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Material characterization and stress analysis of elastomer tyre

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Abstract
The fiber pre-tension method was used to improve the tyre bead ply mechanical properties by applying stresses range between (0-1250 MPa) on each single wire in the specimen. The following results were a comparison between specimens with pre-stressed wires by tension of (1250 MPa) and with non-pre-stressed wires. The results show that the tensile strength and maximum tensile strain of bead specimens increased by (60.87 %) and (23.6%) respectively. The stress strain curves for specimens show a high increase in strength as compared to a little increase in strain. The modulus of elasticity (Young's Modulus) of bead specimens increased by (54.125 %). Also, the results show that the Fatigue life of bead specimens increase by rise Number of cycles by (93.4%). The numerical part is implemented using a (FEM) built on ABAQUS software to examine the influence of passenger tyre modification of bead on dynamic behavior of the tyre. The influences of various pre-stresses levels were applying in model to investigation the rolling and sliding condition. The result showed (von mises, Max. principal stress and Tresca) was increase with increasing pre-stresses while (Min. principal stress and pressure) was decrease with increase pre-stresses.

Keywords: Tyre analysis; Stress of elastomer; Tensile strength and strain strength of rubber; Fatigue life of rubber.

1. Introduction

Elastomers (natural and synthetic rubber) are shapeless polymers, different component are added and got compost. These materials are -changed to rubber after heating and vulcanization, due to their viscoelastic behavior. Beneath shear and compressive deformation, it has high strength, but, a failure hardly occurs due to fatigue when exposed to mechanical load [1]. Elastomers is perfect substance for a lot of engineering applications because it has capacity to resist extremely big strains without everlasting disfigurement or break. Elastomeric substances are used in a lot of engineering application such as tyres, belts and springs in this work will take tyre [2]. Today, Radial tires are seen in nearly every traveler car and lorry with spoil involve better steering, longer life and less rolling resistance [3]. Rubber elastomers are typically reinforced with fiber to enhance tensile strength as well as improve their fatigue life.

Extensive study and review can be found in the literature review on different composite materials. C. J. Liu et al. [4] investigated the advance of the bead wires covering in wagon tyre by change the rubber multiple, decrease in the bead wires shielded plasters, right addition in the carbon black quantity. They result that the mechanical properties of bead wires covering were improved. Palit et al. [5] examination

bead wire disappointment throughout tire manufacture process. Several new metallographic methods have been used for enlarged examination. The results display that the wires disappointment is make happen by the creation of white shallow coating. Z. Chi and T. W. Chou [6] investigated the influence of Pre-tension movable carbon fibers. They use pre- winding to apply stresses on carbon fibers. The results displayed that the strength of the complex was enhanced because pre-winding the carbon threads at stated pre-tension level preceding to the compound industrial. J. Scherf and H. D. Wagner [7] shaped a single fiber compound and after that investigated the effect of fiber pre-tension on mechanical properties of the composite single stuff. The results display that the fragmental strength will rise as pre-stressing rise throughout tensile test. They also note a raise in shear stress at the complex interphase because the rising of pre-stressing level. A. S. Yaser [8] created a composite material built from E-glass fibers and epoxy resin matrix. previous stresses values from (2-20 MPa) were practical to the fibers. To study the stationary and dynamic conduct of this compound and the mechanical properties were study. He concluded important a raise in the mechanical properties because the previous stresses values increasing. L.H. Schlichting et al. [9] worked an examination to estimate the winding properties of two compounds created from E-glass fibers and to various kinds of matrix resins. They note that the previous stresses of the unidirectional E-glass fibers will enlarge the deflection throughout primary disappointment, the flexural strength and the bending stiffness of the two compounds and no influence on the bending modulus of the two compounds.
In addition, the elastomer materials are classification as a composite materials compound from different materials to given best materials with a good materials property, can be used for tire application. Where, the modified of composite materials, in general, investigated from many researchers with various techniques to increasing the mechanical properties and characterizations for its materials. There, due to modified the mechanical properties for composite materials, then, its materials application with different engineering application, as, vibration of plate [10-12], buckling of plate [13-15], stress analysis under static load [16-18], prosthetic parts [19-27], rubber application [28] and other application. In addition, the modified for composite materials investigation by different technique as, reinforcement with various fiber materials [29-32], reinforcement by powder materials [33-35], reinforcement by Nano materials [36-37], reinforcement by natural fiber [38, 39], and other techniques.
This paper includes two section the first section is experimental which studying the influence of pre-stress of steel wires in bead ply on the fatigue life and tensile strength in Babylon Tyre and the second section is numerical which analysis the tyre by apply different levels of pre-stress and see the behavior of it by using ABAQUS program.

2. Experimental work

To investigation the influence of wire pre-stress on mechanical behavior for bead specimens, tensile and fatigue tests were practical to know the influence of wire pre-stress on the general properties of bead. In addition to the formulation steps of IK4110 rubber combination and testing of this combination with a number of mechanical and physical tests to stipulate its properties. It also contracts with the formulation of molds which will be used for bead samples formulation and the formulation of these samples.

2.1 The tensile test

A. The preparation of mold for tensile specimens

This mold was prepared according to ASTM standards D 412. It was created of steel plate with (12 mm) in thickness cut by plasma and machined to final dimensions (380*280*12 mm). The cover was also made of steel plate cut by plasma (380*190*12mm) and machined for making grooves (6*2.5 mm) to contain extra rubber inside. The mold was similar to that used in tensile test of rubber compound in containing two cavities (150*150*3 mm), but they were different in external shape and possibility of including wires. It contained sixteen grooves with (2 mm) in width to hold wires inside (Figure 1).

B. The Specimen preparation

The wires were fixed in the mold and the loads as mention in Table 1 was applied on it. (70) Grams of IK 4110 rubber mixture were put into each cavity as mention in Table 2. The mold cover was put on the mold and inserted together into the thermal hydraulic press under (145 °C) and the pressure was at least (3.5 MPa, 40 ton. the specimens contained wires inside as shown in Figure 2.

C. The Specimens testing

The universal test machine that was used for test as shown in Figure 3. Three specimens were tested for each pre-stress level at strain rate of (10 mm/Min.).

2.2 Fatigue test

A. Preparation of the mold for fatigue test specimens

The mold was prepared to produce fatigue specimens according to ASTM standards D 813. It was created of steel plate with (12 mm) in thickness as exposed in Figure 4. The cover was also made of steel plate cut by plasma (290*210*6.5 mm). The mold contained 12 grooves with (1) mm in width to hold 12 wires inside and the extra rubber was flowed from it. Where, its sample manufacture dependent on the ASTM stander, [40-43].

