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A Study on Applications of Numerical Methods in Sewing Machine

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Abstract- The main aim of this paper is to solve the real world problems using Numerical methods. Numerical methods has vast application in our daily life. It has been used in Image blurring, Network simulation, Weather prediction. This Paper mainly deals with the numerical method in textile industry that has helped to bring the correct force that has to be given to the needle for the better stitching using secant method.

Keywords- Sewing machine, Secant method, Critical buckling load.

1. INTRODUCTION

The paper deals with the application of numerical methods in the field of textile and clothing technology. In view of the complexity of solving the problems of fabric and garment drapery, numerical methods have found application in the field of textile and clothing technology. Fabrics exposed to the action of low stresses behave complexly due to their properties of inhomogeneity, discontinuity, anisotropy and deformability, so it is difficult to describe these states mathematically. Approximating by numerical methods makes it possible to predict their behaviour. Thus, the paper describes the previous applications of numerical methods and the application results in the field of textiles and clothing. Basic postulates of numerical methods from the mathematical point of view are presented as well as their adapting to the application and solution of problems in the field of textiles and clothing.

Introduction to secant method [5] :

In numerical analysis, the secant method is a root-finding algorithm that uses a succession of roots of secant lines to better approximate a root of a function f. The secant method can be thought of as a finite-difference approximation of Newton's method.

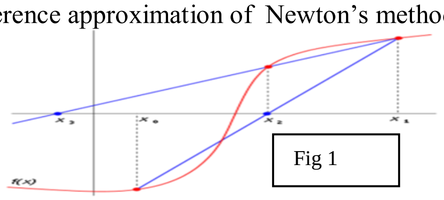

Fig 1

The Secant Method is an iterative method in which the peak displacement response of a structure or structural component is determined from linear dynamic analyses of a model whose stiffness is updated to reflect a computed degree of degradation that is consistent with the computed peak displacement. Numerous descriptions of the Secant Method and related procedures exist in the literature. Division 95 of the City of Los Angeles Building Code, for example, includes a formulation of the Secant Method that is specifically intended for evaluation and rehabilitation of infill frame buildings with limited ductility. In the Secant Method, the degree of degradation of a structure is derived from the secant as determined from nonlinear force-displacement relationships for the structure as a whole or from appropriate sub-assemblies and this information is substituted into the linear dynamic analysis environment. In this way, the dynamic analysis model is updated to approximate intermediate states of degradation until a rational and consistent convergence in each sub-assembly as well as the whole structure is achieved.

Advantages of secant method:

1. It converges at faster than a linear rate, so that it is more rapidly convergent than the bisection method.
2. It does not require use of the derivative of the function, something that is not available in several applications.
3. It requires only one function evaluation per iteration, as compared with Newton's method which requires two.

Application of secant method in sewing machine

The sewing machine[1] needle is an important and vital machine member. The general objective of the sewing needle is to penetrate the sewn materials either single layered or multiple layered and to carry the sewing thread via the sewn fabrics for loop formation. During the penetrations of the sewing needle, a resisting force at the free end of the needle is built up, this subjects the needle to an axial compressive force. This force can lead to the needle buckling in elastic or plastic region of the needles material [steel]. In both cases the sewing needle may be bent.

2. FORMULA FORMATION:

Y=(δ+e) (1-cosλX) ------------(1)

Where,

X – Instantaneous lateral displacement of the needle (vertical axis).

Y – The horizontal axis parallel to the sewing needle axis.

$\lambda - const = \frac{\sqrt{P}}{EI}$ ---------------(2)

P – Axial and actual axial compressive load on the sewing needle due to sewing technology.

E – Young's modulus.

I – Minimum inertia of the sewing needle cross section.

EI – Minimum bending stiffness of the needle.

e – Technological load-penetrating needle force eccentricity i.e. the shift between the needle geometrical axis and the technological force active line.

d – The lateral displacement of the lower free end of the industrial sewing machine's needle.

