Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879


# Investigation of the Mechanical Response of a Fabric-Reinforced Composite Beam with a T-Shaped Profile during a Three-Point Bending Test by Employing FEM

Intesar Khalil Atiyah[1], Waleed Abdulhamza Asker[1], Ruaa Nazar Talib[2], Emad Kamil Hussein[1,*]

[1] Mechanical Power Engineering Department, Mussaib Technical College, Al Furat Al Awsat Technical University, 51006, Babil, Iraq
[2] School Buildings Department, General Directorate of Education/ Baghdad- Al-Karkh 3rd, Ministry of Education, Baghdad, Iraq

**ARTICLE INFO**

***Article history:***
Received 18 March 2024
Received in revised form 21 June 2024
Accepted 4 July 2024
Available online 30 July 2024

***Keywords:***
Ansys; bending test; T-shape; structural analysis; normal stresses

**ABSTRACT**

In this study, three-point bending tests were utilised in order to evaluate the mechanistic behaviour of the composite structure. Investigation and analysis have both made use of profiles in the form of a T for their respective aims. In this particular study, the modelling and meshing of geometry was carried out with the assistance of Ansys Software. The normal stress was the key indication that was utilised in the convergency approach. This indicator was employed to bring the outputs of the mesh and the predictions closer together. One of the tools that is used for simulating static structures was put to use so that the interaction of the composite structure with its surroundings could be modelled in a mechanical way. The normal stress and consequent of the whole deformation as a result of the applied static load have been utilised to carry out the numerical calculations, and the results have been evaluated and interpreted. This is because the normal stress and consequent of the total deformation as a result of the imposed static load. At a temperature of 20 degrees Celsius, the calculations show that the magnitude of the stress induced by the 200 N can reach a maximum of 0.4 MPa. It was discovered that this is really the situation. The total deformation of the entire body has a value of 0.004 millimetres over its entirety. This value accounts for the entirety of the deformation. The output of the numerical findings indicated, at the conclusion of the study, that the composite construction had the potential to resist because of the applied static force.

## 1. Introduction

As a respectable viewpoint in technical contexts, the following are some of its advantages: As opposed to traditional HCBs, which use open T-sections of steel with a limited width-to-depth ratio, encased concrete and thin-walled external steel T-sections work as a prop to delay or even prevent local buckling of the steel [1]. It is also possible for encased concrete and thin-walled exterior steel T-sections to collaborate in order to maximize shear capacity and prevent brittle shear failure [2]. CUCB's peak year was rather short, but the organization's details and forms were quite thorough [3].

* *Corresponding author.*
*E-mail address: emad_kamil72@atu.edu.iq*

https://doi.org/10.37934/arfmts.119.2.2331

studied composite profiled beams, in which open box girders were composed with profiled sheets, before 2000 [4]. The shear capacity, ductility, minimum creep deformation, and low dead weight of these composite beams are all impressive, but they would demand a large number of site supports and humans in order to be propped under building loads. Several CUCB-like layouts have been created since the year 2000, with outside steel kinds varied, thin walled steel U sections cold formed [5]. Slab and column top flanges were simple to install and functioned effectively in hogging areas. However, because of the difficult manufacturing process and the substantial welding quantity, residual stress effects may emerge in the welded light steel section. Mechanical qualities (such as deformability and bearing capacity) are heavily influenced by the integral behavior of composite beams [6]. The CUCB contains two interfaces that are susceptible to failure: one between the encased concrete and the outside steel U-section, and another between the concrete slab and the structure's bottom half. Both of these interfaces are weak points in the structure. (including the concrete that encases the steel U-section and the reinforcement) [5,6]. One of the most significant topics that may be discussed in the technical field of structural mechanics is the reaction of composite structures that are reinforced by BNNTs or CNTs to bending, vibration, and buckling [7]. This is one of the most essential topics that can be taken into consideration. The most important aspects of these nanotubes that were the subject of discussion were, respectively, the mechanical and electrical characteristics of carbon nanotubes (CNTs) and boron nanotubes (BNNTs). During the course of this experiment, an examination of the electro-mechanical buckling of a piezoelectric polymeric shell that was reinforced by double-walled boron nitride nanotubes was carried out. The researchers came to the conclusion that the employment of foam cores that possessed a stronger strength resulted in a significant increase in the buckling strength [8]. This conclusion was reached as a consequence of the outcomes of the investigation. During the course of the research, density functional theory was utilized in order to explore the structure and electrical properties of armchair BNNTs as a function of tube diameter. A continuum technique was utilized in order to ascertain the Young's moduli and Poisson's ratio of boron-nitride crystals. The results of this investigation were found to be in agreement with both the experimental and theoretical values [9]. Piezoelectric polymeric composites that incorporated BNNT reinforcement were subjected to electrothermomechanical loadings in order to determine their level of endurance. The dynamic behavior of visco-elastic double-bonded polymeric nano-composite plates reinforced by FGSWCNTs was investigated using MSGT, a sinusoidal shear deformation model, and a meshless method [10].

