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Response Spectrum Analysis of Single Storey Framed Structure by Numerical Integration Methods

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Abstract

In general, structural response to any dynamic loading is expressed basically in terms of the displacements of the structure. Thus, a deterministic analysis leads directly to displacement time histories corresponding to the prescribed loading history; other related response quantities, such as stresses, strains, internal forces, etc., are usually obtained as a secondary phase of the analysis. On the other hand, a nondeterministic analysis provides only statistical information about the displacements resulting from the statistically defined loading; corresponding information on the related response quantities are then generated using independent nondeterministic analysis procedures. This paper presents a study on displacements, velocity and acceleration of single storied framed structures by comparison Simpson's rule and trapezoidal method. This study involves in examination of theoretical investigations of single storied framed structures. single storey framed structures and two methods were analysed & comparison of all the displacement, velocity, and acceleration at the critical cross-section with same configuration loading by keeping all other parameters constant and various time configuration. The theoretical data are calculated using code IS 1893, IS 4326, IS 13920. The mass and stiffens are analysed under the cantilever condition. The research project aims to provide which method is most accuracy to find the displacement, velocity, and acceleration. The studies reveal that the theoretical investigations trapezoidal rule is most accuracy compare to the Simpson's rule. The maximum displacement, velocity, and acceleration is 76.12% is higher the trapezoidal rule compare than Simpson's rule in same configuration.

Key words: mass, stiffness, displacement, velocity, and acceleration, Simpson's rule, trapezoidal rule

I Introduction

In numerical analysis, Simpson's rule is a method for numerical integration, the numerical approximation of definite integrals. Specifically, it is the following approximation Simpson's rule also corresponds to the three-point Newton-Cotes quadrature rule.

