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جامعة ستاردوم

مجلة ستاردوم العلمية للدراسات الطبيعية والهندسية

مجلة ستاردوم العلمية للدراسات الطبيعية والهندسية
تصدر بشكل نصف سنوي عن جامعة ستاردوم
المجلد الثاني ا العدد الأول- لعام 2024م
رقم الإيداع الدولي : ISSN 2980-3756

بسم الله الرحمن الرحيم

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عناويـن الأبحـــاث

Stardom Journal of Natural and Engineering Sciences (SJNES)

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INVESTIGATION OF ABSORBING THE CRASH IMPACT OF CAR ACCEDIENT DUE TUBE INVERSION

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Abstract

Achieving the safety factor is very important in all vehicles including the Cars. More than 1.3 million people die every year as a result of road traffic accidents, and between 20 to 50 million people suffer from non-fatal injuries, according to United Nations statistics. Minimizing the effect of the impact of car accident can prevent a serious injury or could possibly prevent a deadly accident. The main objective of this study is to reduce the effect of the impact when car accident occurs. In order to make this possible was a suitable design and manufacture a mechanical device performing the external inversion (curling) of circular tubes under dynamic axial-force. Effect of the designed mechanical device on the tube inversion forming process is studied through applying the system and fix it in front of the car in order to absorb the impact of the accident. The effect of used the aluminum and copper tubes in the absorbing the energy is studied through applying the load that is generated by Universal Testing Machine (UTM) and ABAQUS simulation methods. The results show that the 80 mm Copper tube with Die & Foam were satisfying because the amount of energy absorbed was much higher and twice comparing with the ordinary tubes. It is therefore recommended that the 80 mm Copper tube with Die & Foam is suitable design and can be considered as an efficient energy-dissipating device since it provides favorable crashworthiness characteristics and excellent energy absorption capacity for optimum safety while preserving enhanced manufacturability.

Keywords: Impact Testing, Die, Tubes, Dynamic Load, Energy Absorbed, Cracking.

التحقق من امتصاص تأثير الاصطدام لحوادث السيارات بواسطة انعكاس الأنابيب

إن تحقيق عامل الأمان مهم جدًا في جميع المركبات بما في ذلك السيارات. ويموت أكثر من 1.3 مليون شخص كل عام نتيجة لحوادث المرور على الطرق، ويعاني ما بين 20 إلى 50 مليون شخص من إصابات غير مميتة وفقاً لإحصاءات الأمم المتحدة. إن التقليل من تأثير حادث السيارة يمكن أن يمنع وقوع إصابة خطيرة أو ربما يمنع وقوع حادث مميت. الهدف الرئيسي من هذه الدراسة هو تقليل تأثير الاصطدام عند وقوع حادث سيارة. ولجعل ذلك ممكنًا، تم تصميم وتصنيع جهاز ميكانيكي مناسب يقوم بالقلب الخارجي (الشباك) للأنابيب الدائرية تحت القوة المحورية الديناميكية. تمت دراسة تأثير الجهاز الميكانيكي المصمم على عملية تشكيل الأنبوب المعكوس من خلال تطبيق النظام وتثبيته أمام السيارة لامتصاص تأثير الحادث. تمت دراسة تأثير استخدام أنابيب الألمنيوم والنحاس في امتصاص الطاقة من خلال تطبيق الحمل المتولد بواسطة آلة

الاختبار العالمية (**UTM**) وطرق محاكاة **ABAQUS.** أظهرت النتائج أن الأنبوب النحاسي مقاس 80 مم مع القالب والرغوة كان مرضيًا لأن كمية الطاقة الممتصة كانت أعلى بكثير ومضاعفة مقارنة بالأنابيب العادية. ولذلك يوصى بأن يكون الأنبوب النحاسي مقاس 80 مم مع القالب والرغوة تصميمًا مناسبًا ويمكن اعتباره جهازًا فعالاً لتبديد الطاقة لأنه يوفر خصائص ملائمة لمقاومة التصادم وقدرة ممتازة على امتصاص الطاقة لتحقيق السلامة المثلى مع الحفاظ على قابلية التصنيع المحسنة.

الكلمات المفتاحية: اختبار التأثير، القالب، الأنابيب، الحمل الديناميكي، امتصاص الطاقة، التشقق

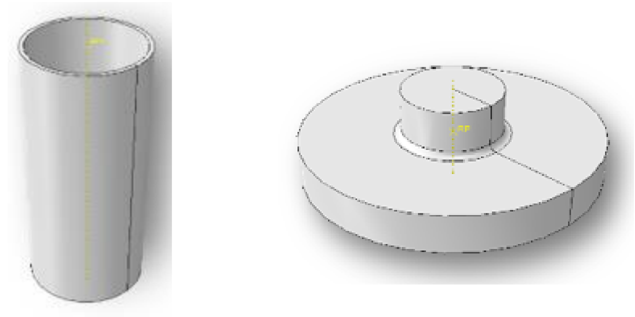
1.0 INTRODUCTION

Thin-walled tubes are widely used in aerospace factories, cars manufacturing, pipelines, etc. These cylindrical tubes are very beneficial in account of its tiny weight, high strength and easy building [1]. As example, tubes are characterized by geometrical effect, radius, thickness and length, and are mostly used as energy absorbents in deformation phenomenon such as buckling, expansion, cracking and inversion [2, 3]. Among the deformation phenomenon described, the expansion of the tube has certain important properties that make it a good absorbent. Studying the importance of the cylindrical tubes of such systems and the dynamic behavior of these structures is our great concern [4, 5]. Hence this study is aimed to Investigate the absorbing the crash impact of car accident due tube inversion by design and manufacture a mechanical device performing the external inversion (curling) of circular tubes under dynamic axial-force. In the present study, in order to recognize the effect of load on the tubes and how much energy is absorbed by the tubes that are located in a steel die the Universal Testing Machine (UTM) used to apply the axial force. UTM also used to test the compressive strength and tensile strength of materials. ABAQUS simulations program was employed to evaluate the effectiveness of the designed mechanical device on the tube inversion forming process is studied through applying the system and fix it in front the car in order to absorb the impact of the accident. Using ABAQUS software is one of the best modeling ways to get the data that we want. ABAQUS is a Finite Element Analysis (FEA) [6]. Due to improved computing capacity and the ability of FEA software packages to model extremely complicated components, structures and systems under a wide range of circumstances and loading conditions, the use of FEA devices has become widespread. ABAQUS/CAE is used for model development (including load assignment, boundary conditions, etc.), analysis, job management, and visualization of the tests [7]. The ABAQUS/Regular tool is used in static and low-speed dynamics to provide reliable stress solutions. ABAQUS/Explicit is used for transient dynamics and is ideal for effects or events of short lasting [8]. The other key product available is ABAQUS/CFD, which is dedicated to fluid dynamics simulation and heat transfer and is suitable for thermal and fluid structural applications.

