Dynamical effects of the impact of falling mass on stiffened rectangular plate

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ABSTRACT.

In this paper, the effect of using the strengtheners on the stress and deflection under the effect of a certain weight falling on plates made of aluminum alloys (Al Mg3)has been studied. The study was carried on through two aspects; experimentally and theoretically; theoretically by using (F.E.M LS. DYNA) program. After comparing the theoretical aspect and experimental aspect, greatly- close results at point of contact were found out, as follows:

When using one strengthener, the stresses reduce by (14 %) and the deflection by (70%) with comparison of without stiffener case .When using two strengtheners at the ends, stresses reduce (77%) and the deflection (65%) .When using two strengtheners 8 cm apart, stresses reduce (56 %) and the deflection (18%) . When using two strengtheners 4 cm apart, stresses reduce (60 %) and the deflection (31%)

Keywords: Impact, Stiffened plates, Rectangular plates, Dropped mass, L-S DYNA.

1. INTRODUCTION

The plate is said to be thin if its thickness is no larger than one-tenth of the length of the smallest lateral dimension. For a given loading, the stiffness of a plate or shell structure can be increased significantly by adding the ribs or stiffeners. Previously, the optimization techniques are mainly on the sizing of the ribs. The more important issue of identifying the optimum location of the ribs has received little attention. Impact on flexible structures is a complex phenomenon which includes the interaction between the projectile and the structure, the response of the structure and the response of the projectile. A complete modeling of an impact event can always be done using a 3D Finite Element model. This method involves the consideration of the contact between the impacting bodies, increasing the time required for numerical simulation. [1]

Deformation of the plate may be divided into two types of deformations:

1. Deformation of the plate in the contact region of the plate and projectile.
2. Deformation of the plate in remaining part of the plate.[2]

To improve the properties of thin plate, stiffeners or ribs can be used for this purpose.

A stiffened plate has low mass and high bending stiffness. To increase the torsional rigidity, cellular plates have been constructed, …. etc [3]
Stiffened plates and shells components have been used for many years in a variety of engineering structures, e.g. in aerospace industry; they are used in the construction of aircraft fuselage and wings, while in the naval architecture, they are used in the construction of ship hulls. Stiffened plates/shells are also utilized in the construction of bridges, buildings, storage

tanks, off-shore structures, and recently in petrochemical processing facilities. The structural system is composed of plate/or shell element, reinforced by a series of stiffeners or ribs, beams, stringers, …etc. that are attached in longitudinal and sometimes in the orthogonal directions. The stiffener profile may be flat, T- shape, Z - shape, L- shape, or closed sections,. The primary advantage of stiffened constructions lies in the structural efficiency of the system, since great savings or conservation of weight can be attained with no losses in strength or serviceability.

Research into stiffened plates has been a subject of interest for many years. Due to the complexity of the problem and many parameters involved, extensive research efforts were devoted over the past years by many researchers to investigate varieties of aspects. Reinforcing the plate or the shell with the stiffener elements complicates the analysis, and several assumptions must be made in order to facilitate a solution. The complications increase if the stiffeners are not identical or unequally spaced. This situation might be beneficial for non uniform pattern of loadings, where larger stiffener sections or smaller spacing are more economical to use near the highly loaded regions. Inclination of the stiffeners might also be useful to improve the structural load carrying capacity. This, however, adds further complications to the analysis and modeling procedures [4].

W.Q. Shen studied theoretically and experimentally the response of rectangular plate due to the falling of a knife edge mass and found the energy absorbed in the plate [5], as:

$$U = \frac{GV_0^2}{2}\left[1-\left(\frac{V_r}{V_0}\right)^2\right] \tag{1}$$

Where: G ≡ mass of the striker, V_r ≡ rebound velocity

D. Bonorchis, G.N. Nurick studied the case when a sphere is dropped on stiffened plate and found that the bulge and stiffener deflection trends were independent of the weld configuration for the same stiffener height [6].

The energy absorption mechanism, that are dominant in an impact situation in which a flat plate is struck by a blunt projectile in an elastic situation is[7] :

$$U = \frac{3\,\pi\, r_c^2 h_0\,(1-\gamma^2)\sigma_y^2}{8E} \tag{2}$$

In this paper, the effect of the stiffeners on stress and defection at the contact point for a rectangular plate built- in at two sides and free from other sides under of a falling sphere made of steel is studied.