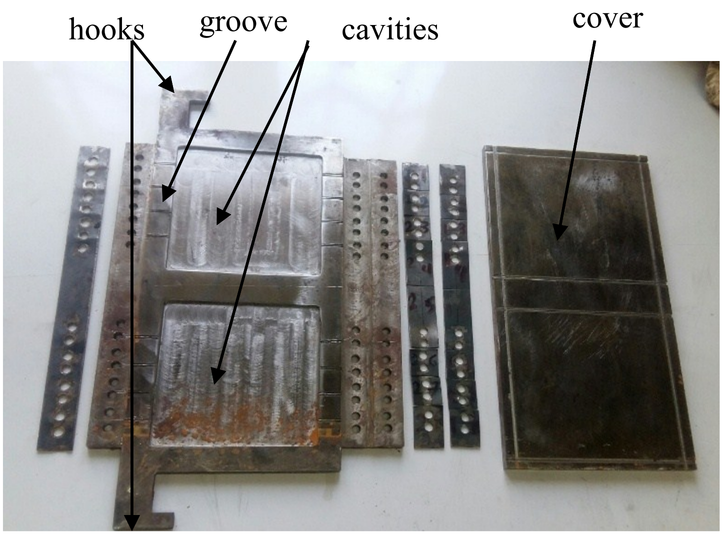


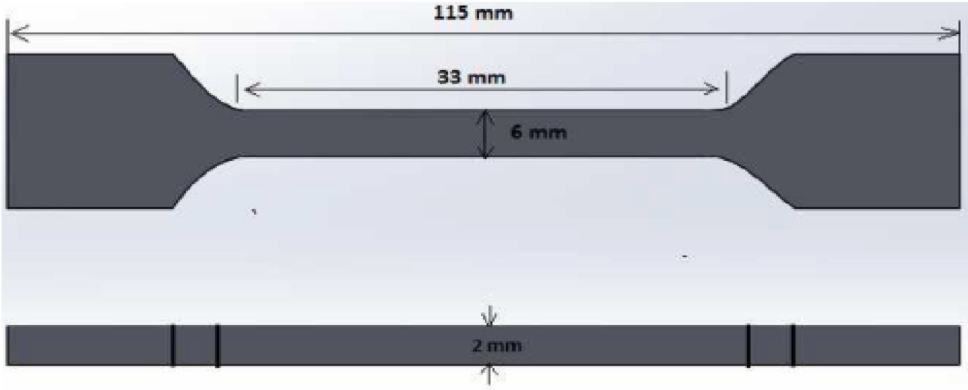
Figure 1. Mold for tensile test bead specimens.

Table 1. The equivalent loads and the wires pre-stresses on wires.

Yield strength= 1325 Mpa		Wire diameter= 0.96 mm
Yield force= 958.579 N		Wire area= 0.7234 mm^2
No.	Wire pre-stresses (Mpa)	Load on wires (N)
1	0	0
2	373	270
3	535	387
4	741	516
5	892	645
6	1071	755
7	1250	904

Table 2. IK4110 rubber compound.

No.	Materials	pphr
1	Natural rubber SMR 20	74.2
2	SBR 1502	25.8
3	Reclaim	50.5
4	Renacit 7	0.1
5	Zinc oxide	4.3
6	Stearic acid	3.4
7	Carbon balick N-660	74.2
8	Process oil	15.1
9	6PPD	0.9
10	TMQ	0.9
11	MBS	0.6
12	SULPHUR	3.8
13	CTP-100	0.7



(a)

(b)

Figure 2. (a, b) Type C-tensile test specimen D 412.

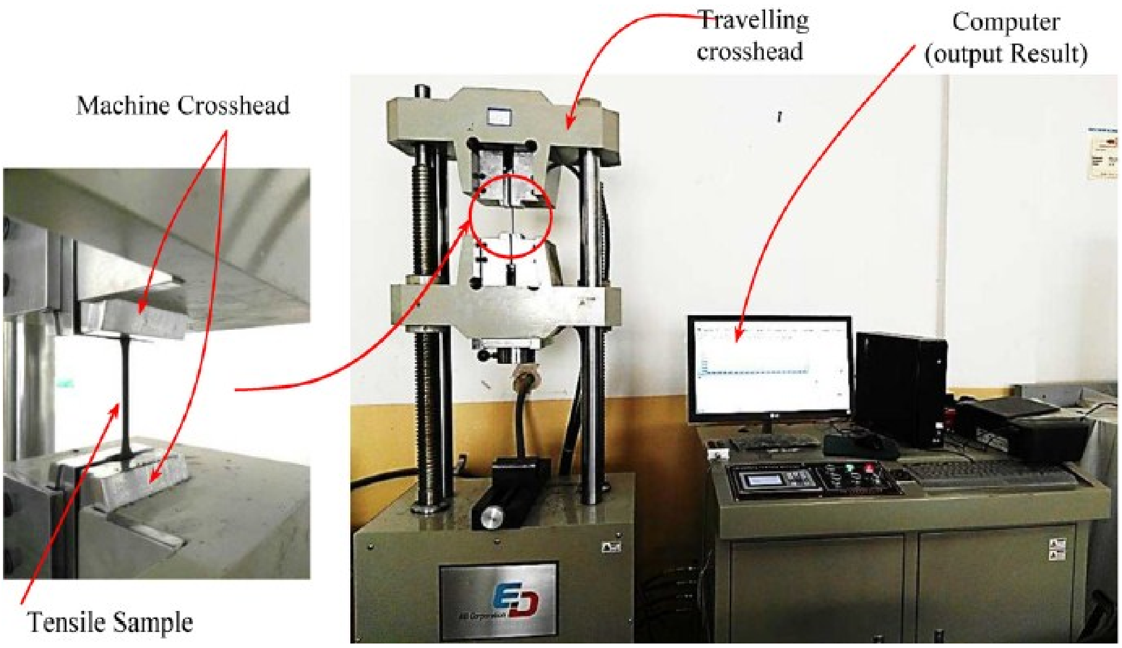


Figure 3. Universal tensile test machine.

B. The specimen's preparation

The specimens were rectangular in shape with dimensions of (L=150mm, w=25 mm, and t=6.35 mm) according to ASTM standards D813 as shown in Figure 5. A known amount of rubber compounds mention in Table 2 was put in mold cavity after wire fixing, applying pre-tension on wires as mention in Table 1, and its contents were inserted in thermal hydraulic press for 20 minutes at 170 °C.

C. testing of specimens

The machine that was used is De Mattia Flexing machine as shown in Figure 6.