2.0 MATERIALS AND METHODS

2.1 Material Preparation

Material used in this study for the tube is Aluminum, copper, a prototype of tube as shown in **Figure (1a)**. Die is made of steel with different geometries and fillet radius with final shape of the die as shown in **Figure (1b)**. The tube was filling by foam to enhance the possibilities of inversion to occur. The reason why is because foam is working as supportive agent and help in avoiding buckling.



(a) **(b)**

Figure 1: (a) Cylindrical Tube, and (b) Die

2.2 Testing Procedure

In the present study, the Universal testing machine (UTM) and Charpy impact machine are the best machines that can be used to apply the axial force and get the amount of energy absorb by the specimen easily and also UTM machine gives possibility to apply the force at different speed. The universal testing machine (UTM) is used to test the compressive strength and tensile strength of materials. UTM has the ability to do all the tests required in this study such as compression, bending, and it performs tension test. The good thing about this machine is the presence of load cells and extensometers that measure the required parameters such as force and deformation. In addition, it is connected to a computer and also used to simulations by ABAQUS program and can be collected data easily as shown in **Figure (2)**.

Figure 2: universal testing machine (UTM).

2.3 Mechanical Property Test

In this study the evaluation of examining the best dimension and characteristics of the tube and the die by Experimental setup and Modeling ABAQUS program. So, ABAQUS contain three important tasks, starting with drawing the parts, and then add the material to the program, and assign the characteristics that we want, such as the density, young modules of and Poisson's ratio, etc. to the part. And simulates the modeling and visualizes the deformation on the material, also, it shows the results that are required. Using this program will give us a good result of our inversion tests, on Aluminum tube and other material that could be used later such as Copper. And be able to know how much energy that the material can absorb and notice the deformation.

2.4 Software Testing and Validation

2.4.1 First simulation trail

Material that is used in this trail is Aluminum. The reason of choosing aluminum because it can deform easily and gives a good result to see either the buckling or the inversion that occurs. The mechanical properties of aluminum tube that used on the ABAQUS program are shown in **Table (1) and Table (2)**.

Table 1: Mechanical properties of Aluminum

Properties	Value

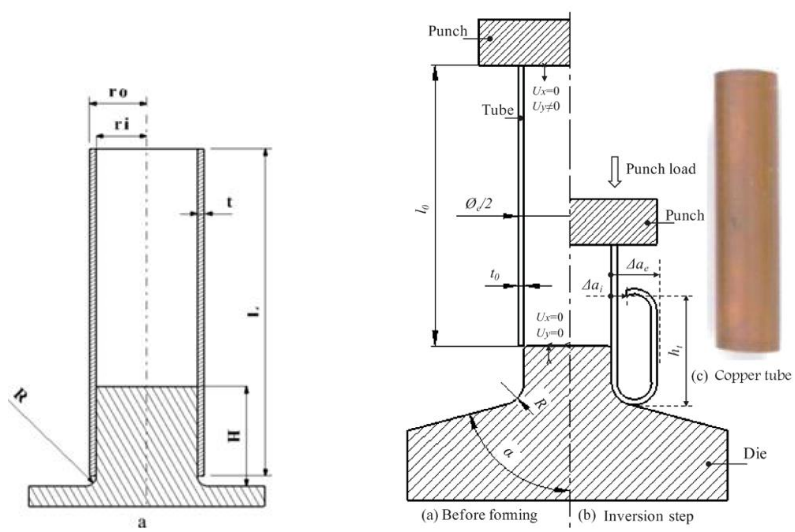
density (ton/mm3)	2.71e-9 ton/mm^3
young modulus (n/mm2)	71700
poisson ratio	0.33
Yield strength (MPa)	185
Ultimate strength (MPa)	214

Table 2: Mechanical properties of Aluminum were used in ABAQUS

Yield Stress	**Plastic Strain**
350	0
368.71	0.001
376.5	0.002
391.98	0.005
403.15	0.008
412.36	0.011
422.87	0.015
444.17	0.025
461.5	0.035

507.9	0.07
581.5	0.15
649.17	0.25
704.22	0.35
728.78	0.4
751.85	0.45
773.68	0.5
794.44	0.55
814.28	0.6

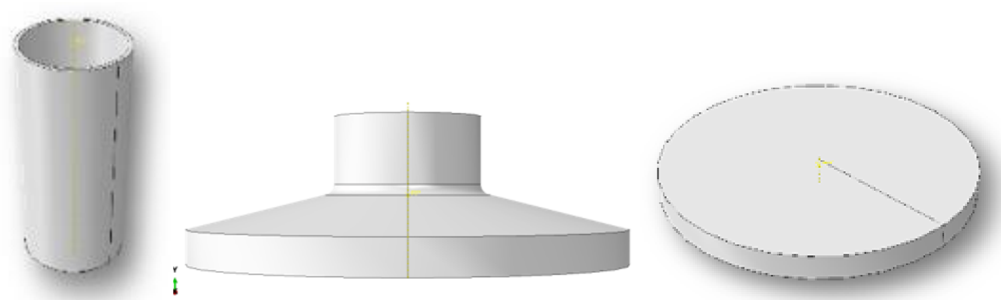
Many parameters have been chosen, to ensure that the external inversion occurs are shown in **Figure (3)**. **Figure (3)** shows the thickness (t) of the tube, ri, ro are the inner and outer radius, respectively. R is the radius of the fillet, and H is the height of inner fillet, instead of using foam, we raise the length of the die, to avoid buckling. And l which is the length of the tube. The dimensions that we used in this experiment for the tube and the die, are given by ld = 25mm, R = 3mm, Rd = 19.5mm, ϴ = 43mm, t = 1.5mm, l = 97mm, α = 75 degree.