Y=(δ+e)(1−$cos\lambda X$)

By putting x=l

Therefore,

Y= (S+ e)(1-cosλl)

Y=e$\frac{(1-cos\lambda l)}{cos\lambda l}$ -------------------(3)

return to eqns. (1) and (3), Then:

Y=e$\frac{(1-cos\lambda x)}{cos\lambda l}$ ------------------(4)

Eq. (4) represents the equation of the sewing needle elastic line (deflection curve), The last formula (4) represents the equation of the needle elastic line (deflection curve).

cos$\lambda l = 1 - \frac{1}{2}\ \lambda^2 l^2$ --------------(5)

Using this quantity of cosλl and neglecting the value $\lambda^2 l^2/2$ in the denominator of expression (3), as being small in comparison with unity, We obtain:

$\delta = \frac{e\lambda^2 l}{2} = \frac{Pe^{l^2}}{2EI}$ ------------------(6)

Application of the Secant's Equation,

The maximum bending moment takes place at the upper end of the sewing needle [a built-in coupled] and its value is :

$M_{max} = P_a$ (e+δ)

=P_a.e.secλl --------------------------(7)

The maximum stress in the sewing needle is $\sigma_{max}$where

σ_{max}=$\frac{Pa^e}{\frac{I\prime}{C}}sec\lambda l$

=$\frac{P_{ec}}{I\prime}$secλl --------------------(8)

But the compressive force Pa can create a tensile stress with value:

$\sigma_{max} = P_{a/A_{min}} = \frac{P_a}{A\prime}$ ---------------- (9)

Therefore the maximum stress $\sigma_{max}$is;

σ_{max}=$\frac{P}{A\prime}$+$\frac{P_{ec}}{I\prime}$secλl ---------------- (10)

where

I'-minimum sewing needle's inertia of cross section,

A_{min}=A'-minimum sewing needle's cross section.

Assume (i'/a') = r_1^2 $where$ r is the minimum radius of gyration about the neutral axis of the needle.

σ_{max}=$\frac{P}{A\prime}$[1+$\frac{ec}{r^2}$ (Sec $\frac{l}{r}\sqrt{\frac{P}{EA\prime}}$)] ------------ (11)

The following part of Secant's formula;

[1+ $\frac{e.c}{r^2}$(Sec $\frac{l}{r}\sqrt{\frac{P}{EA}}$)] ---------------- (12)

By multiplying it by (P/A') as tensile stress

$P_c = \frac{\pi}{4\,l^2}$ x EI ------------- (13)

Therefore the equation is,

$$\boldsymbol{\sigma_{max} = \frac{P}{A\prime}[1+\frac{ec}{r^2}\ (Sec\frac{l}{r}\sqrt{\frac{P_a}{EA\prime}})]}$$

Secant formula for $v_{max}$and σ_{max} [3] :

v_{max}=e$\left[\sec\left(\sqrt{\frac{p}{EI}}\frac{L}{2}\right) - 1\right]$

σ_{max}=$\frac{p}{a}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{p}{EA}}\right)\right]$

3. CRITICAL BUCKLING LOAD [2] :

p_{cr}=$\frac{\pi^2 EI}{(KL)^2}$

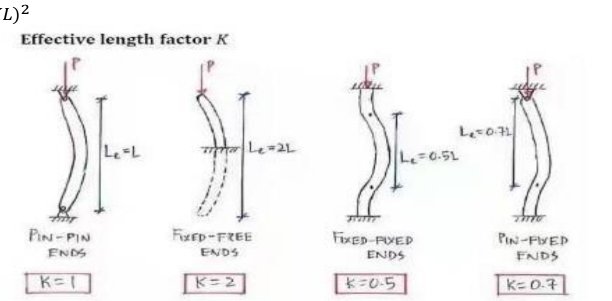

Fig 2

PROBLEMS

PROBLEM 1:

Let e=150mm
c=60mm (Half of cross section height)
p=10kN
L=2m
E=200G pa

Find the maximum stress of the sewing needle.

Solution:

v_{max}=e$\left[\sec\left(\sqrt{\frac{p}{EI}}\frac{L}{2}\right) - 1\right]$

=(150mm)$\left[\sec\left(\sqrt{\frac{10\times10^3 N}{(200\times10^9 p_a)(7.2\times10^{-6}m^4)}}.\frac{2m}{2}\right) - 1\right]$

=0.522mm

$\sigma_{max}=\frac{p}{a}\left[1+\frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{p}{EA}}\right)\right]$

$=$

$\frac{10\times10^3N}{6000mm^2}\left[1+\frac{(150mm)(60mm)}{(34.64mm)^2}\sec\left(\frac{2m}{2\times0.03464m}\sqrt{\frac{10\times10^3N}{(200\times10^9p_a)(6000mm^2)}}\right)\right]$

$=14.21\text{m}p_a$.