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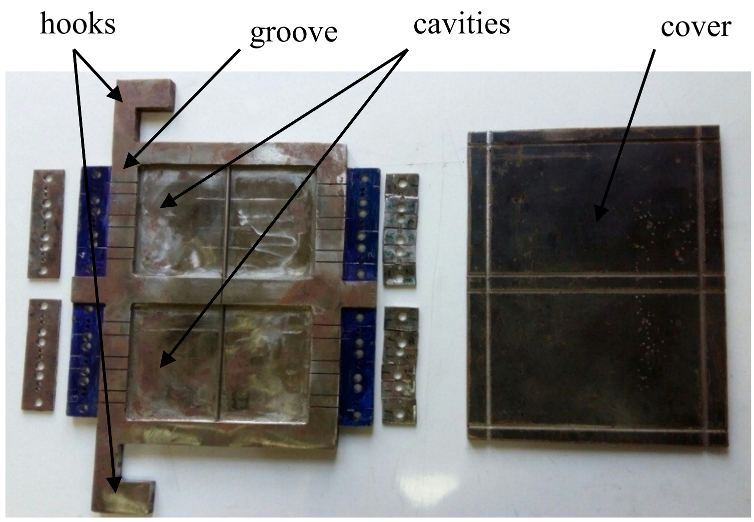
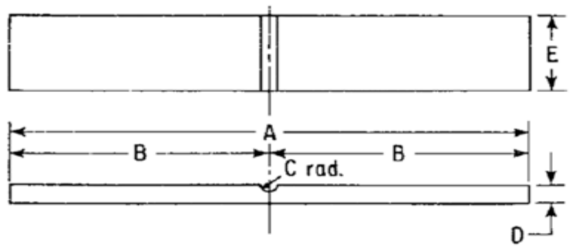
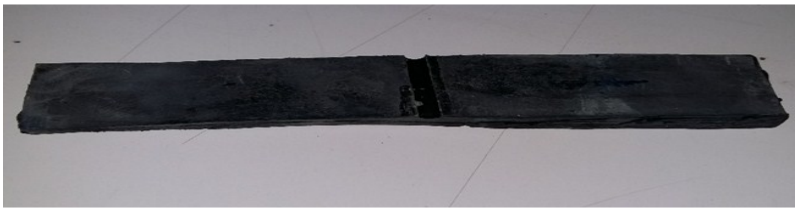


Figure 4. Mold for fatigue test specimens.



	A	B	C	D	E
mm	150	75	2.39 ± 0.03	6.35 ± 0.13	25
in.	6	3	0.094 ± 0.001	0.250 ± 0.005	1

(a)



(b)

Figure 5. (a, b) Fatigue test specimen D 813.

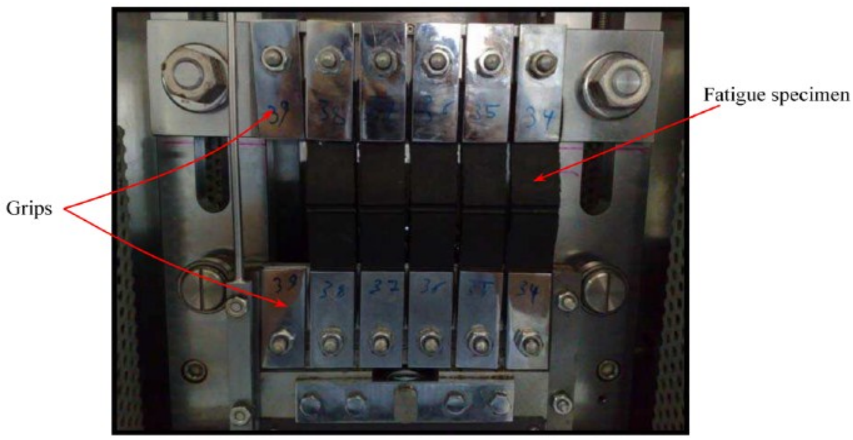


Figure 6. Fatigue test machine.

2.3 Experimental results

The experimental work in general using to evaluate the true behavior for mechanical characterizations for structure under various applied load, [44-46]. The results showed that the stress-strain curve for various level of pre- stress as show in Figure 7 to see the different between them, the maximum tensile strain and tensile strength of bead specimens increased by (23.6%) as show in Figure 8 and (60.87 %) as showed in Figure 9 respectively. The modulus of elasticity increased by (54.125 %) as showed in Figure 10. Also, the results showed that the Fatigue life of bead specimens increase by rise Number of cycles by (93.4%) as showed in Figure 11.

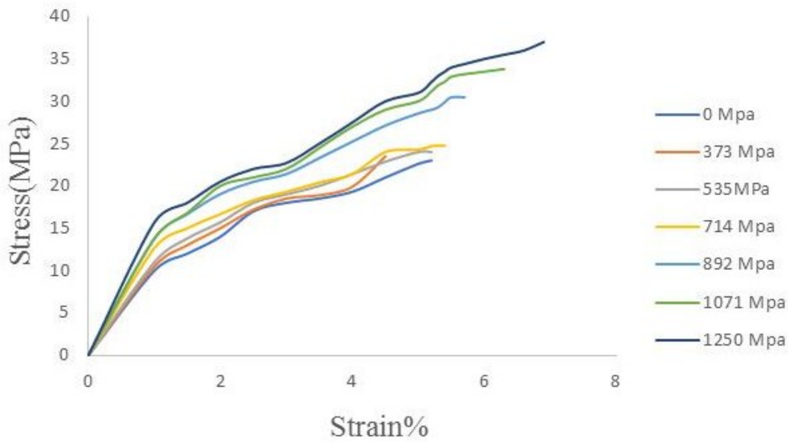


Figure 7. The stress-strain curves for different pre-stress level of bead specimens.

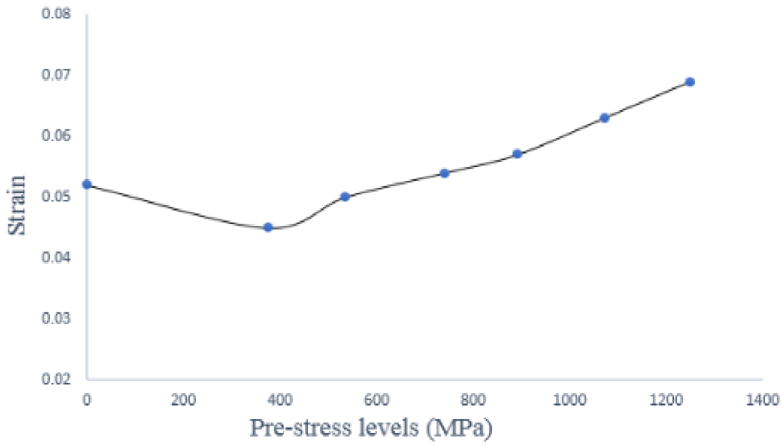


Figure 8. The relation between the pre-stress and maximum tensile strain for bead specimens.