(a) (b)

Figure 3: Details of the specimen design with (a) a rigid die, external inversion, and (b) a rigid die, external inversion.

Figure (4) shows the, Tube, Die and Upper Plate used for Design the mechanical device on the tube inversion forming process is studied through applying the system and fix it in front the car in order to absorb the impact of the accident. **Figure (5)** shows the, assembly of all parts that contact with Aluminum tube, starting from the tube, and also the die that works as the base of the tube, and designed it to be rigid so it will not deform when the load is pushing the aluminum tube downward, and finally the plate, which weighs two tons, so that can crash the tube and make it deform.



(a) **(b)** **(c)**

Figure 4: (a) Tube, (b) Die and (c) Upper Plate.

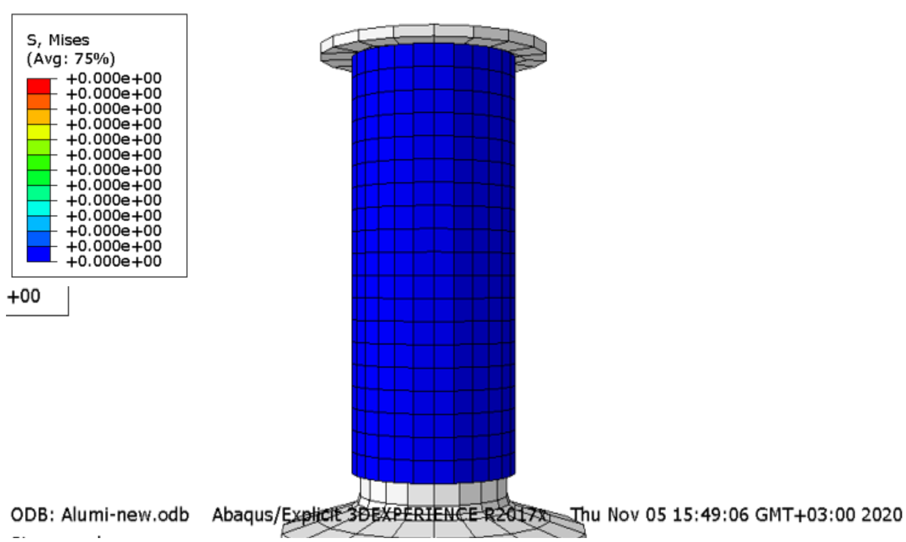


Figure 5: assembly of all parts that contact with Aluminum tube

2.4.2 Second simulation trail:

Material that is used in Second simulation trail is Copper. The reason of choosing Copper because it can deform without needing of big force and give kind of a good result to see either the buckling or the inversion occurs. The mechanical properties of Copper tube that used on the ABAQUS program are shown in

Table (3) and Table (4).

Table 3: Mechanical properties of Copper

Properties	value
density (ton/mm3)	8.96e-9 ton/mm ^3
young modulus (n/mm2)	117000
Poisson ratio	0.34
Yield strength (MPa)	33.3
Ultimate strength (MPa)	210

Table 4: Mechanical properties of Copper were used in ABAQUS

yield stress	plastic strain
297.3730	0.0000
343.2320	0.0012
366.1620	0.0022
390.5250	0.0040
400.5570	0.0060
406.2900	0.0088
410.5890	0.0140
413.4550	0.0213
414.1720	0.0254
414.8890	0.0282

Figure (6) shows the, assembly of all parts that contact with Copper tube, starting from the tube, and also the die that works as the base of the tube, and designed it to be rigid so it will not deform when the load is pushing the aluminum tube downward, and finally the plate, which weighs two tons, so that can crash the tube and make it deform. The dimensions that we used in this experiment for the tube and the die, are given by ld= 25mm, R=2mm, Rd=10mm, Ɵ=22mm, t=0.5mm, l=70mm, α=60 degree.

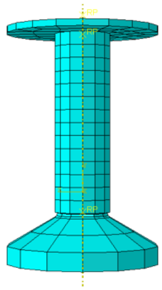


Figure 6: Assembly of all parts that contact Copper tube

2.5 Experimental Setup

In experimental part, the copper tube only chooses with different length and cases as shown in **Figure (7)** and **Figure (8)**. In copper experiment, the load vs Displacement were indicated at Time = 120s and α = 75°, with length = 70 mm & 80 mm, after that use Ls-Prepost software to get area under Load vs Displacement curve witch it will be the amount of energy absorption as shown in **Table (5)**.

(a) **(b)**

Figure 7: (a) Copper tube samples, and (b) Steel die.

(a) First Trail (b) Second Trail (c) Third Trail

(d) Forth Trail (e) Fifth Trail (f) Sixth Trail

Figure 8: Copper tubes samples for different experimental trail

Table 5: The descriptions of the experimental trail

Experimental Trail	Length of Copper Tube (mm)	Description
First	70	without Die
Second	70	with Die
Third	70	with Die & Lubricant
Fourth	80	with Die & Lubricant
Fifth	80	with Die & Lubricant & Foam
Sixth	80	with Die & Foam

3.0 RESULTS AND DISCUSSION

3.1 Results and Discussion of ABAQUS Simulation

First it should be known that ABAQUS is a very sensitive tool, so if there is such a small error, the process will fail, and the tube will buckle, and inversion will not accrue. Unfortunately, the experiment not succeeded as planned, even though we used and define new parameters for the die. The buckling accrues and the fully inversion didn't appear as expected. But despite this we are very satisfied with the result, especially the inversion accrues in the first few seconds. So, after drawing the parts, we assigned aluminum material to the tube, and then we gave the upper plate ((which is a discrete rigid)), with inertia that is as 2 tons' weight, and moving towards the tube with speed of 1 m/s. also, we defined a friction coefficient between the surfaces as 0.2, with step time period as 0.05. This force is generated from the upper plate and going downward will make the tube to be crushed. And in his way, we can observe the reaction that occurs either inversion or buckling. To avoid the die from deforming we made it as discrete rigid, and, we have fixed it, so it will not move in any direction.