The trapezoidal rule is one of a family of formulas for numerical integration called Newton–Cotes formulas, of which the midpoint rule is similar to the trapezoid rule. Simpson's rule is another member of the same family, and in general has faster convergence than the trapezoidal rule for functions which are twice continuously differentiable, though not in all specific cases. However for various classes of rougher functions (ones with weaker smoothness conditions), the trapezoidal rule has faster convergence in general than Simpson's rule. Moreover, the trapezoidal rule tends to become extremely accurate when periodic functions are integrated over their periods, which can be analyzed in various ways. For non-periodic functions, however, methods with unequally spaced points such as Gaussian quadrature and Clenshaw–Curtis quadrature are generally far more accurate; Clenshaw–Curtis quadrature can be viewed as a change of variables to express arbitrary integrals in terms of periodic integrals, at which point the trapezoidal rule can be applied accurately. Manymachine elements in common engineering use exhibit the characteristic of “hysteresis springs”. Plain and rolling element bearings that are widelyused in motion guidance of machine tools are typical examples. The studyof the non-linear dynamics caused by such elements becomes imperative if we wish to achieve accurate control of such machines. This paper outlines the properties of rate-independent hysteresis and shows that the calculation of the free response of a single-degree-of-freedom (SDOF) mass-hysteresis-spring system is amenable to an exact solution.[1] Different procedures are compared and tried to evaluate the more accurate values of some definite integrals. Then it is sought whether a particular method is suitable for all cases. A combined approach of different integral rules has been proposed for a definite integral to get more accurate value for all cases. In this article, to find the numerical approximate value of a definite integral, Trapezoidal rule, Simpson’s 1/3 rule and Weddle’s rule are used and it is seen that the Weddle’s rule gives more accuracy than Simpson’s rule. But these rules can’t be used for all cases. In those cases it may be used the proposed rule to get the better result.[2] Structural analysis is mainly concerned with finding out the behavior of a physical structure when subjected to force. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. In essence all these loads are dynamic, including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. If a load is applied sufficiently slowly, the inertia forces (Newton's first law of motion) can be ignored and the analysis can be simplified as static analysis. An analytical model is proposed to study the nonlinear interactions between beam and cable dynamics in stayed systems. The integro-differential problem, describing the in-plane motion of a simple cable-stayed beam, presents quadratic and cubic nonlinearities both in the cable equation and at the boundary conditions. An analytical and experimental modal analysis has been carried out on the Qingzhou cable-stayed bridge in Fuzhou, China. Its main span of 605 m is currently the longest span among the completed composite-deck cable-stayed bridges in the world. An analytical modal analysis is performed on the developed three-dimensional finite element model starting from the deformed configuration to provide the analytical frequencies and mode shapes [3]. Integration generally means combining parts so that they form a whole. The foundation for the discovery of the integral was laid by Cavelieri, an Italian mathematician, in around 1635. Besides, numerical algorithms are almost as old as human civilization. In numerical analysis, numerical integration constitutes a broad family of algorithms for calculating the numerical value of a definite integral. Numerical integration is a frequently-needed tool in modern Science and Engineering. Engineers and Scientists typically visualize integration as the process of determining the area under a curve. Besides this, because of its many more applications, it is often viewed as a discipline in and of itself. In this paper we develop a mathematical simulator for solving numerical integration problems. This simulator is incorporated with a combination of Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule and rule.[4] Numerical analysis naturally finds applications in all fields of engineering and the physical sciences, but in the 21st century, the life sciences and even the arts have adopted elements of scientific computations. Integrations appear in the movement of heavenly bodies planets, stars and galaxies. Before the advent of modern computers numerical methods often depended on hand calculation in large printed tables. Since the mid 20th century, computers calculate the required functions instead. In this paper we have consider two integrals and solved it with the help of proposed algorithm and existing five Newton-Cotes open integration formulae, a result we have shown that the proposed algorithm is much better than the existing five Newton-Cotes open integration formulae.[5] We give error bounds for the trapezoidal rule and Simpson's rule for "rough" continuous functions—for instance, functions which are Hölder continuous, of bounded variation, or which are absolutely continuous and whose derivative is in Lp. These differ considerably from the classical results, which require the functions to have continuous higher derivatives. Further, we show that our results are sharp, and in many cases precisely characterize the functions for which equality holds. One consequence of these results is that for rough functions, the error estimates for the trapezoidal rule are better (that is, have smaller constants) than those for Simpson'srule.[6] This paper presents a study on mode shape, inertia force, spring force and deflection of multi storied framed structures by comparison of stodola's and Holzer method. This study involves in examination of theoretical investigations of multi storied framed structures. Overall four storey multi storied framed structures and two methods were analysed & comparison of all the mode shape, inertia force, spring force and deflection at the critical cross-section with same configuration loading by keeping all other parameters constant. The theoretical data are calculated using code IS 1893, IS 4326, IS 13920. The all storey mass and stiffens are analysed under the cantilever condition. The research project aims to provide which method is most accuracy to find the mode shape, spring force deflection and inertia force. The studies reveal that the theoretical investigations Stodola's method is most accuracy compare to the Holzer method. The maximum mode shape, spring force, spring deflection and inertia force is 87.29%, 80 %, 89% and 72% is higher the Stodola's method compare than Holzer method in same configuration.[7] An accurate analysis of the natural frequencies and mode shape of a cable stayed bridge is fundamental to the solution of its dynamic responses due to seismic, wind and traffic loads. in most previous studies, the stay cables have been modelled as single truss elements in conventional finite element analysis. this method is simple but it is inadequate for the accurate dynamic analysis of a cable stayed bridge because it essentially precludes the transverse cable vibrations [8]. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. MATLAB is generally programming software as C, unlike C and other programming languages MATLAB is problem-solution kind of software which is much useful to evaluate results instantly. In the present topic use of software is done for calculating Natural Frequencies and Mode shapes of a 20 storey building with basic functions by using MATLAB. The furthur work can be extended for writing the programs of much more complex equations in MATLAB and obtains exact solution. This analysis indicates that the MATLAB can also be used in civil applications and to obtain exact solution with our knowledge [9]. Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed.Finite element method (FEM) is a numerical technique based on principle of discretization to find approximate solutions to engineering problems. The information about the natural frequencies for rotating systems can help to avoid system failure by giving the safe operating speed range. In the present work, finite element method has been used to find these natural frequencies for different possible cases of multi-rotor systems. The various mode shapes for several cases are also shown to illustrate the state of the system at natural frequencies. The results obtained have been compared with Holzer's method and Ansys 14 and ansys 14.5 software version to establish the effectiveness of finite element method for such systems [10]. The objective of current dissertation work is to analysis of vibration characteristics of circular cutters with free boundary condition but having different (numbers of cutting teeth, aspect ratio, effect of radial slots, and enlargement of stress concentration holes) is done here. Analysis for circular cutters with inner edge clamped and outer edge free is done here. For same aspect ratio of annular cutter but variable numbers and variable lengths of radial cracks for inner edge clamped and outer edge frees boundary condition [11].

II. AIM OF THE STUDY

The research project aims to provide which method is most accuracy to find the displacement, velocity and acceleration by trapezoidal rule and Simpson's rule

III .EXPERIMENTAL INVESTIGATION

3.1 Simpson's rule :

In numerical analysis, Simpson's rule is a method for numerical integration, the numerical approximation of definite integrals. Specifically, it is the following approximation: ... Simpson's rule also corresponds to the three-point Newton-Cotes quadrature rule.

