An Alternative Approach for Analyzing Stability of Conservative Pipes Conveying Fluid

Albert E. Yousif **Mohsin J. Jweeg** **Mahmud R. Ismail***

College of Engineering Al-Nahrain University
Baghdad, Iraq
*E-mail: mahmech2001@yahoo.com

Abstract

In many classes of problems of elastic systems such as gyroscopic and circulatory systems stability investigations are being conducted .The concept of a "stability boundary" arising in connection with multiple loading parameters is used for stability investigation. The concept is extended to analyze stability of conservative pipes conveying fluid since they are regarded as gyroscopic systems.

In this approach the pipe system is discretized to a two –degree of freedom by using Galarkin projection. The solution of the Eigen-value problem leads to the characteristic equation describing the parameters -frequency relationship .By plotting the root locus of these characteristic equation the main stability features such as stability, buckling and flutter instability and destabilization has been investigated graphically .The validity of this approach was tested by comparing it with the other published methods The results gave good agreements.

The effect of the fluid parameters such as fluid velocity, fluid pressure and pipe-fluid mass ratio on the pipe stability are also investigated. The results showed that the mass ratio has a major effect on stability behaviors since the sequence of stability can be dramatically changed whereas ,the fluid pressure showed slight effect since the stability sequence is not altered , for wide range of the fluid velocities .

Keywords: stability boundary, buckling, flutter, conservative, gyroscopic,

1 .Introduction

Pipes conveying fluid are classified as gyroscopic systems according to the gyroscopic effect arises from the relative rotation motion of the fluid element as it vibrate laterally to conform with the pipe motion .Moreover pipes are regarded as conservative when the total energy supplied by the fluid to the whole pipe system are nearly zero .Pinned-pinned, clamped-pinned and clamped-clamped pipes belong to this category

In general, fluid-conveyed pipe systems behave as stable at relatively low fluid velocities (pre-critical). At certain critical velocities pipes can lose their stability either by static convergence (buckling) or by exponent growth oscillation (flutter).At further higher velocities (post-critical) pipes behave in different manners, it may still unstable at the same mode (buckling or flutter),regain its stability or change its mode of instability.

Evaluation of the stability regions at various pipe parameters is of a major interest in design of such systems in order to insure that the safe operations for specific pipe and fluid parameters are desirable.

Early, many researcher had been studied the stability for conservative pipes conveying fluid like Bishop [1], Weaver and Unny [2]and recently, Kuiper and Metrlkine [3] and Si-Ung and his coworkers [4] .Their investigations were focused on evaluating of the critical fluid velocities for buckling instability and stability characteristics for pinned-pinned, clamped–pinned and clamped-clamped pipes conveying fluid . However, these studies were based on the complete solution of the equation of motion by using either approximated analytical or numerical solutions. These solutions are normally required calculations.

The concept of "stability boundary" arises in connection with multiple loading parameters has considerable applications in many elastic systems such as gyroscopic (e.g.: rotating flexible shaft) and circulatory systems (e.g.: column subjected to partial follower load).For detailed analysis and applications the interested reader refers to a book by Huseyni [5].

Sundraraian [6] and Huseyni [5], investigated buckling stability for gyroscopic conservative beams subjected to follower loads .They introduced many useful theorems concerning the effect of the variation of the gyroscopic forces on stability and the buckling instability regions. Later, Huseyni and Plaut [7] and Huseyni [8] extended the analysis of stability to include the flutter instability for non-conservative systems such as cantilever with combined concentrated and distributed follower loads .They showed that flutter instabilities can take place in such systems as well as the buckling instabilities.

Recently Li-Qun [9] studied the buckling instability for axially moving beams with pinned or clamped ends .The conserved quantity was applied to demonstrate the Lyapunov stability of the straight equilibrium configuration in transverse nonlinear of beam with a low axial speed. Elfelsou [10] investigated buckling and flutter instability for conservative and non-conservative beams .For conservative beams buckling loads, natural frequencies and associated Eigen-modes were computed. For non-conservative beams the flutter load and instability regions with respect to the elastic concentrated and distributed foundations were identified .The Eigen-modes and non-linear vibrations of beams were investigated based on one mode analysis.

The analogy between the dynamics of pipes conveying fluid and the other dynamical problems such as column under follower loads ,beams with moving loads and moving strings and belts was demonstrated by many researchers such as Plaut[11]who showed that the dynamical behaviors of fluid-pipe systems are identical with the beams of follower loads where the fluid forces and follower loads act dynamically in the same manners .Recently , Paidousiss [12] generalized the idea of the analogy between pipe systems and other dynamical systems and the possibility of exchanging the gained knowledge between each other .