3.1.1 Results and Discussion of ABAQUS for First simulation trail

The dimensions that we used in this experiment for the tube and the die, are given by ld = 25mm, R = 3mm, Rd = 19.5mm, ϴ = 43mm, t = 1.5mm, l = 97mm, α = 75 degree. **Figure (9)** shows the upper plate moves only in Y direction downward, and crash the tube and succeed with the curling of the aluminum tube but while the process continued the buckling occurred. The relationship between the force and the time is given by **Figure (10**). Finally, we have used " LS-PrePost ", to calculate the amount of energy absorbed by the Aluminum tube, **Figure (11)** shows that program, and the energy absorbed was 982 joules.

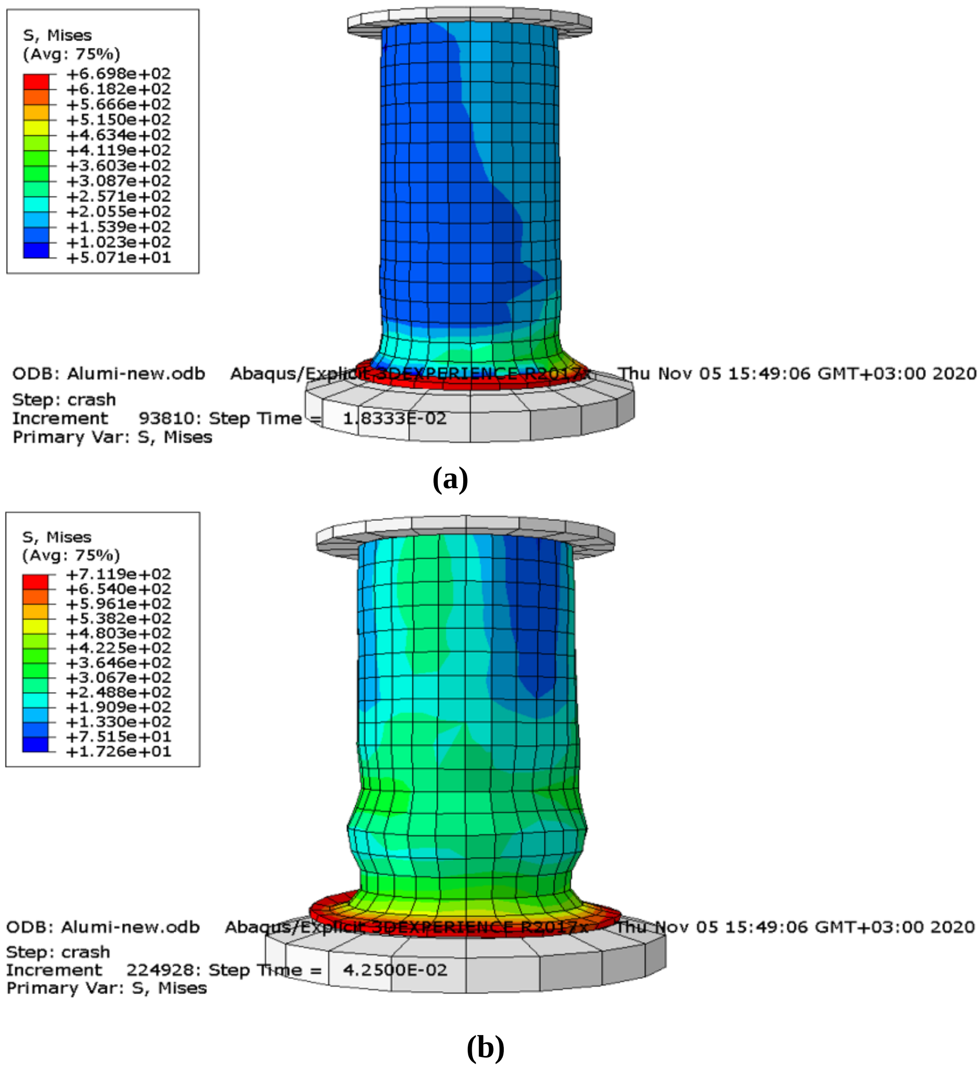


Figure 9: Modeling deformation of first trail

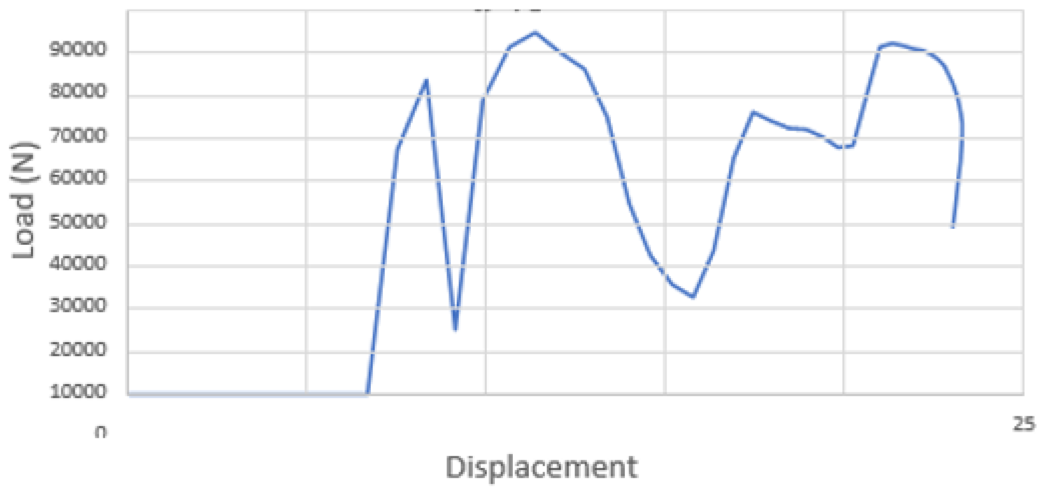


Figure 10: Force VS Displacement for 97mm Aluminum tube with Die & α=75°

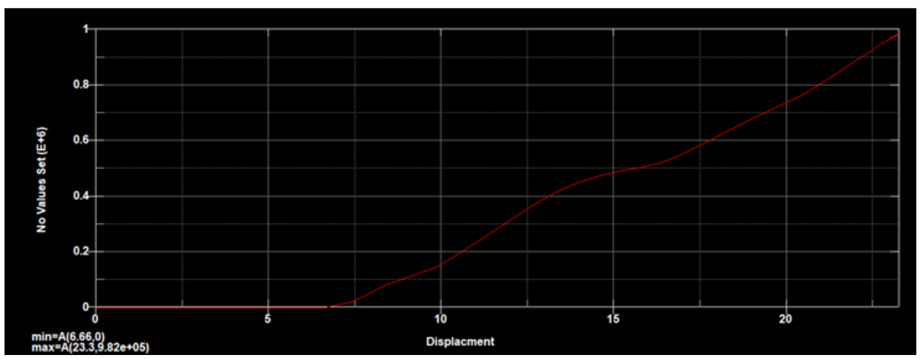


Figure11: Energy absorbed for Aluminum first trail

3.1.2 Results and Discussion of ABAQUS for Second simulation trail

The dimensions that are used in this experiment for the tube and the die, are given by ld = 25 mm, R = 2mm, Rd = 10 mm, ϴ = 22 mm, t = 0.5 mm, l = 70 mm, α = 60 degree. The amount of inertia that is used is 2 tons weight and moving towards the tube with coefficient of friction between the surfaces as 0.2, with step time period as 0.05s. This force that is generated from the upper plate and going downward will make the tube to be crushed. From the results, it has been observed that, the reaction that occurs either inversion or buckling. As you can see from the **Figures (12)** the upper plate moves only in Y direction, and crash the tube and succeed with the curling of the Copper tube but while the process continued the buckling occurred. The relationship between the force and the time is given by **Figure (13)**. Finally, we have used " LS-PrePost ", to calculate the amount of energy absorbed by the Copper tube, **Figures (14)** shows that program, and the energy absorbed was 615 joules.

