International Journal of Advanced Mechanics and Control Systems

Volume 2 , Issue 1 2026

# Large Deflection Theory-Based Validation of the Dynamic Relaxation (DR) Method in Rectangular Laminates

Tiwari, Rohit. Department of Mechanics,Mumbai,India

*Research Article*

**Date of Submission: 10-01-2026 Date of Acceptance: 10-02-2026 Date of Publication: 10-03-2026**

**Abstract—** The nonlinear elastic bending response of rectangular plates is described using first order orthotropic shear deformation equations. The Dynamic Relaxation (DR) method's application utilizing a computer program based on finite differences is described as their solution. By comparing the DR solutions with different precise and approximate solutions, the accuracy and convergence of the DR solutions for the elastic large deflection response of isotropic, orthotropic, and laminated plates are determined. When combined with the finite differences approach, the current Dynamic Relaxation method (DR) demonstrates a rather excellent agreement with other analytical and numerical techniques used in the verification scheme.It was discovered that: Boundary conditions, mesh type and size, fake densities, damping coefficients, time increment, and applied load are some of the variables that affect the DR solution's correctness and convergence. Additionally, the study of various thicknesses for isotropic, orthotropic, or laminated plates under uniform loads may be done using the DR big deflection program with uniform finite differences meshes. For simply supported (SS4) edge circumstances, every comparative result demonstrated that deflection is almost entirely reliant on the direction of the applied load or the layer arrangement.

**Keywords—** Large deflection theory, isotropic and orthotropic laminated plates, dynamic relaxation, and rectangular laminates.

## INTRODUCTION

A little over fifty years ago, composites were initially thought of as structural materials. Since then, they have drawn more and more interest in the fields of theoretical analysis, manufacturing technology, and material science. Since all materials are composites of distinct subunits when studied closely enough, the word "composite" might signify almost anything if taken at face value. However, the word often refers to a matrix material reinforced with fibers in contemporary engineering materials. For example, the name "FRP," which stands for "Fiber Reinforced Plastic," often refers to a thermosetting polyester matrix that contains glass fibers; today's commercial market is dominated by this specific composite. The current study employs a numerical technique called Dynamic Relaxation (DR) in conjunction with finite differences. The DR approach was initially put forward in the 1960s, and Turvey and Osman [4], [8] and [9], Rushton [2], Cassel and Hobbs [10], and Day [11] conducted a number of experiments to confirm its validity. This approach adds damping and inertia factors to the equations of equilibrium to transform them into dynamic equations. After that, they are represented in finite difference form, and iterations are used to find the answer. The structure's matrix characteristics, the applied load, the boundary conditions, and the mesh size all affect the ideal damping coefficient and time increment utilized to stabilize the solution. Other numerical methods outside the DR include the finite element approach, which is often used in current research, such as that of Onsy L. Roufaeil et al. [14], Ying Qing Huang et al. [13], and Damodar R. Ambur et al. [12]. Aalami [15] compared the DR and the finite element approach and discovered that although the storage capacity for finite element analysis is 10 times or more that of DR analysis, the computer time needed for the finite element method is eight times more than that for DR analysis. Putcha and Reddy [16], who pointed out that certain of the finite element formulations need a lot of computer time and storage capacity, corroborate this fact. As a result, the current research requires less processing and computer time. The finite element approach is thought to be less effective than the DR method. While a comparison between one version of the finite element approach and DR revealed a difference of more than 15%, Aalami [15] discovered that the accuracy gap between one version of the finite element method and another may reach a value of 10% or more. As a result, the accuracy of the DR approach may be deemed satisfactory. The DR method's restricted

applicability to certain geometries seems to be its main drawback. Rectangular plates, which are often used in technical applications, are exempt from this restriction.