A finite-element analysis was conducted in order to examine the buckling and free vibration of a tapered FGCNTRC micro Reddy beam while it was being exposed to a longitudinal magnetic field. This was done in order to determine the severity of the beam's behavior. For the purpose of determining the effects of the magnetic field, this investigation was carried out [11,12]. Over the course of this research project, the nonlinear static and vibration characteristics of a Euler-Bernoulli composite beam model that was reinforced by FGSWCNT were examined. This was done in order to get a better understanding of the features. The dynamic and buckling behaviors of composite Timoshenko beams that had been strengthened with carbon nanotubes were evaluated by Abdullah *et al.,* [13] utilizing a base constructed of elastic material. This was done in situations where there were a significant number of weights that were continually changing.

In a study by Raheemah *et al.,* [14], the dynamic behaviour of multiwalled carbon nanotubes with polystyrene wall coatings was examined. Piezoelectric nanocomposites reinforced with FG-SWNTs, to be tested in biaxial and bending directions. In a research done by Santos *et al.,* [15], a Reddy rectangular plate model that had a changed strain gradient was utilised. DQM was used to investigate MSGT micro-composite Reddy plates reinforced by FGSWCNTs under hydro-thermo-mechanical loading conditions [16]. The material properties of these plates changed depending on the temperature. Surface stress and agglomeration have both been explored in connection to the nonlocal biaxial stability of a polymeric nanocomposite plate that has been reinforced by CNT [17].

The overall deformation and normal stresses of the manufactured beam have been calculated and predicted in this work using numerical analysis.

## 2. Methodology

### *2.1 Material Properties*

The T-shaped beam structure has been fabricated using composite material, and the mechanical parameters of these structures have been gathered and are presented in Table 1.

**Table 1**
Mechanical properties of the composite structure

| No. | Properties | Composite materials |
|---|---|---|
| 1 | E (GPa) | 0.7 |
| 2 | passion ratio | 0.341 |
| 3 | Density (kg/m$^3$) | 2560 |

### *2.2 Geometry and Meshing*

T-shaped profile beams have been designed using AutoCAD in this study as shown in Figure 1. Ansys Software's SpaceCalim was used to perform the modelling once the geometry was loaded there. The Ansys programme may be utilised to perform research on the case being studied here. A well-known piece of software called ANSYS is utilised for the modelling and simulation of equations, as well as the generation of the necessary solutions. An additional piece of software called SpaceClaim is an ANSYS pre-processor. Its purpose is to generate and apply the mesh to the geometrical portrayal of the topic that is being investigated. ANSYS MECHANICAL is responsible for both the processing and the post-processing stages of the analysis. In the more challenging sections of the model, Tri-type paves are utilised, whilst Quad-type paves are utilised in the remaining portions of the model [18]. ANSYS allows for total mesh flexibility when working with amorphous meshes, and the grid may be polished or roughened depending on the requirements of the solution. Following the reading of the grid into ANSYS [19].

