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Review of Piecewise Function in Structural Dynamics

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Abstract: This paper deals with an exhaustive review of piecewise polynomial function subjected under variable functions and thus the response of structures of varying loads in vibratory state has been examined. The response of structure can be calculated by using the principle based of piecewise function as it is more useful than various other methods because of the fact that the small steps of overall function can be infinitesimally analyzed and calculated. Brief discussion of various structures under different type of loading has also been done.
Key words: Structural dynamics, Natural Frequency, piecewise polynomial function, Direct integration method.

I. INTRODUCTION

The analysis of the structural dynamics plays an important role in mechanical, civil and ocean engineering. Due to limitation of analysis of computational method, time step integration method has become one of the most popular numerical approaches for analyzing structural dynamics problems.

For determining response of structures under dynamic loads the Step-by-step integration method is very famous and that method can be categories in two basic parts those are Explicit and Implicit. If the current time-step is being used to determine the current step displacement in the equation of motion that method is called Explicit if not used it is called Implicit. Implicit algorithms are stable because of its large time steps, and parallels the calculation is very high per time step particularly in MDOF problems. There are so many researchers have given their methods for the computational analysis of structural dynamics, i.e. Newmark β, the Wilson θ approach, the Houbolt, CH-α method (Chung and Hulbert 1993), and the HP-θ (Hoff and Pahl 1998) methods, etc. these methods are Implicit. In other hand, Explicit requires very less computational effort and these are inexpensive in each time step, because of its simple and straightforward calculation, it can be implemented quite easily as compared to the Implicit algorithms. Explicit time integration methods are frequently being used to solve the nonlinear problems in structural dynamics. Conditionally stability is the biggest disadvantage of Explicit which means there is a critical time-step, Δt_{cr}, which should not be exceeded in the analysis. The natural frequency of the linearized system will be responsible for the magnitude of this critical time-step. This means that, a very small time step is required to obtain a stable integration result. To improve this problem, there are so many Explicit methods introduced with unconditional stability proposed by Chang (2002, 2007), the fourth order L-stable Runge–Kutta methods (Hairer et al. 1993, 1996) for linear dynamic problems. Now a day, researchers are looking for straight forward and simple step-by-step method. For that regarding most of researchers are using piecewise polynomial functions in Explicit methods, i.e. Liu (2001, 2002) has used piecewise Lagrange polynomial functions and piecewise Birkhoff polynomial functions Gholampour (2011) has used Taylors series expansion than Shojaee et al. have implemented the cubic B-spline polynomial function and quantic B-spline polynomial function for the numerical solution of the dynamic responses of a Single-Degree-Of-Freedom (SDOF) systems and they generalized their method for solving MDOF systems.

All authors have accepted the equation of the governing equation of interest is given by

$$M\ddot{u}(t) + D\dot{u}(t) + Ku(t) = F(t)$$

A. *Piecewise polynomial function in structural dynamics*

As an extension of the procedure in which an arbitrary dynamic loading is approximated by piecewise linear segments, the second- and third-degree piecewise Lagrangian interpolating polynomials have employed to approximate an arbitrary dynamic loading in the Duhamel integral for the solution of dynamic response of a SDOF system by Liu [[1]-[2]] in 2001. The proposed method offers computational advantage over the traditional step-by-step solution techniques for comparable accuracy, and far better accuracy than the piecewise linear approximation procedure for the comparable time interval when the loading cannot be represented by straight-line segments. The response of a SDOF system has determined by using the piecewise Lagrange interpolation polynomials to represent the variation of load. The equations associated with the second- and third-degree piecewise Lagrange interpolation polynomials have provided. An exact result has obtained from the proposed methods. An exact result as not obtained from proposed method, but the error has rather small. The proposed method has a higher accuracy than the traditional step-by-step integration procedure and the piecewise linear approximation procedure in those cases when the loading varies with the form of a curve. As a result, the proposed method requires much less computational effort as compared to the effort involved in the other two methods. The proposed method not only has very high accuracy at a very large interpolation interval, it also converges to the exact result rapidly as the interpolation interval has reduced. In another paper he has proposed an algorithm by using the piecewise Birkhoff interpolation polynomials and the modal superposition method for the solution of dynamic response of MDOF system. By proposed algorithm an exact result can be obtained when each loading can be represented by a piecewise polynomial, the proposed method not only can considerably reduce computational effort compared to the traditional step-by-step integration solution technique, but also can thoroughly avoid the problems of accuracy, convergence and stability encountered in many other numerical procedures. He has determined response of a multi-story framed structure by means of the modal superposition method and the Duhamel integral. Firstly, one can approximate every applied loading pj(t) with a piecewise Birkhoff interpolation polynomial. Secondly, one can integrate precisely the Duhamel integrals for each mode and for each loading. Thirdly, one can calculate the displacements, velocities and accelerations expressed in geometric coordinates by the normal coordinate transformation. Finally, one can obtain the elemental forces. The equations associated with the first, third and fifth degree piecewise Birkhoff interpolation polynomials have presented. For the applied loadings which each can be represented by a piecewise polynomial in which the number of degrees has not more than five, an exact result has obtained from the proposed method. The proposed method has a higher accuracy than the traditional step-by-step integration procedure and the piecewise linear approximation procedure in the case when each loading varies with the form of a curve. For long-duration loads, the proposed method requires much less computational effort as compared to the effort involved in the step-by-step integration method. For proving he has given an example, the computational time consumed by the proposed method is less than 0.5% of the time consumed by the step-by-step method for comparable accuracy and storage space, for the framed structure in numerical examples. Unlike the step-by-step integration solution technique, the error brought by the proposed method has not remarkably increased in the order of magnitude as the time of response goes on, even when the structure has subjected to an extremely long duration loading. The proposed method not only has very high accuracy at a very large interpolation interval, it also converges to the exact result rapidly as the interpolation interval has reduced.

II. CONCLUSION

On the basis of present review following conclusions can be obtained

A. Piecewise method provides far superior results than other methods if integration is subjected to small parts.

B. The level of accuracy can be more increased if the integration is performed using curve fitting functions.

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