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The Smart Ambulance Stretcher

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Abstract
The smart stretcher is a device used to transport individuals who need medical attention, the stretchers are typically utilized by emergency medical services (EMS). The suggested prototype of smart stretcher model consist of A two-parts: the upper part (portable stretcher consist of central bed, middle part and handle part), and the lower part consist of the passive and active suspension systems. The portable stretcher is suggested to reduce the disturbance to patient, where the control system is consist of the Arduino Uno, two stepper motors (for controlling the pitch and the roll motions), the MPU6050 for sensing the roll and pitch angles of handling part and two of the SC60C sensors are placed in the central bed for measure it's the roll and the pitch angles. In this study, the Simulink/MATLAB was used to investigated and controlling by using the PID controller with the active suspension to reduce the vibrations which transfer to upper part. Form the suggested model of smart stretcher can conclude the active suspension show the effective suspension and can be use in transporting of patients.

Keywords: smart stretcher, active suspension, passive suspension, roll angle, pitch angle .

1. Introduction

A stretcher, gurney, litter or pram is a medical transport device that is used to transfer people who require medical attention . A wheeled stretcher usually has adjustable height frames, wheels, tracks, or skids.

In emergency medical services (EMS), stretchers have wheels to make it simpler to transfer across pavement in addition to a lock and straps to keep the patient safe while being transported **[1].** To prevent movement during transit an internal lug on the stretcher engages a sprung clasp inside the ambulance hydraulics driven by batteries may be seen on modern stretchers that lift and the legs automatically collapse. Several studies have discussed the active suspension system and the passive suspension system for stretchers. **[2]** has studied the conduct a thorough examination of the loads that ambulance employees apply when loading or unloading ambulance stretchers. In a force handle configuration a load cell is used to calculate the forces required by way of ambulance staff for each system. The process of loading and unloading operation is a video captured for all types of systems to record the ambulance employees' stance at different stages of the procedure.**[3]** studied a double-wheeled robot momentum gained due to its function and reliability when complete some tasks. This search provides answers in comparison of linear quadrature regulator performance (LQR) PID-PID controllers for non-linear, dual-wheel balance robot. **[4]** have created a retractable canopy that could be bolted onto an existing striker emergency medical stretcher to shield the patient from the elements. The canopy is divided into two halves one at the stretcher's head and the other at the stretcher's foot. The foot device may be pulled out over the patient's lower half and up to their chest while the top device can be pulled over their head. The canopy according to our expertise has numerous advantages. **[5]** have studied the impact the influence of stretcher type on patient safety as well as care in an emergency room. Six stretchers were customary group A, six were brand-new technology group B and six stretchers in group C were comparable to those in group B in terms of technology but cost more. As a result, stretchers with good ergonomics and a reasonable price are equivalent when it comes to stretchers' safety and comfort that are more expensive. **[6]** have investigated using a MEMS (Micro Electro Mechanical System) sensor that is based on gyroscopic it offers a study of the phenomenon by experimentation of a two-dimensional gimbals structure platform's stability. **[7]** have used a single symmetrically rotating DC motor. An accelerometer and gyroscope are included in an inertial measurement unit to provide the sensor with the necessary balancing. Only on the x-axis does the vehicle move in a controlled manner. Even on uneven and inclining roads the PID is employed to maintain balance and movement on a flat surface. With Pens-Wheel, will be able to (an electric vehicle uses one wheel able to balance itself. **[8]** have investigated a nonlinear vibration reduction device's effectiveness was improved a lying human body on a stretcher is vibrating at a lower frequency. The structural nonlinear vibrations optimization the emphasis of the reduction system on the stretcher foundation it includes a stretcher as well as a container. Prior to optimizing the structure shock absorbers with no stiffness a foundation that stretches and a human body in a supine position are linked since the human body is connected in a supine position to the stretcher base without a damper or a spring they're regarded as a single unit also known as "stretcher base" later. Because the influence of vertical vibration is greater on the comfort of the human body a nonlinear vibration reduction system model ignores two horizontal orientations. **[9]** have studied a genetic algorithm (GA) with global searching capability was presented as a way of finding the weighting coefficient. In the optimum control theory which is based on whole-state feedback all states should be assessed. The Kalman filter was applied to the control technique to estimate the state variables in order to solve the problem. To test the efficiency of the suggested control scheme, numerical computations were performed when compared to the passive stretcher suspension it indicates that optimal control reduces vertical and pitch vibration transmission significantly. **[10]** have suggested a suspension with a pneumatic system that can rigidity of the suspension and a magnetorheological system that is semi–active (MR) damper that has the ability to alter the suspension damping. This suspension is MR/Pneumatic can be configured in eight different ways by combining there are two stiffnesses (compliant and stiff) and four damping techniques to choose from (low level at all times, high level of consistency, control of the skyhook (on/off) & balancing control (on/off). **[11]** has decreased vibrations by inserting an active stabilizing mechanism between the stretcher mattress and the stretcher legs. This dynamic technology compensates for vibrations in real time. A data logger is used to control the system which captures vibrational data from the road and sends it to the control system.