Due to this evident analogy, therefore, it is possible to extend the concept of a "stability boundary" to include the conservative pipes conveying fluid such as pinned-pinned, (p-p), clamped-pinned (c-p) and clamped –clamped (c-c) pipes. To accomplish this analysis the equation of motion is discretized to two-degree of freedom in the vicinity of the equilibrium configuration by using Galarkin method. The equation of the characteristics curves for this reduced system can readily be derived in terms of the pipe parameters . The various boundaries of stable and unstable regions can simply be investigated against the variation of the fluid velocity, mass ratio and pressure as loading parameters.

2. Theoretical Consideration

The fluid conveying pipe under consideration is assumed to obey Euler–Bernoulli Beam theory. The structure of the pipe has a small deformation, the conveyed fluid is assumed as non-viscous and incompressible and the effect of gravity and internal damping are neglected.

Consider a uniform tubular beam shown in fig.(1) of length L, mass per unit length m_p, and flexural rigidity EI, conveying fluid of mass per unit length m_f ,flowing axially with velocity V, the fluid cross sectional area is A_f, and the fluid pressure measured above the atmospheric is P.

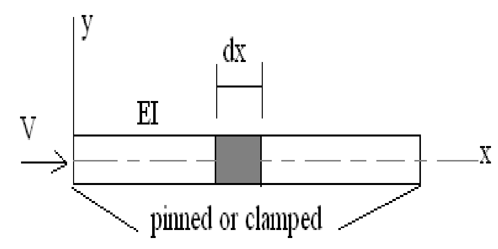

Figure (1): Pipe model

Fr small displacement the x-component of the fluid velocity can be assumed to be V. And the y-component is [13];

$$\frac{\partial y}{\partial t} + V\frac{\partial y}{\partial x}$$

For a small pipe segment of length *dx*, the kinetic energy is [1];

$$dT = \frac{1}{2} m_p \left(\frac{\partial y}{\partial t}\right)^2 dx + \frac{1}{2} m_f \left[V^2 + \left(\frac{\partial y}{\partial t} + V\frac{\partial y}{\partial x}\right)^2\right] dx \qquad \ldots (1)$$

The strain energy is [1];

$$dS = \frac{1}{2} EI\left(\frac{\partial^2 y}{\partial x^2}\right)^2 dx + \frac{1}{2} PA_p \left(\frac{dy}{dx}\right)^2 dx \qquad \ldots (2)$$

Using Hamilton's principle, one get [1];

$$\delta \int_0^t \int_0^x \{ \frac{1}{2} m_p \left(\frac{\partial y}{\partial x}\right)^2 + \frac{1}{2} m_f \left[V^2 + \left(\frac{\partial y}{\partial t} + V\frac{\partial y}{\partial x}\right)^2\right] - \frac{1}{2} EI\left(\frac{\partial^2 y}{\partial x^2}\right)^2 dx - \frac{1}{2} PA_p \left(\frac{dy}{dx}\right)^2 dx \}\, dxdt = 0 \qquad \ldots (3)$$

Performing the variation and integrating by parts results the following equation of motion is obtained;

$$EI\frac{\partial^4 y}{\partial x^4} + (m_f V^2 + PA_p)\frac{\partial^2 y}{\partial x^2} + 2m_f V\frac{\partial^2 y}{\partial x \partial t} + (m_f + m_p)\frac{\partial^2 y}{\partial t^2} = 0 \qquad \ldots (4)$$

Eq. (4) can be written in the following dimensionless form;

$$\eta^{IV} + (U^2+\gamma)\,\eta'' + 2U\beta\eta' + \ddot{}\ddot{}\Omega^2 = 0 \qquad \ldots (5)$$

Where;

$\zeta = x/L$, $\eta = y/L$, $U = VL.\sqrt{m_f / EI}$,

$\gamma = PA_p L^2 / EI$,

$\beta = m_f/(m_f+m_p)$ and

$$\tau = (t/L^2).\sqrt{EI/(m_f + m_p)} \quad \text{.... (6)}$$

2.1 Characteristic Equation

Galarkin method is employed to discrete Eq. (6).For this purpose the following series is selected [8] ;

$$\eta(\zeta,\tau)= \sum_{n=1}^{\infty} \Phi_n(\zeta) u_n(\tau) \quad \text{... (7)}$$

Where, Φ_n (ζ) are the shape functions and u_n (τ) are time functions.

