AHI EVRAN

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Odlar Yurdu University
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FULL TEXTS BOOK Volume-2

Editors
Prof. Dr. Ahmet KAZANKAYA
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TÜRKİYE
TR: +90 342 606 06 75
E posta: kongreiksad@gmail.com
www.iksad.org www.iksadkongre.org

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CONTENT

NUMERICAL SIMULATION OF VIBRATION FTEQUENCIES FOR THIN ELASTIC CIRCLE PLATE

Anton KOROBKA

Student, V.N. Karazin Kharkiv National University

Elena SIERIKOVA

PhD, National University of Civil Defence of Ukraine, Kharkiv, Ukraine

ORCID ID: 0000-0003-0354-9720

Ivan VIERUSHKIN

PhD student, A.M. Podgorny Institute for Mechanical Engineering Problems NAS of Ukraine, Kharkiv, Ukraine

ORCID ID: 0000-0002-3837-5567

ABSTRACT

The problems of vibrations of critical structural elements have been the focus of attention of many researchers and engineers over the past decades [1,2]. Each new design requires additional research. New modern materials are being developed, special devices for vibration damping are being introduced [3-5]. At the same time, new efficient numerical methods are being developed [6,7].

Thin round elastic plates are often used as critical elements of complex engineering structures. Suppose, deformation of the plate is described by function w. Natural modes w_l and their corresponding natural frequencies $\boldsymbol{\Omega}_l$ are determined by solving such a spectral problem

$$D\Delta\Delta w_k + (K - \rho_p h\Omega_k^2)w_k = 0, \quad (1)$$

$$w|_{r=R} = 0, \quad \left.\frac{dw}{dr}\right|_{r=R} = 0. \quad (2)$$

Keywords: vibrations, circle plate, numerical methods for evaluation of roots

INTRODUCTION

Since equations (1),(2) have solutions in the next form

$$w_{km}(r,\theta) = F_k(r)\cos m\theta,$$

then it have been concluded that equation (1) allows reduction by $\cos m\theta$.

We have restricted by the case of axially symmetric oscillations, that is, we assume that m=0. Introducing the following notation

$$\alpha^4 = \frac{\Omega^2\rho_p h}{D} - \frac{K}{D},$$

One can see that equation (1) takes the form $(\Delta - \alpha^2)(\Delta + \alpha^2)F = 0$ and could reduced to the next system

$$\frac{d^2F}{dr^2} + \frac{1}{r}\frac{dF}{dr} - \alpha^2 F = 0, \quad (3)$$

$$\frac{d^2F}{dr^2} + \frac{1}{r}\frac{dF}{dr} + \alpha^2 F = 0. \quad (4)$$

The solutions of equation (3) are Bessel functions of the first and second kind of zero order $J_0(\alpha t)$ and $Y_0(\alpha r)$, and the solutions of equation (4) are modified Bessel functions of the first and second kind of zero order $\mathrm{I}_0(\alpha r)$ and $K_0(\alpha r)$. So, the general solution of equation (1) has the following form

$$F(r) = a\,J_0(\alpha r) + b\,Y_0(\alpha r) + c\,I_0(\alpha r) + dK_0(\alpha r), \quad (5)$$

where a, b, c, d are constants.

Since at $r \to 0$ functions $Y_0(\alpha r)$ and $K_0(\alpha r)$ grow endlessly, it has been assumed that $b = 0,\ d = 0$, to avoid non-physical movements. Next, the boundary conditions for fixing the plate along the contour was used. In the case of rigid fixation we have

$$F|_{r=R} = 0, \ \left.\frac{dF}{dr}\right|_{r=R}.$$

Using (5) we receive

$$\begin{cases} a\,J_0(\alpha R) + c\,I_0(\alpha R) = 0 \\ a\,J_1(\alpha R) + c\,I_1(\alpha R) = 0 \end{cases} \quad (6)$$

In order for the system (7) to have a nonzero solution, it is necessary that the determinant of this system is equal to zero. Therefore, there have been got the characteristic equation for finding the unknown quantity α

$$\begin{vmatrix} J_0(\alpha R) & I_0(\alpha R) \\ J_1(\alpha R) & I_1(\alpha R) \end{vmatrix} = J_0(\alpha R)\,I_1(\alpha R) - I_0(\alpha R)\,J_1(\alpha R) = 0. \quad (7)$$

Then we find numerical value of roots of equation (7) using following computational technique

To find the numerical values of the roots of the above equation, the mathematical environment MATLAB was used.