Regardless of material, geometry, or edge circumstances, the Dynamic Relaxation (DR) algorithm used in this work is intended for the examination of rectangular plates. The program's functions include reading the file data, calculating the laminate's stiffness, fictitious densities, velocities, displacements, mid-plane deflections, and stresses; verifying the numerical computations' stability, solution convergence, and incorrect convergence; computing through-thickness stresses in the direction of plate axes; and transforming through-thickness stresses in the lamina principal axes. At the conclusion of each iteration, the DR solution's convergence is verified by comparing the velocities over the plate domain with a predefined value, which varies from 10−9 for minor deflections to 10−6 for high deflections. The solution is considered convergent and the iterative process is stopped when all velocities are less than a predefined value. The DR solution may sometimes converge to an incorrect solution. The variable's profile is compared to a predicted profile throughout the domain in order to verify that. For instance, the solution should have a similar profile if the function's value on the borders is zero and it is anticipated to rise from edge to center. It is difficult to make the solution converge to the proper value by changing the damping coefficients and time increment when the calculated profile differs from the predicted values. As a result, if the boundary conditions are incorrect, they should be reviewed and fixed. The discretization error, which results from substituting a discrete function for a continuous function, is one of the inherent errors in the DR technique ([17]–[27]). Another error arises from the fact that the discrete equations are not precisely solved because of variations in the velocities from the plate's edge to its center. Because there are more computations involved, finer meshes increase the round-off error but decrease the discretization error.

LARGE DEFLECTION THEORY

The equilibrium, strain, constitutive equations and boundary conditions are introduced below without derivation

Equilibrium equations:

$$\frac{\partial N_x}{\partial x} + \frac{\partial N_{xy}}{\partial y} = 0$$

$$\frac{\partial N_{xy}}{\partial x} + \frac{\partial N_y}{\partial y} = 0$$

$$N_x \frac{\partial^2 w}{\partial x^2} + 2\frac{\partial N_x}{\partial y}\frac{\partial w}{\partial x} + N_y \frac{\partial^2 w}{\partial y^2} + \frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} + q = 0 \qquad (1)$$

$$\frac{\partial M_x}{\partial x} + \frac{\partial M_{xy}}{\partial y} - Q_x = 0$$

$$\frac{\partial M_{xy}}{\partial x} + \frac{\partial M_y}{\partial y} - Q_y = 0$$

Strain equations

The large deflection strains of the mid – plane of the plate are as given below:

□ *v*° 1 □ □ *w* □2 □□

□ ° □ □ – □ □ □ *z*

*y* □ *y* 2 □ □ *y* □ □ □ □ □ (2)

□ *y* □ □

□ *u* ° □ *v*° □ *w* □ *w*

□ ° *x y* □ □ *y* □ □ *x* □ *x* □ □ *y* □ *z* □ □ *y* □ □ *x* □

□ □

°ε □ □ *w* □□

*x z* □ *y*

°ε □ □ *w* □ □

*y z* □ *x*

The constitutive equations

The laminate constitutive equations can be represented in the following form:

{ *Ni* } = *Aij* ε*o*

[ ] ß*o*j }

*Mi* *Bij* j

*Bij*

*N* ε*o*

*Dij*

(3)

*Aij*

*Bij*

{ *i* } = [ ] { j }

*Mi* *Bij* *Dij* 3 *o*

Where*Ni* refers to $N_x$ ,$N_y$ and,$N_{xy}$ and $M_i$ denotes$M_x$ ,$M_y$ and$M_{xy}$ .$A_{ij}$ ,$B_{ij}$ and $D_{ij}$ (*i, j=1, 2, 6)* are respectively the

membrane rigidities, coupling rigidities and flexural rigidities of the plate.$\overline{3}^{o}$ Denotes$\partial\overline{\phi}$, $\partial\tilde{\circ}$ and$\partial\phi$ + $\partial\tilde{\circ}$ .*A* , *A* and