In case of beam –like pipes the normal modes of beams can be used as shape functions as a good approximation for the pipes vibrations as well as they automatically satisfy all the boundary conditions.

By substituting eq.(7) into eq.(5) the following relation is obtained;

$$\sum_{n=0}^{\infty} (\Phi_n^{IV} + (U^2+\gamma)\Phi_n'' + 2i\beta U\Omega\Phi_n' - \Omega^2\Phi_n)u_n = 0 \quad \text{.... (8)}$$

In which $\Phi_n(\zeta)$ and $u_n(\tau)$ are replaced by Φ_n and u_n for simplicity. Then multiplying eq. (8) by the boundary residual value function Φ_k and integrating along the whole span of the pipe and setting the final result to zero, to get;

$$\int_0^1 \{ \sum_{n=1}^{\infty} (\Phi_n^{IV} + (U^2+\gamma)\Phi_n'' + 2i\beta U\Omega\Phi_n' - \Omega^2\Phi_n) \sum_{k=1}^{\infty} \Phi_k \} = 0 \quad \text{..... (9)}$$

It was demonstrated that the analysis of stability of gyroscopic systems can satisfactory be made by using two mode Galarkin analysis [5] .For non-conservative pipes such as cantilever the accurate analysis require more than five modes [13].Hence, the present analysis is restricted for conservative pipes only.

Using two mode beam analysis (n =2, k =2) the following matrix equation is resulted;

$$([C] + R\,[A] + 2i\beta\, U\Omega\, [B] - \Omega^2\, [I])\, \{u\} = 0 \quad \text{.... (10)}$$

Where;
$R=U^2+\gamma$,
[I]: is identity matrix and;

$$[A]=\begin{bmatrix} \int_0^1 \Phi_1'' \Phi_1 d\zeta & \int_0^1 \Phi_2'' \Phi_1 d\zeta \\ \int_0^1 \Phi_2'' \Phi_2 d\zeta & \int_0^1 \Phi_2'' \Phi_2 d\zeta \end{bmatrix},$$

$$[B]=\begin{bmatrix} \int_0^1 \Phi_1' \Phi_1 d\zeta & \int_0^1 \Phi_2' \Phi_1 d\zeta \\ \int_0^1 \Phi_2' U_2 d\zeta & \int_0^1 \Phi_2' \Phi d\zeta \end{bmatrix},$$

$$[C]=\begin{bmatrix} \int_0^1 \Phi_1'''' \Phi_1 d\zeta & \int_0^1 \Phi_2'''' \Phi_1 d\zeta \\ \int_0^1 \Phi_2'''' U_2 d\zeta & \int_0^1 \Phi_2'''' \Phi_2 d\zeta \end{bmatrix} \quad \text{..... (11)}$$

and Φ_1 and Φ_2 are the first and second beam mode functions for specific boundary conditions.

In the following the three types of conservative pipes conveying fluid will be investigated:-

I.pinned –pinned pipe

In this case the mode functions and the Eigen-values are [14];

$\Phi_n(\zeta)=\sin \eta_n \zeta$, $\eta_{1,2\ n}= n\pi$, n=1,2 ….(12)

Substitute eq.(12) into eq.(11) and performing the integrations and making use of the orthogonally concept, the matrices **[A], [B]** and **[C]** can be evaluated.

For nontrivial solution one must have;

$$\begin{vmatrix} -0.5\Omega^2 - 4.9348R + 48.705 & i2.667\Omega\beta U \\ -i2.667\Omega\beta U & -0.5\Omega^2 - 19.739R + 779.28 \end{vmatrix} = 0 \quad \text{.... (13)}$$

Where;
$R=U^2+\gamma$

Expansion the determinant in eq.(13) leads to the following characteristic equation;

$$\Omega^4-(28.443\,\beta^2U^2-49.348R+1656.0)\,\Omega^2+389.63R^2-19228.0R+151822.0=0 \quad \text{.... (14)}$$

II.clamped-pinned pipes

The mode functions and the Eigen-values are [14];

$$\Phi_n(\zeta)=\cos\eta_n\zeta-\cosh\eta_n\zeta-\frac{\cos\eta_n-\cosh\eta_n}{\sin\eta_n-\sinh\eta_n}(\sin\eta_n\zeta-\sinh\eta_n\zeta),\quad \eta_{1,2}=3.927, 7.069, n=1,2 \quad \text{...(15)}$$