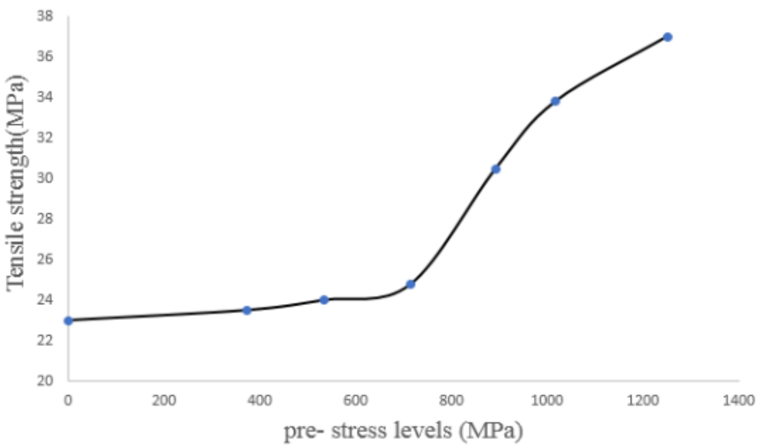


Figure 9. The relation between the pre-stress and maximum tensile strength for bead.

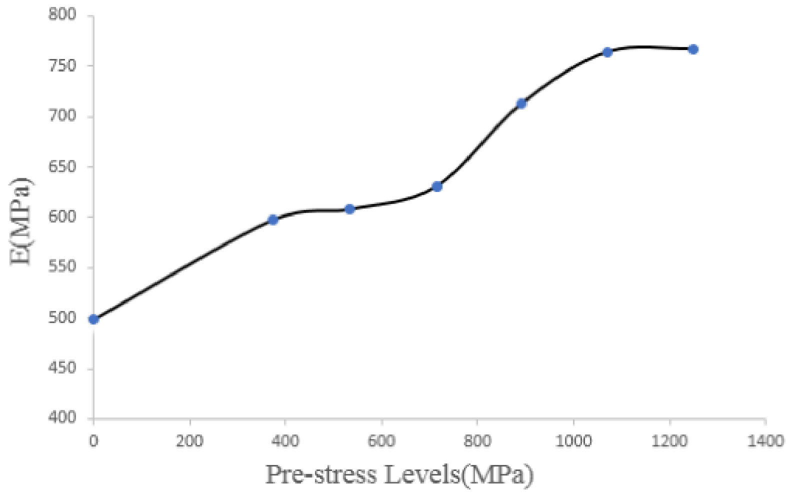


Figure 10. The relation between pre-stress level and Modulus of elasticity.

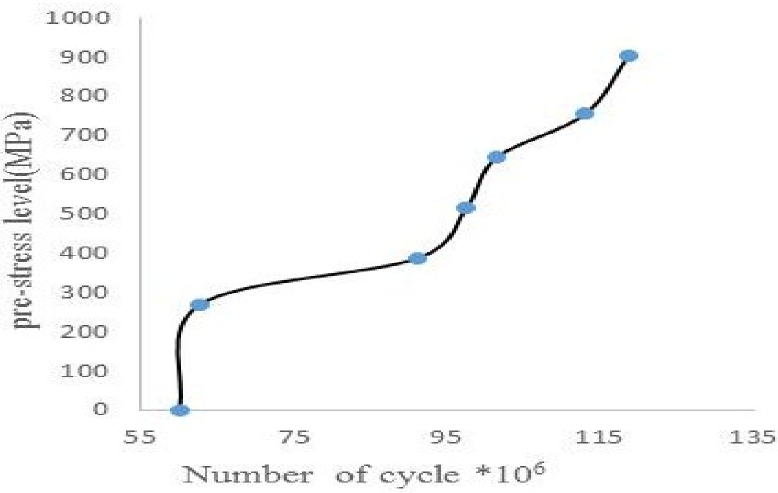


Figure 11. The relation between pre-stress level and Number of cycle of specimens.

3. Numerical work

The numerical technique in general using for evaluating approximate results for mechanical behavior under different applied load, [47-49]. This section will be achieved by use finite element program (ABAQUS) to analysis the tyre size of 175 R 14 in different levels of pre-stress and without pre-stress and see behaviors of its. The layers of tyre shows in Figure 12, the element uses in this model show in Figure 13, the static boundary condition shows in Figure 14, Simulate the tyre dynamic behavior under traction rolling process at traveling speed of 80 km/h and Simulate the tire slipping effects at 2o slip angle. Where, the number of elements must be selecting by using mesh generation for results to given best element number to evaluate the best results for problem, [50-52].

This model was used for all of the tyre pre-stress under investigation. A pre-stress levels (0, 373, 535, 741, 892, 1071, 1250 MPa) were investigated to see the different in behaviors of zero pre-stress and others levels. The results show (von mises, Max. principal stress and Tresca) was increase with increasing pre-stresses as showed in Figures (15-17) while (Min. principal stress and pressure) was decrease with increase pre-stresses as showed in Figures 18 and 19.

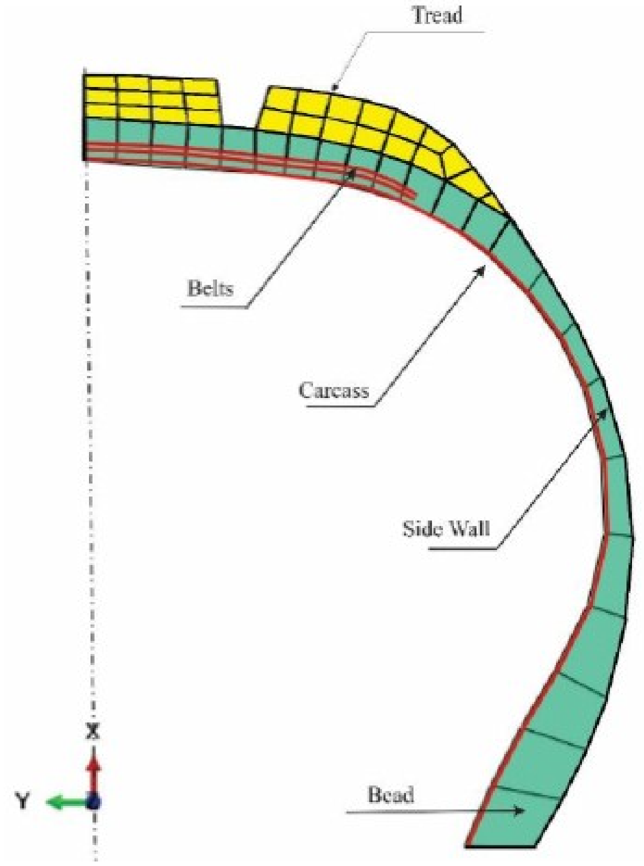


Figure 12. Layers of tyre.