2.Mathematical Modeling

The smart stretcher model is used in this paper consist of A two-parts as shown in the figure (1). The control system of upper part consists of: the first stepper motor for controlling the pitch motion, the second stepper motor for controlling the roll motion, the MPU6050 was placed on the handling part for sensing the roll and pitch angles of handling part and two of the SC60C sensors are placed in the central bed for measure roll and pitch angles.

The upper part (portable stretcher) consist of central bed, middle part and handle part. The lower part consist of frame, the passive and suspension system. In this paper will establish the hydraulic actuator's governing equations for the heave, roll angle and pitch angle equations of the smart stretcher. The hydraulics actuators are used to prevent the disturbance of sprung and unsprung masses to lessen the patient's vertical motion (z_c) when rolling on a bumpy road as well as stretcher body motions such roll angle (α) and pitch angle (γ). Frictional forces are nonlinear F_{ri} generated by piston seals rubbing against the for a realistic model the cylinder wall within the actuators is also taken into account. The following are the equations of difference for the stretcher's active nonlinear suspension system the third law of motion derived from Newton's[12].

1-The following equations regulate the sprung mass's movements.

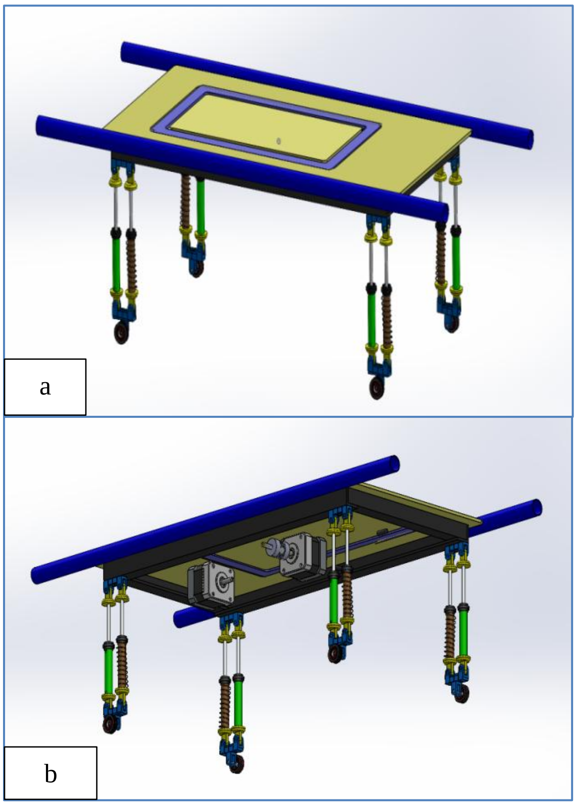

Fig.1 Smart stretcher with active suspension, (a) upper part, (b) lower part.

- **Movement in the horizontal plane**

$$M\ddot{z}_c - \sum_{i=1}^{4} f_{Ksi} - \sum_{i=1}^{4} f_{Ci} + \sum_{i=1}^{4} f_{ai} \quad \ldots.(1)$$

Where:

f_{Ksi} : is a spring nonlinear force.
f_{Ci} : is a damper nonlinear force.
can be expressed as follows

$$f_{Ksi} = K_{si}(z_i - w_i) + \mu K_{si}(z_i - w_i)^3 \quad \ldots(2)$$

$$f_{Ci} = C_i(\dot{z}_i - \dot{w}_i) + \mu C_i(\dot{z}_i - \dot{w}_i)^2 \operatorname{sgn}(\dot{z}_i - \dot{w}_i) \quad \ldots..(3)$$

Where:

w_i : unsprung masses' vertical displacements.
μ : operator with empirical data.