Strain energy due to bending of plates and beams is [8]:

$$U = \frac{M^2 L}{2EI} \tag{3}$$

$$For\ Elastic\ limit\ M = M_y$$

$$\sigma_y = \frac{M.Y}{I} \quad \rightarrow \quad M_y = \frac{\sigma_y . I}{y} \tag{4}$$

$$U = \frac{\sigma_y^2 I^2}{y^2} * \frac{L}{2EI} \quad \rightarrow \quad U = \frac{\sigma_y^2 * I * L}{2E * y^2}$$

$U \equiv$ Strain energy $\quad due\ to\ impact\ loading = work\ done \quad = mgh$

$$mgh = \frac{\sigma_y^2 * I * L}{2E * y^2} \quad \rightarrow h = \frac{\sigma_y^2 * I * L}{2m * g * E * y^2}$$

$$I = \frac{bh^3}{12} = \frac{0.2(0.002^3)}{12} = 13.333 * 10^{-12}$$

$$h = \frac{(70)^2 * 13.333 * 10^{-12} * 0.3}{2 * 0.261 * 9.81 * 72 * 10^9 * (1 * 10^{-3})^2}$$

$h = \ 0.0531\ m \ = 5.31\ cm$ This is the height for elasticity

2. THEORETICAL WORK :

In this paper, the height necessary to keep the plate within the limits of elasticity was (5 cm) and by using the limited elements procedure (LS. DYNA) program. AUTODYN (ANSYS, version 11), was specially designed for non-linear transient dynamic events such as ballistic impact, penetration and blast problems. The software is based on explicit finite difference, finite volume and finite element techniques which use both grid based and griddles numerical methods. A new material model, specifically designed for the shock response of anisotropic material has been implemented and couples of non-linear anisotropic constitutive relations with a Mie-Grüneisen equation of state. This program studies the status of the moving objects and tries to find out the outcome stresses. In most of the published research papers, most attention was given to study the high speeds of the objects and penetration status .But in this research, High light was shed on lower speeds as considering them the basic state in the engineering applications.

The case of the plate of entirely two fixed sides and free for the other two sides was studied. Five cases were studied ; the first of a plate without strengthener , the second state was with one medium content .The third was by using two terminal strengtheners .And the fourth case was by using two strengtheners 8 cm a part. The fifth was by using two strengtheners 4 cm apart .In all these cases, the strengtheners were 1 cm wide and 2 mm deep; to have them longitudinally used .i.e., the ends of the plates at the fixing points .The dimensions of the plate were 30 cm x 20 cm and 2 mm deep.

3. EXPERIMENTAL WORK:

Practically, a 4 mm - thick plate was used. Skimming or reducing its thickness to 2 mm was done except for the points of strengtheners and to avoid errors resulting by using adhesives resulting by and attain the most precise results .But in the real engineering applications, strengthened plates are made by adhering or sticking the strengtheners or welding on the basic plate by using certain adhesives .After skimming the plate, the process of stress removal is carried out by Ageing at 155 -165 C^0 for 6 -12 hours.

After the process of heat – treatment of these plates was completed, they were fixed as shown in **Fig. (1)** using a falling weight which is a steel ball of 2cm radius.

To ensure the ball falling on the center of the plate, a hollow tube of an inner-side radius 2.1 cm was used in order not to hinder the falling ball and to have a free fall. After that the deflection at the center of the plate is measured .This process was repeated for the rest of the plates.

4. RESULTS AND DISCUSSION:

Experimentally: in the experimental work, the results of the deflection for all of the tests listed in **Table (2)**.

Theoretically: all results of this part are shown in **Figs. (4), (5) and (6)**.The results were also represented by **Fig. (1)**

After comparing the theoretical and the experimental work, a greatly- close results were found. When using one strengthener , the maximum stress went down by(14 %) and the maximum deflection by(70%) with comparison of without stiffener case .When using strengtheners at the ends, maximum stress was reduced to(77%) and the deflection to (65%).When using strengtheners 8 cm a part , maximum stress went down by (56 %) and the maximum deflection by (18%) . When using strengtheners 4 cm a part, maximum stresses went down by (60 %) and the maximum deflection by (31%).