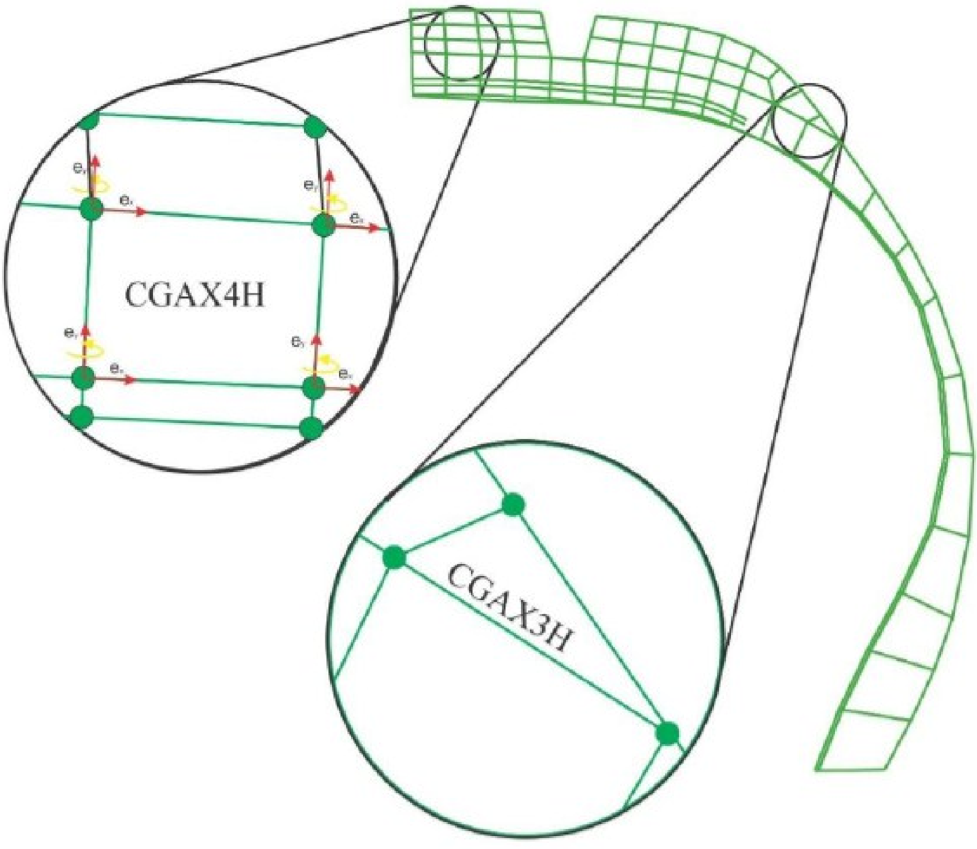


Figure 13. Element types used in axisymmetric model.

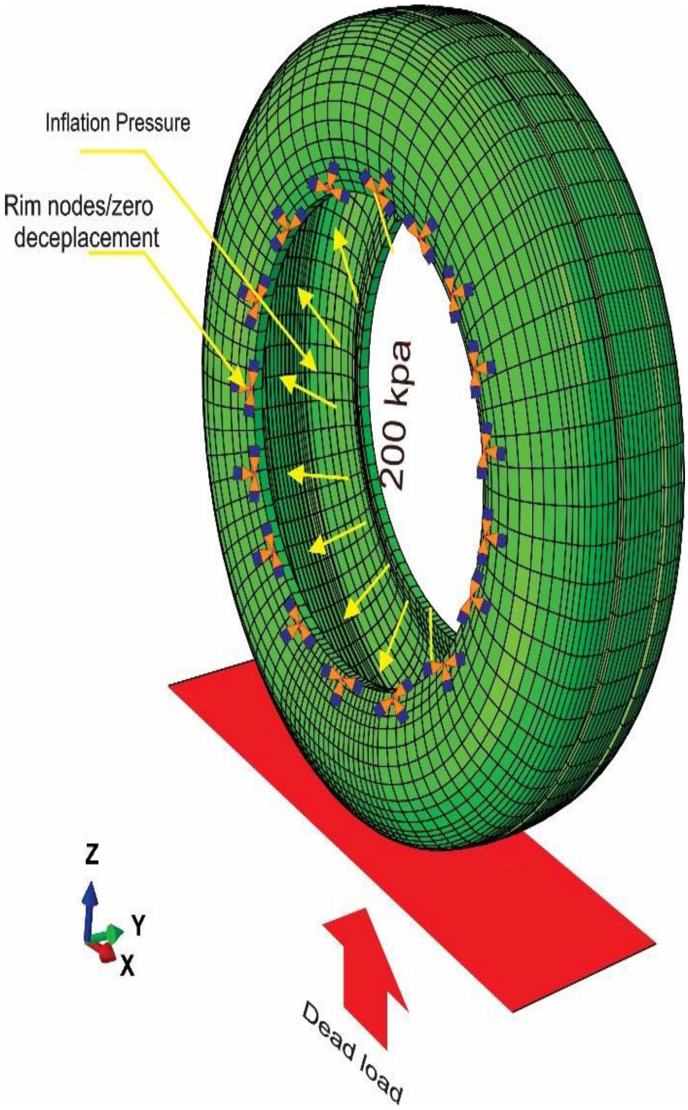


Figure 14. Static boundary condition.

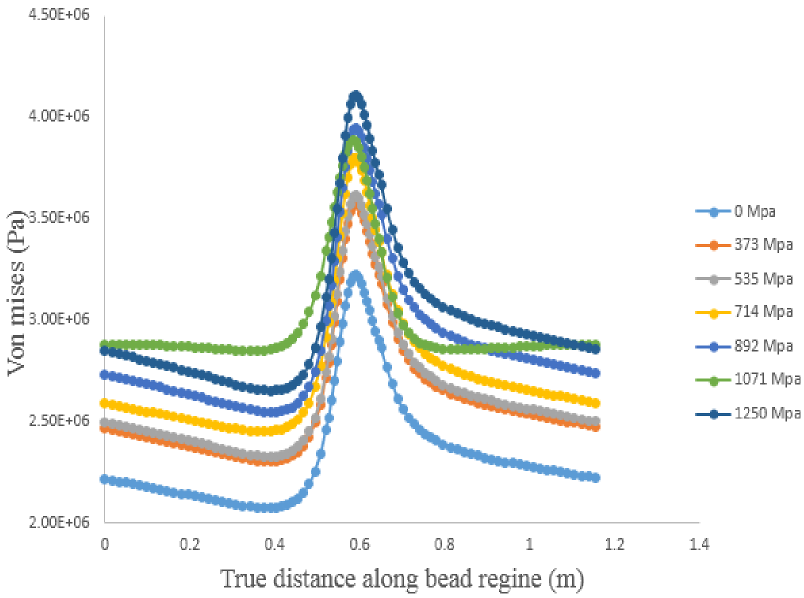


Figure 15. Effect of pre-stress on Von mises along the path of bead.

