Journal of Engineering and Sustainable Development

www.jeasd.org
Vol. 22, No.03, May 2018
ISSN 2520-0917

Experimental Responses of MWCNTs Reinforced Cross-Ply Thin Composite Shells under Transverse Impact and Thermal Loads

Dr. Fathi Al-Shamma[1], Dr.Wedad Ibrahim Majeed[2], *Hayder Abdul Khaliq Ali[3]

1) Assist Prof., Mechanical Engineering Department, Baghdad University, Baghdad, Iraq.
2) Assist Prof., Mechanical Engineering Department, Baghdad University, Baghdad, Iraq.
3) Asst. Lecturer, Mechanical Engineering Department, Mustansiriyah University, Baghdad, Iraq.

Abstract: Experimental study of transient response for different load ratio (0.3, 0.4, 0.5, and 1.0)wt% of Multi-Walled Carbon Nano-Tubes (MWCNTs) reinforced matrix of composite in addition to woven carbon fiber. Thermal Low Velocity Impact (TLVI) apparatus have been designed to meet the different testing conditions. The effect of transient vibration by impact loading on simply supported curved composite shell with and without thermal condition has been studied experimentally. An improvement occurred in settling time about 62.0% at increased of weight ratio reinforcement up to 1.0wt% of MWCNTs, and under thermal condition the settling time reduced about 44.0%. The results showed that the material which be selected under thermal condition must be include the weighed ratio 0.4wt% because all the specimens reinforced with the mentioned weighted ratios of MWCNTs failed under thermal test except those that containing 0.4wt% and these results enhanced by other results such as the Differential Scanning Calorimetry (DSC). In addition to the passivity of the composite shell structure due to reinforcement by woven carbon fiber and MWCNTs, active double integral of sliding mode controller (SMC) is used with piezoelectric components. The results indicated that an important improvement in transient response at maximum over shoot of the middle surface point about (95.8%) and (50%) in settling time, with SMC the specimens reach the steady state at short time.

Keywords: *MWCNTs, HSDT, impact of shell under thermal effect, Active-Passive control, SMC.*

الاستجابات التجريبية لالواح القشريات المركبة والمدعمة بانابيب الكربون النانوية ـ متعددة الجدران والرقائق ذات الالياف المتقاطعة تحت احمال حرارية وعرضية مفاجئة

الخلاصة: الدراسة العملية تضمنت الاستجابة العابرة للقشريات ذات الراتنج المعزز بالاضافة الى الياف الكاربون المنسوجة بالنسبة الوزنية المختلفة (0.3, 0.4, 0.5, and 1.0)wt% من انابيب الكاربون النانوية والمتعددة (MWCNTs) الجدران. جهاز (TLVI) والذي قام الباحث بتصميمه ليلبي فحوصات متعددة وبظروف مختلفة. وقد تم دراسة تاثير الاهتزاز العابر بفعل حمل الصدم على القشريات المقوسة ذات الاسناد البسيط مع او بدون الحمل الحراري عمليا. حدث تحسن في زمن الاستقرار حوالي 62.0% عند زيادة النسبة الوزنية صعودا الى 1.0%wt من MWCNTs، وتحت الظرف الحراري فان زمن الاستقرار انخفظ الى 44%. اظهرت النتائج بان المادة التي يجب اختيارها للفحوصات الحرارية تحتوي على النسبة 0.4wt% لان جميع العينات المعززة بالنسب الوزنية المذكورة من MWCNTs فشلت تحت الاختبار الحراري باستثناء تلك التي تحتوي على النسبة 0.4wt% وهي معززة بنتائج اخرى مثل المسح الكالومتري التفاضلي (DSC). بالإضافة إلى السيطرة السلبية لهيكل القشريات المركبة والمعززة من ألياف الكربون المنسوجة و MWCNTs استخدام المسيطر الانزلاقي النشط (SMC) ذو التكامل المزدوج مع عناصر كهرضغطية. لوحظ من خلال النتائج الى أن تحسنا هاما في الاستجابة العابرة لأقصى قفزة لمنحني الاستجابة من نقطة الوسطية للسطح حوالي (95.8%) و (50%) في وقت الاستقرار، مع المسيطر (SMC) النماذج تصل إلى حالة الاستقرار في وقت قصير.

---

*Corresponding Author hayder_ab_k@yahoo.com

1. Introduction

Consider a structure which designed carefully and subjected to varying thermal conditions, this structure as a result of the thermal gradients will distort. One way to prevent this is to build the structure from a composite material thermally stable [1] this is the passive approach. The possibility of delamination and fiber breakage making of composite materials be more brittle than metals. Structures excited into resonant vibration exposed to very high over shoot amplitude displacements which these structures are inversely proportional to their internal passive damping. At synchronization the transmission loss of such composite panels is also weak. The structures passive damping properties [2] and attempts to improve their damping at the design, the damping stage properties are important because effect on the structure wave transmission loss specifically in the critical frequency range and also when the structure vibration response to excitation. Recently several groups have explored the possibility of using carbon nanotubes as filler [3] of composite materials to improve the mechanical damping in composite structures instead of increasing the strength or stiffness. Extremely large interfacial contact area such as (for example) the compression between multi-walled carbon nanotubes (MWCNTs) could have a specific area of (100 m2/g) and competing fillers used for damping applications of about (10 m2/g) for rubber grade carbon block so low mass density and high aspect ratio implicate that the interfacial sliding [4] of nanotubes fibers within a polymer matrix causes big dissipation of energy with minimal weight retribution [5].

Alternatively, by using a set of sensors connected by a feedback loop and actuators which are connected forward such as active structure control, in this case it must be reduce the sensitivity of the sensors to the uncomfortable noises, parameter variations and to reduce the effect of disorder within the bandwidth of the control system. Smart materials are widely used in suppression of wave propagation and structural control of vibration. Most of existing studies using smart materials in the form of patches or films when they focused on the vibration control [6].

The ability to control on the orientation of laminated fiber either to resist load or absorb energy is an advantage of composites. It is therefore necessary to have some information of the contribution of the plies [7]. In [8] study, the dynamic response behavior and the corresponding the capabilities of absorption energy for single side curved panel composites have been inspected after the performance of drop impact tests. Five various surface ply orientations using an instrumented drop test device of impact test conducted with singly curved symmetrical composite panels.

2. Impact Response Classification

An important factor in evaluation the type of impact response is impact velocity [9]. High velocity impact usually elaborates about larger amplitude transverse deflection with more damage effect and even perforation. Hence, according to their impact velocities the type of impact response is briefly divided into high and low velocity impacts. Therefore, there are two criteria used to distinguish between a low and high velocity impact. One of these criteria based on the damage and structural deformation and the other on the structural response, amount of damage or plastic deformation around the contact zone governed the difference between high and low velocity impacts. At low velocity impact plastic deformation is localized around the contact area. The other hand, high velocity impact causes a larger area of deformation and or damage around the area of contact [10], therefore, the mass should be taken into consideration simultaneously with the impact velocity. In addition, the impact response and damage may be completely different from impact at same velocity with different impact masses. Besides, the impact duration is also an important parameter that distinguishes a high velocity impact response from a low velocity impact one.