Substituting eq.(15) into eq.(11) and proceeding as in the above will yield the following characteristic equation;

$$\Omega^4+(54.415R-35.903\beta^2U^2-2734.5)\,\Omega^2-(0.0374R\beta U+1.4091\,\beta U)\,i\Omega+475.55R^2-38951.0R+593844.0=0 \quad \text{...... (16)}$$

III. clamped-clamped pipes.

The mode functions and the Eigen-values are [14]:-

$$\Phi_n(\zeta)=\cos\eta_n\zeta-\cosh\eta_n\zeta-\frac{\cos\eta_n-\cosh\eta_n}{\sin\eta_n-\sinh\eta_n}(\sin\eta_n\zeta-\sinh\eta_n\zeta)\ ,\quad \eta_{1,2}=4.73, 7.853\ ,n=1,\ldots..(17)$$

Substituting eq.(17) into eq.(11) and proceeding as for the case of pinned-pinned pipe will result in the following characteristic equation:-

$$\Omega^4-i0.014489\Omega^3\beta U+(58.291R-\ 44.762\beta^2U^2-4303.1)\Omega^2-(0.10977R\beta U-5.6809\ \beta\ U)i\ \Omega + 565.83R^2-69807R+\ 1.9034\text{x}10^{\wedge}6=0 \quad \ldots.(18)$$

3. Results and Discussions.

For the purpose of illustration, a typical plot of the stability boundary for clamped-pinned pipe conveying fluid at γ=0 and β=0.9 is constructed in fig.(2).To construct such a figure the roots of eq.(16) are evaluated for various values of the dimensionless velocity *U*. It should be mentioned that the fourth order polynomial equation like eq.(16) gives four roots for Ω .However in this case(and for others ,also) each two of these four roots are equal in magnitude but with opposite signs .If these roots are squared then only two values of them are different . Finally the square values of the roots and *U* are plotted to get the root locus as shown in fig.(2).

To inspect the stability behavior the following rules are followed [7]:-

1. When all the roots lie in the first quarter (or to the right of the line Ω^2=0) in Ω^2-U^2 plane the pipe is stable.
2. If at least one of the two roots lies in the second quarter the pipe is unstable.
3. Buckling instability initiates at the points of intersection of the root locus with the line Ω^2=0
4. Flutter instability initiates at the maximum point of the root locus.

Now, referring to fig.(2) the following sequence of the stability behaviors can be observed:-

- At U^2 Є[0,20],the pipe is stable since all values of Ω^2 lie to the right of the line Ω^2=0.
- At U^2 Є[20, 62], the pipe is under buckling instability since some values of Ω^2 lie to the left.
- At U^2 Є[62, 71], the pipe regains its stability as in the first case.
- For U^2 >71 the pipe is at flutter instability.
- Points A and B are the critical points of buckling instability since they lie on the line Ω^2=0 -
- Point C is the critical point of flutter instability which is the maximum point in the plot.

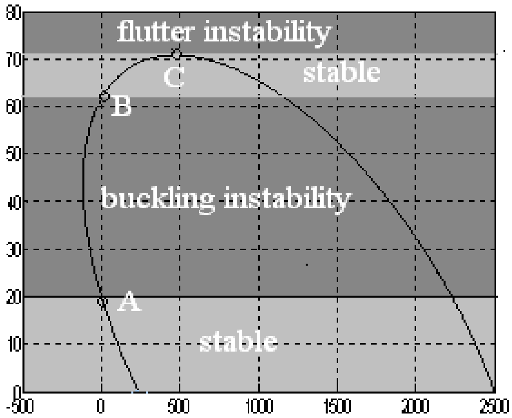

Figure (2): Stability boundary for c-p pipe at γ=0,β=0.5

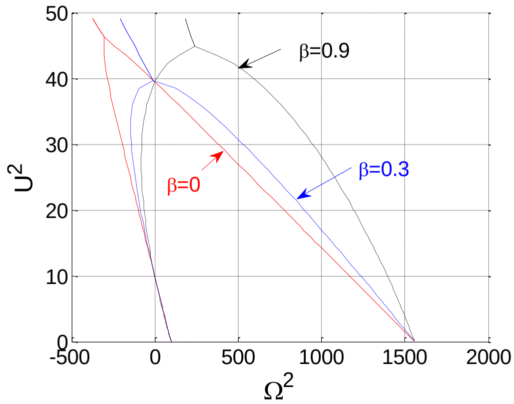

Figure (3): Stability boundary of p-p pipe at γ=0.