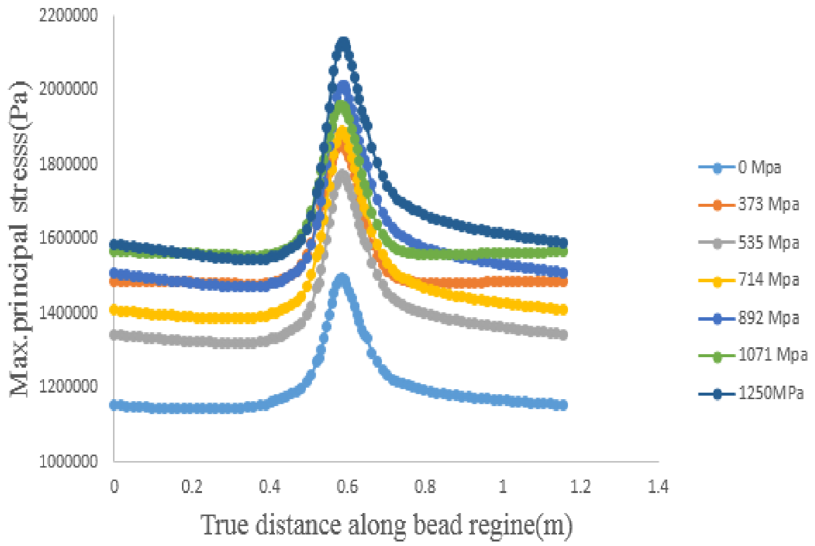


Figure 16. Effect of pre-stress on Maximum principal stress along the path of bead.

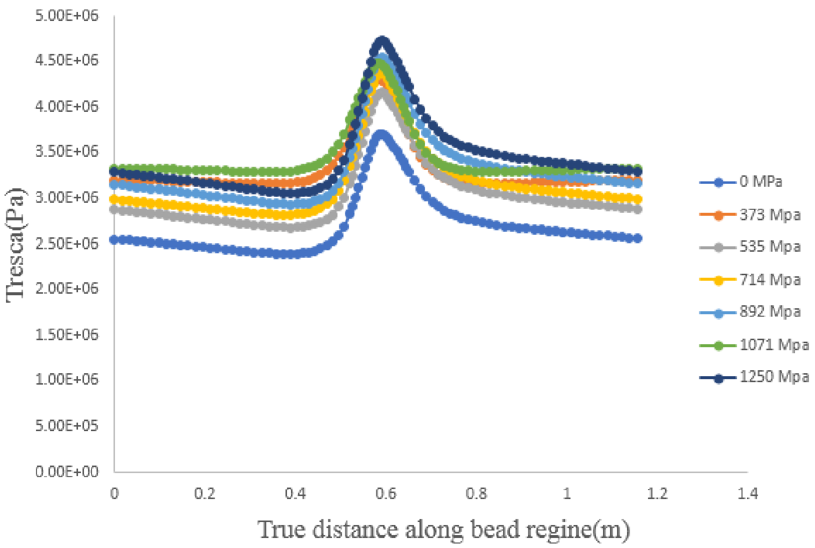


Figure 17. Effect of pre-stress on Tresca along the path of bead.

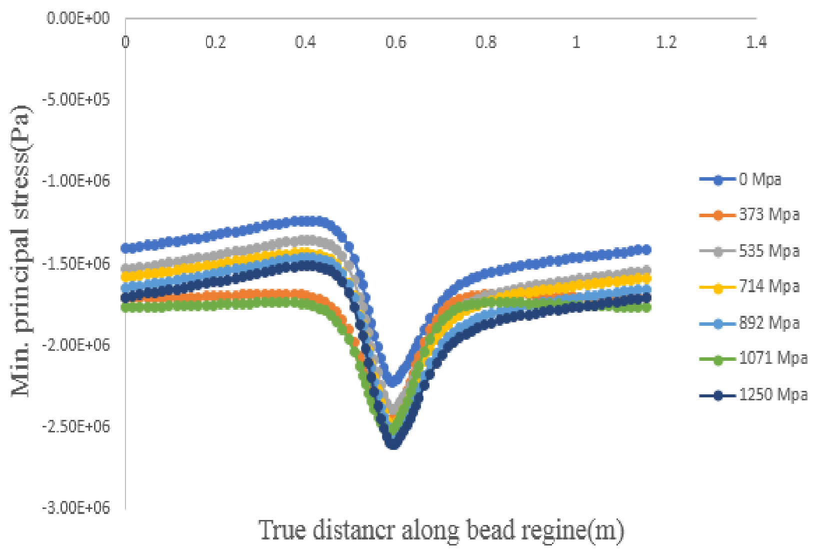


Figure 18. Effect of pre-stress on Minimum principal stress along the path of bead.

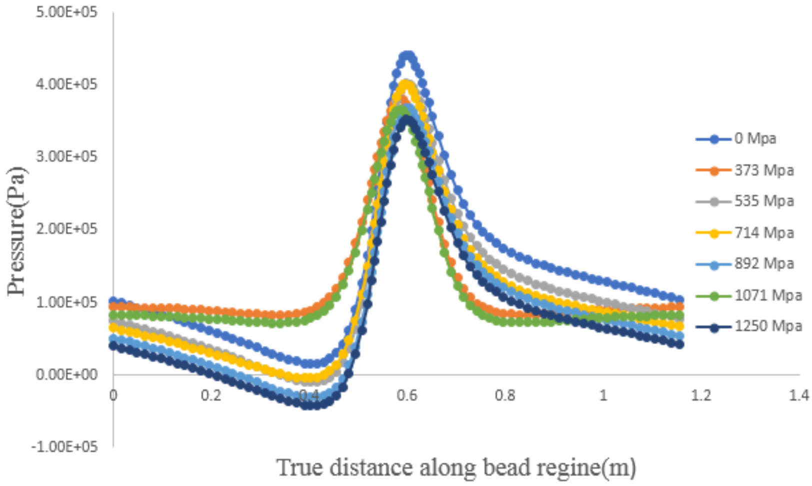


Figure 19. Effect of pre-stress on pressure along the path of bead.

4. Conclusions

From the above consequences, the following achieving comments can be outgoing as a comparison between previous-tension steel wires with tension of (1250 MPa) and non-previous-tension wires:

1. The pre-stressing of wires increases the tensile strain by (23.6%) and tensile strength (60.87 %).
2. The pre-stressing increases the young's Modulus for bead specimens by (54.124%).
3. The pre-stressing of fibers increases the Number of cycles for bead specimens by (93.4%).
4. The numerical shows that the Von mises, Maximum principal stress and Tresca increased when the pre-stresses increase.
5. The numerical shows that the Minimum principal and pressure decrease when the pre-stresses were increase.

References

[1] GENT A. N., "Engineering with Rubber: How to Design Rubber Components", Hanser Publishers, 2012.