The low velocity impact test facility consists of a drop tower weight equipped with an impactor and a variable cross-head weight arrangement, a high speed data acquisition system, and a load transducer mounted in the impactor. All the impact tests are performed using various drop weight machines such as, the dynatup 8250 impact drop tower device [10], specially designed vertical drop-weight testing machine (L-Shaped base steel) [11] or any other drop weight machine such as in, [12], [4], [13], [14], [15].

3. Objectives

The main aim of this paper is to control and suppression the internal waves in the composite shell due external transverse impact load at low velocity under special thermal condition. To control the doubly curved thin composite shell materials passively by stacking the laminate of material (0/90) and (45/-45) also to get an improvement in performance of composite material by reinforcement the matrix of these composite with MWCNTs in addition to woven carbon fabric. Also using active controller to suppression the vibration of internal wave before these waves are reached to the boundary. Thus, to work with this type of tests required to design and manufacture a TLVI apparatus to heated small square surface area. The most important characteristic of TLVI apparatus is a gun system responsible of dynamic compression process, the operating of the gun system depends on the spring force to generate addition force to the gravitational force of the drop weight which it is lead to increases the velocity instead of increasing drop height that used in most devices. This allows flexibility for testing, easy operating mechanism and choosing the required velocity for the test.

4. Sliding Mode Controller (SMC)

The sliding mode controller (SMC) in this thesis it is represented in principle of SM control to design sliding surface that will direct the trajectory of state variables toward a design origin when coincided [16], [17], [18]. In the present work the controller function as:

$$u = 0.5(1 + sign(S)) \qquad (1)$$

Where: u is a design signal control controlled by SMC.

S: is a sliding surface, in the present study represented as a linear third order polynomial.

$$S = \bar{\alpha}_1 x_1 + \bar{\alpha}_2 x_2 + \bar{\alpha}_3 x_3 + \bar{\alpha}_4 x_4 \qquad (2)$$

Where: $\bar{\alpha}_1, \bar{\alpha}_2, \bar{\alpha}_3$, and $\bar{\alpha}_4$ represented the control parameter which it is referred to sliding coefficients, x_1, x_2, x_3, and x_4 are desired state feedback variables to be controlled by enforcing $S = 0$, as described in fig.3. The state variables which must be controlled are the voltage error x_1 , the rate change of the voltage error x_2, the integral of the error x_1, and the double integral of error x_4. The equivalent control signal of the proposed SMC double integral:

$$\frac{dS}{dt} = \bar{\alpha}_1 \dot{x}_1 + \bar{\alpha}_2 \dot{x}_2 + \bar{\alpha}_3 \dot{x}_3 + \bar{\alpha}_4 \dot{x}_4 = 0 \qquad (3)$$

Then by applying Routh's stability [19],[20]criteria to the equation (3) after rearrange equation led to obtain the conditions of stability that all the coefficients of sliding mode controller must be positive, and that $\bar{\alpha}_1 \bar{\alpha}_3 > \bar{\alpha}_2 \bar{\alpha}_4$ to ensure that the all roots have negative real parts [16].

In the present work, experimentally with using the interface program as LaBview version14 after the impactor crash the middle point of shell the control system have two types of sensors as load cell and Piezo-sensor. The sensing signal obtained from mentioned sensors are transferred to computer through input channels of NI DAQ device. Know the SMC regular the Piezo-sensor signal only in order to suppression the internal generated wave due to impact load as shown in fig.1. Before Piezo-sensors signal insert to SMC it were

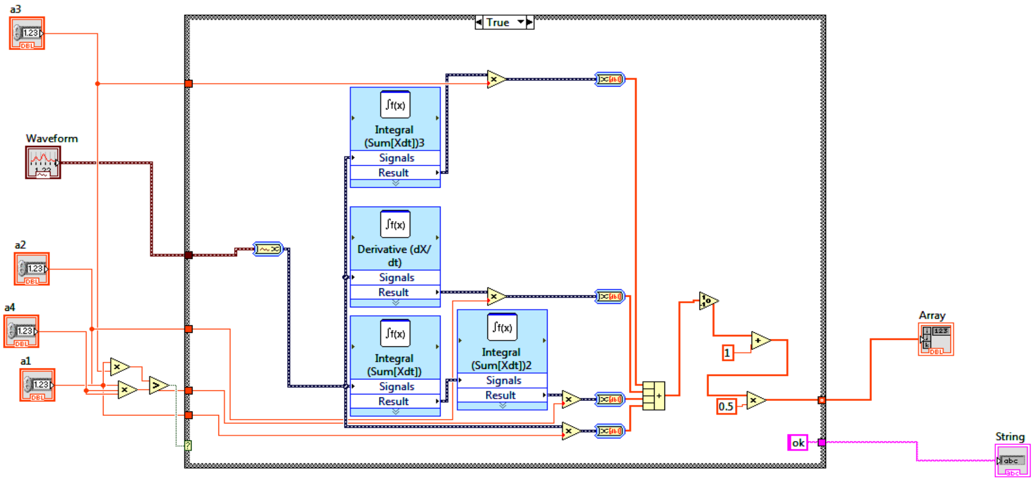


Figure 1. Sub VI of LabView program for an active SM controller.

Compared with reference signal (set input = 0), but the other signal measured such as load cell signal, these signal represented acceleration which integrated twice to get displacement signal (in volte) then calibrated by the relation (unit volte/unit acceleration), finally the displacement signal data saved as technical data management (TDM) file and plotted in wave form figure window.

5. Experimental Work

In this study, woven Carbon Fiber Fabric type Plain weave is used according to the required woven structure with highest properties of lightness of weight, high modulus, high strength electrical conductivity and high ray of breakthrough. A real weight of woven carbon fiber fabric is 300 g/m^2 ∓ 15 g/m^2 at width fabric design thickness 0.166 mm. Multi-Walled Carbon Nanotubes (MWCNTs) with outside side diameter (6-9) nm and length of tube 5 µm (O.D. = 6-9nm & L= 5 µm) [21] as a filler in addition to woven fabric to reinforced the lamination 80:20 resin, then the mixture by Ultrasonic Homogenizer of Environmental Research Laboratory at the University of Technology are mixing homogeneously.Testing of these materials and under special thermal conditions has become great need to design Thermal Low Velocity Impact (TLVI) apparatus at high strain rate. The second main objective of this work is devoted to illustrate the design and manufacture of a TLVI apparatus specially designed for the shocking the specimens with transverse strikes or what is known as impact tests.

5.1 New Thermal Low Velocity Impact (TLVI) apparatus

The TLVI apparatus is designed and manufactured as shown in Fig.2 to deal with specific impact or thermal impact tests, small square thermal reign exposed the surface of the shell to diffusion heat transferred from the hot space at upper portion in electrical franc (oven) which supplied with modify heaters across the square duct at barrier until reach to center of upper surface for composite shell specimens.