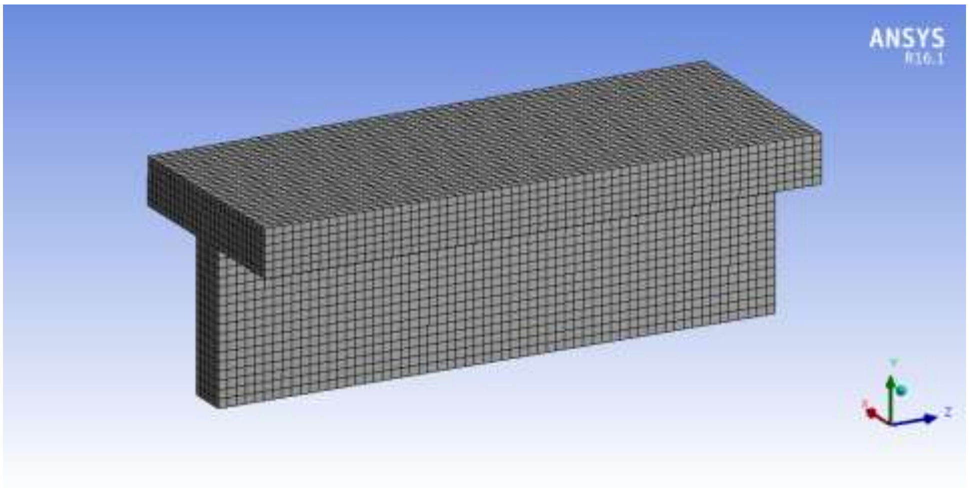


**Fig. 1.** Meshed model of the T-shape of the composite structure

*2.3 Boundary Conditions*

A numerical analysis was carried out in Ansys mechanical r2 for the purpose of this particular inquiry. A static structural tool has been utilized in order to carry out the project that is now being developed. a beam that was functioning as a structure was bent in three distinct directions all at once. The central force is responsible for maintaining two fixed places, and the boundary conditions are the ones that decide where these positions are. As can be seen in Figure 2, the kind of force that is being discussed here is a static load, and the number that is being discussed here is 200 N. The setting of the programme has been adjusted to reflect the ambient temperature, which was determined to be 20 degrees Celsius.

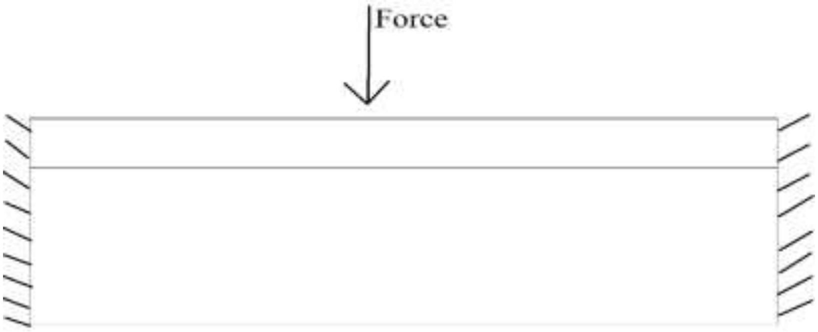


**Fig. 2.** The applied load with fix support

## 3. Results and Discussion

*3.1 Grid-independent Test*

The total number of items that have been considered in this study is 56445. The mesh that represents the current geometry has been adjusted to reflect the converged state. The geometry of the analysis has been meshed, and the results have converged correspondingly. The employment of normal stresses as the primary indication of the convergence strategy has been a prevalent practice for a considerable amount of time because it gives more accuracy in the results [20]. As can be seen in Figure 3, the stress at this number of components is equal to 0.88 when there is an applied load of 200 N. Even with increasing the number of pieces to 5744, the stress is still only 0.88 MPa when the applied load is the same as before, which is 200 N at 20 C.