Conclusively, it is evident that it is better to use strengtheners at the ends or terminals , which is the best choice for such applications , because they reduce the stresses and deflection on the point of contact as possible. If reducing the stress and deflection of whole plate was prefered, the use of stiffeners at 4 cm a part is more suitable.

Fig. (4) shows the relation between the stress and time which is calculated from the moment of contact . After that the stress is the rebound of the ball on plate. **Fig. (5)** shows the relation between the deflection at the center of the plate with time, the deflection measurement should be at the moment of contact of the falling ball. After that the deflection is the result of ball rebound. It is evident that there are deflection values greater than the deflection at the moment of contact, because of the rebound of the ball when the plate deflects down wards. Therefore, the total deflection is an accumulative value.

5. REFERENCES

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MATERIALS USED:

Table (1): Mechanical and Physical properties:

1. Target : ALMg3

Casting method	Temper	Yield strength (MPa)	Tensile strength (MPa)	Elongation A_s(%)	Hardness (HB)	Fatigue strength $50*10^6$
S	F	70	140	3	50	75

Density (Kg/m^3)	Young modulus (GPa)	Lin. Expansion Coeff. 20-200^{0}C (10^{-6}/K)	Thermal conductivity (W/m.k)	Electrical conductivity (m/Ωmm^2)	Solidification range (^{0}C)
2674	72	24	120-160	16-23	650-600

2. Steel Sphere :-

Yield strength (Mpa)	Tensile strength (Mpa)	Young modulus $*10^9$	Coe.of thermal Expansion $10^{-6}/{}^0C$	Modulus of rigidity Gpa	Density Kg/m^3
250	400	200	11.7	79	7800

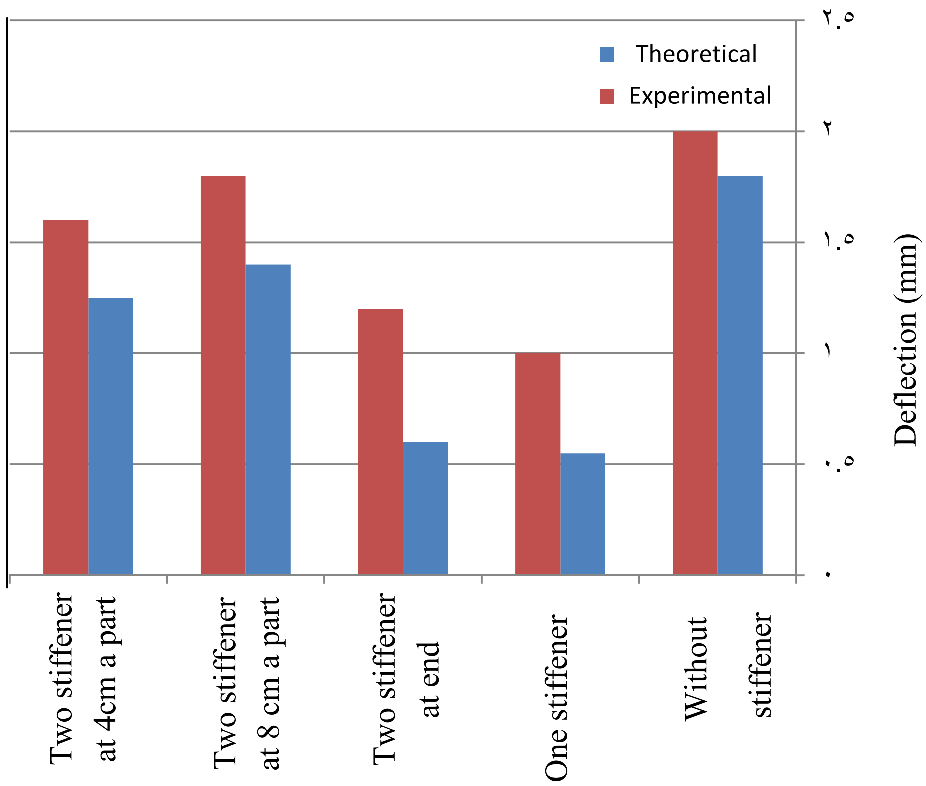


Figure (1): the comparison between the theoretical and experimental work.