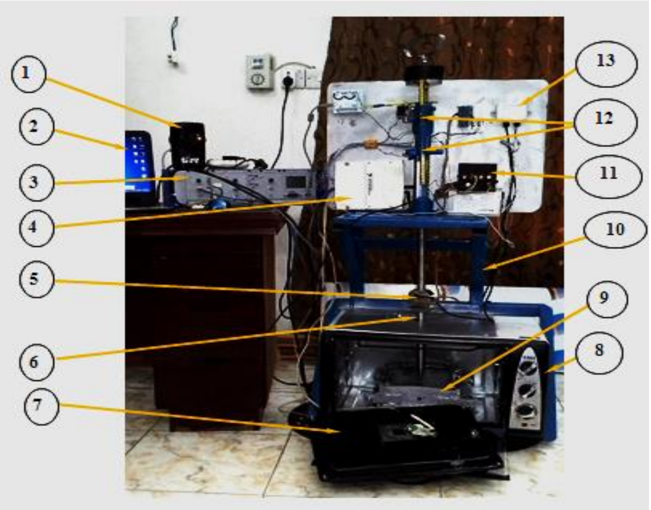


Figure 2. Gun spring system and impactor of vertical TLVI rig.
1- USB power regulator, 2-Computer, 3- DC Power amplifier PI E-515 IX,
4- Data acquisition NI DAQ Pad-6015, 5- Load cell S-type SS-300. 5- Impactor rod,
7- Barrier. 8- Oven, 9- Boundary steel structural, 10- Steel frame of LTVI apparatus,
11- DC Power supply, 12- Infrared reflection switch sensor,

13- Load cell amplifier 24 V DC.

The TLVI is flexible apparatus can easy remove the oven to eliminate the thermal test see Fig.2. Practical tests in this work include two types of tests. First, if the influence of thermal out-offs the present work in this type and this means separate electric furnace woven form iron structure. Second, the electrical oven is an essential part of the TLVI apparatus which provide two modes of heat transfer or radiation from hot upper space inside the oven separated by a barrier equipped with a square hole in the form of a channel for heating small square area as shown in Fig.3 of the other side under the barrier at the middle upper surface of the specimen.

Figure 3. Barrier equipped with a square taper duct channel.

IR-Thermo Click is an accessory sensor, a compact and easy solution in order to add InfraRed (Ir) Thermometer to design, Fig.4. The sensor is designed to use 5V power supply only. Led diode indicates the presence of power supply.

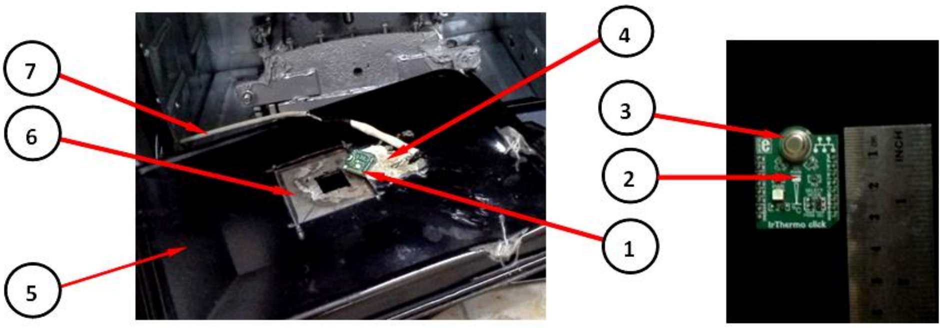


Figure 4. Location of IR-Thermo click 5V sensor on the bottom of barrier.

1-Location of IR-Thermo click 5V sensor, 2- Ambient temperature sensing for IR-Thermo click, 3- Target temperature sensing of IR-Thermo click, 4- Epoxy adhesive, 5- Barrier. 6- Square hole taper duct, 7- Data cable.

It is calibrated in wide temperature ranges: -40 to 85°C for the ambient temperature and -70 to +380 °C for the object temperature. These features make this sensor ideal for automotive, industrial control, body temperature and many more.

5.2. Details of Data Acquisition Devices

To get such a response, sensing devices require high accuracy and good working at variable thermal conditions. Also using interface device to transfer, explore and saving data in computer programs. A strain gage commonly is made of strips of metallic films arrange in a grid pattern such as load cell S-type (SS-300) shown in Fig.5. In the present work the static and dynamic calibration are take in to consideration, in order to get validate experimental results by using the equilibrium of energy equation, and from the principle of strain energy equal to the energy lost by falling object. An available NI DAQ Pad-6015 as shown in Fig.5 data acquisition device is provided connection to 16 single ended analog input (AI) channels (±10 V), analog output two channel with 5 V with resolution 16 bits.

Figure 5. a) Load cell S-type SS-300, b) NI DAQ Pad-6015 data Acquisition device, c) Piezo- actuator and sensor type QP16N, film thickness 0.01 in.

The interface program such as LabView (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and improvement environment for a visual program language from National Instruments. In the present work it must be place the QP16N at the best location on the upper surface (for sensing) of the specimen and at the bottom surface (for actuating) of the shell specimen as shown in fig.6. To choose the best location of the piezoelectric for both sensor and actuator it must be substitute the first three vibration modes in displacement equation, with a sequence values of x once and y again. The intersection between the maximum amplitude of oscillatory curves gives the best location of piezoelectric.

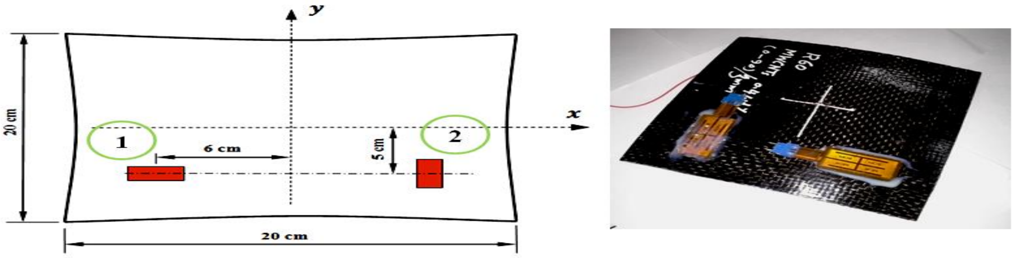


Figure 6. The location of piezoelectric for both sensing and actuating.

For both cases studied in present work unique kind of boundary conditions frame to support the composite doubly curved shell specimens is used. Impactor (Gun bar) pulls to the top at launch position in order to generate potential energy in the spring of gun system, when the IR-Thermo–5V sensing the desired temperature, Pull the launch handle for releasing the gun spring which turn allows the striker rod to crush the specimen at the middle surface.