3.1.1 Theoretical investigations of Simpson's rule **for single stored framed structures shown in Figure 1**

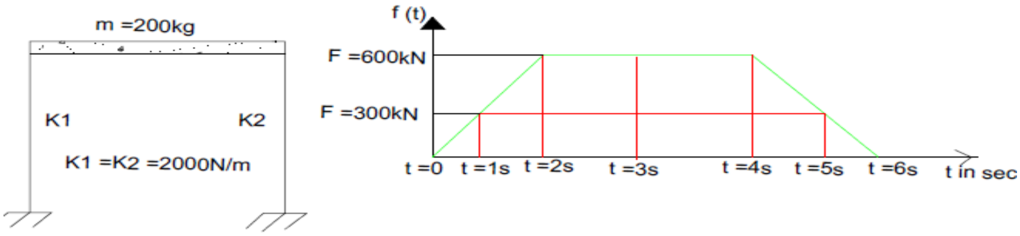

Figure 1 single stored framed structure

Simpson's rule

Solution

m = 200 kg

k = 2000N/m

$\omega_n = \sqrt{k}/m = 3.132$ rad /sec

Δt = 1 ,2, 3, 4 ,5 ,6

$y_0 = f_0 \cos \omega_n t_0 = 0 \text{ x } \cos \text{ x } 3.132\ 0 = 0$

$y_1 = f_1 \cos \omega_n t_1 = 300 \text{ x } \cos \text{ x } 3.132 \text{ x } 1 = 2.99$

$y_2 = f_2 \cos \omega_n t_2 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 2 = 11.94$

$y_3 = f_3 \cos \omega_n t_3 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 3 = 17.97$

$y_4 = f_4 \cos \omega_n t_4 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 4 = 23.96$

$y_5 = f_5 \cos \omega_n t_5 = 300 \text{ x } \cos \text{ x } 3.132 \text{ x } 5 = 14.97$

$y_6 = f_6 \cos \omega_n t_6 = 0 \text{ x } \cos \text{ x } 3.132 \text{ x } 6 = 0$

$x_0 = f_0 \sin \omega_n t_0 = 0 \text{ x } \cos \text{ x } 3.132 \text{ x } 0 = 0$

$x_1 = f_1 \sin \omega_n t_1 = 300 \text{ x } \cos \text{ x } 3.132 \text{ x } 1 = 0.163$

$x_2 = f_2 \sin \omega_n t_2 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 2 = 0.655$

$x_3 = f_3 \sin \omega_n t_3 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 3 = 0.982$

$x_4 = f_4 \sin \omega_n t_4 = 600 \text{ x } \cos \text{ x } 3.132 \text{ x } 4 = 1.310$

$x_5 = f_5 \sin \omega_n t_5 = 300 \text{ x } \cos \text{ x } 3.132 \text{ x } 5 = 0.0327$

$x_6 = f_6 \sin \omega_n t_6 = 0 \text{ x } \cos \text{ x } 3.132 \text{ x } 6 = 0$

Find the displacement using Simpson's rule equation (1)

Displacement X(max) = $1 / m\,\omega_n \{ (\sin \omega_n t\, [\, y_0 + 4\, y_1 + y_{2+}\, y_3 + y_{4 \ldots\ldots\ldots}\, y_n) /3 - (\cos \omega_n t\, [$

$x_0 + 4\, x_1 + x_{2+}\, x_3 + x_{4 \ldots\ldots\ldots}\ \ x_n) /3 \}$ ------------------------(1)

Find the velocity using the equation (2)

Velocity ($\dot{x}_{max}$) = A ω_n ------------------------------------ (2)

Find the acceleration using the equation (3)

Acceleration $\ddot{X}$ (xmax) = A ω_n^2 ---------------------- (3)

Find the amplitude using the equation (4)

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Amplitude (A) = $\sqrt{x_{max}^2 + (\dot{x}max/2)^2}$ ------------------ (4)

Table 1 - Theoretical investigations of displacement, velocity and acceleration by Simpson's rule

Δt	1sec	2sec	3sec	4sec	5sec	6sec
$X_{(max)}$ Displacement	0.410	0.820	1.23	1.64	2.05	0
Velocity $\dot{x}_{max}$	1.28	2.53	3.85	5.136	6.42	0
Acceleration $\ddot{X}(xmax)$	3.97	8.04	12.06	16.08	20.10	0

3.1.2 Theoretical investigations of Trapezoidal rule **for single stored framed structures shown in Figure 1**

Trapezoidal rule

The trapezoidal rule is one of a family of formulas for numerical integration called Newton–Cotes formulas, of which the midpoint rule is similar to the trapezoid rule. Simpson's rule is another member of the same family, and in general has faster convergence than the trapezoidal rule for functions which are twice continuously differentiable, though not in all specific cases. However for various classes of rougher functions (ones with weaker smoothness conditions), the trapezoidal rule has faster convergence in general than Simpson's rule.