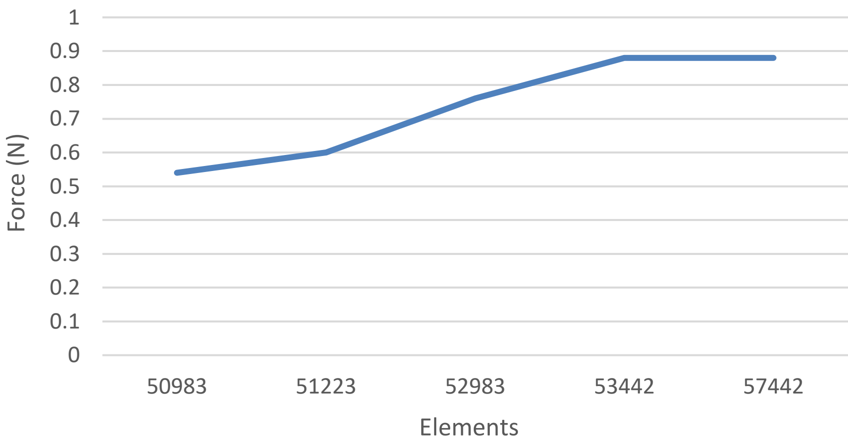


**Fig. 3.** Grid-independent test

### *3.2 Investigation of Normal Stresses*

The effect that the artificially induced static load had on the structural composite beam is depicted graphically in Figure 4, which may be seen here. In the figure that came before this one, this impact is visually shown. The technique of simulation revealed that the component of the composite structure that was situated in the center was the one that was subjected to the greatest amount of stress as a consequence of the simulation. It has been determined that 0.04 MPa is the new record for the greatest stress that has been attained. A value of two hundred Newtons (N) was assigned to the load that was applied. For the purpose of determining the normal stress, the results of measurements that were obtained along the X-axis in a global coordinate system at a temperature of 20 degrees Celsius were examined.

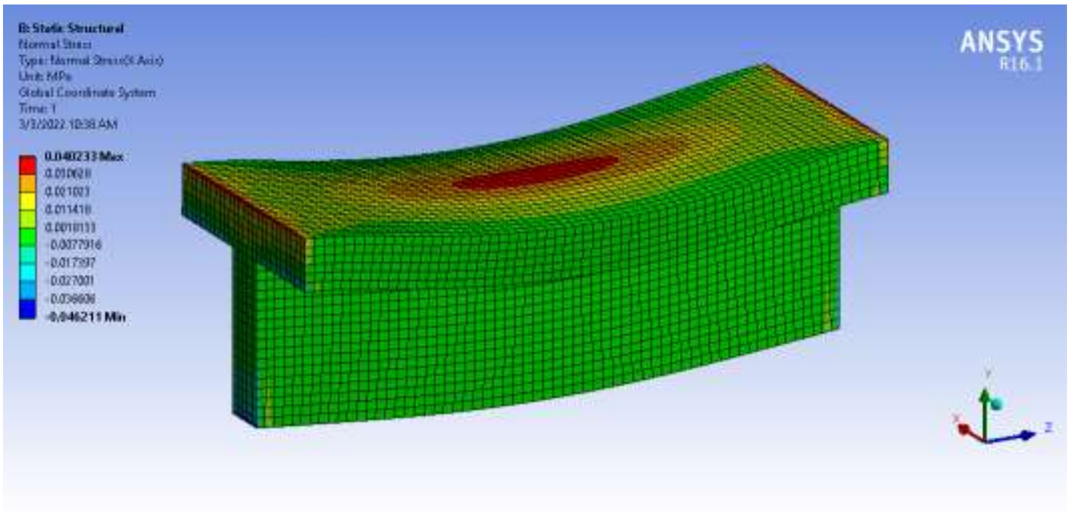


**Fig. 4.** Numerical results of the normal stresses

Figure 5 illustrates the stress that was triggered as a result of the imposed static stresses. These are examples of situations in which a number of loads have been applied in a coordinated style. Using the instrument for static structural analysis, the loads of 200, 150, 100, 50, 25, and 10 N have each been modeled and simulated in their respective positions. Loads have been applied to each of the six equalized time periods during the course of the simulation session.

On the basis of the findings of the simulation, the region that was subjected to a force of 200 Newtons and a pressure of 0.04 megapascals experienced the highest possible amount of stress. The smallest amount of stress that could be produced was ten newtons at a pressure of 0.015 MPa.

