American Journal of Mechanical Engineering, 2015, Vol. 3, No. 3, 98-104
Available online at http://pubs.sciepub.com/ajme/3/3/5

DOI:10.12691/ajme-3-3-5

Comparison between Theoretical, Analytical & Experimental Vibration Analysis Method & Different Circular Tile Cutter by Using FFT&ANSYS

Hirave S.H.[1,*], Jadhav S.M.[1], Joshi M.M.[2], Gajjal S.Y.[2]

[1]Department of Mechanical Design Engineering, NBN Sinhgad School of Engineering, Pune
[2]Department of Mechanical Engineering, NBN Sinhgad School of Engineering, Pune
*Corresponding author: sunilhrv@gmail.com

Received May 18, 2015; Revised June 02, 2015; Accepted June 28, 2015

Abstract Circular cutters with uniform radial cracks are extensively used in the cutting processes. Unwanted noise, vibration & accidental failure associated with the cutting process have become an important economic and technological problem in the industry. The knowledge of natural frequencies of components is of great interest in the study of response of structures to various excitations. Hence, it is important to study a circular tile cutter with central hole, which fixed at inner edge and free at outer edge with its dynamic response. In this study some efforts are taken for analyzing vibration characteristics of tile cutter used in tile cutting industries with free boundary condition but having different (enlargement of stress concentration holes, slot end hole diameter ,numbers of cutting teeth's, aspect ratio, effect of number and length of cracks, variable radial slit, circular concentric slit, thickness).Results From the FEA and FFT it is found that, this study is needful for design data preparation to avoid resonance and vibration in tile cutting industries from which finding out natural frequency and vibration w.r.t. different changes in tile cutter. Thus Theoretical, ANSYS & FFT results obtained are to be compared.

Keywords: *circular tile cutter, aspect ratio, teeth's, radial slit, circular concentric slit, different cracks, vibration ,FFT & ANSYS*

Cite This Article: Hirave S.H., Jadhav S.M., Joshi M.M., and Gajjal S.Y., "Comparison between Theoretical, Analytical & Experimental Vibration Analysis Method & Different Circular Tile Cutter by Using FFT&ANSYS." *American Journal of Mechanical Engineering*, vol. 3, no. 3 (2015): 98-104. doi: 10.12691/ajme-3-3-5.

1. Introduction

Unwanted noise, vibration & accidental failure associated with the cutting process has become an important economic and technological problem in the industry that can be solved by this dissertation work. Also natural frequency of theoretical, analytical & experimental methods are to be compared by using some theoretical formulae, FFT and ANSYS. Comparison results are tabulated in table and comparison graphs plotted in bellow. Natural frequency determine by 3 vibration method as discussed in short as bellow phases.

Figure 1. Sample of circular Tile-Cutter

Test Specimens:-Spring steel are chosen with same b/a ratio i.e. aspect ratio (Inner to outer radius ratio).Following are the material properties for the specimen tile cutter.

Young's modulus (E) = 2.1 X 10 ^{11} N/m^2
Poisson's ratio (γ) = 0 .3
Density of material (ρ) = 7800 kg/m^3
Dia =110 mm, t= 1.85mm, N=14500 rpm.

Different changes in Geometry:-Specimens with variable increase in no. radial crack, increase length of radial crack, slot end hole diameter, geometry of cutter tooth, enlargement of stress concentration holes, different thickness, aspect ratios , different no of cutting teeth are selected. These specimen sizes are chosen to facilitate the measurements by using the same fixture for all the specimens. As boundary conditions for cutter are inner edge fixed and outer edge free.

2. Different Phases

2.1. Theoretical Method

W. T. Norris and J. E. T. Penny have given values of $(\beta a)^2$ for various ratios of inner radius to outer radius and different mode characteristics. First six harmonics are given in order for aspect ratio (b/a =0.1). $(\beta a)^2$ Is non dimensional frequency parameter used to calculate natural frequencies of annular tile cutter.

$$(\beta\alpha)^2 = \omega a^2 \sqrt{\frac{3\rho(1-\upsilon^2)}{Eh^2}}$$

Where, h = half thickness in mm
E = Young's modulus N/m^2
ρ = Density of the tile cutter material in kg/m^3
ω = frequency in rad/s.
υ = Poisson's ratio taken as 0.3
a = Outer radius of tile cutter in mm

By putting all theoretical values as mentioned in test specimen w.r.t. different mode given bellow results are as tabulated follows. We will compare only aspect ratio and thickness these two parameter with theoretical, FFT & ANSYS results. Beside from that, remaining parameter will get from comparison in between different individual values of results. In that FFT as an experimental method & ANSYS as an analytical method.

2.2. Experimental Method

Procedure-Experimental work is done by using FFT analyzer. Natural frequencies are detected by hitting the tile cutter with impact hammer which was mounted on vice jaw. The response at a point of a plate is measured by using an accelerometer. FFT analyzer analyzed the output of accelerometer. Analysis is done experimentally with the help of FFT analyzer, accelerometer, impact hammer.