The following is a description of the applied nonlinear forces F_{ai} formed by hydraulic actuators:

$$f_{ai} = f_{hyi} - f_{fri} \quad \ldots(4)$$

f_{hyi} : is a nonlinear hydraulic real force
f_{ri} : is a nonlinear frictional forces .

- **Motion in the direction of rolling**

$$J_x\ddot{\alpha} = (f_{KS1} - f_{KS2} - f_{KS3} + f_{KS4})\frac{b}{2} + (f_{C1} - f_{C2} - f_{C3} + f_{C4})\frac{b}{2} + (f_{a3} - f_{a1} + f_{a2} - f_{a4})\frac{b}{2} + T_x \quad \ldots.(5)$$

Where:

J_x : the roll moments of inertia about X-axis.

$\ddot{\alpha}$: is the roll angle.

T_x : is a cornering torque .

b : is a width of track .

- **Motion of pitch**

$$J_y\ddot{\gamma} = (f_{KS3} + f_{KS4})l_2 - (f_{KS1} + f_{KS2})l_1 + (f_{C3} + f_{C4})l_2 - (f_{C1} + f_{C2})l_1 + (f_{a1} + f_{a2})l_1 + (f_{a3} + f_{a4})l_2 + T_y \quad \ldots.. \quad (6)$$

Where

J_y : the pitch moment of inertia about Y-axis.

$\ddot{\gamma}$: the pitch angle.

l_1 : the distance between the center of front wheel axle and center of gravity of the stretcher.

l_2 : the distance between the center of rear wheel axle and the center of gravity of the stretcher.

T_y : is a braking torque.

By using the state space representation and Simulink/MATLAB for study the dynamics characteristics for a stretcher hydraulic actuator for a nonlinear active suspension system.

3. Results and Discussion

The smart stretcher was investigated in two part, theoretical study and experimental study. The dynamic characteristics of active suspension system were investigated by using Simulink/MATLAB. Then the stability of portable part was tested experimentally. As shown below:

3.1.Theoretical Results

The stretcher nonlinear active suspension model with hydraulic actuators was simulated using the MATLAB and SIMULINK tools. The open-loop reaction plots will reveal whether the proposed model's control objectives can be satisfied compare with using a the passive suspension system. The active suspension system isolates more than the passive suspension when compared to rolling and pitching active time is also lower. When the stretcher is exposed to square input as shown in the figures (2-8) with amplitude(0.01) and Frequency(0.1).