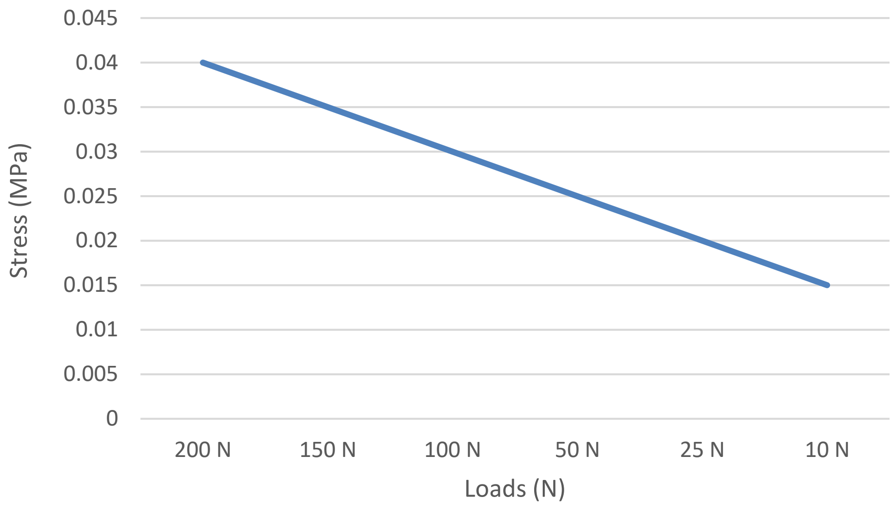


**Fig. 5.** Stress due to the applied load

### *3.3 Investigation of Total Deformation*

As can be seen in Figure 3, which illustrates the graphical impact that the applied static load has on the structural t-shape profile of the composite beam, the entire deformation has been mathematically expected. This can be seen in the figure. The findings of the simulation technique indicate that the composite structure's center is the location of the biggest overall deformation, which measures 0.0014 millimeters and happens in the center of the structure. 0.0014 millimeters is the highest degree of tension that has ever been recorded. Two hundred Newtons was the force that was delivered to the load. The findings for normal stress were obtained along the X-axis; this was done within the framework of the global coordinate system. A small deformation of five e-tenths of a millimeter may be seen throughout the whole body of the composite structure, as seen in Figure 6.

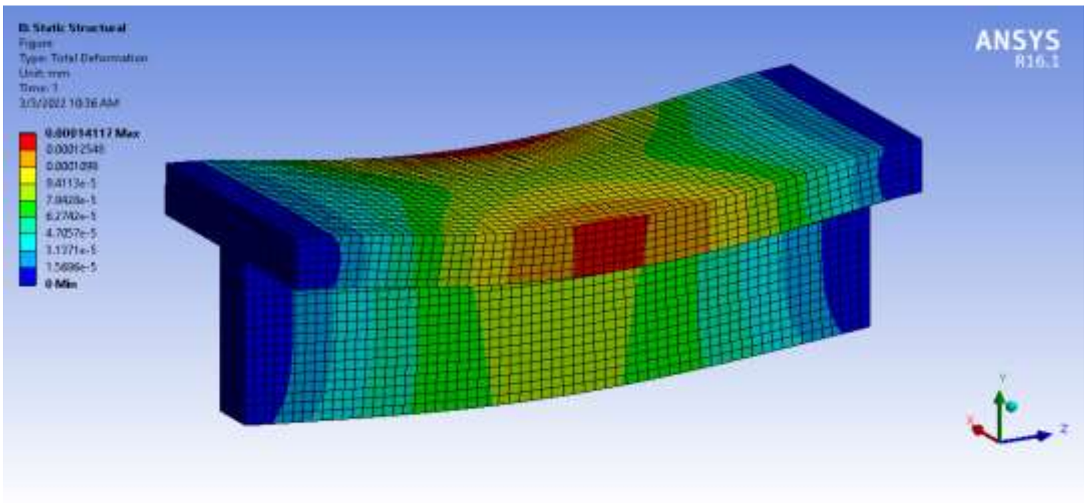


**Fig. 6.** Total deformation results

Figure 7 depicts the stress induced by the applied total deformation. The following instances illustrate scenarios in which several loads have been systematically imposed in a coordinated manner. Models and simulations of loads with respective values of 200, 150, 100, 50, 25, and 10 N have been added into the apparatus that is used for static structural analysis. Throughout the course of the simulation, a number of different loads were given to each of the six time periods that were equivalent to one another.