Text fixture- Clamping was obtained by using two 20mm diameter nuts and one bolt with washers are fastened below the tile cutter. Bolt is used to restrict the movement at inner edge of annular tile cutter in x and y and z direction. The fixture was hold in vice, which is rigidly fixed on table in which concrete foundation.

2.3. Analytical Method

ANSYS is universal software, which is used on simulation of the interactions in physics structures, vibration, fluid dynamics, thermal transfer and electro mechanics for engineers. We can simulate with ANSYS structures and then test them in the virtual environment. ANSYS can import CAD data and sketch of the geometry. ANSYS Workbench is a platform, which integrates simulation technologies and parametric CAD systems with unique automation and performance. some steps for analyzing as geometry Creation, Material Data selection, Boundary Condition, Mesh of Finite Elements and Modal Analysis.

3. Comparitive Results

3.1. Aspect Ratio

Sr.No	Natural frequency(Hz) by Aspect ratio(R)(CUTTER 1,6,&7)								
(Mode)	a =110 mm,R=0.182 (CUTTER 1)			a =108 mm,R=0.185 (CUTTER 6)			a =105mm,R=0.190 (CUTTER 7)		
	Theoretical	**Analytical**	**FFT**	**Theoretical**	**Analytical**	**FFT**	**Theoretical**	**Analytical**	**FFT**
1	563.60	570.31	566.4	589.74	593.05	634.8	633.82	630.6	595.7
2	616.69	659.2	664.1	643.64	679.31	732.4	687.73	716.13	683.6
3	774.88	1035.5	1084	807.76	1060.3	1093.8	861.31	1091.7	1093.8

3.2. Thickness

Natural frequency by thickness (CUTTER 1&8)					
a =110 mm, R=0.182 t=1.85 mm(CUTTER 1)			a =110 mm, R=0.182 t=1.2 mm(CUTTER 8)		
Theoretical	**Analytical**	**FFT**	**Theoretical**	**Analytical**	**FFT**
563.60	570.31	566.4	450.84	468.96	488.3
616.69	659.2	664.1	493.37	560.11	585.9
774.88	1035.5	1084	619.93	871.43	878.9

3.3. Other Parameter

Making stress concentration holes (cutter 2) and enlargement them (cutter 3)-Compare cutter 1,2 &3

Sr.No.	Natural frequency (ω in Hz)					
Mode	Cutter 1 (without hole)		Cutter 2 (making hole)		Cutter 3(enlarge hole)	
	FFT	Analytical	FFT	Analytical	FFT	Analytical
1	605.5	570.31	576.2	564.41	546.9	562.09
2	664.1	659.2	664.1	645.97	654.3	645.95
3	1084.0	1035.5	1054.7	1012	1044.9	1013.8

Increasing slot end diameter (cutter 4) and Number of teeth (cutter 5)-Compare cutter 1,4 &5

Sr.No.	Natural Frequency (ω in Hz)					
Mode	Cutter 1 (Original 9 teeth 4mm slot end dia.)		Cutter 4 (9 teeth & Increasing slot end diameter i.e.6 mm)		Cutter 5 (Increasing slot end 6 mm with10 teeth)	
	FFT	Analytical	FFT	Analytical	FFT	Analytical
1	605.5	570.31	546.9	545.65	556.6	548.52
2	664.1	659.2	654.3	647.9	654.3	648.59
3	1084.0	1035.5	1005.9	997.8	986.3	987.91

Variable radial slit (cutter 9) and circular concentric slit (cutter 10)-Compare cutter 1, 9 & 10

Sr No.	Natural Frequency (ω in Hz)					
Mode	Cutter 1 (Original)		Cutter 9 (3 cracks of length 24.5 mm with 2 mm dia.end circle)		Cutter 10 (3 cracks of length 24.5 mm with 2 mm circular end crack)	
	FFT	Analytical	FFT	Analytical	FFT	Analytical
1	605.5	570.31	556.6	547.59	566.4	551.4
2	664.1	659.2	644.5	640.56	654.3	644.16
3	1084.0	1035.5	1015.6	1007.1	1025.4	1018.9

Increasing number of cracks of same length 24.5 mm from centre with same teeth and outer dia.- Compare cutter 11,12 & 13.