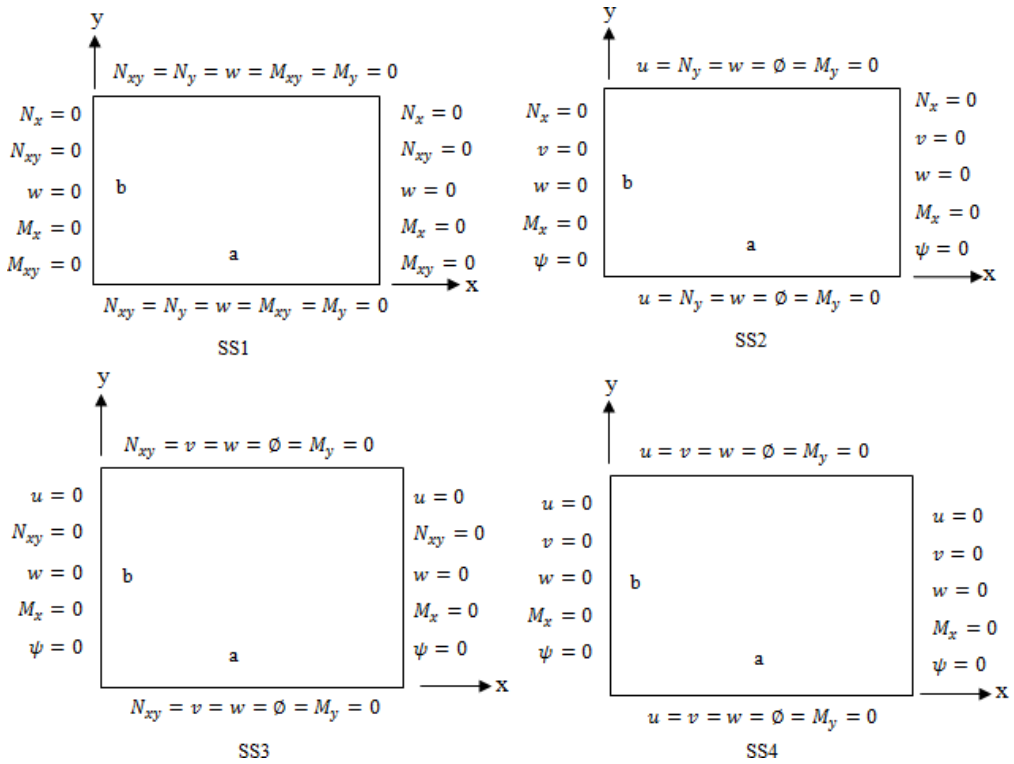
denote the stiffness Coefficients and are calculated as j $\partial x$ $\overline{\partial y}$ $\overline{\partial y}$ $\partial x$ 44 45 follows:- 55

$$A_{ij} = \sum_{k-1}^{n} k_i k_j \int_{z_k}^{z_k+1} C_{ij}\, dz, (i, j = 4, 5)$$

Where$C_{ij}$ the stiffness of a lamina is referred to the plate principal axes, and$K_i$ , $K_j$ are the shear correction factors.

Boundary conditions

Four sets of simply supported boundary conditions are used in this paper, and are denoted as SS1, SS2,




SS3, and SS4 as has been shown in Fig. (1) Below:

Fig. (1) Simply supported boundary conditions

DYNAMIC RELAXATION OF THE PLATE EQUATIONS

An exact solution of the plate equations is obtained using finite differences coupled with dynamic relaxation method. The damping and inertia terms are added to equations (1). Then the following approximations are introduced for the velocity and acceleration terms:

(4)

In which $\alpha \equiv u, v, w, \phi, \ldots$. Hence equations (1) become:

$$N_{xy}^{b} \quad t \quad M_y$$

$$t \quad 1 \; k \quad \ell \quad t \quad x \quad y \quad Q_y \qquad (5)$$

The superscripts a and b in equations (4) and (5) refer respectively to the values of velocities after and before the time increment$\delta t$ and $^{*} \quad ^{1} \quad \ell^{-1}$. The displacements at the end of each time increment,$\delta t$, are evaluated using the following integration procedure:

$$k_{\alpha} = {}_{2} k_{\alpha} \delta t \; \alpha \qquad (6)$$

$$\alpha^{a} = \alpha^{b} + \delta t \frac{\partial \alpha^{b}}{\partial t}$$

Thus equations (5), (6), (2) and (3) constitute the set of equations for the dynamic relaxation solution. The DR procedure
operates as follows:
Set initial conditions.
Compute velocities from equations (5).
Compute displacement from equation (6).
Apply displacement boundary conditions.
Compute strains from equations (2).
Compute stress resultants and stress couples from equations (3).
Apply stress resultants and stress couples boundary conditions.
Check if velocities are acceptably small (say $10^{-6}$).
Check if the convergence criterion is satisfied, if it is not repeat the steps from 2 to 8.

It is obvious that this method requires five fictitious densities and a similar number of damping coefficients so as the solution will be converged correctly.