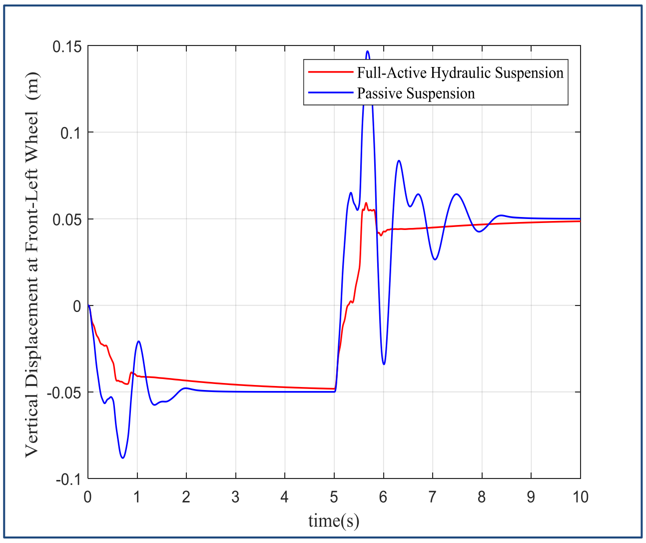

Fig.2 Time response of vertical displacement at P_1

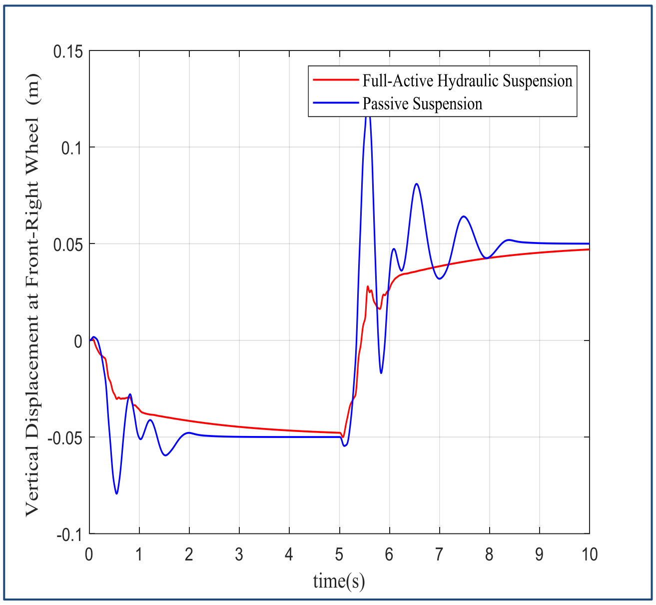

Fig.3 Time response of vertical displacement at P_2

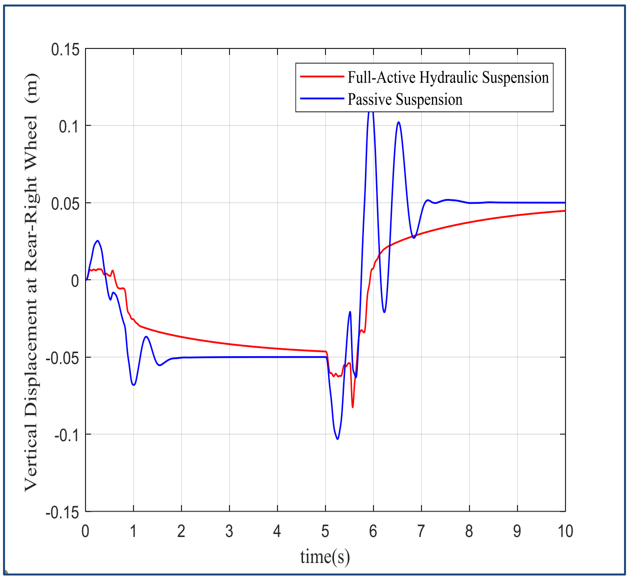

Fig.4 Time response of vertical displacement at P_3

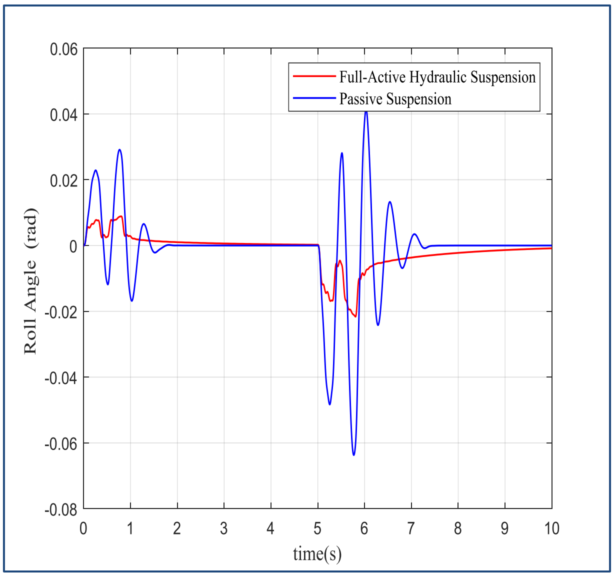

Fig.7 Time response of roll angle

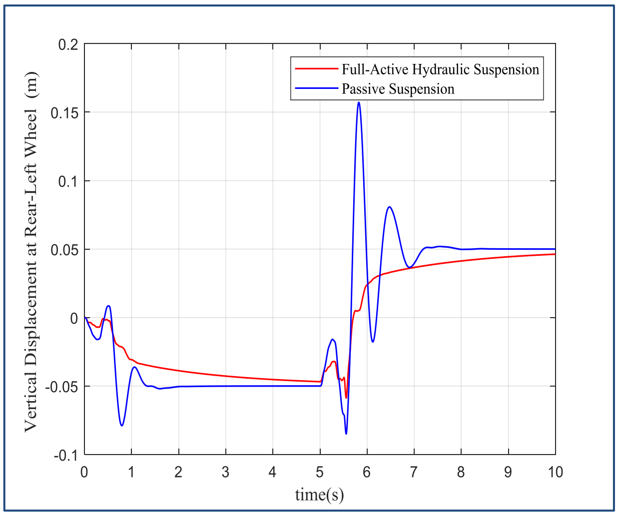

Fig.5 Time response of vertical displacement at P_4

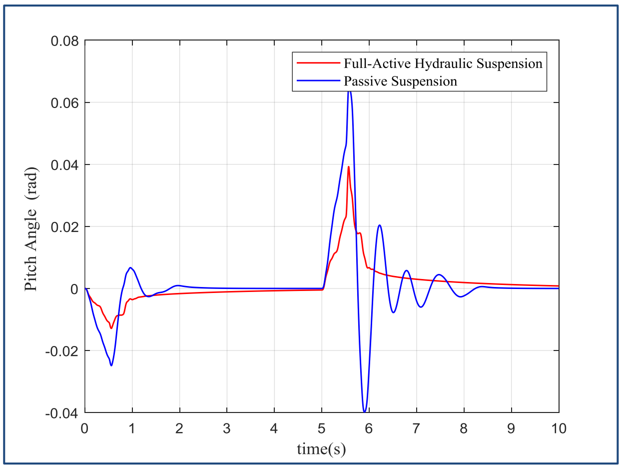

Fig.8 Time response of pitch angle

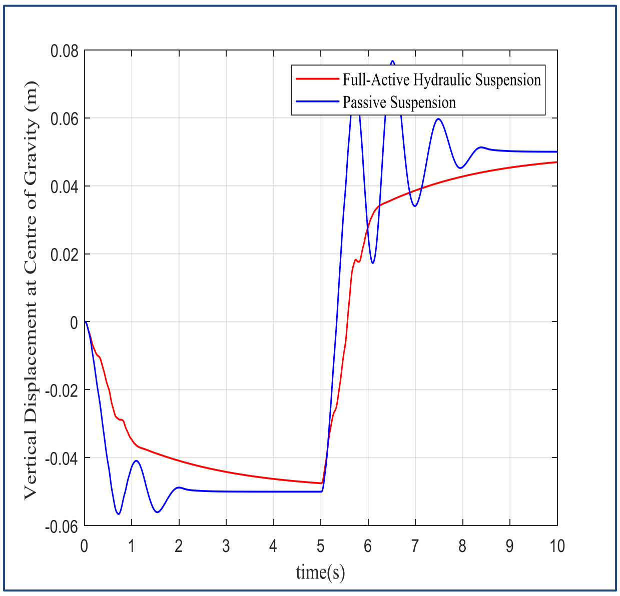