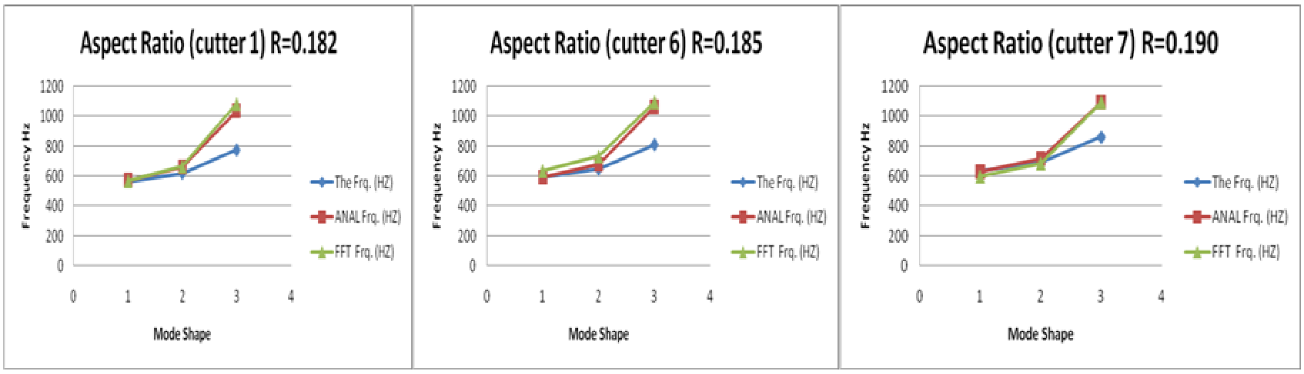
Sr No.	Natural Frequency (ω in Hz)(cracks from same length 24.5 mm)					
Mode	Cutter 11 (3 cracks)		Cutter 12 (6 cracks)		Cutter 13 (9 cracks)	
	FFT	Analytical	FFT	Analytical	FFT	Analytical
1	537.1	554.29	517.6	531.76	507.8	**518.36**
2	644.5	648.27	644.5	632.3	654.3	**633.99**
3	1044.9	1027	1035.2	1007.1	1044.9	**1022.5**

Increasing length of cracks up to 30 mm from centre with same teeth and outer dia.-Compare cutter 11,12,14 & 15

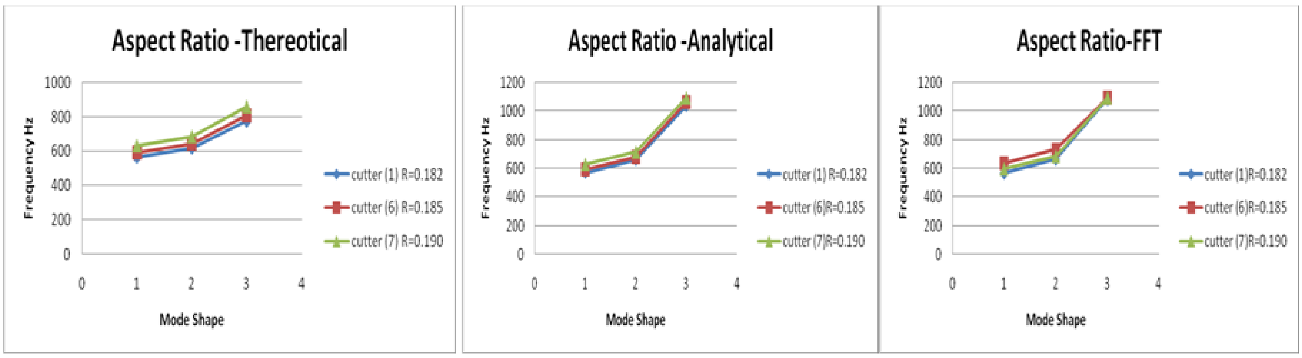
Sr.No.	Natural Frequency (ω in Hz)							
Mode	(3 cracks)				(6 cracks)			
	Cutter 11 (24.5 mm crack length)		Cutter 14 (30 mm crack length)		Cutter 12 (24.5 mm crack length)		Cutter 15 (30 mm crack length)	
	FFT	Analytical	FFT	Analytical	FFT	Analytical	FFT	Analytical
1	537.1	554.29	527.3	543.5	517.6	531.76	498.0	507.42
2	644.5	648.27	556.6	644.28	644.5	632.3	517.6	628.08
3	1044.9	1027	1044.9	1017.1	1035.2	1007.1	996.1	995.55

4. Comparitive Graphs

4.1. Aspect Ratio

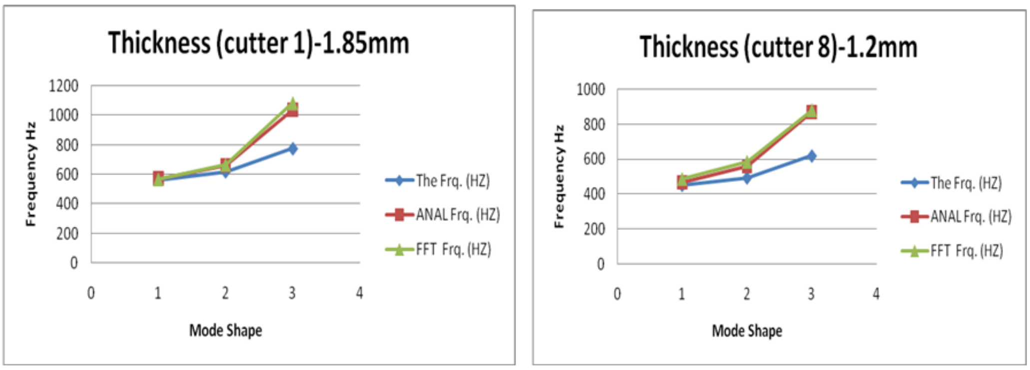


Graph (a.1). (1,6,7)-Natural frequency for same cutter with different theoretical ,analytical & FFT values