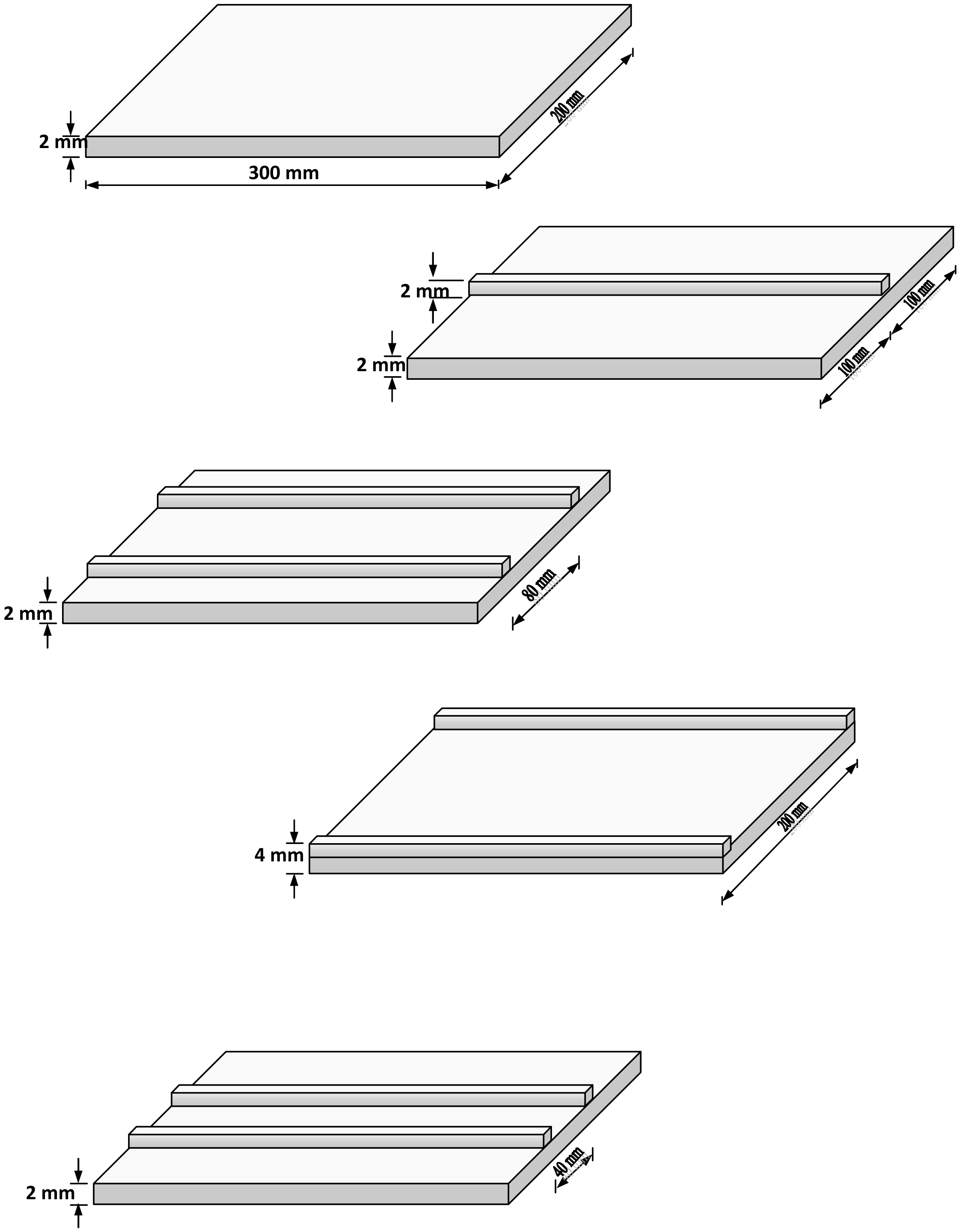


Figure (2): types of stiffened plates.