6. Results and Discussion

In the experimental work the specimen of MWCNTs reinforced of SSSS doubly curve shallow shell have been tested under low velocity impact loading and taking into consideration the thermal condition of small square portion on the center of the top surface. The dimensions of the specimens used in this test have the span of the shell in x and y directions are 20 cm, thickness of the shell specimens are: 1, 2, 3 mm, impactor head from the middle point at the surface of the specimen about 19 cm.

When comparing the specification of transient response results for the following two fig.s (7-8) at same impact velocity, material weighted ratio of MWCNTs, material thickness and dimensions lead to important notes such as settling time of transient response with (45/-45) ply taking time longer than (0/90) and the maximum over shoot lower than (0/90) ply. That’s clear the energy is best dispelled in Fig.8 but it reaches the steady state late.

So in experimental work it has been taken the effect of different weighted ratio of MWCNTs on the transient response specifications as shown in fig.9. This showed that the ratio 0.4wt% the best allowed response. then at different thickness (1, 2, 3mm) of the reinforced shell of 0.4%MWCNT on the displacement in the midpoint as shown in Fig.10 and the most effect is the recovered time have minimum value for 1 mm thickness with minimum dynamic energy which means with increasing the thickness the passive control will be more complicated.

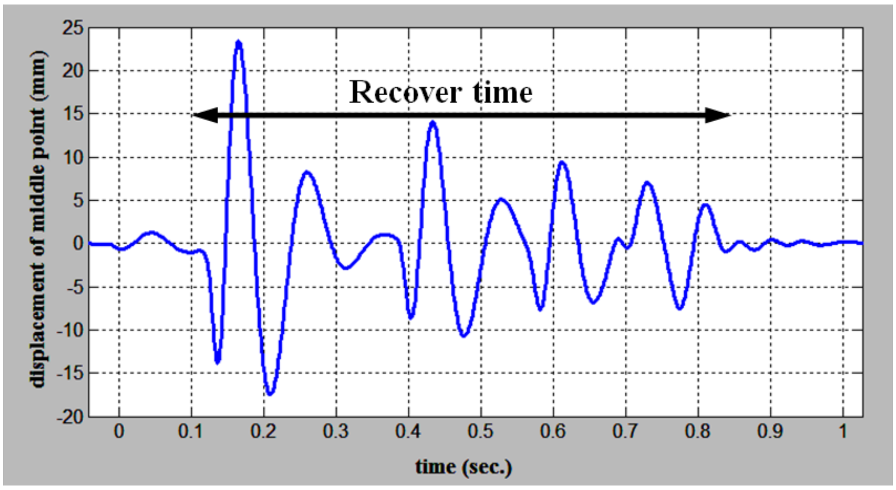


Figure 7. Transient temporal response curves for 0.4wt% MWCNTs reinforced composite shell of thickness 1mm, ply (0/90) at velocity 7.5 m/s.

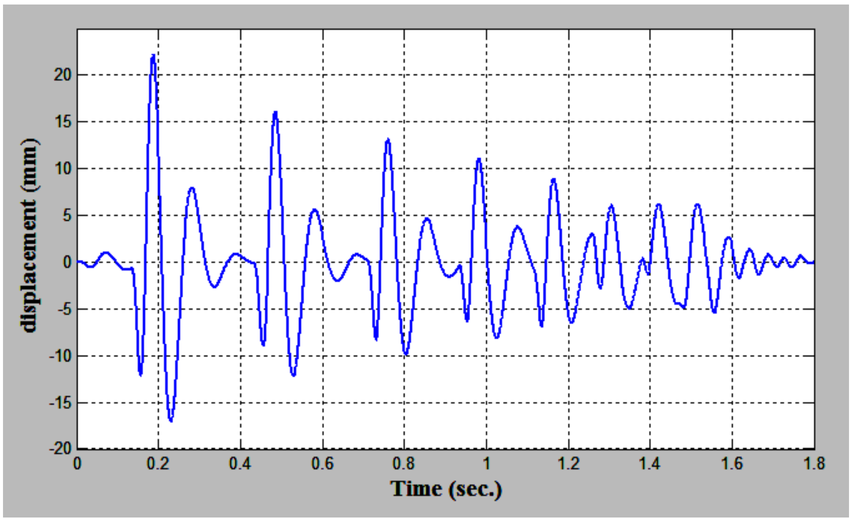


Figure 8. Transient temporal response curves for 0.4wt% MWCNTs reinforced composite shell of thickness 1mm, ply (45/-45) at velocity 7.5 m/s.

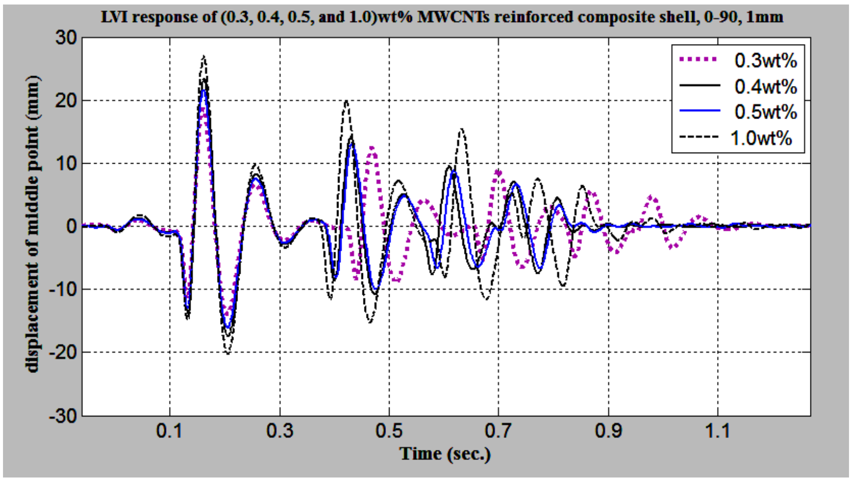


Figure 9. Comparing of transient responses of composite shell fillers with different weight percentage of MWCNTs reinforced composite shell of thickness 1mm, ply (0/90) at velocity 7.5 m/s.

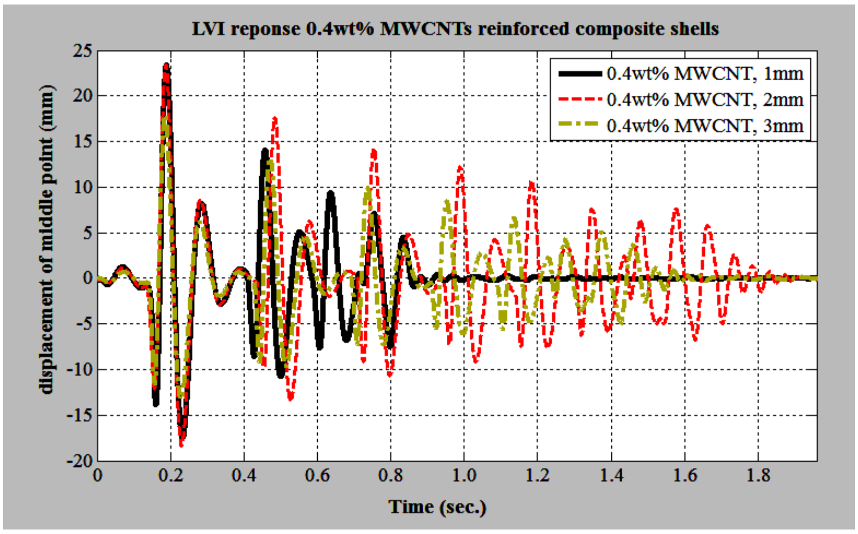


Figure 10. Comparison of transient responses when increasing the thickness of composite shell with ply (0/90) at velocity 7.5 m/s.