According to the results of the simulation, it was seen that the region that was subjected to a force magnitude of 200 N and a pressure value of 0.00014 m had the maximum level of stress. 10 Newtons of force with a magnitude of 0.0001 millimeters was the least amount of tension that could be created.

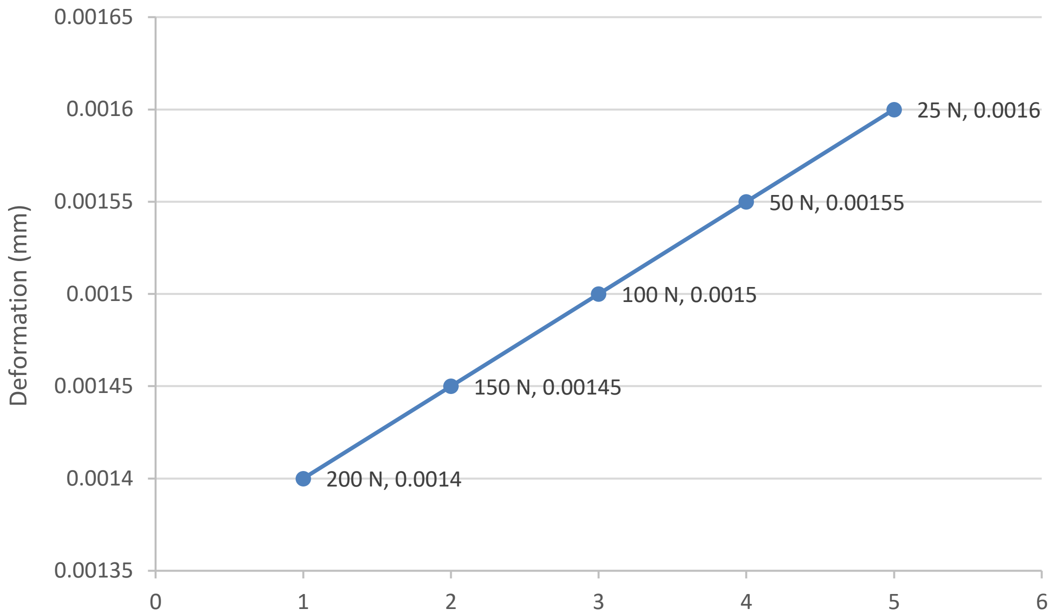


**Fig. 7.** Total deformation due to the applied static loads

## 4. Conclusions

In this investigation, the mechanical behaviour of the composite structure was investigated by means of bending experiments conducted from three different angles. In order to analyse and make sense of the data, T-shaped profiles were utilised. For modelling and meshing the geometry included in this inquiry, Ansys Software was utilised. When trying to converge the mesh and the outcomes that were projected, a crucial indicator of the convergency approach was using normal stress at 20 C. A static structure tool was utilised in order to do a simulation of the mechanical behaviour of the composite construction. The normal stress and the total deformation that occurred as a consequence of the imposed static load were used in the calculation of the numerical results. Because of the force of 200 N, the numerical calculations show that the greatest stress is 0.4 MPA, and the total body deformation is 0.004 mm. This results in a total stress of 0.4 MPA and a total deformation of 0.004 mm. In conclusion, the computational findings demonstrated that the composite structure had the capacity to resist the static force that was applied to it.