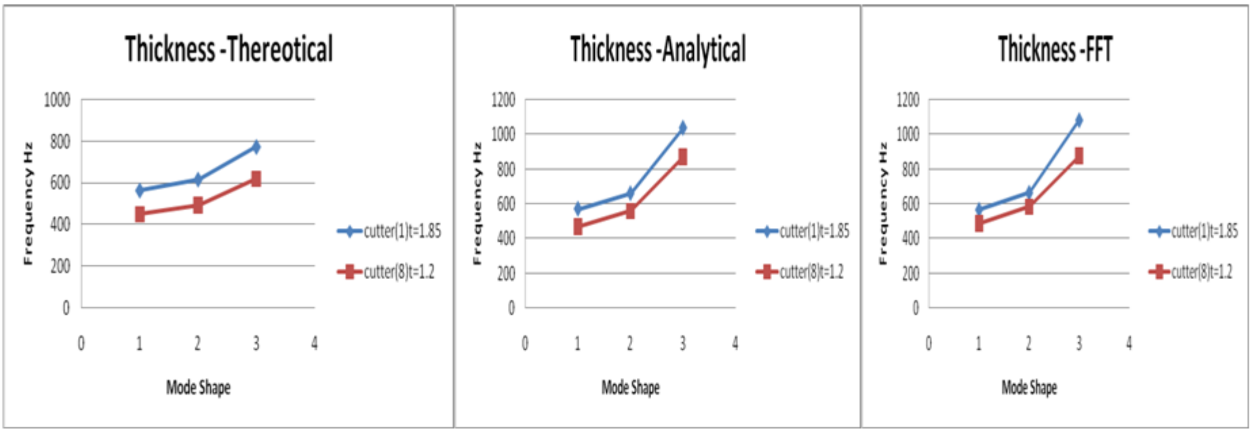


Graph (a.2). (1,6,7)-Natural frequency for different cutter with same theoretical ,analytical & FFT values

4.2. Thickness



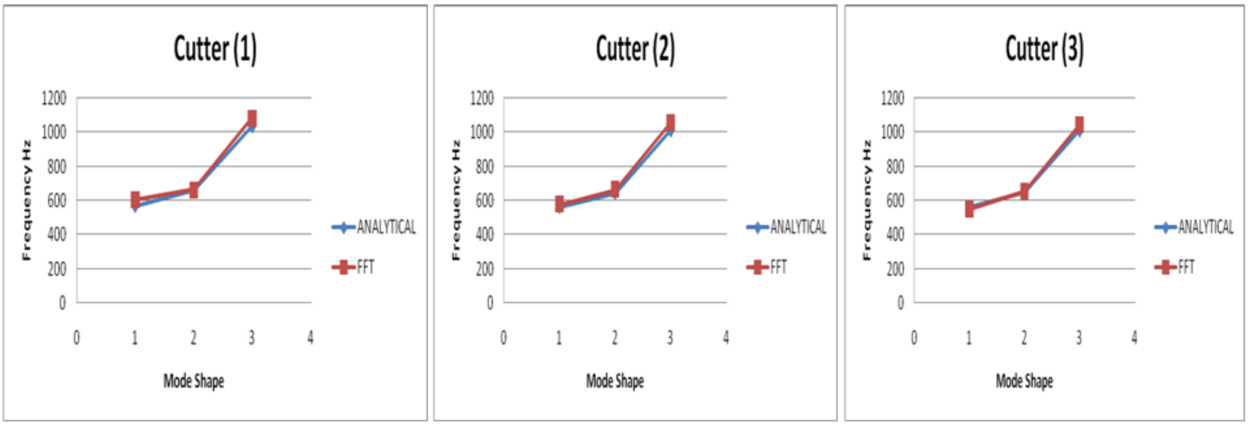
Graph (b.1). (1,8)-Natural frequency for same cutter with different theoretical ,analytical & FFT values



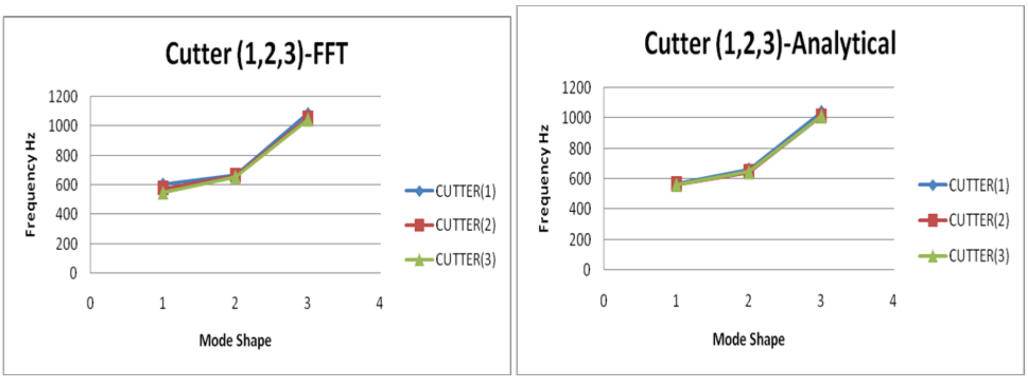
Graph (b.2). (1,8)-Natural frequency for different cutter with same theoretical ,analytical & FFT values