RESULTS AND DISCUSSIONS

Isotropic, orthotropic, and laminated rectangular plates were used in a variety of dynamic relaxation (DR) technique verification exercises employing big deflection theory, as seen below: Deflections, stress resultants, and stress couples in simply supported in-plane free (SS2) isotropic plates are presented in Table 1. The current findings were calculated using 6 x 6 uniform meshes. These findings accord very well with those of Aalami et al. [1] who used the finite difference approach (i.e., for deflections, the difference varies between 0.35% at $\bar{q} = 20.8$ and 0% when the pressure is raised to 97). Table 2 presents a comparable analysis of the two outcomes for the simply supported (SS3) condition. It is clear that there is excellent agreement between the center deflections, stress couples, and stress resultants. While the corner stress results exhibit significant discrepancies, the mid-side stress results do not exhibit comparable agreement. This might be explained by the kind of mesh that was used in each investigation. Rushton [2], who used the DR approach in conjunction with finite differences, is compared here with a set of thin plate findings. Table 3 lists the current findings for simply supported (SS4) square plates that were calculated using an 8 x 8 uniform mesh for two thickness ratios. As of right now, the current findings are somewhat different from those reported in [2]. Tables 4 and 5, respectively, provide another comparison for simply supported (SS4) square isotropic plates under uniformly distributed loads for deflection analysis of thin and moderately thick plates. The center deflection of the current DR study and those of Azizian and Dawe [3], who used the finite strip approach, are found to be in reasonably excellent agreement in this comparison (i.e., with a maximum error not surpassing 0.09%).

The DR software was used to compare big deflection for orthotropic plates. The results are contrasted with the DR findings of Reddy [5], Turvey and Osman [4], and Zaghloul et al. [6]. For a thin, evenly loaded square plate with simply supported in-plane free (SS2) edges manufactured of material I, whose parameters are shown in Table 6. Table 7 displays the center deflections, where DR demonstrated strong agreement with the other three.A large deflection comparison for laminated plates was made by recomposing sun and chin‟s results [7] for
$[90^o/0^0]$ using the DR program and material II which its properties are cited in Table 6. The results were obtained for
4 4
quarter of a plate using a 5 × 5 square mesh, with shear correction factors$k^2 = k^2 = 5/6$. The analysis was made for
4 5
different boundary conditions and the results were shown in Tables 8, and 9 as follows: The present DR deflections of two layer anti–symmetric cross – ply simply supported in – plane fixed (SS4) are compared with DR results of Turvey and Osman [8] and with sun and chin‟s [7] values for a range of

loads as shown in Table 8. The good agreement found confirms that for simply supported (SS4) edge conditions, the deflection depends on the direction of the applied load or the arrangement of the layers. Table 9 shows a comparison between the present DR, and DR [8] results, which are approximately identical. The difference between laminates$[0^o/90^o]$ and$[90^o/0^o]$ at$b/a$ = 5is 0.3% whilst it is 0% when$b/a$ = 1.

The comparisons made between DR and alterative techniques show a good agreement and hence the present DR large deflection program using uniform finite difference meshes can be employed with confidence in the analysis of moderately thick and thin flat isotropic, orthotropic and laminated plates under uniform loads. The program can be used with the same confidence to generate small deflection results.

Table 1 comparison of present DR, Aalami and Chapman‟s [1] large deflection results for simply supported (SS2) square isotropic plate subjected to uniform pressure ($h/a$ = 0.02, $v$ = 0.3)

| $\bar{q}$ | S | $\bar{w}_c$ | $\bar{M}_x(1)$<br>$\bar{M}_y(2)$ | $\bar{N}_x(1)$<br>$\bar{N}_y(2)$ |
|---|---|---|---|---|
| 20.8 | 1<br>2 | 0.7360<br>0.7386 | 0.7357<br>0.7454 | 0.7852<br>0.8278 |
| 41.6 | 1<br>2 | 1.1477<br>1.1507 | 1.0742<br>1.0779 | 1.8436<br>1.9597 |
| 63.7 | 1<br>2 | 1.4467<br>1.4499 | 1.2845<br>1.2746 | 2.8461<br>3.0403 |
| 97.0 | 1<br>2 | 1.7800<br>1.7800 | 1.4915<br>1.4575 | 4.1688<br>4.4322 |

S (1): present DR results (6 × 6uniform mesh over quarter of the plate) S (2): [1] results (6 × 6graded mesh over quarter of the plate)