PROBLEM 2:

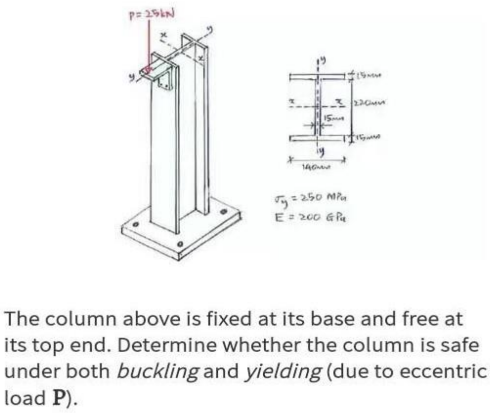

Fig 3

The column is fixed at its base and free and its top end for both the x-x and y-y axes.

Therefore buckling would first occur about the y-y axes sinceI_{yy}<I_{xx}.For fixed-free ends .

,k=2.

We need $I_{yy}$for buckling but for the eccentric load p It causes bending about x-x .

Therefore we need I_{xx} as well.

$I_{xx}=\frac{1}{12}bh^3$

$=\frac{1}{12}(140)(250)^3-\frac{1}{12}(125)(250)^3\text{m}m^4$

$=71.375\times10^6\text{m}m^4$

$I_{yy}=\frac{1}{12}bh^3$

$=\frac{1}{12}(220)(15)^3+\frac{1}{12}(30)(140)^3\text{m}m^4$

$=6.922\times10^6\text{m}m^4$

A=15mm×(140mm+140mm+220mm)

$=7500\text{m}m^2$

$\mathbf{r}=\sqrt{\frac{I_{xx}}{A}}=\sqrt{\frac{71.375\times10^6\text{mm}^4}{7.500\text{mm}^2}}$

= 97.55mm.

L=4m

KL=2 ×4=8m.

4. CHECKING FOR BUCKLING FIRST [4]:

$p_{cr}\,\frac{\pi^2EI_{yy}}{(KL)^2}=\frac{\pi^2(200\times10^9p_a)(6.922\times10^6\text{mm}^4)}{(8m)^2}$

213.5KN

Since p_{1000}=25KN<p_{cr}, column does not fail under buckling.

Checking for $\sigma_{max}(\sigma_y$=250Mp_a):

Listening values for parameters required:

e=180mm

c=125mm (Half the cross section height about the x-x axis)

p=25kN

L=4m

E=200G p_a

$\sigma_{max}=\frac{p}{a}\left[1+\frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{p}{EA}}\right)\right]$

$=\frac{25\times10^3N}{7500mm^2}\left[1+\frac{(180mm)(125mm)}{97.55mm)^2}\sec\left(\frac{4m}{2\times0.09755m}\sqrt{\frac{25\times10^3N}{(200\times10^9p_a)(7500\times10^{-6m^2})}}\right)\right]$

$=11.24\text{m}p_a<250\text{m}p_a(\sigma_y)$

Therefore column does not fail under yielding.

PROBLEM 3:

Let e=150mm

c=60mm (Half of cross section height)

P=10kN

$\frac{P_a}{P_{cr}}=1$

Find maximum stress of the sewing needle. Also check the value for $\frac{P_a}{P_{cr}}$

Solution:

$\sigma_{\max}=\frac{P}{A}\left[1+\frac{ec}{r^2}\sec\frac{\Pi}{2}\right]\sqrt{\frac{P_a}{P_{cr}}}$

$\sigma_{\max}=$

$\frac{10\times10^3N}{6000mm^2}\left[1+\frac{(150mm)(60mm)}{(34.64mm)^2}Sec\sqrt{1}\right]$

$\sigma_{\max}=\infty$

$\therefore\frac{P_a}{P_{cr}}$

Should not be unity. They must be less than unity.

5. CONCLUSION:

This Paper will help us to solve the issues that arise generally during Stitching. The Secant method in Numerical method helps us to calculate the right bending moment of the needle for the better stitching without causing damage to the sewing needle during the stitching process. It has also helps us in sorting out the issues that arise during buckling by calculating the buckling load and checking whether it could manage the weight during the process of stitching.

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