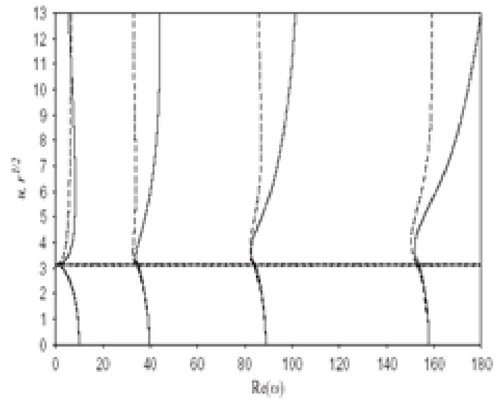

Figure.(4): Stability analysis of p-p pipe , Ref[11]

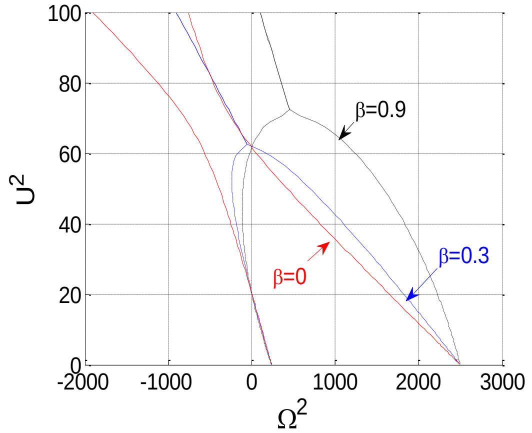

Figure (5): Stability boundary of c-p pipe at γ=0

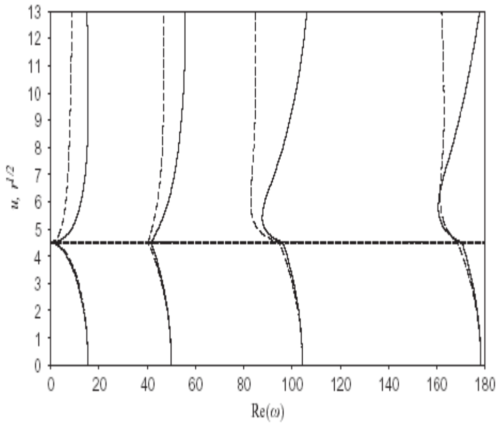

Figure (6): Stability analysis of c-p [11]

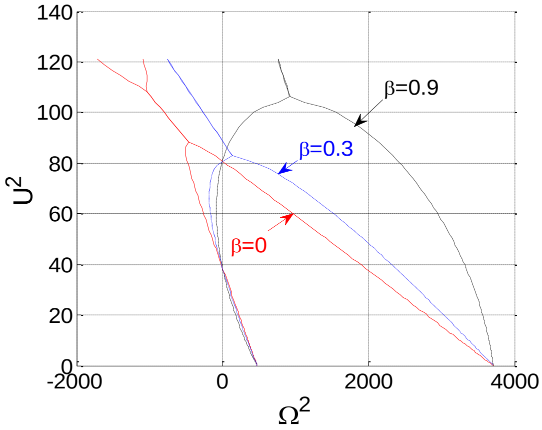

Figure (7): Stability boundary of c-c pipe at γ=0

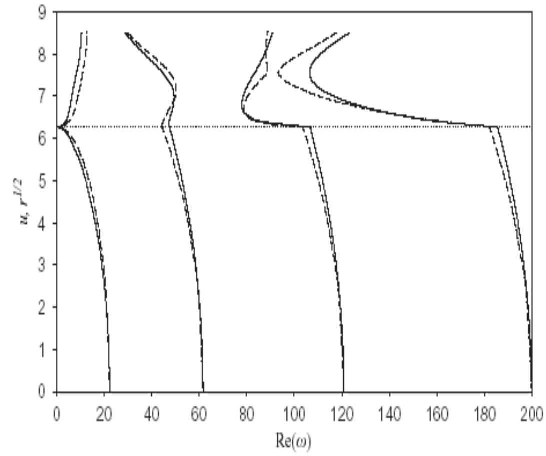

Figure (8): Stability analysis of c-c pipe 11]

