ 0 & 0 & \partial/\partial y \\ 0 & \partial/\partial y & \partial/\partial x \end{bmatrix} \big[[0] \quad [F_b]\big]_{3\times 20}\{\alpha\} = [R_b]\{\alpha\} \tag{26}$$

$$\{\gamma_z{}^0\} = \begin{bmatrix} \partial/\partial x & 1 & 0 \\ \partial/\partial y & 0 & 1 \end{bmatrix} \big[[0] \quad [F_b]\big]_{3\times 20}\{\alpha\} = [R_s]\{\alpha\} \tag{27}$$

The strain–displacement relationship is obtained by substituting Eq. (22) into Eqs. (25–27), giving:

$$\{\varepsilon^0\} = [R_m][C]^{-1}\{\delta^e\} = [\mathrm{B_m}]\{\delta^e\} \tag{28}$$

$$\{\kappa\} = [R_b][C]^{-1}\{\delta^e\} = [\mathrm{B_b}]\{\delta^e\} \tag{29}$$

$$\{\gamma_z{}^0\} = [R_s][C]^{-1}\{\delta^e\} = [\mathrm{B_s}]\{\delta^e\} \tag{30}$$

Where $[\mathrm{B_m}]$, $[\mathrm{B_b}]$,, and $[\mathrm{B_S}]$, denote the membrane, bending, and shear strain–displacement matrices, respectively, and are expressed as follows:

$$[\mathrm{B_m}] = [R_m][C]^{-1}; [R_b][C]^{-1}; [B_s] = [R_s][C]^{-1} \tag{31}$$

2.3.3 Derivation of elemental matrices

The element stiffness matrix is constructed by combining five individual submatrices, as expressed below [41]:

$$\begin{aligned}[K_e] = &\left(\int_S [B_m]^T [D_m][B_m]\,dS\right) + \left(\int_S [B_m]^T [D_{mb}][B_b]\,dS\right) + \left(\int_S [B_b]^T [D_{mb}][B_m]\,dS\right) \\ &+ \left(\int_S [B_b]^T [D_b][B_b]\,dS\right) + \left(\int_S [B_s]^T [D_s][B_s]\,dS\right)\end{aligned} \tag{32}$$

The element nodal equivalent load vector, corresponding to the applied distributed transverse load q(x,y), is formulated as follows [41]:

$$\{F_e\} = \int_S [N]\,q(x,y)\,dS \tag{33}$$

For static analysis:

$$[K_e]\{\delta_e\} = \{F_e\} \tag{34}$$

For free vibration analysis :

$$\begin{aligned} &[K_e]\{\delta_e\} + [M_e]\left\{\ddot{\delta}_e\right\} = 0 \\ &\left([K_e] - \omega^2 [M_e]\right)\{\delta_e\} = 0 \end{aligned} \tag{35}$$

Where ω is the fundamental frequency, $[M_e]$ is the mass matrix of the element, that is given by :

$$[M_e] = \int_S [N]^T [I_0][N]\, dS \tag{36}$$

Where

$$[I_0] = \rho \begin{bmatrix} h & 0 & 0 & 0 & 0 \\ 0 & h & 0 & 0 & 0 \\ 0 & 0 & h & 0 & 0 \\ 0 & 0 & 0 & \dfrac{h^3}{12} & 0 \\ 0 & 0 & 0 & 0 & \dfrac{h^3}{12} \end{bmatrix} \tag{37}$$

3 Numerical findings and discussion

This study analyzes the free vibration behavior of square, skewed, and elliptical laminated plates using the developed finite element model. The results are validated against existing analytical and numerical solutions. The influence of key parameters—such as the number of layers, aspect ratio, fiber orientation, and boundary conditions—is systematically examined. The material properties used in the analysis are listed in Table 1. Two boundary conditions are considered:

- For simply supported boundaries (SSSS) :

$$\left(v = w = \beta_y = 0\right) \; ; \; x = 0, a$$

$$\left(u = w = \beta_x = 0\right) \; ; \; y = 0, b$$

- For clamped boundaries (CCCC) :

$$x = 0, a \quad y = 0, b$$

For convenience, the following nondimensional formulas are assumed :

$$\overline{\omega} = \left(\omega a^2/\pi^2\right)\sqrt{\rho h/D_0} \;\text{ with }\; D_0 = \left(E_2 h^3/12\left(1 - \nu_{12}\nu_{21}\right)\right) \tag{38}$$

$$\overline{\overline{\beta}} = \left(\omega a^2/\pi^2 h\right)\sqrt{\rho/E_2} \tag{39}$$

Table 1. *Material properties of the composite laminate.*

Properties	Material (M)						
	M_1	M_2	M_3	M_4	M_5	M_6	M_7
$\mathbf{E_{11}(Gpa)}$	25	3	10	20	30	40	2.45
$\mathbf{E_{22}(Gpa)}$	01	01	01	01	01	01	01
$\mathbf{G_{12}(Gpa)}$	0.5	0.6	0.6	0.6	0.6	0.6	0.48
$\mathbf{G_{13}(Gpa)}$	0.5	0.6	0.6	0.6	0.6	0.6	0.48
$\mathbf{G_{23}(Gpa)}$	0.2	0.5	0.5	0.5	0.5	0.5	0.2
$\boldsymbol{\nu_{12} = \nu_{23} = \nu_{13}}$	0.25	0.25	0.25	0.25	0.25	0.25	0.23
$\boldsymbol{\rho}$	01	01	01	01	01	01	01

3.1 Square laminated plates

The convergence analysis is performed on a three-layer cross-ply [0°/90°/0°] square laminated plate with clamped boundary conditions. Various aspect ratios (a/h = 5, 10, 20, 100) are considered using material M6, whose properties are listed in Table 1. The non-dimensional frequencies ($\bar{\omega}$) obtained with the proposed HSDT-SBQMLP20 element for four mesh refinements (8×8, 16×16, and 20×20) are presented in Table 2. The corresponding mode shapes for the case of a/h = 10 are shown in Fig. 8. The computed results demonstrate excellent agreement with those reported by Liew [42] using FSDT, as well as with smoothed FEM formulations (ES-DSG3, MISQ20) by Nguyen-Van et al. [43], and the strain-based element (SBQLP) proposed by Belounar et al[37]., which is also based on FSDT.