4.3. Other Parameter

Making stress concentration holes (cutter 2) and enlargement them (cutter 3)-Compare cutter 1,2 &3

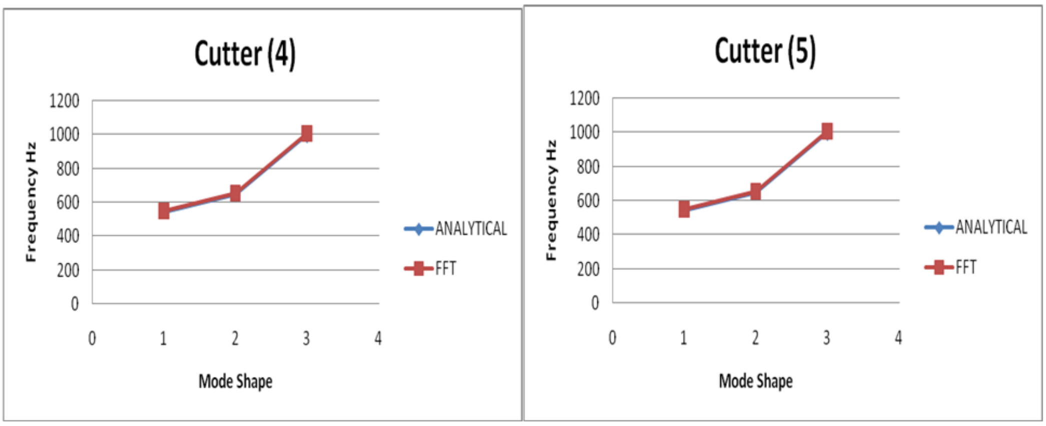


Graph (c.1.a). (1,2,3)-Natural frequency for same cutter with different analytical & FFT values

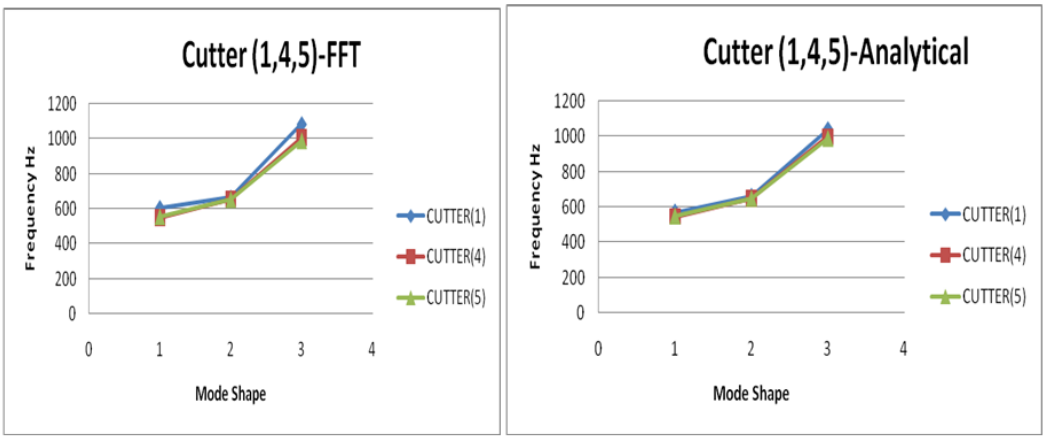


Graph (c.1.b). (1,2,3)-Natural frequency for different cutter with same theoretical ,analytical & FFT values

Increasing slot end diameter (cutter 4) and Number of teeth (cutter 5)-Compare cutter 4&5

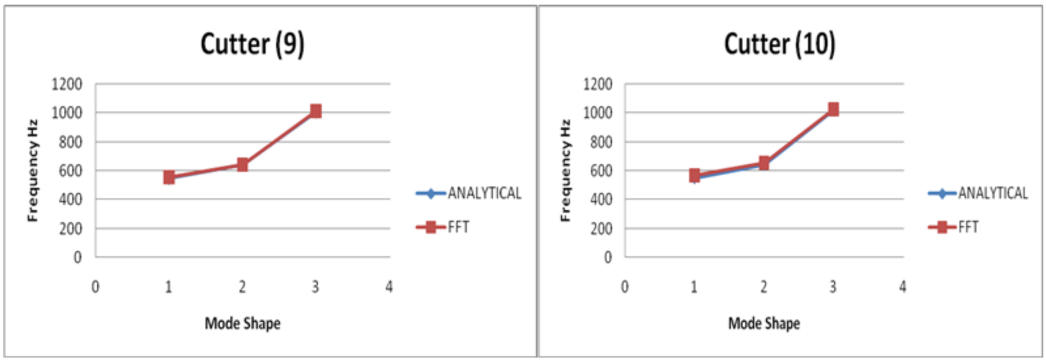


Graph (c.2.a). (1,4,5)-Natural frequency for same cutter with different analytical & FFT values