Figure (3): The apparatus used in experimental work.

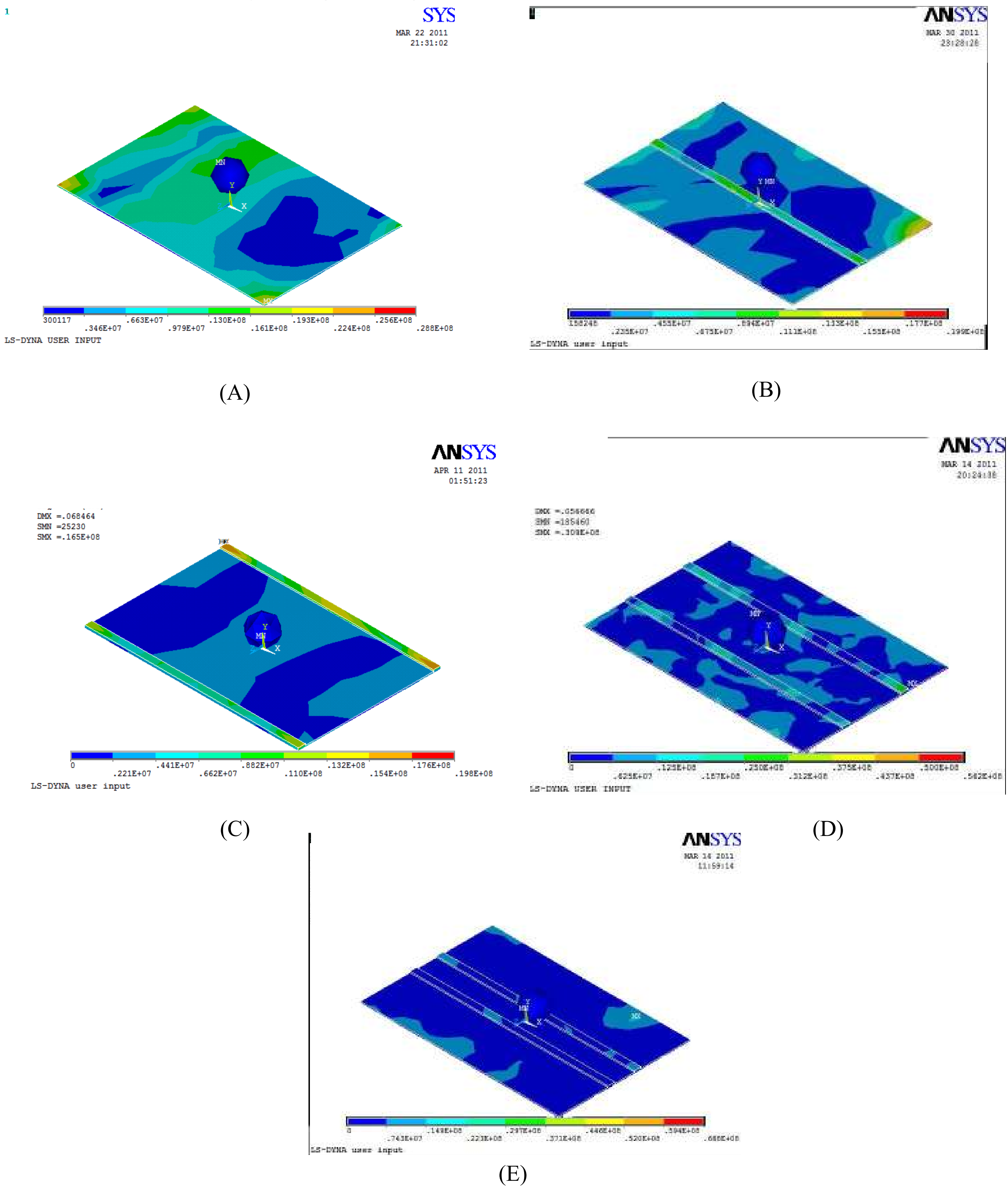
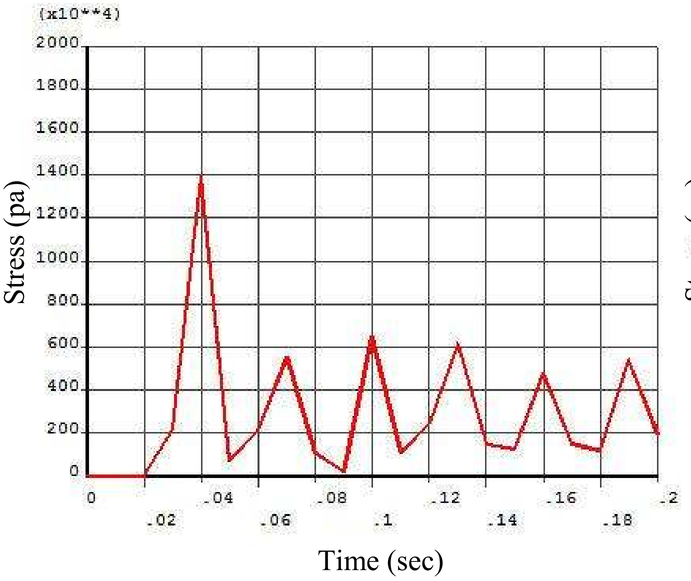
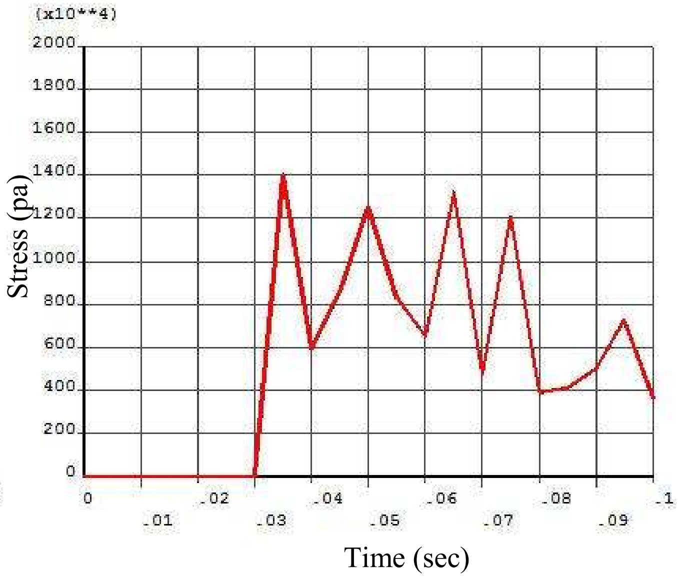