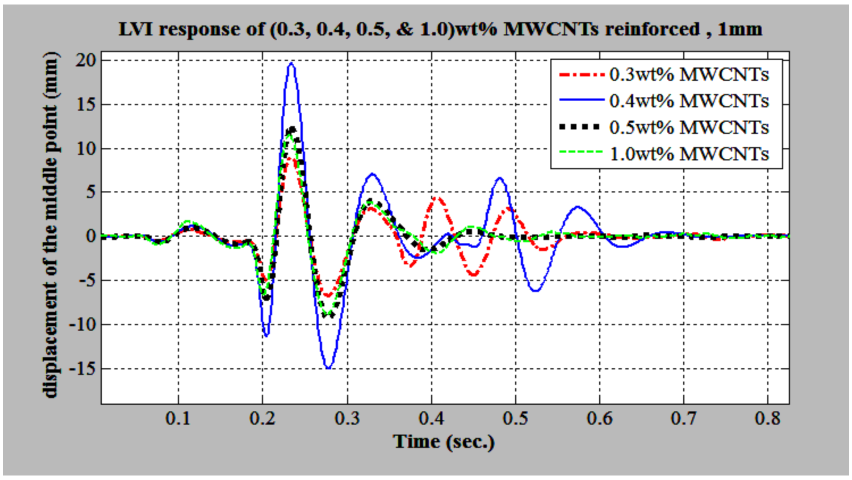


Figure 11. Compared to the transient responses for SSSS composite reinforced shells, with thermal effects (116°C at 21.12 min).

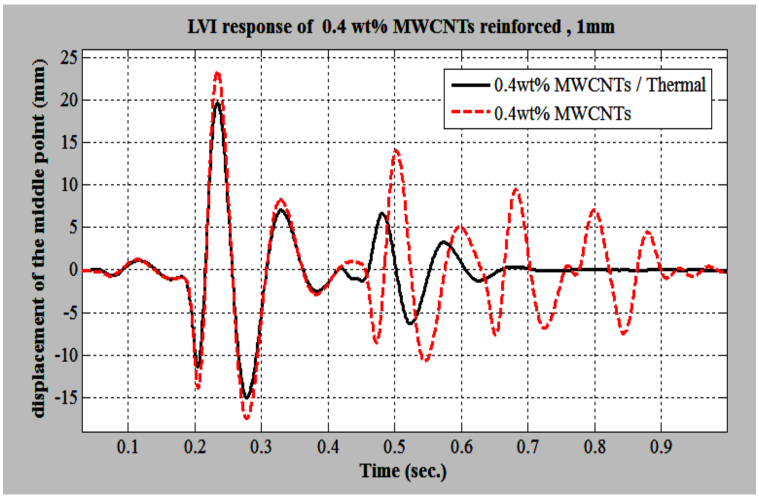


Figure 12. Compared to the transient responses of SSSS composite shells, ply (0/90) at velocity 7.5 m/s with/without thermal effects conditions (116oC at 21.12 min).

The transient response characteristics of the mentioned weight percentage of MWCNTs reinforced composite shell specimens at same parameters, impact load and velocity under thermal conditions (25°C and 116°C) as shown in fig.(11, and 12) yield that the specimen which reinforced by 0.4%wt approximately not effected by thermal load with increasing temperature to 116°C. Sliding mode controller (SMC) used as an active controller in the present closed loop system of 3mm thickness for smart 0.4wt% cross-ply composite shell specimen at 7.5 m/s. The tuning of sliding coefficient at attempt 1 as in table (1) contributed in results of figs (13-15).

The result in fig.(13) showed an agreement reduction in maximum over shoot at the middle point of shell surface about (95.8%) after several attempts if it is compared to similar one without using SMC as in fig.(14). But the internal waves of the composite material have high discrepancy at the two actuators positions 1 and 2 in maximum over shoots as shown in figs (15, and 16).

Table 1: Tuning of sliding coefficient.

Attempt	$\overline{\alpha}_1$	$\overline{\alpha}_2$	$\overline{\alpha}_3$	$\overline{\alpha}_4$
1	0.085	0.002	0.095	0.0015
2	0.065	0.00123	0.098	0.0013

In addition the second attempt in table 1 gave a little discrepancy effect about (2.44%) in the results as shown in figs (17, 18) at the middle surface of specimen. An important improvement in transient response of figs (19, and 20) at maximum over shoot of the two positions 1, 2 when it is compared with previous one in similar position.

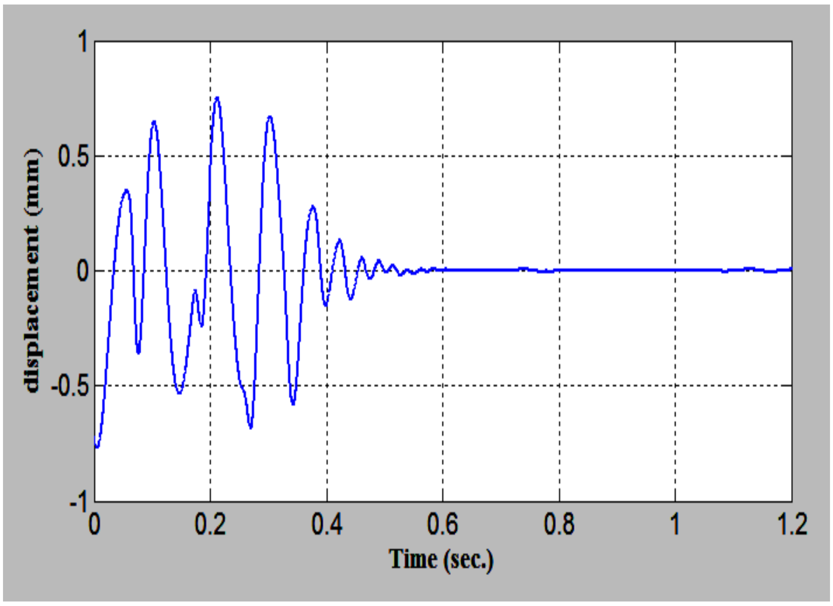


Figure 13. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at middle surface, (using tuning coefficient for attempt 1), and ply (0/90) at velocity 7.5 m /s.