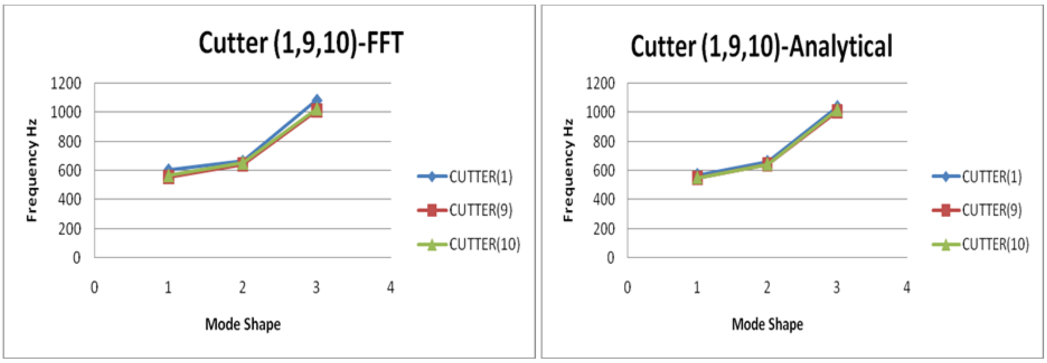


Graph (c.2.b). (1,4,5)-Natural frequency for different cutter with same analytical & FFT values

Variable radial slit (cutter 9) and circular concentric slit (cutter 10) –Compare cutter 1, 9 & 10

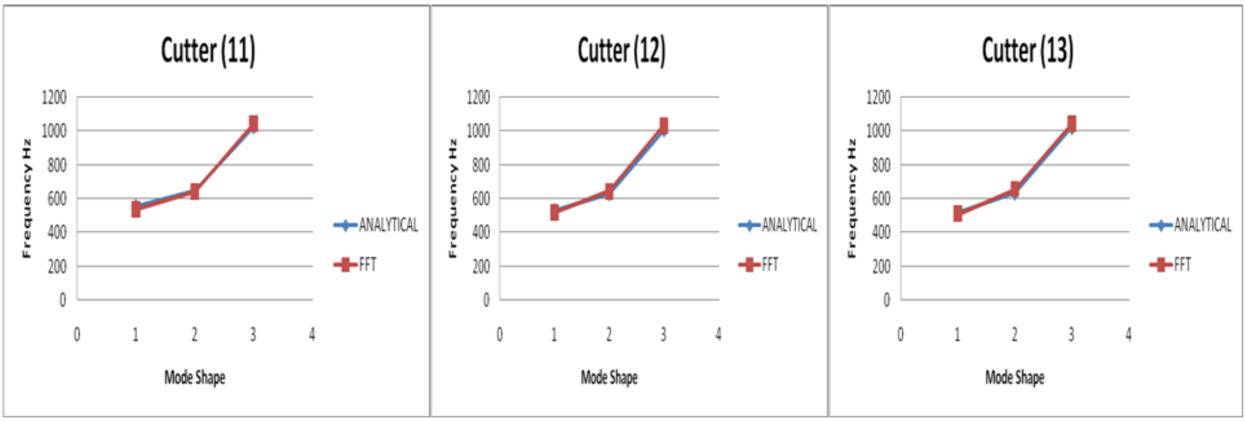


Graph (c.3.a). (1,9,10)-Natural frequency for same cutter with different analytical & FFT values

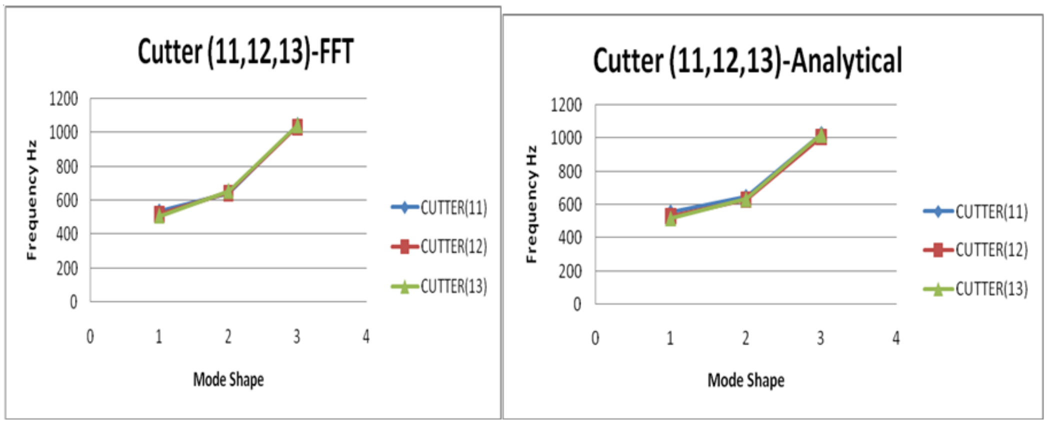


Graph (c.3.b). (1,9,10)-Natural frequency for different cutter with same analytical & FFT values.