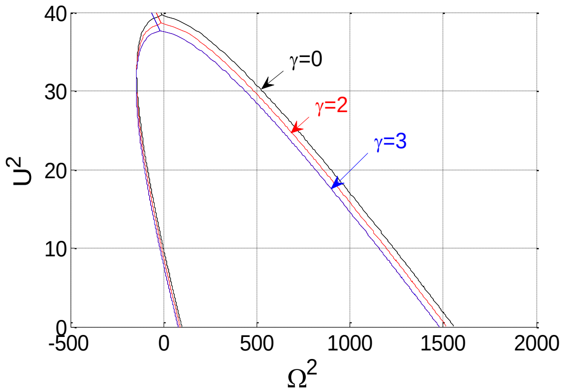

Figure (9): Stability boundary of p-p pipe at β=0.5,

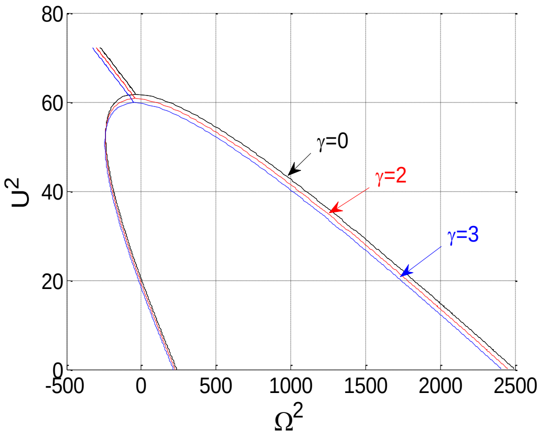

Figure (10): Stability boundary of c-p pipe at β=0.5.

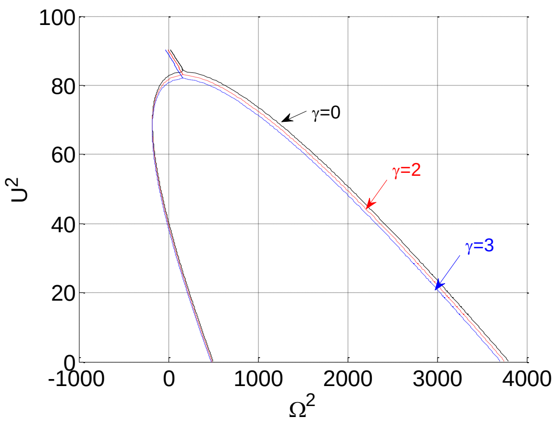

Figure (11): Stability boundary of c-c pipe at β=0.5.

To check the validity of the present approach the results of stability of p-p, c-p and c-c pipes according to the present approach are plotted in figs.(3,5 and 7) while those according to Ref.(11) are shown figs.(4,6 and 8) .As it can be seen from these figures that the critical velocities of buckling are coincided (taking into account that they are squared in the present approach) .Also, the natural frequencies of the first and the second modes are nearly the same .

For further checking, many points in figs. (3,5 and 7) are compared with the other available results in the literature .For example at U^2=0 these figures gives the square of the first and second natural frequencies of corresponding beams which are 79 and 41 for pinned-pinned , 1559 and 237 for clamped-pinned and 2497and 500.6 for clamped-clamped pipes as seen in Meirovitch [14]. This is true since the pipe is reduced to a beam as the fluid velocity becomes zero according to eq.(6). Also, in figs.(3-5) the lowest points of intersections of the plots with the line Ω^2=0 for any β are 9.61, 20.25 and 40.7, respectively. These are nearly the square of π,4.5and 2 π ,respectively which are the critical velocities for first mode buckling of the mentioned pipes as they are given in refs [2] and [3].

The fundamental natural frequencies Ω_1 at $\gamma = 0$ can be calculated from the following approximated formulas taken from ref. [13]:-

$$\Omega_1 = \pi^2 \sqrt{1 - \frac{U^2}{\pi^2}}$$

$$\Omega_1 = 3.93^2 \sqrt{1 - 0.747 \frac{U^2}{3.93^2}}$$

$$\Omega_1 = 4.73^2 \sqrt{1 - 0.55 \frac{U^2}{4.73^2}} \quad \text{.... (19)}$$

for p-p, c-p and c-c pipes, respectively.
Table (1) show such calculation and associated error between the present approach results and those of ref.[13]

Table (1): Comparison Ω and U values between the present approach and those of ref.[13]