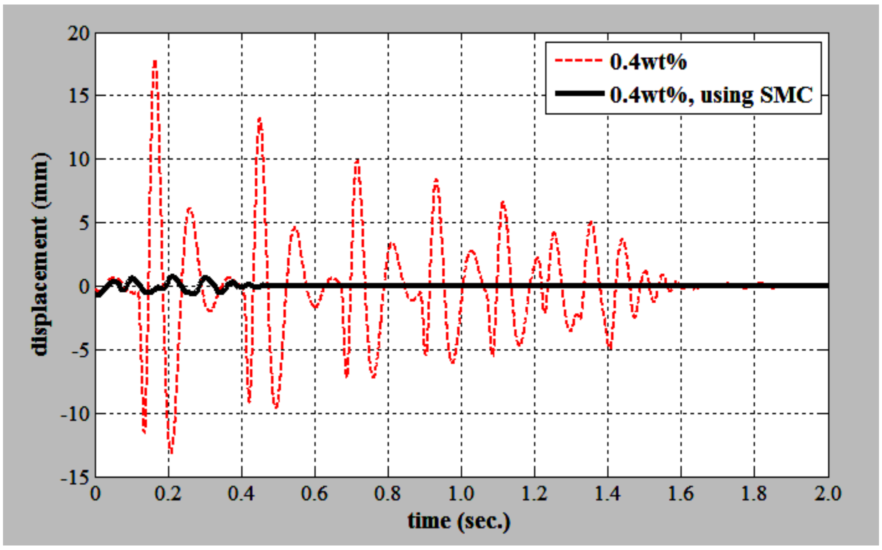


Figure 14. Comparing responses of 0.4wt% MWCNTs reinforced SSSS composite shells at middle point, without/with using tuning coefficient for attempt 1of SMC.

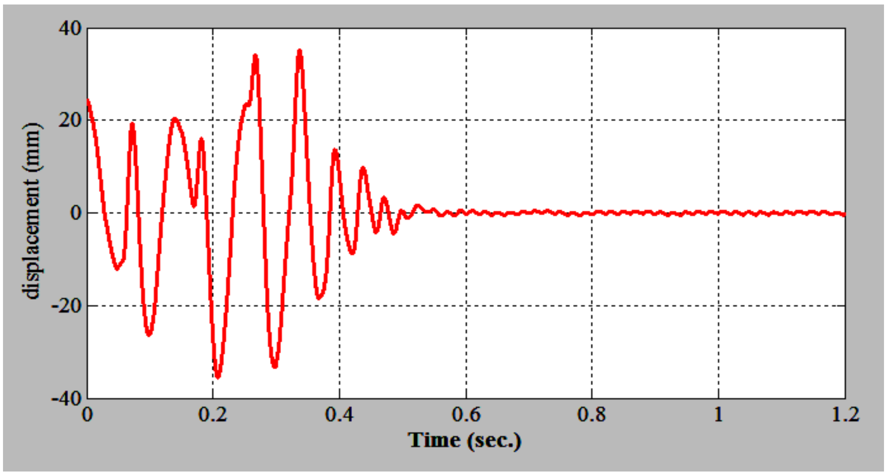


Figure 15. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at position 1 as in figure 10, 3mm, and ply (0/90) at velocity 7.5 m /s. (tuning coefficient for attempt 1)

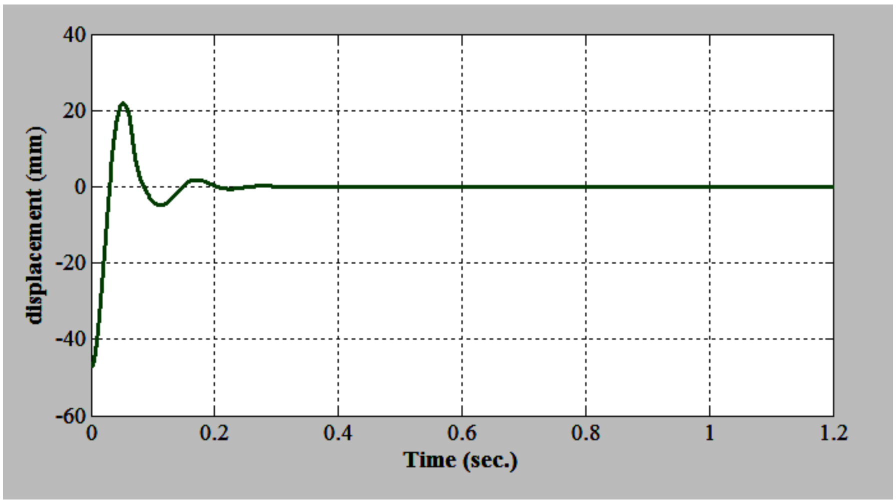


Figure 16. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at position 2 as in figure 10, 3mm, and ply (0/90) at velocity 7.5 m /s. (tuning coefficient for attempt 1)

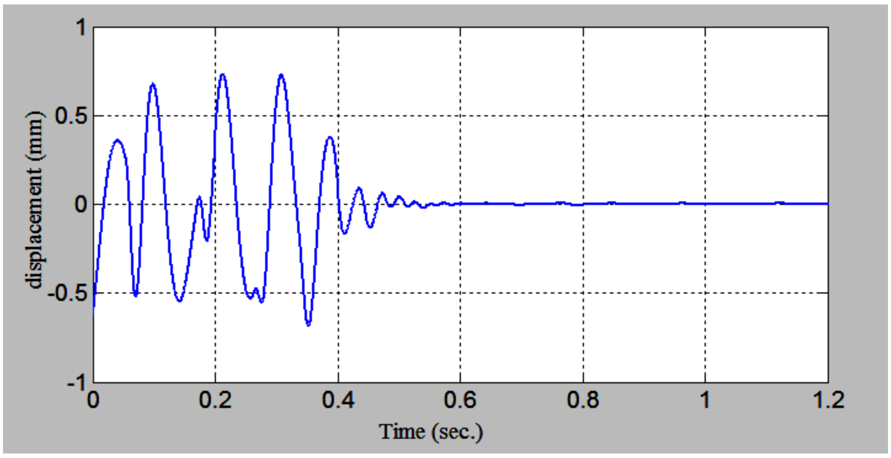


Figure 17. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at middle surface, 3mm, (tuning coefficient for attempt 2) and ply (0/90) at velocity 7.5 m /s.