Table2*. Non-dimensional natural frequencies ($\bar{\varpi}$) of clamped cross-laminated square plates with various length-to-thickness ratio.*

a/h	Theory	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
5	**HSDT-SBQMLP20 (8×8)**	4.5326	6.8075	8.0033	9.4799	10.2470
	HSDT-SBQMLP20 (16×16)	4.5009	6.6752	7.8768	9.3226	9.8132
	HSDT-SBQMLP20 (20×20)	4.4973	6.6601	7.8618	9.3043	9.7635
	SBQLP (20×20) [28]	4.4519	6.6665	7.7235	9.2113	9.8215
	p-Ritz Liew [42]	4.447	6.642	7.700	9.185	9.738
	MISQ20 [41]	4.4671	6.7365	7.7706	8.7678	9.2988
10	**HSDT-SBQMLP20 (8×8)**	7.5371	10.6868	14.3857	16.1635	16.5079
	HSDT-SBQMLP20 (16×16)	7.5137	10.4885	14.2215	15.6437	16.0392
	HSDT-SBQMLP20 (20×20)	7.5113	10.4683	14.2020	15.5529	16.0287
	SBQLP (20×20) [28]	7.4168	10.4271	13.9509	15.5788	15.8220
	p-Ritz Liew [42]	7.411	10.393	13.913	15.429	15.806
	MISQ20 [41]	7.4542	10.5909	14.0808	16.0497	16.0868
20	**HSDT-SBQMLP20 (8×8)**	11.0896	14.1951	21.8375	23.9942	24.9741
	HSDT-SBQMLP20 (16×16)	11.0578	14.1041	20.6822	23.6514	25.1988
	HSDT-SBQMLP20 (20×20)	11.0544	14.0994	20.5767	23.6099	25.2316
	SBQLP (20×20) [28]	10.9664	14.0480	20.5667	23.2866	24.9647
	p-Ritz Liew [42]	10.953	14.028	20.388	23.196	24.978
	MISQ20 [41]	11.0454	14.2988	21.4609	23.6389	25.4605
100	**HSDT-SBQMLP20 (8×8)**	14.6050	17.3880	25.9217	39.3539	39.6438
	HSDT-SBQMLP20 (16×16)	14.4661	17.3392	24.4598	36.2244	38.2577
	HSDT-SBQMLP20 (20×20)	14.4525	17.3528	24.3758	35.8093	38.0996
	SBQLP (20×20) [28]	14.7043	17.6157	24. 6527	36. 1657	39. 5037

3.2 Skew Laminated Plates

This section analyzes the normalized frequencies$(\bar{\beta})$ of five-layer skew laminated square plates with the stacking sequence [45°/−45°/45°/−45°/45°], under CCCC boundary conditions. The material used is M6 with a/h = 10 (see Table 1).

A 13 × 13 node grid is employed (Figure 3), and results obtained using the HSDT-SBQMLP20 element are listed in Table 7 for inclination angles (θ) from 0° to 60°.

Comparison with MLSDQ [44] ,RBF [45], and B-spline [46]methods shows excellent agreement, confirming the accuracy of the proposed model for angle-ply composite plates.

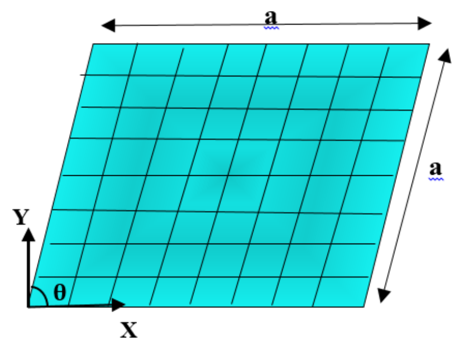

Figure 3. *Skew FG plate element (HSDT-SBQMLP20).*

Table 3. Dimensionless fundamental frequencies$(\bar{\beta})$ for CCCC angle- ply -laminated plate [45°/-45°/45°/-45°/45°] with different angles

Theory	θ = 0°	θ = 15°	θ = 30°	θ = 45°	θ = 60°
HSDT-SBQMLP20 (12×12)	**2.2744**	**2.3527**	**2.6832**	**3.4353**	**4.8926**
MLSDQ [44]	2.2787	2.3504	2.6636	3.3594	4.8566
RBF [45]	2.3324	2.3962	2.6981	3.3747	4.8548
FSDT [46]	2.2462	2.3109	2.6185	3.3009	4.7841
HSDT [46]	2.2413	2.2763	2.5504	3.1921	4.6325

4 Conclusion

The developed HSDT-SBQMLP20 element has demonstrated high accuracy and computational efficiency in predicting the free vibration characteristics of laminated composite plates with various geometries and boundary conditions. The convergence study confirms the element's stability and rapid accuracy improvement with mesh refinement. Excellent agreement with benchmark solutions—including p-Ritz, MLSDQ, RBF, and FSDT/HSDT models—validates the reliability of the proposed formulation. The results also highlight the strong influence of geometric parameters, fiber orientation, and boundary conditions on the dynamic response. The element successfully captures both square and skew plate behaviors, confirming its robustness and applicability to complex laminated structures

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