1

(1) $x = y =$

$-a, z = 0$ 2

Table 2 Comparison of present DR, Aalami and Chapman‟s [1] large deflection results for simply supported (SS3) square isotropic plate subjected to uniform pressure ($h/a$ = 0.02, $v$ = 0.3)

| $\bar{q}$ | S | $\bar{w}_c$ | $\bar{M}_x(1)$<br>$\bar{M}_y(1)$ | $\bar{N}_x(1)$<br>$\bar{N}_y(1)$ | $\bar{N}_x(2)$<br>$\bar{N}_y(3)$ | $\bar{N}_x(3)$<br>$\bar{N}_y(2)$ | $\bar{N}_x(4)$<br>$\bar{N}_y(4)$ |
|---|---|---|---|---|---|---|---|
| 20.8 | 1<br>2 | 0.5994<br>0.6094 | 0.6077<br>0.6234 | 1.0775<br>1.0714 | 0.2423<br>0.2097 | 1.1411<br>1.1172 | 0.1648<br>0.2225 |
| 41.6 | 1<br>2 | 0.8613<br>0.8783 | 0.8418<br>0.8562 | 2.2435<br>2.2711 | 0.5405<br>0.4808 | 2.4122<br>2.4084 | 0.3177<br>0.4551 |
| 63.7 | 1<br>2 | 1.0434<br>1.0572 | 0.9930<br>1.0114 | 3.3151<br>3.3700 | 0.8393<br>0.7564 | 3.6014<br>3.6172 | 0.4380<br>0.6538 |
| 97.0 | 1<br>2 | 1.2411<br>1.2454 | 1.1489<br>1.1454 | 4.7267<br>4.8626 | 1.2604<br>1.1538 | 5.1874<br>2.2747 | 0.5706<br>0.9075 |

S (1): present DR results (6 × 6uniform mesh over quarter of the plate) S (2): [1] results (6 × 6graded mesh over quarter of the plate)

(1) $x = y = 1$ 1 1

$-a, z = 0; (2)x = -a, y = z = 0; (3)x = 0, y - a, z = 0; (4)x = y = z = 0$ 2

2 = 2

Table 3 Comparison of present DR, and Rushton‟s [2] large deflection results for simply supported (SS4) square isotropic plate subjected to uniform pressure ($v$ = 0.3)

| $\bar{q}$ | S | $\bar{w}_c$ | $\bar{\sigma}1(1)$ |
|---|---|---|---|
| | 1 | 0.3172 | 2.3063 |

| | | | |
|---|---|---|---|
| 8.2 | 2<br>3 | 0.3176<br>0.2910 | 2.3136<br>2.0900 |
| 29.3 | 1<br>2<br>3 | 0.7252<br>0.7249<br>0.7310 | 5.9556<br>5.9580<br>6.2500 |
| 91.6 | 1<br>2<br>3 | 1.2147<br>1.2147<br>1.2200 | 11.3180<br>11.3249<br>11.4300 |
| 293.0 | 1<br>2<br>3 | 1.8754<br>1.8755<br>1.8700 | 20.749<br>20.752<br>20.820 |

S (1): present DR results ($h/a$ = 0.02; 8 × 8uniform mesh over quarter of the plate) S (2): present DR results ($h/a$ = 0.01; 8 × 8uniform mesh over quarter of the plate) S (3): [2] results (thin plate 8 × 8 uniform mesh over quarter of the plate)

$x = y = \frac{1}{2}, z = -\frac{1}{2}h$

Table 4 Comparison of the present DR, and Azizian and Dawe‟s [3] large deflection results for thin shear deformable simply supported (SS4) square isotropic plate subjected to uniform pressure ($h/a$ = 0.01, $v$ = 0.3)

| $\bar{q}$ | S | $\bar{w}_c$ |
|---|---|---|
| 9.2 | 1<br>2 | 0.34693<br>0.34677 |
| 36.6 | 1<br>2 | 0.80838<br>0.81539 |
| 146.5 | 1<br>2 | 1.45232<br>1.46250 |
| 586.1 | 1<br>2 | 2.38616<br>2.38820 |

S (1): present DR results (6 × 6uniform mesh over quarter of the plate) S (2): Azizian and Dawe [3] results.

Table 5 Comparison of the present DR, and Azizian and Dawe‟s [3] large deflection results for moderately thick shear deformable simply supported (SS4) square isotropic plates subjected to uniform pressure ($h/a$ = 0.05, $v$ = 0.3)

| $\bar{q}$ | S | $\bar{w}_c$ |
|---|---|---|
| 0.92 | 1<br>2 | 0.04106<br>0.04105 |
| 4.6 | 1<br>2 | 0.19493<br>0.19503 |
| 6.9 | 1<br>2 | 0.27718<br>0.27760 |
| 9.2 | 1<br>2 | 0.34850<br>0.34938 |

S (1): present DR results (6 × 6uniform mesh over quarter of the plate) S (2): Azizian and Dawe [3] results.