U	Ω of p-p pipe			Ω of c-p pipe			Ω of c-c pipe		
	Present	Ref.(13)	E%	Present	Ref.(13)	E%	Present	Ref.(13)	E%
0	9.6631	9.8696	-2.03	15.215	15.4182	-1.3	22.2580	22.3733	-0.55
0.6283	9.4889	9.6702	-1.86	15.156	15.2700	-0.7	22.0668	22.2645	-0.90
1.2566	8.7500	9.0456	-3.20	14.625	14.8167	-1.14	21.689	21.9347	-0.92
1.8850	7.6589	7.8957	-2.92	13.8596	14.0285	-1.0	21.1258	21.3739	-1.12
2.5133	5.5890	5.9218	-5.10	12.6256	12.8441	-1.56	20.314	20.5630	-1.45
*3.1416	0	0	0	9.895	10.1377	-2.31	19.0589	19.4709	-2.63
3.7699				8.255	8.6042	-4.65	17.5258	18.0466	-2.77
*4.3982				0	0	0	15.458	16.2026	-4.93
5.0265							9.1548	9.7716	-6.43
5.6549							3.50589	3.8432	-7.89
*6.2832							0	0	0

*: critical

In figs.(3, 5 and 7), the stability boundaries at β = 0.3, 0.5 and 0.9 are presented, also. As it is clear from these figures the effect of varying β is significant on flutter instability since the maximum points on the plots are either shifted to the right as β increased or it may vanish as in fig.(4) for β =0.3. It should be noted that according to this effect the sequence of stability is dramatically altered. For example in fig.(3) at β=0.3 the sequence of stability is:- stable, buckling, and flutter while at β=0.9 it becomes:- stable, buckling, stable and flutter .This also true for the other figures .However β has no effect on buckling instability since the critical points for buckling (the intersection points with line Ω^2=0) are not affected in all cases.

The effect of the fluid pressure is presented in figs.(9),(10) and(11) where γ =0,2 and 3 are selected .It is clear from these figures that the effect of increasing γ is to slightly shifted of the stability boundary to lower values for all of the considered pipes .However the sequences of stability are not altered .

Finally it is important to state that ;the graphical results given in this study can be used to test the stability of any conservative pipe since they are given in dimensionless form .For example for a specific pipe (dimensions , material and boundary conditions) containing a specific fluid at given velocity and pressure , the dimensionless parameters U,β and γ can be calculated from eq.(6) and the stability can be tested using the corresponding figure .

4. Conclusions

The concept of a "stability boundary" can be used as an alternative approach for investigating the sequence of stability for conservative pipes conveying fluid. This approach provide a simple and effective method for analyzing stability at a wide range of the fluid velocities.

The validity of present approach was examined by comparing the present results with the available data in the literature, and show good agreement.

The fluid-mass ratio has a significant effect on the flutter instability and hence the stability behaviors .However the effect of increasing the fluid pressure is to shift the boundaries to a slightly lower values without altering the sequence of the stability.

5. References

1- Bishop R.E. and Fawzy I,"Free and Forced Oscillation of Vertical Tube Containing a flowing Fluid", Philosophical Transactions of Royal Society of London, Ser.A 284, 1976, 1-47

2- Weaver D.S. and Unny T.E.,"On the Dynamic Stability of Fluid Conveying Pipe" ASME, 1973, 48-50

3- Kuiper G.L. and Metrlkine A. V.,'On stability of a Clamped-Pinned Pipe Conveying Fluid', Heron, Vol 49 No.3, 2004, 211-230

4- Si-Ung R., Yoshihiko S. and Bong-Jo R. , "Eigenvalue Branches and Modes for Flutter of Cantilevered Pipes Conveying Fluid" Computers and Structures Vol.80 ,2002, 1231–1241

5- Huseyni K. ,"Vibrations and Stability of Multiple Parameter Systems ", Noordhoff International Pub., 1986

6- Sundraraian C. "On the Stability of Divergence-Type Elastic Systems", Devel. Theoret. Appl. Mech. Washington. D.C., 1974, 475-481.