[2] Frank Abraham, "the Influence of Minimum Stress on the Fatigue Life of Non-Strain Crystallizing Elastomers", ph. D. These, Coventry University in collaboration with the Deutsches Institut für Kautschuk Technologie, 2002.

[3] Arun Kumar Doradla, "Failure Mode of the Weftless Bead and Evaluation of Improved Continuous Single Wire Based Bead", Master's Theses, University of Kentucky, 2005.

[4] Liu, Cai Jun, Jie Ma, and Jun Chen. "The Improvement of Bead Wire Coating for Lorry Tyre." Advanced Materials Research. Vol. 756. Trans Tech Publications, 2013.

[5] Palit, Piyas, Souvik Das, and Jitendra Mathur. "Metallurgical investigation of wire breakage of tyre bead grade." Case studies in engineering failure analysis4 (2015): 83-87.

[6] Manders, Peter W., and Tsu-Wei Chou. "Enhancement of strength in composites reinforced with previously stressed fibers." Journal of Composite Materials 17.1 (1983): 26-44.

[7] Scherf, J., and H. D. Wagner. "Interpretation of fiber fragmentation in carbon/epoxy single fiber composites: Possible fiber pre-tension effects." Polymer Engineering & Science 32.4 (1992): 298-304.

[8] Yasir, Ali Sadiq. The Effect of Fiber Pre-Tension on the Static and Dynamic Behavior of Composite Plates. Ph. D thesis, University of Technology, 2007.

[9] Schlichting, Luís Henrique, et al. "Composite resin reinforced with pre-tensioned glass fibers. Influence of prestressing on flexural properties." Dental materials 26.2 (2010): 118-125.

[10] Luay S. Al-Ansari, Muhannad Al-Waily, Ali M. H. Yusif 'Vibration Analysis of Hyper Composite Material Beam Utilizing Shear Deformation and Rotary Inertia Effects' International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 12, No. 04, 2012.

[11] Muhsin J. Jweeg 'A Suggested Analytical Solution for Vibration of Honeycombs Sandwich Combined Plate Structure' International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 16, No. 02, 2016.

[12] Mohsin Abdullah Al-Shammari ‘Experimental and FEA of the Crack Effects in a Vibrated Sandwich Plate’ Journal of Engineering and Applied Sciences, Vol. 13, No. 17, pp. 7395-7400, 2018.
[13] Muhsin J. Jweeg, Muhannad Al-Waily, Alaa Abdulzahra Deli ‘Theoretical and Numerical Investigation of Buckling of Orthotropic Hyper Composite Plates’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 15, No. 04, 2015.
[14] Muhannad Al-Waily, Zaman Abud Almalik Abud Ali ‘A Suggested Analytical Solution of Powder Reinforcement Effect on Buckling Load for Isotropic Mat and Short Hyper Composite Materials Plate’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 15, No. 04, 2015.
[15] Mahmud Rasheed Ismail, Zaman Abud Almalik Abud Ali, Muhannad Al-Waily ‘Delamination Damage Effect on Buckling Behavior of Woven Reinforcement Composite Materials Plate’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 18, No. 05, pp. 83-93, 2018.
[16] Muhsin J. Jweeg, A. A. Alhumandy, H. A. Hamzah ‘Material Characterization and Stress Analysis of Openings in Syme’s Prosthetics’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 17, No. 04, 2017.
[17] Mohsin Abdullah Al-Shammari, Emad Q. Hussein, Ameer Alaa Oleiwi ‘Material Characterization and Stress Analysis of a Through Knee Prosthesis Sockets’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 17, No. 06, 2017.
[18] Noor Dhia Yaseen, Jumaa S. Chiad, Firas Mohammed Abdul Ghani ‘The Study and Analysis of Stress Distribution Subjected on the Replacement Knee Joint Components using Photo-Elasticity and Numerical Methods’ International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 08, No. 06, pp. 449-464, 2018.
[19] Muhsin J. Jweeg, Sameer Hashim Ameen ‘Experimental and theoretical investigations of dorsiflexion angle and life of an ankle-Foot-Orthosis made from (Perlon-carbon fibre-acrylic) and polypropylene materials’ 10th IMEKO TC15 Youth Symposium on Experimental Solid Mechanics, 2011.
[20] Ayad M. Takhakh, Fahad M. Kadhim, Jumaa S. Chiad ‘Vibration Analysis and Measurement in Knee Ankle Foot Orthosis for Both Metal and Plastic KAFO Type’ ASME 2013 International Mechanical Engineering Congress and Exposition IMECE2013, November 15-21, San Diego, California, USA, 2013.
[21] Bashar A. Bedaiwi ‘Analyzing of Impact, Vibration Response and Stability of Artificial Upper Limb’ American Society of Mechanical Engineering, ASME 2013 International Mechanical Engineering Congress and Exposition, Biomedical and Biotechnology Engineering, Vol. 3B, 2013.
[22] Ahmed M. Hashim, E. K. Tanner, Jawad K. Oleiwi ‘Biomechanics of Natural Fiber Green Composites as Internal Bone Plate Rafted’ MATEC Web of Conferences, 2016.
[23] Zainab Yousif Hussien, Kadhim Kamil Resan ‘Effects of Ultraviolet Radiation with and without Heat, on the Fatigue Behavior of Below-Knee Prosthetic Sockets’ International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 07, No. 06, 2017.
[24] Saif M. Abbas, Ayad M. Takhakh, Mohsin Abdullah Al-Shammari, Muhannad Al-Waily ‘Manufacturing and Analysis of Ankle Disarticulation Prosthetic Socket (SYMES)’ International Journal of Mechanical Engineering and Technology (IJMET), Vol. 09, No. 07, pp. 560-569, 2018.
[25] Fahad M Kadhim, Jumaa S Chiad, Ayad M Takhakh ‘Design and Manufacturing Knee Joint for Smart Transfemoral Prosthetic’ IOP Conference Series: Materials Science and Engineering, International Conference on Materials Engineering and Science, Vol. 454, 2018.
[26] Saif M. Abbas, Kadhim K. Resan, Ahmed K. Muhammad, Muhannad Al-Waily ‘Mechanical and Fatigue Behaviors of Prosthetic for Partial Foot Amputation with Various Composite Materials Types Effect’ International Journal of Mechanical Engineering and Technology (IJMET), Vol. 09, No. 09, pp. 383–394, 2018.
[27] Muhsin J. Jweeg, Zaid S. Hammoudi, Bassam A. Alwan ‘Optimised Analysis, Design, and Fabrication of Trans-Tibial Prosthetic Sockets’ IOP Conference Series: Materials Science and Engineering, 2nd International Conference on Engineering Sciences, Vol. 433, 2018.
[28] Marwah Mohammed Abdulridha, Nasreen Dakel Fahad, Muhannad Al-Waily, Kadhim K. Resan ‘Rubber Creep Behavior Investigation with Multi Wall Tube Carbon Nano Particle Material Effect’

International Journal of Mechanical Engineering and Technology (IJMET), Vol. 09, No. 12, pp. 729-746, 2018.