Table 6 Material properties used in orthotropic and laminated plate comparison analysis.

| Material | $E_1/E_2$ | $G_2/E_2$ | $G_{13}/E_2$ | $G_{23}/E_2$ | $v_{12}$ | $SCF(k^2 = k^2)$<br>4 5 |
|---|---|---|---|---|---|---|
| I | 2.345 | 0.289 | 0.289 | 0.289 | 0.32 | 5/6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| II | 14.3 | 0.5 | 0.5 | 0.5 | 0.3 | 5/6 |

Table 7 Comparison of present DR, DR results of [4], finite element results [5] and experimental results [6] for a uniformly loaded simply supported (SS2) square orthotropic plate made of material I (*h/a* = 0.0115)

| $\bar{q}$ | $\bar{w}_c(1)$ | $\bar{w}_c(2)$ | $\bar{w}_c(3)$ | $\bar{w}_c(4)$ |
|---|---|---|---|---|
| 17.9 | 0.5859 | 0.5858 | 0.58 | 0.58 |
| 53.6 | 1.2710 | 1.2710 | 1.30 | 1.34 |
| 71.5 | 1.4977 | 1.4977 | 1.56 | 1.59 |
| 89.3 | 1.6862 | 1.6862 | 1.74 | 1.74 |

S (1): present DR results (5 × 5uniform non – interlacing mesh over quarter of the plate). S (2): DR results of [4].

S (3): Reddy‟s finite element results [5].

S (4): Zaghloul‟s and Kennedy‟s [6] experimental results as read from graph.

Table 8 Deflection of the center of a two – layer anti symmetric cross ply simply supported in – plane fixed (SS4) strip under uniform pressure (*b/a*= 5,*h/a*= 0.01)

| $\bar{q}$ | S | $\bar{w}_1[0^o/90^o]$ | $\bar{w}_2[90^o/0^o]$ | $\bar{w}_o(B_{ij} = 0)$ | %(1) | %(2) | %(3) |
|---|---|---|---|---|---|---|---|
| 18 | 1 | 0.6851 | 0.2516 | 0.2961 | 131.4 | - 15.0 | 172.3 |
| | 2 | 0.6824 | 0.2544 | | 130.5 | - 14.1 | 168.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 0.6800 | 0.2600 | | | | |
| | 1 | 0.8587 | 0.3772 | | 88.1 | - 17.4 | 127.7 |
| 36 | 2 | 0.8561 | 0.3822 | 0.4565 | 87.5 | - 16.3 | 124.0 |
| | 3 | 0.8400 | 0.3900 | | | | |
| | 1 | 1.0453 | 0.5387 | | 61.0 | - 17.0 | 94.0 |
| 72 | 2 | 1.0443 | 0.5472 | 0.6491 | 60.9 | - 15.7 | 90.8 |
| | 3 | 1.0400 | 0.5500 | | | | |
| | 1 | 1.1671 | 0.6520 | | 50.0 | - 16.2 | 79.0 |
| 108 | 2 | 1.1675 | 0.6630 | 0.7781 | 50.0 | - 14.8 | 76.1 |
| | 3 | 1.1500 | 0.6600 | | | | |

S (1): present DR results S (2): DR results [8].
S (3): Values determined from sun and chin‟s results [7].
: $100 \times (\bar{w}_1 - \bar{w}_O)/\bar{w}_O$
: $100 \times (\bar{w}_2 - \bar{w}_O)/\bar{w}_O$
: $100 \times (\bar{w}_1 - \bar{w}_2)/\bar{w}_2$

Table 9 Center deflection of two – layer anti – symmetric cross – ply simply supported in – plane free (SS1) plate under uniform pressure and with different aspect ratios ($h/a$ = 0.01; $\bar{q}$ = 18).