Fig.6 Time response of a vertical displacement at P_c

3.2. Experiment Results

In the figure(8), the relationship between the roll angle of MPU6050 sensor and the roll angle of SC60C#1 sensor with the time, it is represents the movement of the roller in the middle piece and the handle taken from the MPU6050 sensor while the horizontal line is represents the movement of the central piece taken from the sensor SC60C#1 .

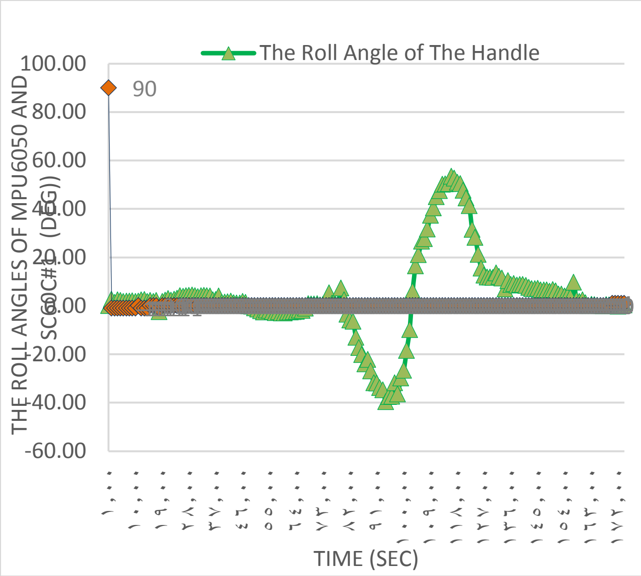

Fig.8 The relationship between the roll angle of MPU6050 sensor and the roll angle of SC60C#1 sensor with the time .