## Acknowledgement
This research was not funded by any grant.

## References
[1] Bachi Al-Fahad, Imad O., Azzam D. Hassan, Batool Mardan Faisal, and Hussein Kadhim Sharaf. "Identification of regularities in the behavior of a glass fiber-reinforced polyester composite of the impact test based on ASTM D256 standard." *Eastern-European Journal of Enterprise Technologies* 124, no. 7 (2023). https://doi.org/10.15587/1729-4061.2023.286541

[2] Ouyang, Yiwei, Baozhong Sun, and Bohong Gu. "Finite element analyses on bending fatigue of three-dimesional five-directional braided composite T-beam with mixed unit-cell model." *Journal of Composite Materials* 52, no. 9 (2018): 1139-1154. https://doi.org/10.1177/0021998317722203

[3] Bachi Al-Fahad, Imad O., Hussein Kadhim Sharaf, Lina Nasseer Bachache, and Nasseer Kassim Bachache. "Identifying the mechanism of the fatigue behavior of the composite shaft subjected to variable load." *Eastern-European Journal of Enterprise Technologies* 123, no. 7 (2023). https://doi.org/10.15587/1729-4061.2023.283078

[4] Saleh, Mohamed Nasr, and Constantinos Soutis. "Recent advancements in mechanical characterisation of 3D woven composites." *Mechanics of Advanced Materials and Modern Processes* 3 (2017): 1-17. https://doi.org/10.1186/s40759-017-0027-z

[5] Basha, Neelufer Z., F. Mebarek-Oudina, Rajashekhar Choudhari, Hanumesh Vaidya, Balachandra Hadimani, K. V. Prasad, Manjunatha Gudekote, and Sangeeta Kalal. "Thermal Radiation Effect on Mixed Convective Casson Fluid Flow over a Porous Stretching Sheet with Variable Fluid Properties." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 111, no. 1 (2023): 1-27. https://doi.org/10.37934/arfmts.111.1.127

[6] Balachandra, H., Choudhari Rajashekhar, Hanumesh Vaidya, Fateh Mebarek Oudina, Gudekote Manjunatha, Kerehalli Vinayaka Prasad, and Prathiksha Prathiksha. "Homogeneous and heterogeneous reactions on the peristalsis of bingham fluid with variable fluid properties through a porous channel." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 88, no. 3 (2021): 1-19. https://doi.org/10.37934/arfmts.88.3.119

[7] Sharaf, Hussein Kadhim, Sadeq Salman, Mohammad Hassan Dindarloo, Valery I. Kondrashchenko, Alla Andronikovna Davidyants, and Sergey V. Kuznetsov. "The effects of the viscosity and density on the natural frequency of the cylindrical nanoshells conveying viscous fluid." *The European Physical Journal Plus* 136 (2021): 1-19. https://doi.org/10.1140/epjp/s13360-020-01026-y

[8] Sharaf, Hussein Kadhim, Nawal Aswan Abdul Jalil, and Sadeq Salman. "A simulation on the effect of ultrasonic vibration on ultrasonic assisted soldering of Cu/SAC305/Cu joint." *Journal of Advanced Research in Applied Mechanics* 36, no. 1 (2017): 1-9.

[9] Salman, Sadeq, Hussein Kadhim Sharaf, Ahmed Faeq Hussein, Najlaa Jasim Khalaf, Mohammed Khudhair Abbas, Ashham Mohammed Aned, Alaa Abdulazeez Turki Al-Taie, and Mustafa Musa Jaber. "Optimization of raw material properties of natural starch by food glue based on dry heat method." *Food Science and Technology* 42 (2022): e78121. https://doi.org/10.1590/fst.78121

[10] Alyaseri, Nagham Hameed Abdulkhudhur, Mazen Dawood Salman, Rabab Wahhab Maseer, Emad Kamil Hussein, Kussay Ahmed Subhi, Saleemah Abdullah Alwan, Jasim Gshayyish Zwaid et al. "Exploring the Modeling of Socio-Technical Systems in the Fields of Sport, Engineering and Economics." *Revista Iberoamericana de Psicología del Ejercicio y el Deporte* 18, no. 3 (2023): 338-341.