Increasing number of cracks of same length 24.5 mm from centre with same teeth and outer dia.- Compare cutter 11,12 & 13

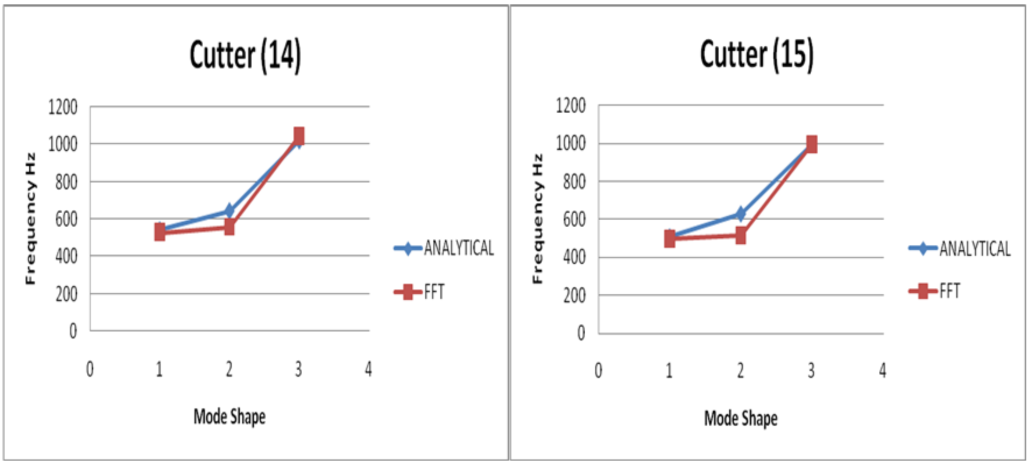


Graph (c.4.a). (11,12,13)-Natural frequency for same cutter with different analytical & FFT values

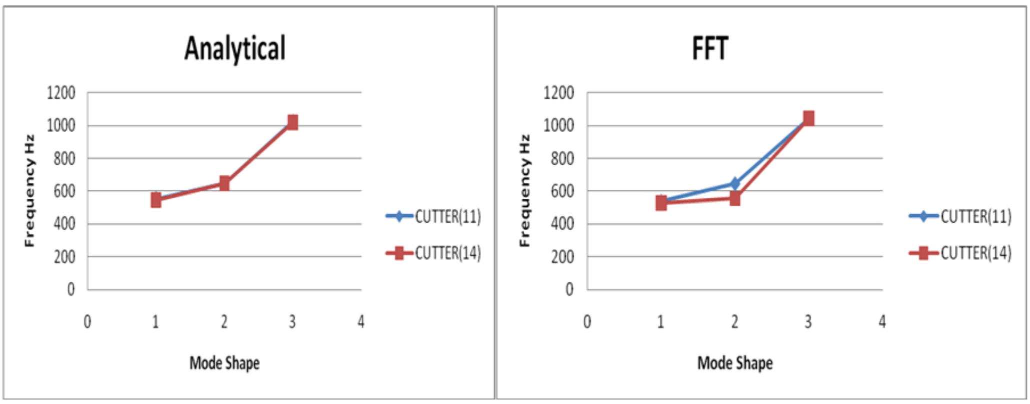


Graph (c.4.b). (11,12,13)-Natural frequency for different cutter with same analytical & FFT values.

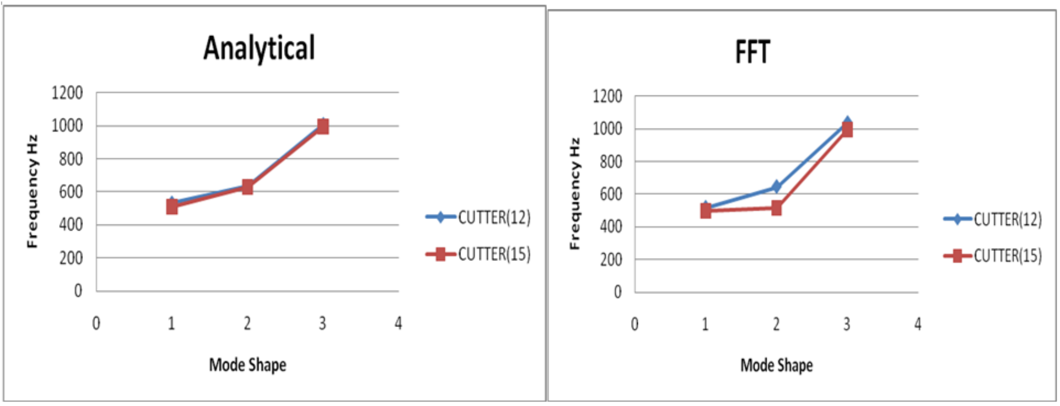
Increasing length of cracks up to 30 mm from centre with same teeth and outer dia.-Compare cutter 11,12,14 & 15