In the figure (9), the relationship between the pitch angle of MPU6050 sensor and the pitch angle of SC60C#2 sensor with the time. Which is represents the movement of the pitch in the middle piece and the handle taken from the MPU6050 sensor while the horizontal line is represents the movement of the central piece taken from the sensor SC60C#2

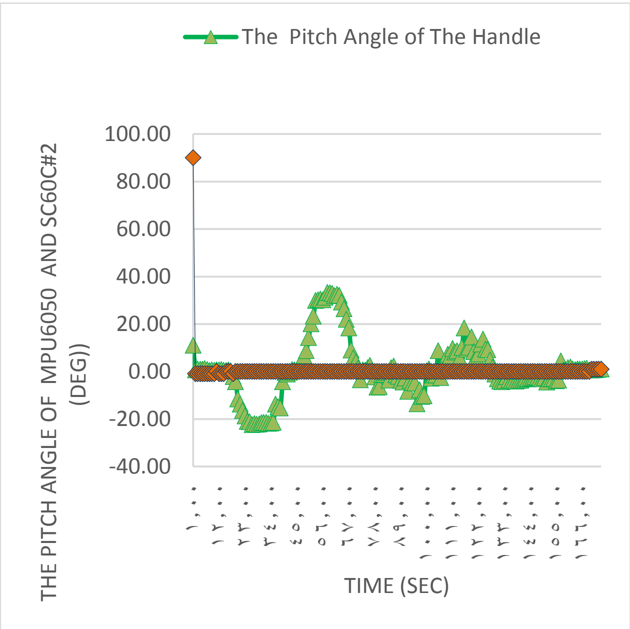

Fig.9 The relationship between the pitch angle of MPU6050 sensor and the pitch angle of SC60C#2 sensor with the time.

4. Conclusions

In view of the importance of the smart stretcher in transporting and maintain the patient's movement stability where the suggested model of stretchers which consists of an upper part, a lower part and a control system to maintain the stability of the central stretcher which consists of an Arduino and two sensors (SC60C) for measuring inclination in central piece and a MPU6050 sensor for measuring inclination in the handle and instructing the Arduino to maintain the balance in the central piece was studied.

Conclude the following from the research :

1- It is possible to use the smart stretcher to transport patients.
2- The balancing system in the upper part maintains the stability of the central piece.
3- Active suspension achieves better isolation than passive suspension although it needs external power**.**

References

[1]"The stretcher", Available: https://ar.wikipedia.org/wiki , [Accessed: Mar. 12,2022].

[2] G. Cooper and E. Ghassemieh, "Risk Assessment of patient handling with ambulance stretcher systems using biomechanical failure criteria", *National Center for Biotechnology Information* , 7, 87 , 2007.

[3] A. N. Nasir , M. A. Ahmad and R. R. Ismail, "The control of a highly nonlinear two-wheels balancing robot: A comparative assessment between LQR and PID-PID control schemes". *World Academy of Science, Engineering and Technology*, 10, 227 , 2010.

[4] H. S. Juang and Lum K. Y., "Design and control of a two-wheel self-balancing robot using the arduino microcontroller board" , 2013 10thIEEE Internatio nal Conference on Control and Automation (ICCA) , 2013.[5] A. Durhan , Ü. Öztürk , Y. Tekelioğlu, T. Ocak , and M. Emet, "The effect of stretcher type on safety and ease of treatment in an emergency department", *Turkish Journal of Medical Sciences* ,10, 986, 2013.

[6] S. Dey , S. Halder and M.P. Nandakumar , "Gyroscopic stabilization of two-dimensional gimbals platform using fuzzy logic control" , *International Journal of Electrical, Electronics and Data Communication (IJEEDC)*, 2 , 36 , 2014.

[7] D. Riattama , E. Binugroho , R. Dewanto and D. Pramadihanto , "Pens-Wheel (one-wheeled self balancing vehicle) balancing control using PID controller", Conference International Electronics Symposium (IES) , 2016

[8] M. Yang, M. Wang and J. Hu ,"The structure optimization for nonlinear vibration reduction system of the tracked ambulance", *Journal of Vibroengineering*, 1, 577 , 2017.

[9] L. Hou , S. Liu, Q. Sun, N. Niu and L. Sun , "Optimal control of active ambulance stretcher suspension based on genetic algorithm" , Conference *Chinese Automation Congress (CAC)*, 2017.

[10] A. L. Morales, A. J. Nieto, J. M . Chicharro and P. Pintado , "A semi–active vehicle suspension based on pneumatic springs and magnetorheological dampers", *Journal of Vibration and Control* , 4 ,808 , 2018.

[11] V. Anil & Menon , "Product development approach for a stabilised ambulance stretcher", *Journal of Committee on Publication Ethics (COPE)*, 4, 3 ,2018.

[12] A. A. Aldair ," Neurofuzzy Controller Based Full Vehicle Nonlinear Active Suspension Systems" , Ph.D. dissertation, Sussex University, Brighton UK, 2012.