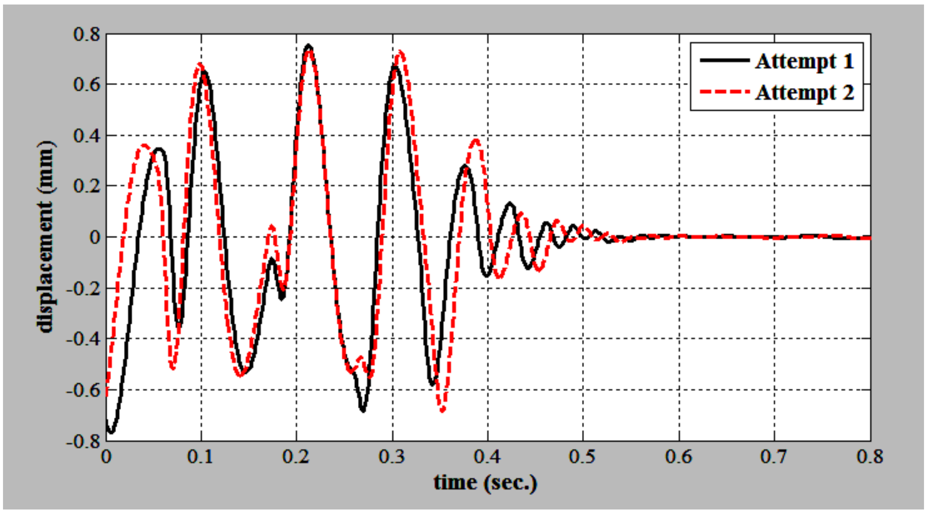


Figure 18.Comparing responses of 0.4wt% MWCNTs reinforced SSSS composite shells at middle surface, 3mm, between tuning coefficient of attempt 1 and 2).

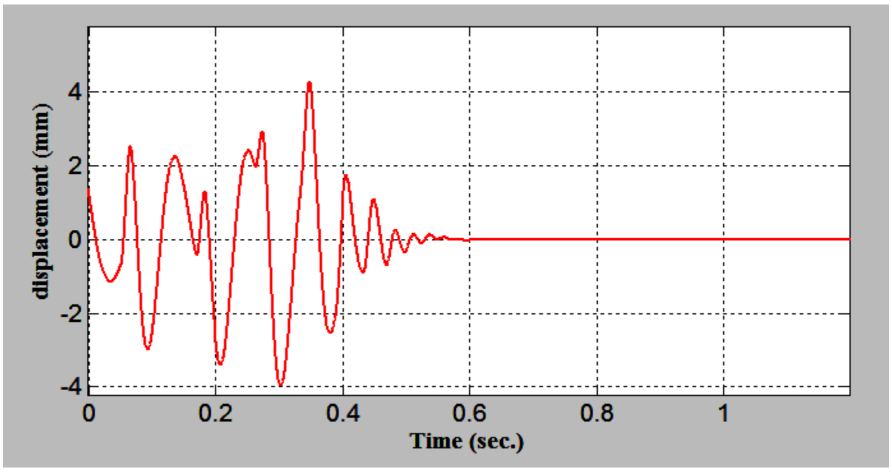


Figure 19. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at position 1 as in figure 10, 3mm, and ply (0/90) at velocity 7.5 m /s. (tuning coefficient for attempt 2)

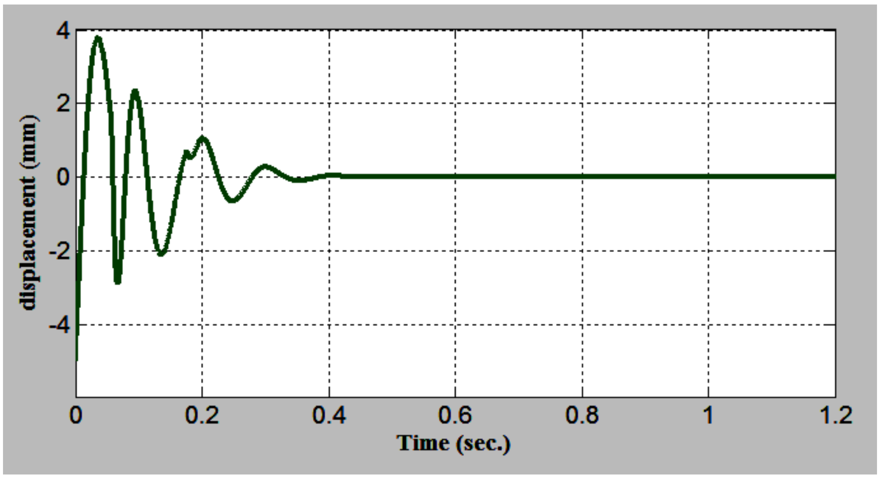


Figure 20. Transient response of 0.4wt% MWCNTs reinforced SSSS composite shells at position 2, 3mm, and ply (0/90) at velocity 7.5 m /s. (tuning coefficient for attempt 2).

Last but not least, Researcher hopes to arrive in the results, such as the result mentioned in the fig.20 and at the lowest height over shoot in order to suppression of vibration due to internal waves created under transverse impact load of the vertical LTVI apparatus.

7. Conclusions

Several conclusions can be drawn from this study:

1. Experiments have been carried out with a vertical LTVI apparatus specially designed for the low velocity impact under special thermal condition tests. This design allowed to test the specimen with velocity range exceeds 15 m/s in a simplified manner due to the employment of the mechanism of the spring system.
2. At 25°C, observed an improvement in settling time (reducing in recover time) about (62, 62.4, 60) % for reinforcement the composite shell with 0.4wt%, 0.5wt%, and 1.0wt% respectively. But under thermal condition at 116°C these percentages of settling time column reduced about (41, 50, 24.8) % for (0.4, 0.5, and 1.0) wt% respectively based on the 0.3wt% percentage of MWCNTs reinforced composite shell
3. Based on the percentage of 1.0 wt% reinforced with maximum amplitude of the transient vibration (over shoot) of 27.53 mm the improvement in results occur here due to decreasing in amplitude of over shoot about (49.3, 17.65, and 27.0) % for the weight percentages (0.3, 0.4, and 0.5) wt% respectively. At 116°C the specimen of 0.4wt% endured this test conditions.
4. In addition to the passivity of the composite shell structure due to reinforcement by woven carbon fiber and MWCNTs it was used the active double integral of sliding mode controller (SMC) indicated that an important improvement in transient response at maximum over shoot of the middle surface point about (95.8%) and (50%) in settling time, with SMC the specimens reach the steady state at short time.