[29] Muhsin J. Jweeg, Ali S. Hammood, Muhannad Al-Waily ‘Experimental and Theoretical Studies of Mechanical Properties for Reinforcement Fiber Types of Composite Materials’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 12, No. 04, 2012.

[30] Muhsin J. Jweeg, Muhannad Al-Waily, Ahmed K. Muhammad, Kadhim K. Resan ‘Effects of Temperature on the Characterisation of a New Design for a Non-Articulated Prosthetic Foot’ IOP Conference Series: Materials Science and Engineering, Vol. 433, 2nd International Conference on Engineering Sciences, Kerbala, Iraq, 26–27 March, 2018.

[31] Ayad M. Takhakh, Saif M. Abbas ‘Manufacturing and Analysis of Carbon Fiber Knee Ankle Foot Orthosis’ International Journal of Engineering & Technology, Vol. 07, No. 04, pp. 2236-2240, 2018.

[32] Ayad M. Takhakh, Saif M. Abbas, Aseel.K. Ahmed ‘A Study of the Mechanical Properties and Gait Cycle Parameter for a Below-Knee Prosthetic Socket’ IOP Conference Series: Materials Science and Engineering, 2nd International Conference on Engineering Sciences, Vol. 433, 2018.

[33] Muhannad Al-Waily, Kadhim K. Resan, Ali Hammoudi Al-Wazir, Zaman Abud Almalik Abud Ali ‘Influences of Glass and Carbon Powder Reinforcement on the Vibration Response and Characterization of an Isotropic Hyper Composite Materials Plate Structure’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 17, No. 06, 2017.

[34] Jumaa S. Chiad, Muhannad Al-Waily, Mohsin Abdullah Al-Shammari ‘Buckling Investigation of Isotropic Composite Plate Reinforced by Different Types of Powders’ International Journal of Mechanical Engineering and Technology (IJMET), Vol. 09, No. 09, pp. 305–317, 2018.

[35] Ameer A. Kadhim, Muhannad Al-Waily, Zaman Abud Almalik Abud Ali, Muhsin J. Jweeg, Kadhim K. Resan ‘Improvement Fatigue Life and Strength of Isotropic Hyper Composite Materials by Reinforcement with Different Powder Materials’ International

[36] Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 18, No. 02, 2018.

[37] Ehab N. Abbas, Muhsin J. Jweeg, Muhannad Al-Waily ‘Analytical and Numerical Investigations for Dynamic Response of Composite Plates Under Various Dynamic Loading with the Influence of Carbon Multi-Wall Tube Nano Materials’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 18, No. 06, pp. 1-10, 2018.

[38] Ahmed A. Taher, Ayad M. Takhakh, Sabah M. Thaha ‘Experimental Study and Prediction the Mechanical Properties of Nano-Joining Composite Polymers’ Journal of Engineering and Applied Sciences, Vol. 13, No. 18, pp. 7665, 7669, 2018.

[39] Abdulkareem Abdulrazzaq Alhumdany, Muhannad Al-Waily, Mohammed Hussein Kadhim Al-Jabery ‘Theoretical and Experimental Investigation of Using Date Palm Nuts Powder into Mechanical Properties and Fundamental Natural Frequencies of Hyper Composite Plate’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 16, No. 01, 2016.

[40] Muhannad Al-Waily, Alaa Abdulzahra Deli, Aziz Darweesh Al-Mawash, Zaman Abud Almalik Abud Ali ‘Effect of Natural Sisal Fiber Reinforcement on the Composite Plate Buckling Behavior’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 17, No. 01, 2017.

[41] Ahmed Khaleel Abdulameer, Mohsin Abdullah Al-Shammari ‘Fatigue Analysis of Syme’s Prosthesis’ International Review of Mechanical Engineering, Vol. 12, No. 03, 2018.

[42] Ayad M. Takhakh ‘Manufacturing and Analysis of Partial Foot Prosthetic for The Pirogoff Amputation’ International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 18, No. 03, pp. 62-68, 2018.

[43] Jawad K. Oleiwi, Ahmed Namah Hadi ‘Experimental and numerical investigation of lower limb prosthetic foot made from composite polymer blends’ International Journal of Mechanical and Production Engineering Research and Development, Vol. 08, No. 02, pp. 1319-1330, 2018.

[44] Bashar A. Bedaiwi, Jumaa S. Chiad ‘Vibration analysis and measurement in the below knee prosthetic limb part I: Experimental work’ ASME 2012 International Mechanical Engineering Congress and Exposition, Proceedings (IMECE), 2012.

[45] Mohsin Abdullah Al-Shammari, Sahar Emad Abdullah ‘Stiffness to Weight Ratio of Various Mechanical and Thermal Loaded Hyper Composite Plate Structures’ IOP Conference Series: Materials Science and Engineering, 2nd International Conference on Engineering Sciences, Vol. 433, 2018.

[46] Lara E. Yousif, Kadhim K. Resan, Raad M. Fenjan 'Temperature Effect on Mechanical Characteristics of A New Design Prosthetic Foot' International Journal of Mechanical Engineering and Technology (IJMET), Vol. 09, No. 13, pp. 1431-1447, 2018.
[47] Muhsin J. Jweeg 'Application of finite element analysis to rotating fan impellers' Doctoral Thesis, Aston University, 1983.
[48] Mohsin Abdullah Al-Shammari, Muhannad Al-Waily 'Theoretical and Numerical Vibration Investigation Study of Orthotropic Hyper Composite Plate Structure' International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 14, No. 06, 2014.
[49] Mohsin Abdullah Al-Shammari, Lutfi Y. Zedan, Akram M. Al-Shammari 'FE simulation of multi-stage cold forging process for metal shell of spark plug manufacturing' 1st International Scientific Conference of Engineering Sciences-3rd Scientific Conference of Engineering Science, ISCES 2018–Proceedings, 2018.
[50] Muhsin J. Jweeg, Ali S. Hammood, Muhannad Al-Waily 'A Suggested Analytical Solution of Isotropic Composite Plate with Crack Effect' International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS, Vol. 12, No. 05, 2012.
[51] Jumaa S. Chiad 'Study the Impact Behavior of the Prosthetic Lower Limb Lamination Materials due to Low Velocity Impactor' ASME 2014 12th Biennial Conference on Engineering Systems Design and Analysis, ESDA, 2014, July 25–27, 2014.
[52] Mohsin Abdullah Al-Shammari, Muhannad Al-Waily 'Analytical Investigation of Buckling Behavior of Honeycombs Sandwich Combined Plate Structure' International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 08, No. 04, pp. 771-786, 2018.