| $b/a$ | S | $\bar{w}_1[0^o/90^o]$ | $\bar{w}_2[90^o/0^o]$ | $\bar{w}_o(B_{ij} = 0)$ | %(1) | %(2) | %(3) |
|---|---|---|---|---|---|---|---|
| 2.5 | 1 | 0.8325 | 0.8422 | 0.3907 | 113.1 | 115.6 | - 1.15 |
| | 2 | 0.8328 | 0.8424 | 0.3907 | 113.2 | 115.6 | - 1.1 |
| 2.0 | 1 | 0.7707 | 0.7796 | 0.3807 | 102.4 | 104.8 | - 1.14 |
| | 2 | 0.7712 | 0.7799 | 0.3807 | 102.6 | 104.9 | - 1.1 |
| 1.75 | 1 | 0.7173 | 0.7248 | 0.3640 | 97.0 | 99.1 | - 1.0 |
| | 2 | 0.7169 | 0.7251 | 0.3640 | 97.0 | 99.2 | - 1.1 |
| 1.5 | 1 | 0.6407 | 0.6460 | 0.3335 | 92.1 | 93.7 | - 0.82 |
| | 2 | 0.6407 | 0.6455 | 0.3325 | 92.7 | 94.1 | - 0.70 |
| 1.25 | 1 | 0.5324 | 0.5346 | 0.2781 | 91.4 | 92.2 | - 0.4 |
| | 2 | 0.5325 | 0.5347 | 0.2782 | 91.4 | 92.2 | - 0.4 |
| 1.0 | 1 | 0.3797 | 0.3797 | 0.1946 | 95.1 | 95.1 | 0.0 |
| | 2 | 0.3796 | 0.3796 | 0.1949 | 94.8 | 94.8 | 0.0 |

S (1): present DR results S (2): DR results [8].
: $100 \times (\bar{w}_1 - \bar{w}_O)/\bar{w}_O$
: $100 \times (\bar{w}_2 - \bar{w}_O)/\bar{w}_O$
: $100 \times (\bar{w}_1 - \bar{w}_2)/\bar{w}_2$

**CONCLUSIONS**

Using first order shear deformation theory (FSDT), a dynamic relaxation (DR) algorithm based on finite differences has been created for large deflection analysis of rectangular laminated plates. It is assumed that the displacements are linear over the plate's thickness. For evenly loaded thin, moderately thick, and thick plates with simply supported edges, a number of novel findings have been reported. Ultimately, a number of numerical comparisons have been made to show how accurate the DR software is. These comparisons demonstrate the following: 1. Boundary conditions, mesh size, fake densities, and applied load are some of the variables that affect the DR solution's convergence.
2. Moderately thick and flat isotropic, orthotropic, or laminated plates under uniform loads may be confidently analyzed using the DR large deflection program employing uniform finite differences meshes.
3. The DR program may provide tiny deflection outcomes with the same level of assurance.
4. The time increment plays a critical role in managing numerical calculations and accelerating convergence. The solution becomes unstable when the increment is too big, and the convergence becomes tiresomely sluggish when it is too little. For all boundary circumstances, the appropriate time

increment in this investigation is assumed to be 0.8.
5. The damping coefficient that results in critical motion is the ideal one. The motion is over-damped and the convergence is very sluggish when the damping coefficients are high. Conversely, under-damped motion may lead to numerical instability when the coefficients are tiny. To avoid under-damping and over-damping, the damping coefficients must be properly chosen.