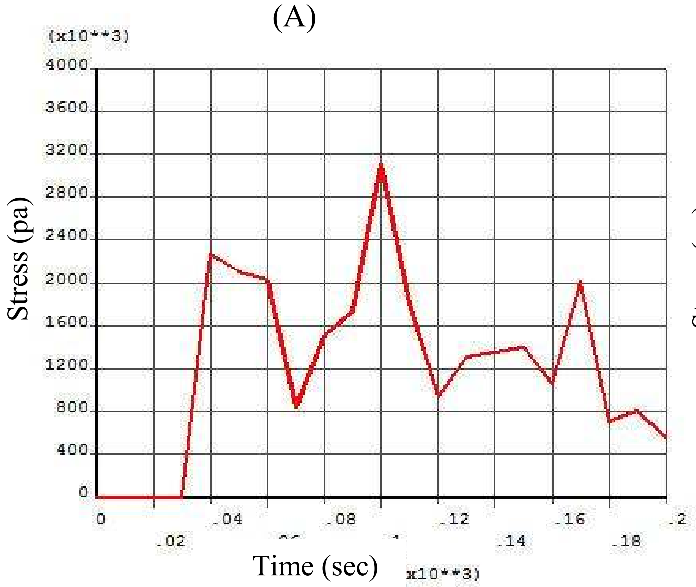
Figure (4) : Stress of the plates **(A)** without stiffener, **(B)** one stiffener,**(C)** two stiffeners at end, **(D)** two stiffeners at 8 cm, **(E)** two stiffeners at 4 cm respectively.