Graph (c.5.a). (11,12,14,15) -Natural frequency for same cutter with different analytical & FFT values



Graph (c.5.b). (11,14)-Natural frequency for different cutter with same analytical & FFT values



Graph (c.5.c). (12,15)-Natural frequency for different cutter with same analytical & FFT values.

5. Conclusion

Thus vibration analysis of circular tile cutter is done by using some theoretical, FFT & ANSYS. After prediction of natural frequency it will gives that future design scope to avoid resonance and vibration in tile cutting industries. Vibration described in terms of deformation in ANSYS analytical method and in terms of acceleration in FFT experimental method. From overall comparing all graph result it can gives that as,

a) Aspect ratio increases natural frequency increase. Also vibration will minimum in high aspect ratio tile cutter.(cutter 1,6& 7)

b) Thickness of tile cutter reduced then natural frequency also reduced. But vibration will more in reduced thickness tile cutter.(cutter 1 &8)

c) By making and enlargement of stress concentration holes natural frequency reduced. But enlargement of dia. of hole may cause high vibration (cutter 3) than only making of holes (cutter 2). So selected only making of mini. dia of holes causes less vibration.

d) Increasing slot end dia. natural frequency will minimum and as vibration also minimum.(cutter 1 &4)

e) Increase in number of teeth natural frequency will increases and vibration also increases.(cutter 4& 5)

f) By making 3 cracks at end of crack there is small hole having low natural frequency and high vibration than same no of crack but at end of crack there is small circular crack. (cutter 9 & 10)

g) Increasing no of cracks from 3 to 6 of same crack length (24.5 mm) natural frequency decreases with increase in vibrations. Next 6 to 9 cracks natural frequency and vibration both will increased. So select tile cutter with minimum no of cracks, up to 6 cracks will be fine w.r.t. mini. vibration.(cutter 11,12&13)

h) Increasing length of cracks (30 mm) with same no of cracks (3 or 6) natural frequency will decreases but vibration will more. So select minimum length of crack and minimum no of crack for minimum vibration than original cutter (1) (cutter 11,12, 14 & 15).

References

[1] W.M. Lee a, J.T.Chen, "Eigen solutions of a circular flexural plate with multiple circular holes using the direct BIEM and addition theorem", Journal of Engineering Analysis with Boundary Elements, Vol.2 Issue.4, July 2010, Pgs:1064-1071.

[2] L. Cheng,Y.Y. Li, L.H. Yam ,"Vibration analysis of annular-like plates ",Journal of Sound and Vibration ,2003, Pgs: 1153-1170.

[3] Sasank Sekhar Hot ,Payodhar Padhi ,"Vibration of plates with arbitrary shapes of cutouts", Journal of Sound and Vibration, 2007, Pgs: 1030-1036.

[4] D.V.Bambill, S.La.Malfa, C.A.Rossit, P.A.A.Laura, "Analytical and Analytical Investigation on Transverse Vibration of Solid, Circular and Annular Tile cutters Carrying a Concentrated Mass at an Arbitrary Position with Marine Applications", Journal of ocean Engineering, vol31, Pgs: 127-138.

[5] K. Ramesh, D.P.S. Chauhan and A.K. Mallik, "Free Vibration of Annular Tile cutter with Periodic Radial Cracks", Journal of sound and vibration, 1997, Pgs: 266-274.

[6] J.C. Bae and J.A. Wickert, "Free Vibration of Coupled Tile cutter-Hat Structures", Journal of sound and vibration, 2000, Pgs: 117-132.

[7] M. Haterbouch, R. Benamar "Geometrically nonlinear free vibrations of simply supported isotropic thin circular plates" Journal of Sound and Vibration, 2005, Pgs:903-924.

[8] P.A. Lauraa, U. Masia, D.R. Avalosb, "Small amplitude, transverse vibrations of circular plates elastically restrained against rotation with an eccentric circular perforation with a free edge" Journal of Sound and Vibration, 2006, Pgs: 1004-1010.

[9] W.T. Norris and J.E.T Penny, **"**Computation of the Resonant Frequencies of an Annular Tile cutter Encysted at its Inner Edge and Free at its Outer Edge", Aston University, Dec 2002.

[10] Chi-Hung Huang, "Vibration of Cracked Circular Tile cutters at Resonance Frequency"Journal of Sound and vibration, 2000, Pgs: 637-656.