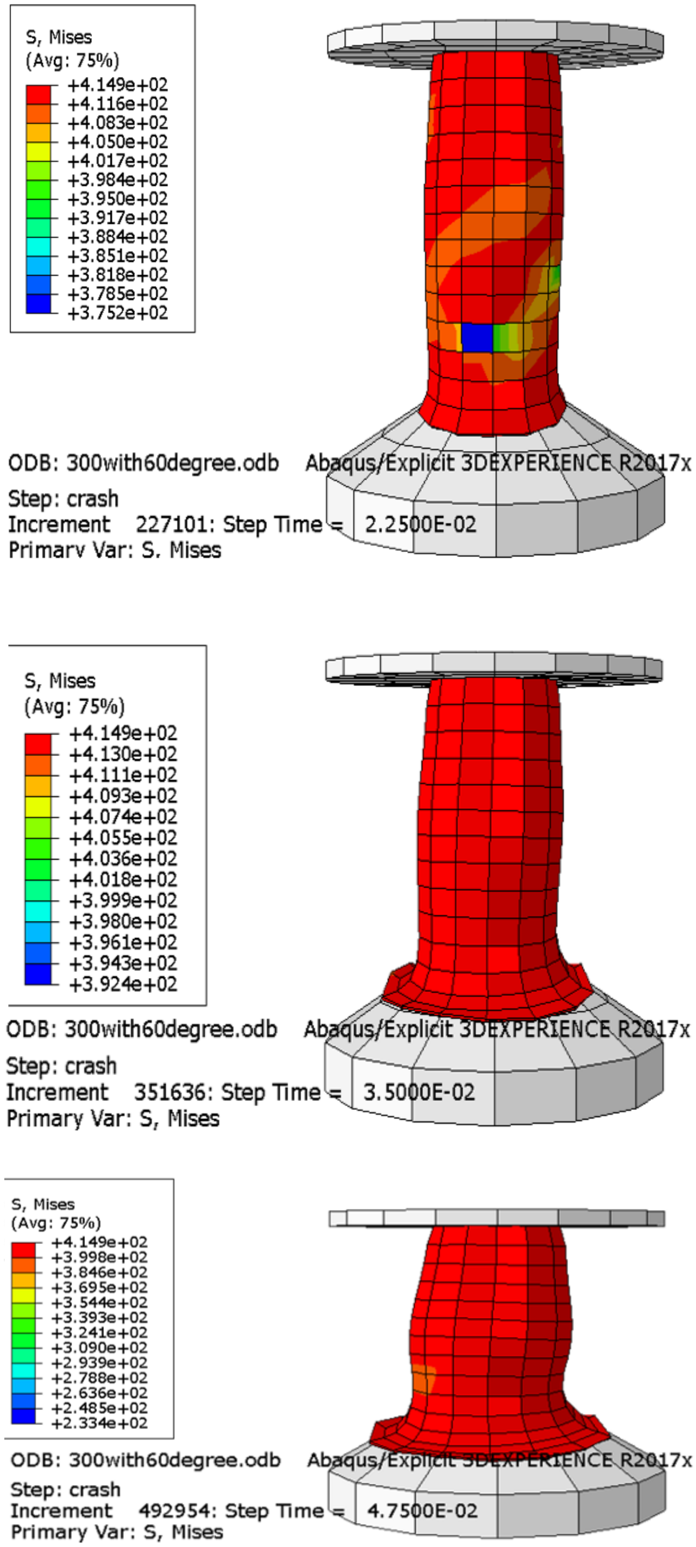


Figure 12: Modeling deformation of Second trail

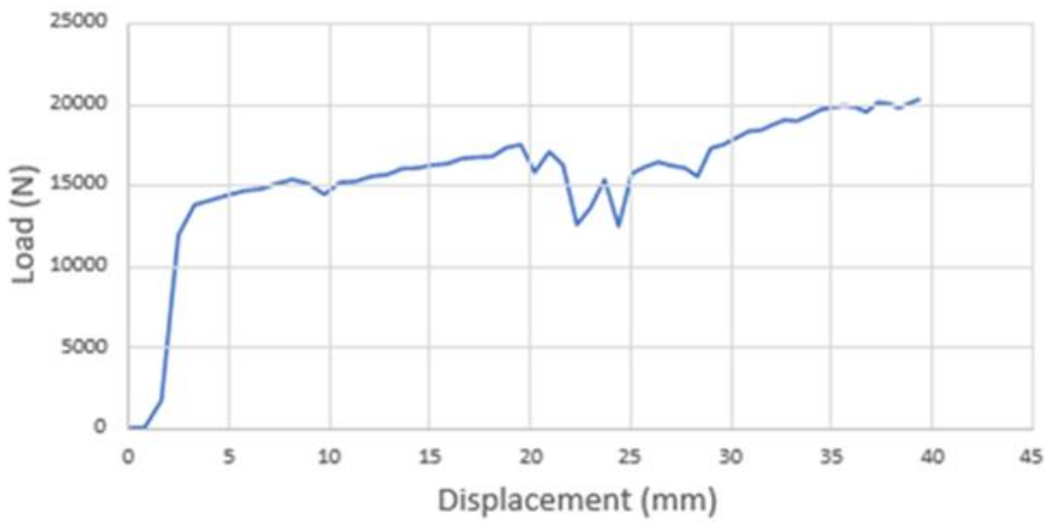