7- Husyin K. and Plaut R. H. "Divergance and Flutter Boundary of Systems under Combined Conservative and Gyroscopic Forces ', Proc. IUTAM Symp. Dyn. Rotors, Lyngby, Denmark. Springer –Veriag, 1975, 182-205

8- Huseyin K., "Standard Forms of the Eigenvalue Problems Associated with Gyroscopic Systems" J. sound Vib. 45(1), 1976, 29-37

9- Li-Qun C. and Wei-Jia, Z. "A Conserved Quantity and the Stability of Axially Moving Nonlinear Beams ", Journal of Sound and Vibration Vol.286, 2005, 663–668

10- Elfelsou Z. and Azrar L., "Buckling, Flutter and Vibration Analyses of Beams by Integral Equation Formulations" Comp. Struct. , Vol. 83, 2005, 2632–2649

11- Plaut R.H., "Post buckling and Vibration of End-Supported Elastic Pipes Conveying Fluid and Columns under Follower Loads", J. Sound Vib. 289, 2006, 264–277

12-Paidousiss, M.P." The Canonical Problem of the Fluid-Conveying Pipe and Radiation of the Knowledge Gained to Other Dynamics Problems Across Applied Mechanics." J. Sound Vib. Vol.310, 2008, 462–492.

13- Huang, Y., Liu, Y. , Li, B., Li, Y. and Yue, Z.," Natural Frequency Analysis of Fluid Conveying Pipeline with Different Boundary Conditions" ,Nuclear Engineering and Design Vol.240 ,2010,461–467

14- Meirovitch, L. "Elements of Vibration Analysis", McGraw-Hill, USA, 1986

Notations and Nomenclature

(') : $\dfrac{\partial}{\partial \zeta}$

(.) : $\dfrac{\partial}{\partial \tau}$

p-p: Pinned-pinned pipe

c-p: Clamped-pinned pipe

c-c: Clamped-clamped pipe

A_f, A_p : Fluid and pipe cross sectional area , respectively. (m^2)

E: Modulus of elasticity. (N/m^2)

I: Area moment of inertia (m^4)

L: Pipe length. (m)

m_f, m_p: Fluid and pipe mass per unit length, respectively. (kg/m)

P: Fluid pressure. (N/m^2)

U: Dimensionless fluid velocity.

u_n: Generalized coordinates

Φ_n: Shape functions

V: Fluid velocity. (m/s)

η, ζ: dimensionless coordinates

U, β, γ: Dimensionless velocity, mass ratio, and dimensionless pressure, respectively

Ω: Dimensionless frequency = $\omega L^2[(m_f + m_p)/E\,I)^{1/2}$

ω :Circular frequency .(rad/sec)

τ: Dimensionless time.

ρ_f ,ρ_p :Fluid and pipe material density, respectively (kg/m^3)

أسلوب بديل لتحليل الاستقرارية للأنابيب الناقلة للموائع ذات الطاقة المحفوظة

البرت ايليا يوسف **محسن جبر جويج** **محمود رشيد اسماعيل**

كليه الهندسة - جامعه النهرين
بغداد-العراق
E-mail: mahmech2001@yahoo.com

الخلاصة:

تواكب بحوث الاستقرار العديد من المنظومات المرنة كالمنظومات الجايروسكوبية و الدورية ويستخدم مفهوم" حد الاستقرار" في تحليل الاستقرارية لتلك المنظومات عندما تتعرض الى احمال بارامترية (parametric loads) .تم في هذا البحث , توسيع هذا المفهوم ليشمل تحليل الاستقرار للانابيب الناقلة للموائع ذات الطاقة المحفوظة باعتبارها نوع من المنظومات الجايروسكوبية ايضا.في الطريقة الحالية , تم تجزئة منظومة الانبوب الى منظومة ذات درجتين من الحرية باستخدام طريقه "جالركين" وبعد حل المصفوفة المميزة الناشئة من تطبيق الظروف الحدية تم الحصول على معادلة الخصائص التي تربط بين معاملات المنظومة وتردداتها الطبيعية ومن خلال رسم مخططات المحال الهندسي لجذورهذه المعادلة تم تحديد المعالم الاساسية للاستقرار مثل الانبعاج والرفرفة واستعادة الاستقرار .كما وتم التاكد من صحه الطريقة من خلال مقارنة نتائجها مع نتائج منشوره اخرى , فبينت النتائج توافقا جيدا.كذلك تم البحث في تاثير خصائص المائع كالسرعه والضغط والنسبة الكتلية على استقرار الانابيب , فبينت النتائج التي اجريت على مدى واسع من سرع المائع ان للنسبة الكتلية التاثير الاكبر على تصرفات الاستقرار لكون تتابع اطوار الاستقرار يمكن ان يتغير بشكلواضح جدا , بينما يكون تاثير الضغط بسيطا لكونه لا يؤثر على ذلك التتابع .