[11] Jawad, Karrar Kareem, Nagham Hameed Abdulkhudhur Alyaseri, Saleemah Abdullah Alwan, Emad Kamil Hussein, Kussay Ahmed Subhi, Hussein Kadhim Sharaf, Ahmed Faeq Hussein et al. "Contingency in Engineering Problem Solving Understanding its Role and Implications: Focusing on the sports Machine." *Revista Iberoamericana de Psicología del Ejercicio y el Deporte* 18, no. 3 (2023): 334-337.

[12] Sharaf, Hussein Kadhim, Shahad Alyousif, Najlaa Jasim Khalaf, Ahmed Faeq Hussein, and Mohammed Khudhair Abbas. "Development of bracket for cross arm structure in transmission tower: Experimental and numerical analysis." *New Materials, Compounds and Applications* 6, no. 3 (2022): 257-275.

[13] Abdullah, Yussra Malallah, Ghadeer Salim Aziz, Hala Kaydar Salah, and Hussein Kadhim Sharaf. "Simulate the Rheological Behaviour of the Solar Collector by Using Computational Fluid Dynamic Approach." *CFD Letters* 15, no. 9 (2023): 175-182. https://doi.org/10.37934/cfdl.15.9.175182

[14] Raheemah, Saddam Hussein, Kareem Idan Fadheel, Qais Hussein Hassan, Ashham Mohammed Aned, Alaa Abdulazeez Turki Al-Taie, and Hussein Kadhim. "Numerical analysis of the crack inspections using hybrid approach for the application the circular cantilever rods." *Pertanika Journal of Science & Technology* 29, no. 2 (2021): 1109-1117. https://doi.org/10.47836/pjst.29.2.22

[15] Santos, Thiago F., Caroliny M. Santos, Mariana Dias, Lucas Zilio, Katia M. Melo, Maria Eduarda Cavalcante, Luiz Filipe Castro, Emad Kamil Hussein, and Marcos Aquino. "Mechanical behavior of natural/synthetic weft-knitted structures commonly used as reinforcement of hybrid composites via full factorial design: yarn compositions and float stitches." In *Green Hybrid Composite in Engineering and Non-Engineering Applications*, pp. 261-283. Singapore: Springer Nature Singapore, 2023. https://doi.org/10.1007/978-981-99-1583-5_15

[16] Mandumpal, Jestin Baby, Debra Sharon Ferdinand-James, Parisa Ziarati, Emad Kamil Hussein, Krishnan Umachandran, and Ian G. Kennedy. "Innovation-based learning (InnBL): Turning science and engineering undergraduate degree programmes towards innovation." *Journal of Creativity* 32, no. 1 (2022): 100013. https://doi.org/10.1016/j.yjoc.2021.100013

[17] Hussein, Emad Kamil, Kussay Ahmed Subhi, and Tayser Sumer Gaaz. "Effect of Stick-Slip Phenomena between Human Skin and UHMW Polyethylene." *Pertanika Journal of Science & Technology* 29, no. 3 (2021). https://doi.org/10.47836/pjst.29.3.06

[18] Subhi, Kussay Ahmed, Emad Kamil Hussein, Shaymaa Abdul Khader Al-Jumaili, and Zaid Ali Abbas. "Implementation of the numerical analysis of dynamic loads on the composite structure employing the FE method." *Eastern-European Journal of Enterprise Technologies* 1, no. 7 (2022): 115. https://doi.org/10.15587/1729-4061.2022.253545

[19] Shomran, Ali Talib, Batool Mardan Faisal, Emad Kamil Hussein, Thiago Santos, and Kies Fatima. "Identifying some regularities of the fatigue behavior of the reinforced carbon-fiber with $Al_2O_3$ nanoparticles composite structure of the prosthesis foot." *Eastern-European Journal of Enterprise Technologies* 121, no. 7 (2023). https://doi.org/10.15587/1729-4061.2023.274573

[20] Abdullah, Ahmed Kareem, Mohanad Mubdir Kadhim, Faris Mohammed Al-Juaifry, and Emad Kamil Hussein. "Utilizing the Piezoelectric Effect in the Harvest of Mechanical Vibration Energy." *Journal of Engineering, Science and Technological Trends* 1, no. 1 (2023): 14-21.