Figure 13: Force VS Displacement for 70mm Copper tube with Die & α=60°

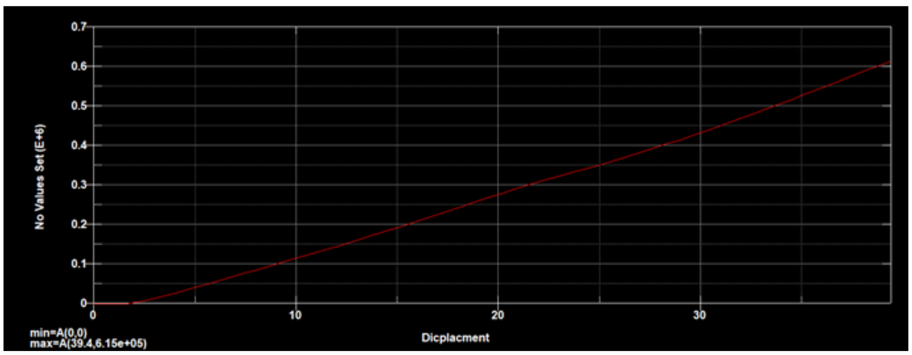
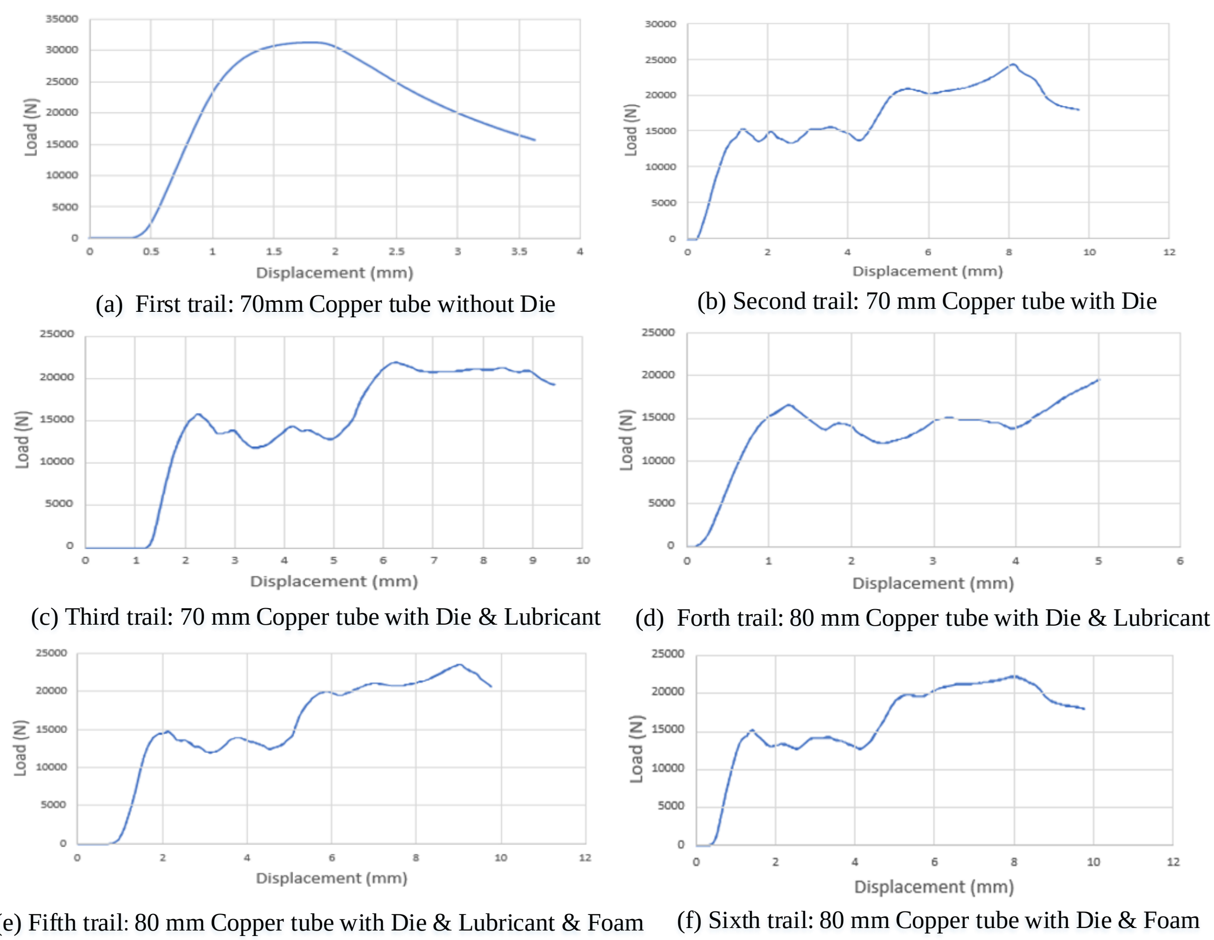