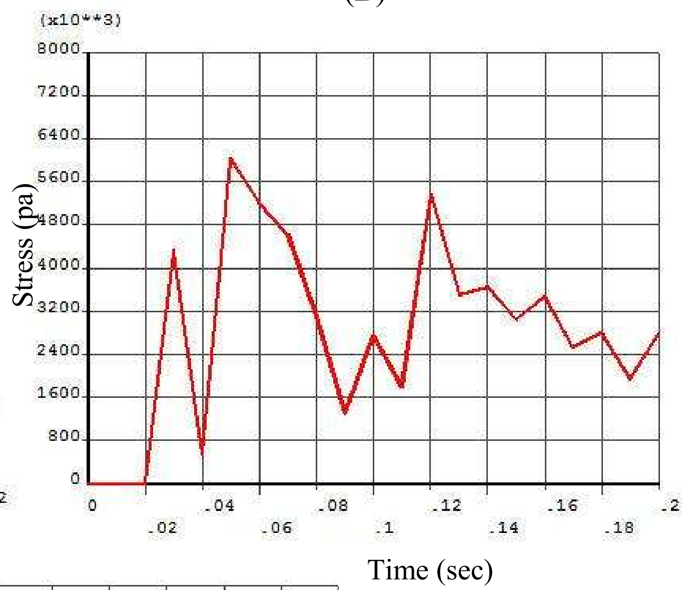
(A)



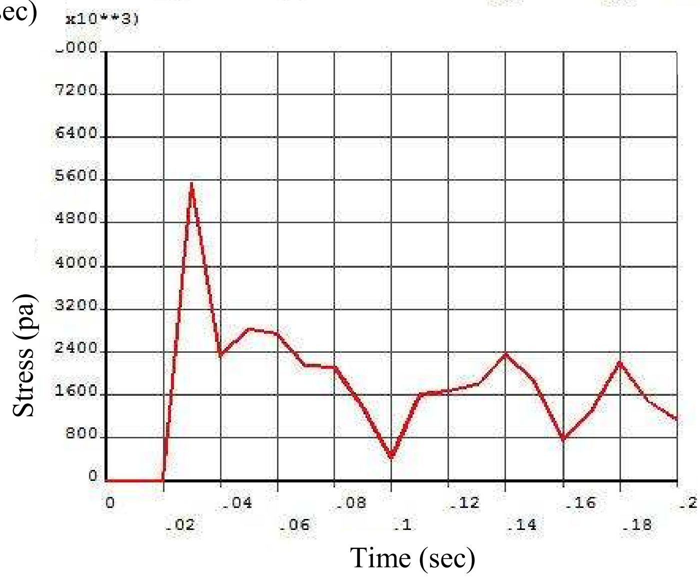
(B)



(C)



(D)



(E)

Figure (5): The relationship between stress and time of the plates **(A)** without stiffener, **(B)** one stiffener, **(C)** two stiffeners at end, **(D)** two stiffeners at 8 cm, **(E)** two stiffeners at 4 cm respectively.