**REFERENCES**

[1] Large deflection behavior of rectangular orthotropic plates under transverse and in-plane loads, Proceedings of the Institution of Civil Engineers, (1969), volume 42, pp. 347–382, Aalami, B., and Chapman, J.C.
[2] Rushton K. R., "large deflection of variable-thickness plates," International Journal of Mech. Sciences, issue 10, pp. 723–735 (1968).
[3] Azizian Z. G. and Dawe D.J., "Geometrically non-linear analysis of rectangular Mindlin plates using the finite strip method," Computers and Structures, volume 22, No. 3, (1985), pp. 523–436.
[4] Large deflection study of orthotropic Mindlin plates by Turvey G.J. and Osman M.Y., Proceedings of the 12th Energy Resources Technical Conference and Exhibition, Houston, Texas (1989), pp. (163–172).
[5] Reddy J.N., "Energy and variation methods in applied mechanics," pp. 379–387, John Wiley & Sons, New York, 1984.
[6] Kennedy J.B. and Zaghloul S.A., "Nonlinear behavior of symmetrically laminated plates," Journal of Applied Mechanics, number 42, (1975), pp. 234–236.
[7] Sun C.T. and Chin H., "On large deflection effects in unsymmetrical cross-ply composite laminates," Journal of Composite Materials, volume 22 (1988), pp. 1045–1059.
[8] Turvey G.J. and Oman M.Y., "Large deflection effects in anti-symmetric cross-ply laminated strips and plates," I.H. Marshall, Composite Structures, volume 6, Paisley College, Scotland, Elsevier Science Publishers, (1991), pp. (397–413).
[9] "Elastic large deflection analysis of isotropic rectangular Mindlin plates," Turvey G. J. and Osman M. Y., International Journal of Mechanical Sciences, volume 22, (1990). pages 1 through 14.
[10] Cassel A.C. and Hobbs R.E., "Numerical stability of dynamic relaxation analysis of nonlinear structures," International Journal for Numerical Methods in Engineering, volume 35, No.4, (1966), pp. 1407–1410.
[11] Day A.S., "An introduction to dynamic relaxation," The Engineer, issue 219, No. 5668, (1965), pp. 218–221.
[12] Damodar R. Ambur, Navin Jounky, Carlos G. Davila, and Mark Hilburger, "Progressive failure analysis of compression loaded composite curved panels with and without cutouts," Composite Structures, volume 65, (2004), pp. (143–155).
[13] "Bending analysis of composite laminated plates using a partially hybrid stress element with interlaminar continuity" by Ying Qing Huang, Shenglin Di, Chang Chun Wu, and Huiya Sun Volume 80, Computer and Structures (2002), pp. 403–410.
[14] "Finite strip elements for laminated composite plates with transverse shear strain discontinuities" by Onsy L. Roufaeil and Thanh Tran-Cong Volume 56, Composite Structures (2002), pp. 249–258.
[15] Aalami B., "Large deflection of elastic plates under patch loading," Journal of Structural Division, ASCE, volume 98, No. ST 11, (1972), pp. (2567–2586).
[16] Reddy J.N. and Putcha N.S.,A improved mixed shear flexible finite element for nonlinear laminated plate analysis, Computers and Structures, volume 22, No. 4, (1986), pp. 529–538.
[17] "Nonlinear bending analysis of radial stiffened annular laminated plates with dynamic relaxation method" by M. Mehrabian and M.E. Golma Kani Volume 69, Journal of Computers and Mathematics with Applications, 2015, pp. 1272–1302.
[18] M. Huttner, J. Maca, P. Fajman, "The effectiveness of dynamic relaxation method in static analysis of cable structures," Journal of Advances in Engineering Software, 2015.
[19] Journal of Computers and Structures, volumes 114–115, (2013), pp. 84–97; Javad Alamatian,

"Displacement based methods for calculating the buckling load and tracing the post buckling regions with dynamic relaxation method."
[20] M. Rezaiee Pajand, S. R. Sarafrazi, H. Rezaiee, "Efficiency of dynamic relaxation method in nonlinear analysis of truss and frame structures," Journal of Computers and Structures, volumes 112–113, (2012), pp. (295–310).
[21] Kyoung Soo Lee, Sang Eul Han, and Taehyo Park, "A simple explicit arc-length method using dynamic relaxation method with kinetic damping," Journal of Computers and Structures, volume 89, issues 1–2, (2011), pp. (216–233).
[22] J. Alamatian, "A new formulation of fictitious mass of the dynamic relaxation method with kinetic damping," Journal of Computers and Structures, 90–91 (2012), pp. 42–54.
[23] M. Rezaiee Pajand et al., "A new method of fictitious viscous damping determination for the dynamic relaxation method," Journal of Computers and Structures, volume 89, issues 9–10, (2011), pp. (783–794).
[24] B. Kilic and E. Madenci, "An adaptive dynamic relaxation method for quasi-static simulations using the peridynamic theory," Journal of Theoretical and Applied Fracture Mechanics, volume 53, number 3, (2010), pp. (194–204).
[25] C. Douthe and O. Baverel, "Design of nexorades or reciprocal frame systems with the dynamic relaxation method," Journal of Computers and Structures, volume 87, issues 21–22, (2009), pp. (1296–1307).
[26] Osama Mohammed Elmardi, "Using small deflection theory to verify the dynamic relaxation method in isotropic, orthotropic, and laminated plates," International Journal of Advanced Science and Technology, 72 (2014), pp. 37–48.
[27] Osama Mohammed Elmardi, "Nonlinear analysis of rectangular laminated plates using large deflection theory," Volume 2, Issue 5, International Journal of Emerging Technology and Research (2015), pp. 26–48.