Solution

m = 200 kg

k = 2000N/m

$\omega_n = \sqrt{k/m}$ =3.132 rad /sec

Δt = 1 ,2, 3, 4 ,5 ,6

Find the displacement using Trapezoidal rule equation (5)

Displacement X(max) = $1/m\,\omega_n$ { (sin ω_n t 0.5 [y_0 +2 y_1 + $2y_{2+2}$ y_3 + $2y_4$……… y_n) – (cos ω_n t 0.5 [x_0 +2 x_1 + $2x_{2+}$ $2x_3$ + $2x_4$……… x_n) } -----------------(5)

Find the velocity using the equation (6)

Velocity ($\dot{x}_{max}$) = A ω_n ----------------------------------- (6)

Find the acceleration using the equation (7)

Acceleration $\ddot{X}$ (xmax) = A ω_n^2 ---------------------- (7)

Amplitude (A) = $\sqrt{x_{max}^2 + (\dot{x}_{max}/2)^2}$

Table 2 - Theoretical investigations of displacement, velocity and acceleration by Trapezoidal rule

Δt	1sec	2sec	3sec	4sec	5sec	6sec
$X_{(max)}$ Displacement	1.74	3.48	5.22	6.96	8.703	0
Velocity $\dot{x}_{max}$	5.44	10.89	16.34	21.79	27.25	0
Acceleration $\ddot{X}$(xmax)	17.06	34.13	51.20	68.27	85.99	0

IV RESULT AND DISCUSSION

A single storied framed structure is analysis and **comparison** of all the displacement, velocity, and acceleration by trapezoidal rule and Simpson's rule method. In this study the mass, stiffness, natural frequency is same for all storey level and other parameters is constant for the entire storey and various time configurations. The mass and stiffens are analysed under the cantilever condition of structures. The theoretical data are calculated using code IS 1893, IS 4326, IS 13920. The theoretical results of trapezoidal rule the maximum deviation of displacement, velocity, and acceleration is 76.29% is higher compare than Simpson's rule in same configuration. In this analyse the final result, displacement, velocity, and acceleration the results are shown in table 1& 2comparison displacement, velocity, and acceleration given in figure 2,3& 4

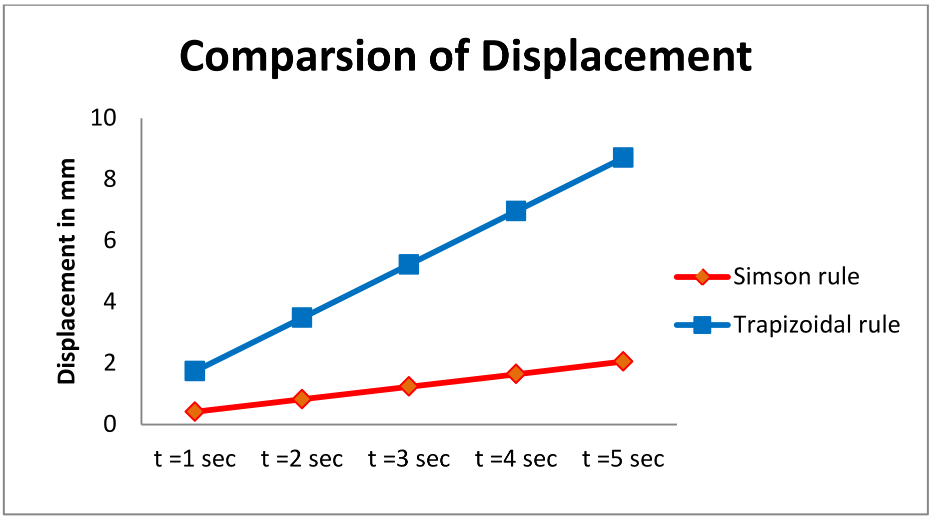

Figure .2 Comparison of displacement

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The displacement is 76.29 % higher the trapezoidal rule compare than the Simpson rule in time seconds is gradual increase and same cross section structures. The shown figure .2