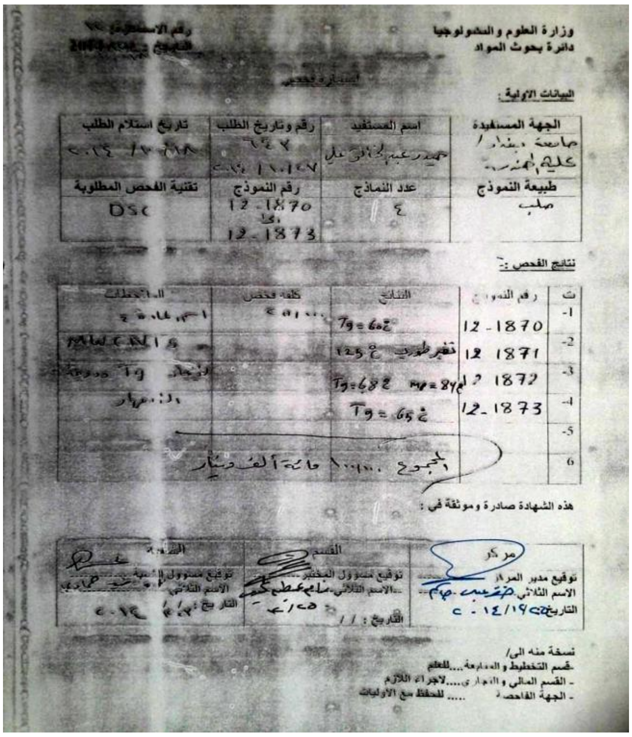
6. References

1. M.K. Rath, (2013),*"Experimental Investigation for Free Vibration of Woven Fiber Composite Plates Subjected to Hygrothermal Loading"*, National Institute of Technology, Rourkela-769008, TEPE Volume 2, Issue 3.
2. Crocker, (2006), *"Development of Composite Materials with High Passive Damping Properties"*, Auburn university mechanical engineering department, Alabama 36849.
3. Ewelina Ciecierska, (2013), *"The effect of carbon nanotubes on epoxy matrix nanocomposites"*, Concordia Center for Composites, Department of Mechanical, Canada.
4. W. Wang, *"Carbon Nanotube Enhanced Composite Materials"*, Zyvex Performance Materials 1255 Kinnear Rd. Columbus OH 43212, (www.zyvextech.com).
5. Mubingxuy, (2005), *"Adaptive passive and active control of vibration and wave propagation in cylindrical shells using smart materials"*, in partial fulfillment of the requirement for the degree of doctor of philosophy , university of Akron.
6. J. Njuguna, (2006), *" Static and dynamic analyses of actively/passively controlled composite structures"*, Department of Materials, School of Industrial and Manufacturing Science, Canfield University, Cranfield, Bedfordshire MK43 0AL, England, UK.
7. Ceyla Akin, (2010), *"An Experimental Study of Low Velocity Impact Response for Composite Laminated Plates"*, Dumlupinar University, the Institute of Science and Technology, Department of Mechanical Engineering, 43270, Kutahya.
8. David H Nash, (2011), *"Low Velocity Heavy Mass Impact Response of Singly Curved Composites"*, Department of Mechanical & Aerospace Engineering, University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ.
9. F. Ashenai Ghasemi, (2008), *"Modeling & Simulation of the Dynamic Response of Smart Hybrid Composite Structures Subjected to Low-Velocity Impact"*, Department of Mechanical Engineering, Shahid Rajaee Teacher Training University (SRTTU) Lavizan, Postal Code: 1678815811, Tehran, Iran.
10. G. B. Chai and S. Zhu**,** (2011), *"A review of low-velocity impact on sandwich structuress"*, Proceedings of the Institution of Mechanical Engineers, Part L: DOI: 10.1177/1464420711409985.
11. Gautam S. Chandekar, (2010), *"On the Behavior of Fiberglass Epoxy Composites under Low Velocity Impact Loading"*, Department of Mechanical Engineering, Tennessee Technological University, Cookeville, TN 38505, USA.
12. Ajay Kumar, (2013), *"Analysis of laminated composite skew shells using higher order shear deformation theory"*, department of Civil Engineering, Indian Institute of Technology, Roorkee-247 667, India.
13. M.A. Hassan, (2014), *"Low-velocity impact damage of woven fabric composites: Finite element simulation and experimental verification"*, Mechanical Engineering Department, Faculty of Engineering, University Malaya, Malaysia.
14. Emre Erbil, (2008), *"Impact Loading in Laminated Composites Theory"*, Izmir, August.

15. Leonidas Dokos, (1999), *"Low Velocity Impact Detection and Damage Assessment in Composite Materials Using Fibre Bragg Grating Sensors"*, Department of Engineering Materials, University of Southampton, ID 1387.
16. Enaam A. Khaliq, 2009," A Power Controller Based Sliding Mode Controlled for Induction Heating Application", a thesis of electrical Engineering department, Baghdad University.
17. Junfeng Hu, 2011,*"Vibration Control of Smart Structure Using Sliding Mode Control with Observer"*, School of Mechanical & Electrical Engineering, Jiangxi University of Science and Technology, Ganzhou.
18. Erika A. Ooten, 1999, *"Command Generation with Sliding Mode Control for Flexible systems"*, Department of Mechanical Engineering Georgia Institute of Technology Atlanta, GA 30332 USA.
19. K. Ogata, 2002, *"Modern Control Enigineering"*, Forth Ed., ISBN 0-13-043245-8.University of Minnesota, USA.
20. R. C. Dorf, 2011, *"Modern Control System"*, twelfth Ed., ISBN-13:978-0-13-602458-3.University of California, USA.
21. Sigma-Aldrich, *"Product Specification sheet of MWCNTs"*, 3050 Spruce Street, Saint Louis, MO 63103, USA. www.sigmaaldrich.com

Appendix – A

The results of the Differential Scanning Calorimetry (DSC) showed that the material which be selected for thermal condition test must be include the weighed ratio 0.4wt% of MWCNTs, change in phase happened under DSC test as shown in fig. A1.



وزارة العلوم والتكنولوجيا
دائرة بحوث المواد

رقم الاستمارة: [illegible]
التاريخ: [illegible]

استمارة فحص

البيانات الأولية:

الجهة المستفيدة	اسم المستفيد	رقم وتاريخ الطلب	تاريخ استلام الطلب
جامعة بغداد / كلية الهندسة	حيدر عبد الخالق علي	٦٤٢ ٢٧/١٠/٢٠١٤	٢٨/١٠/٢٠١٤
طبيعة النموذج	عدد النماذج	رقم النموذج	تقنية الفحص المطلوبة
صلب	٤	12-1870 الى 12-1873	DSC

نتائج الفحص :-

ت	رقم النموذج	النتائج	كلفة فحص	الملاحظات
-1	12-1870	Tg = 60 م	٢٥,٠٠٠	[illegible]
-2	12 1871	تفحم طري 125 م		MWCNTs
-3	12 1872	Tg = 68 م mp = 84 م		[illegible] Tg [illegible]
-4	12-1873	Tg = 65 م		[illegible]
-5				
6		المجموع ١٠٠,٠٠٠ مائة ألف دينار		

هذه الشهادة صادرة وموثقة في :

مركز	القسم	الشعبة
توقيع مدير المركز	توقيع مسؤول المختبر	توقيع مسؤول الشعبة
الاسم الثلاثي [illegible]	الاسم الثلاثي [illegible]	الاسم الثلاثي [illegible]
التاريخ ٢٠١٤/١٢/١٤	التاريخ : / /	التاريخ [illegible] ٢٠١٤

نسخة منه الى/
- قسم التخطيط والمتابعة ....للعلم
- القسم المالي والاداري ....لاجراء اللازم
- الجهة الفاحصة ..... للحفظ مع الاوليات

Figure A1. Results of the Differential Scanning Calorimetry (DSC).