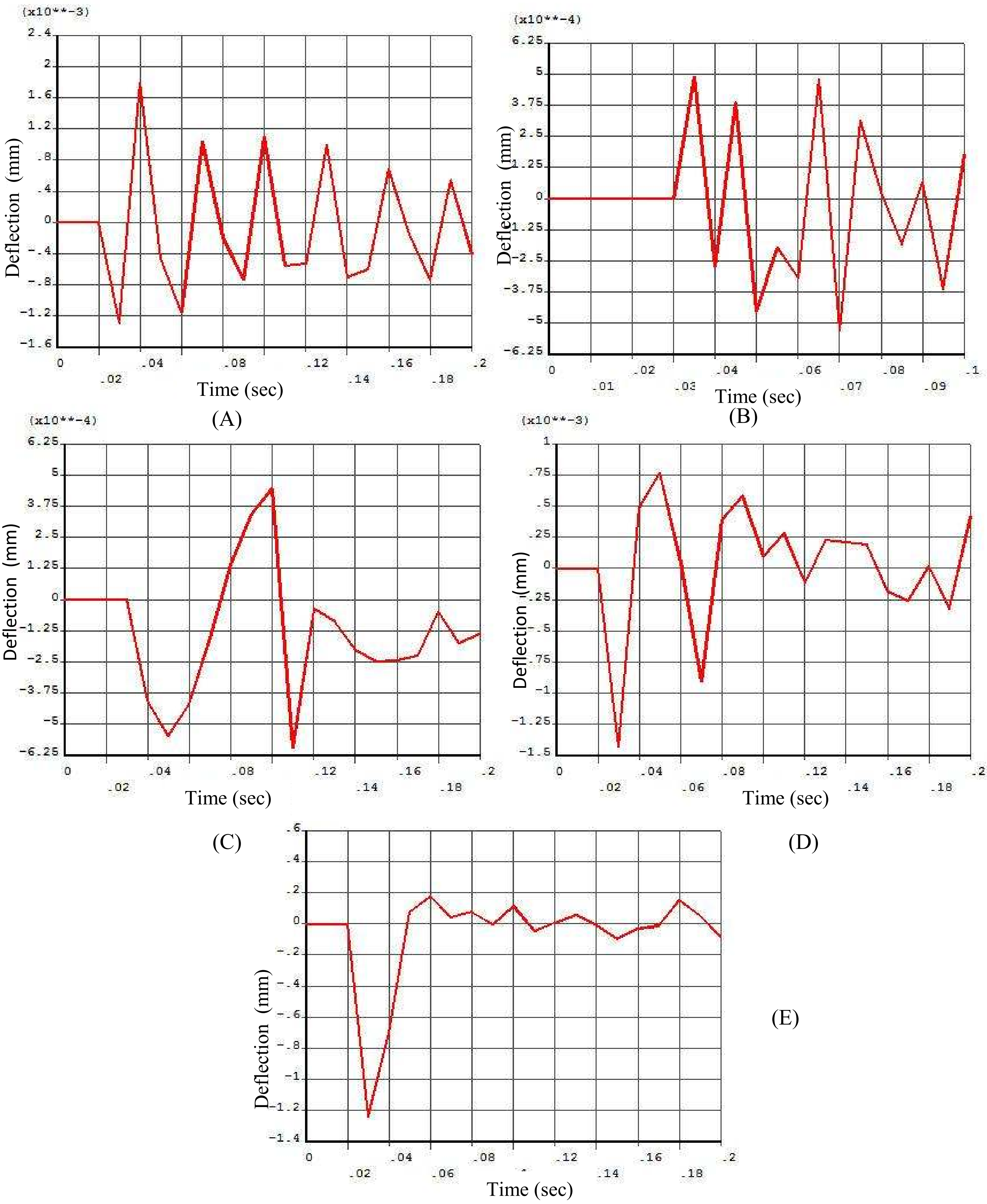


Figure (6): The relationship between deflection and time of the plates **(A)** without stiffener, **(B)** one stiffener, **(C)** two stiffeners at end, **(D)** two stiffeners at 8 cm, **(E)** two stiffeners at 4 cm respectively.

التاثير الحركي لصفيحة مستطيله مقواة تحت تأثير ثقل ساقط

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الخلاصـه:

استعرض البحث تأثير الدعامات على الأنحراف والأجهاد في الصفائح الرقيقة تحت تأثير ثقل ساقط لسبيكة الألمنيوم (Al Mg3) . وكانت الدراسة على شقين عمليا ونظريا والدراسة النظريه من خلال البرنامج (F.E.M LS. DYNA) وعند مقارنة النتائج النظرية والعملية فقد وجدنا تقارب بين النتائج. وعند أستخدام دعامه واحدة قلت الأجهادات عند نقطة التصادم بمقدار(14 %) و الأنحراف بمقدار (70 %) بالمقارنه مع حالة الصفيحه بدون دعامات و عند استخدام دعامتان عند الأطراف قلت الاجهادات عند نقطة التصادم بمقدار (77 %) و الأنحراف بمقدار (65 %) وعند أستخدام دعامتين تفصل بينهما مسافة 80 ملم قلت الأجهادات عند نقطة التصادم بمقدار (56 %) و الأنحراف بمقدار (18 %) وعند أستخدام دعامتين تفصل بينهما مسافة 40 ملم قلت الأجهادات عند نقطة التصادم بمقدار (60 %) و الأنحراف بمقدار (31 %) .