Figure 14: Energy absorbed for second trail for copper

3.2 Experimental Result

Figure (15) and Figure (16) show a comparison between the different experimental result trail. It can be observed that for all the experimental result trail, the first experiment for copper, we take load vs Displacement at Time=120s and α = 75° after that we use Ls-Prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 70 mm, without Die. Amount of energy absorbed in the first trail was = 72.3 J. For second trail using copper we did the experiment, and we take load vs Displacement at Time=120s and α = 75°, after that we use Ls-prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 70mm, with Die. Amount of energy absorbed in the second trail was = 167 J. For third trail using copper we did the experiment, and we take load vs Displacement at Time=120s and α = 75°, after that we use Ls-prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 70mm, with Die & Lubricant. Amount of energy absorbed in the third trail was = 136 J. For forth trail using copper we did the experiment, and we take load vs Displacement at Time=120s and α = 75° after that we use Ls-Prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 80 mm, with Die & Lubricant. Amount of energy absorbed in the fourth trail was = 67.2 J. For fifth trail using copper we did the experiment, and we take load vs Displacement at Time=120 s and α = 75°, after that we use Ls-Prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 80mm, with Die & Lubricant & Foam. Amount of energy absorbed in the fifth trail was = 149 J. For sixth trail using copper we did the experiment, and we take load vs Displacement at Time=120s and α = 75°, after that we use Ls-prepost software to get area under Load Vs Displacement curve witch it will be the amount of energy absorption. The length of copper tube is 80mm, with Die & Foam. Amount of energy absorbed in the sixth trail was = 158 J.



(a) First trail: 70mm Copper tube without Die

(b) Second trail: 70 mm Copper tube with Die

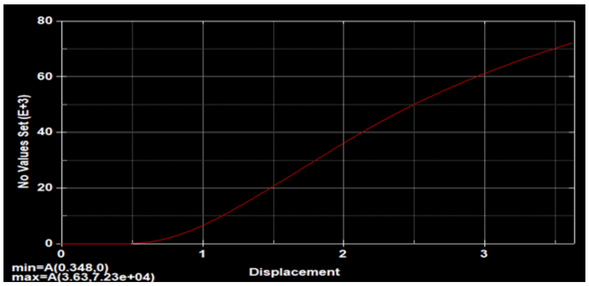
(c) Third trail: 70 mm Copper tube with Die & Lubricant

(d) Forth trail: 80 mm Copper tube with Die & Lubricant

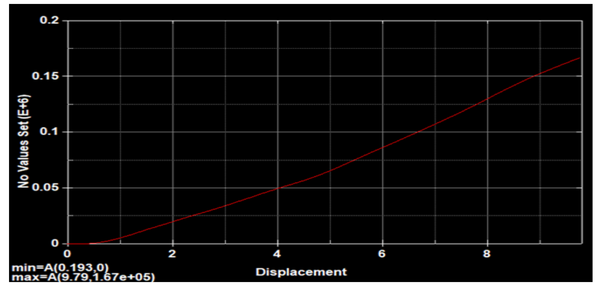
(e) Fifth trail: 80 mm Copper tube with Die & Lubricant & Foam

(f) Sixth trail: 80 mm Copper tube with Die & Foam

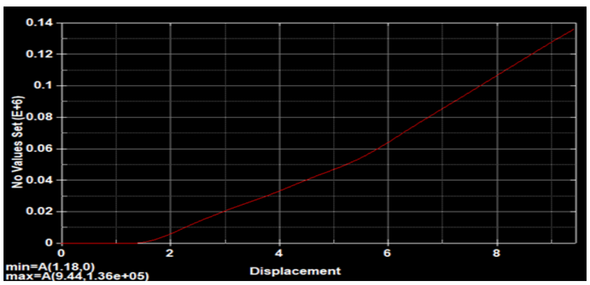
Figure 15: Energy absorbed for different trails for copper



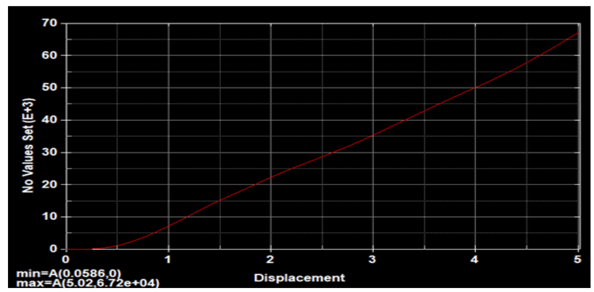
(a) First trail



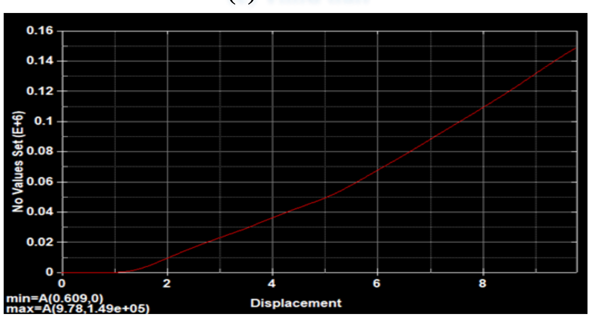
(b) Second trail



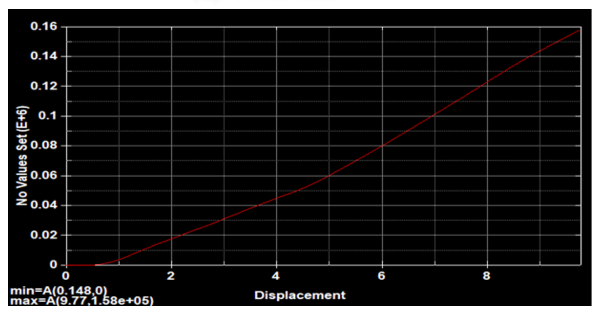
(c) Third trail



(d) Forth trail



(e) Fifth trail



(f) Sixth trail

Figure 16:

Energy absorbed for different trail for copper

3.3 Comparison of results of Experimental trails and Simulations

The method executed to assess the investigation of absorbing the crash impact of car accident due tube inversion was by compare the result of experimental and simulation of the different trails are shown in **Figure (17)** and **Table (6)**. From the results, it has been observed that, 80 mm Copper tube with Die & Foam is good material for absorbing the crash impact of car accident. The amount of energy absorbed for 80 mm Copper tube with Die & Foam is higher about 158 J. The results show that the amount of energy absorbed for 80 mm Copper tube with Die & Foam recorded the higher comparing with the another trails.

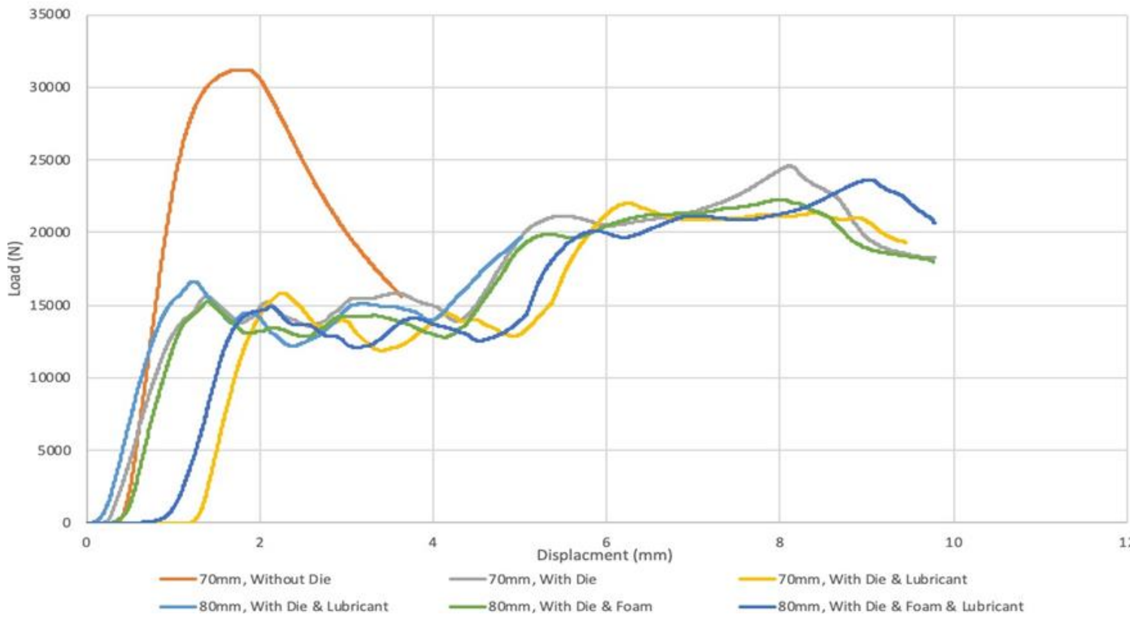


Figure 17: Comparison between load vs displacement of copper with different length & situations

Table 6: Comparison of the amount of energy absorbed and Energy density of different trails

ABAQUS		
Test mood	**Amount of energy absorbed (J)**	**Energy density (MJ/m^3)**
97 mm Aluminum tube with Die & $\alpha = 75°$	98 2	153.45130 5
70 mm Copper tube with Die& $\alpha = 60°$	61 5	133.17046 26
Experimental		

70 mm Copper tube without Die	72.3	15.6556495
70 mm Copper tube with Die	167	36.16173537
70 mm Copper tube with Die & Lubricant	136	29.44907791
80 mm Copper tube with Die & Lubricant	67.2	12.73239545
80 mm Copper tube with Die & Lubricant & Foam	149	28.23105538
80 mm Copper tube with Die & Foam	158	29.93628691

4.0 CONCLUSION

This study has presented the results of an experimental and simulation of different trails that aimed to assess the design and manufacture a mechanical device performing the external inversion (curling) of circular tubes under dynamic axial-force. The effect of the designed mechanical device on the tube inversion forming process is studied through applying the system and fix it in front the car in order to absorb the impact of the accident. The die has a fillet radius of 3 mm and high of 25 mm, the radius of the die is Rd = 19.5 mm, α = 75 degree. In experimental part the copper tube only chooses with different length and cases. The copper material has been given a good result in the previous researches. The length of the samples that used in the experiments was 70 mm and 80 mm with thickness of 1 mm. In simulation part the aluminum material as added beside copper material because not able to provide aluminum material in the experimental part. The dimension that used in simulation part are much similar to the experimental part. From the results, it has been observed that, the 80 mm Copper tube with Die & Foam has excellent energy absorption ability compared to the ordinary tube. The amount of energy absorbed for 80 mm Copper tube with Die & Foam recorded the higher comparing with the another trails about 158 J. Therefore, the 80 mm Copper tube with Die & Foam can be considered as an efficient energy-dissipating device since it provides favorable crashworthiness characteristics, while preserving enhanced manufacturability.

Acknowledgement

The authors would like to acknowledge the support from the Faculty of Engineering, University of Aden. The authors also are grateful to the staff of the Mechatronics and Industrial Engineering Department for facilitate the permission to use the Materials Science Laboratory for conducting the experimental for this study.

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Stardom Scientific Journal of Natural and Engineering Sciences

STARDOM SCIENTIFIC JOURNAL OF NATURAL AND ENGINEERING SCIENCES
PUBLISHED TWICE A YEAR BY STARDOM UNIVERSITY
Volume 2 - 1st issue 2024
International deposit number : ISSN 2980-3756