To begin with, this equation was visualized:

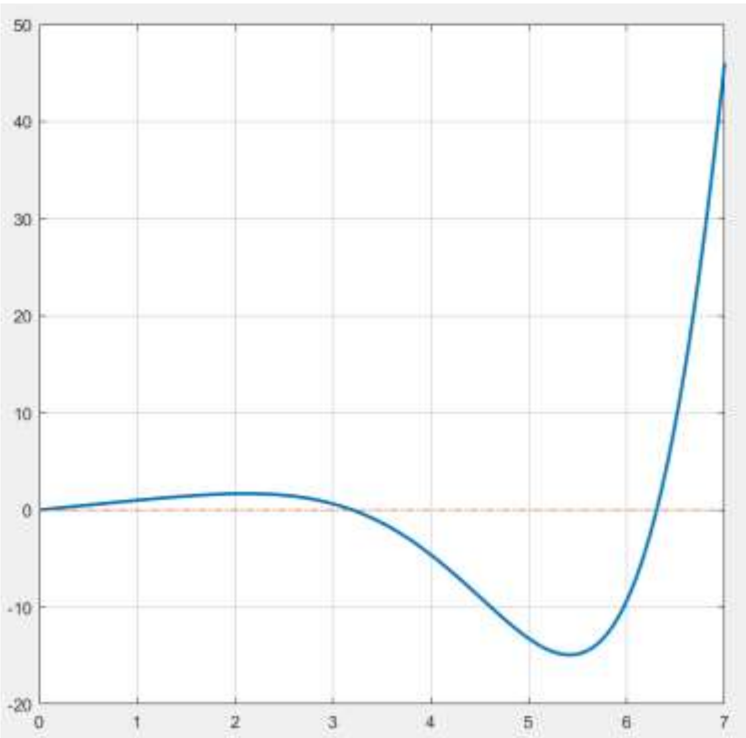

Figure 1. Behavior of function $J_0(\alpha R)\,I_1(\alpha R) - I_0(\alpha R)\,J_1(\alpha R)$.

As we can see from Fig.1, the root of the equation is within the vertical axis from 2 to 4 units.

To find the root of the equation, the "Chord method" was used. Fig. 2. Also, the "Half Length Method" was used as a comparison, although the resulting root values were correct, but the value of the function at this point was inaccurate.

```
a = 2;
b = 4;
x0 = a;
yb = (besselj(0,b)*besseli(1,b))+(besseli(0,b)*besselj(1,b));
yx0 = (besselj(0,x0)*besseli(1,x0))+(besseli(0,x0)*besselj(1,x0));
x = x0 - ((b-x0)*(yx0))/((yb)-(yx0));
while abs(x-x0) > e
    x0 = x;
    yb = (besselj(0,b)*besseli(1,b))+(besseli(0,b)*besselj(1,b));
    yx0 = (besselj(0,x0)*besseli(1,x0))+(besseli(0,x0)*besselj(1,x0));
    x = x0 - ((b-x0)*(yx0))/((yb)-(yx0));
end
```

Figure 2. Chord method code

As a result, the following value of the root of the equation with a radius equal to one was obtained, Figure 3:

$$\alpha = 3.1962$$

The value of the function when the root is found:

$$J_0(\alpha R)\, I_1(\alpha R) - I_0(\alpha R)\, J_1(\alpha R) = 1.7131 \times 10^{-8} \approx 0$$

```
Chord method
x = 3.1962
f(x) = 1.7131e-08
>>
```

Figure 2. The result of the program execution

So, the lowest value of the own frequency according to [8] can be obtained as f=25.2047Hz.

CONCLUSION

Auxiliary program code is elaborated to solve the problem of vibrations of axisymmetric designs. In the future, a software package will be developed for calculating the strength and vibrations of axisymmetric structures when interacting with the aquatic environment.

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