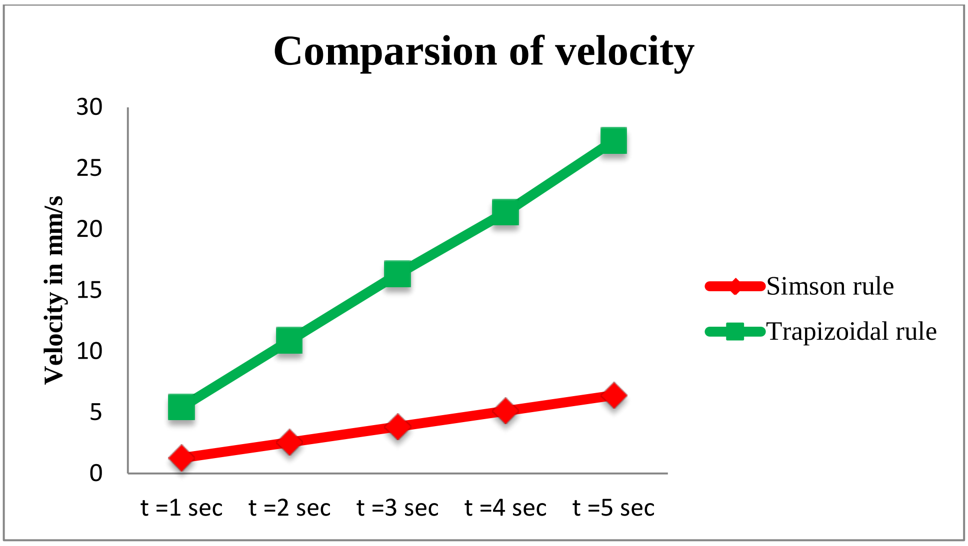

Figure .3 Comparison of velocity

The velocity is 76.29 % higher the trapezoidal rule compare than the Simpson rule in time seconds is gradual increase and same cross section structures. The shown figure .3

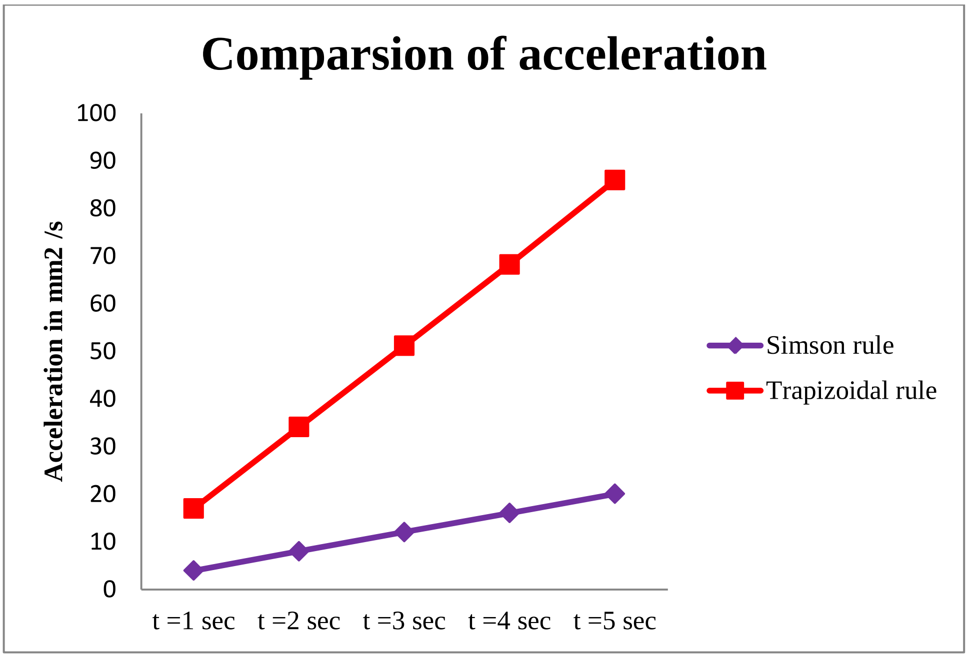

Figure .4 Comparison of acceleration

The acceleration is 76.29 % higher the trapezoidal rule compare than the Simpson rule in time seconds is gradual increase and same cross section structures. The shown figure .4

V CONCLUSIONS

- The theoretical investigation, trapezoidal rule have higher displacement, velocity, and acceleration for various time seconds compare than the Simpson rule.
- The conclusions of in this study find the displacement, velocity, and acceleration by theoretical investigation of trapezoidal rule and Simpson rule in same mass ,stiffness and Natural frequency & all other parameters are constant.
- The final result and conclusions of theoretical investigation, trapezoidal rule method is most accuracy method to find the displacement, velocity, and acceleration.
- The maximum displacement, velocity, and acceleration is 76.29 is higher the trapezoidal rule method compare than Simpson rule in same configuration.

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