Minimazation In Vibration Behaviour of Tile Cutters Using FFT Analyzer And FEA Technique

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Abstract- *To analyse the vibration characteristics of circular tile cutter with respect to increase no. radial cracks, length of radial crack, increase slot end hole diameter, adding damping material, reduction in operating and peripheral velocity, reduction in width, reduction in area, height of teeth and no of teeth, diameter of hole, Analysis of stress distribution depending on depth of cut and cutting speed, adding quantity of concentrated mass and in related to material selection. Experimental set up of tile cutter is done for inner edge clamped and outer edge free boundary condition.*

Keywords- Vibration characteristics, tile cutter, FFT analyser, impact hammer.

I. INTRODUCTION

In tile cutting operation only one type of cutter is selected. People are getting trouble by using that cutter with respect to vibration point of view. Vibrations are creating in tile cutting operation. From same sample cutters are selected with respect to different changes so that we comment on vibration and natural frequency. There many parameter required to consideration for minimize vibration in tile cutter. Which contain increase in no. radial crack, increase length of radial crack, slot end hole diameter, geometry of cutter tooth, material selection, adding damping material, enlargement of stress concentration holes, applying mass concentration. Primary purpose of modification of such tile cutter beside from minimization of vibration is to allow thermal expansion during the cutting process without development of circumferential stresses. Often in practice a hole is cut at the end of slots in order to relieve the radial stress introduced by the slot which can cause by cracking. Further modern trend to manufacturer tile cutter with computer aided laser. Also examine usefulness of various Laser cut slot pattern including radial slots. Also by applying rotational velocity stress distribution known at centre is high around the cutter hole which will minimizes outwards and at outer edge again maximum.

1. Problem Statement

Effect of vibration analysis is important for circular tile cutter. This is made for determining different parameters like natural frequency, mode shapes, as it is important to reduce vibration in many tile cutting industries. Hence experimental work is necessary to conduct on circular tile cutter with inner edge clamped and outer edge free for different condition like radial crack, slot end hole diameter ,geometry of cutter tooth, material selection ,damping ,mass concentration, stress concentration.

II. THEORETICAL METHOD FOR FINDING NATURAL FREQUENCIES

Assumptions-

1) Scratching of the middle surface of the tile cutter is neglected in order to keep the equation of motion linear.
2) Influence of the shear force and rotary inertia is ignored. It is also assumed that the plane cross section before and after deformation remain plain.
3) The deflection considered is also small.
4) Tile cutter is thin, i.e. thickness of the tile cutter is small than its outer dimensions.

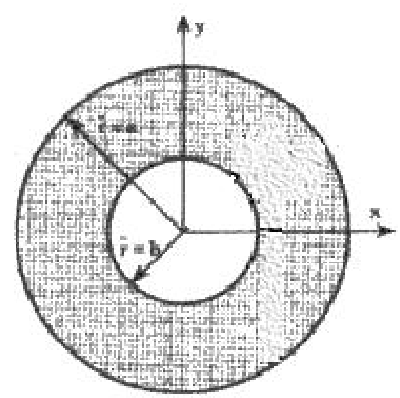

Figure 1. Selecting Circular cutter as Tile Cutter [Ref.9]

Prof.W. T. Norris and J. E. T. Penny, Ref.[9] have given values of $(\ a)^2$ for various ratios of outer radius to inner radius and different mode characteristics. First six harmonics are given in order for aspect ratio (b/a =0.1). $(\ a)^2$

Is non dimensional frequency parameter used to calculate natural frequencies of circular tile cutter.

$$(\;a)^2 = \mu\ a^2 \sqrt{\frac{3\,^\circ\,(1-{}^{3\,2})}{Eh^{2}}}$$

Where,
h=half thickness inmm,
E=Young's modulus N/m2)= 2.1 X 10 11 N/m2
$^\circ$ = Density of the tile cutter material in kg/m3= 7800 kg/m3
μ = frequency in rad/s,
^{3} = Poisson's ratio taken as 0.3
a = Outer radius of tile cutter in mm,
Thickness of the tile cutter 2h= 1.85mm

A. Different changes in tile cutter

1. Original cutter with having 110 mm outer diameter and 20 mm inner diameter.
2. Making 1 mm hole diameter with 120 degree in between inner and outer diameter with respect to same 9 teeth and slot end dia.4 mm.
3. Enlargement of hole up to 2 mm diameter with 120 degree in between inner and outer diameter with respect to same 9 teeth and slot end dia.4 mm.
4. Reducing thickness up to 1.2 mm for same 9 teeth.
5. Making 3 cracks with 120 degree of length 24.5 mm from centre with respect to same teeth and outer diameter is 110 mm.
6. Making 6 cracks with 60 degree of length 24.5 mm from centre with respect to same teeth and outer diameter is 110 mm.
7. Making 3 cracks with120 degree of length 30 mm from centre with respect to same teeth and outer diameter is 110 mm.
8. Making 6 cracks with60 degree of length 30 mm from centre with respect to same teeth and outer diameter is 110 mm

2. Finding Natural frequency for tile cutter with aspect ratio=0.182 & a = 55mm

Dimensions of circular cutter test specimen are as below:
Inner radius of the tile cutter b=10 mm
Outer radius of the tile cutter a=55 mm
Thickness of the tile cutter 2h= 1.85mm

We know, $(\;a)^2 = \mu\ a^2 \sqrt{\frac{3\,^\circ\,(1-{}^{3\,2})}{Eh^{2}}}$

For first mode, $(\;a)^2$ =4.56

$$(\;a)^2 = \mu\ a^2 \sqrt{\frac{3\,^\circ\,(1-{}^{3\,2})}{Eh^{2}}}$$

$\therefore\ \mu =$ 563.60 Hz

For second mode, $(\;a)^2$ = 4.99

$$(\;a)^2 = \mu\ a^2 \sqrt{\frac{3\,^\circ\,(1-{}^{3\,2})}{Eh^{2}}}$$

$\therefore\ \mu =$ 616.69 Hz

For third mode, $(\;a)^2$ =6.27

$$(\;a)^2 = \mu\ a^2 \sqrt{\frac{3\,^\circ\,(1-{}^{3\,2})}{Eh^{2}}}$$

$\therefore\ \mu =$ 774.88 Hz

III. NUMERICAL METHOD (FINITE ELEMENT ANALYSIS)

Modal analysis determines the vibration characteristics (natural frequencies and mode shapes) of a structure or machine components. Same set of command is used for modal analysis that used in any other type of finite element analysis. Likewise, choose similar option from the graphical user interface (GUI) to build and solve models. Steps involved in modal analysis

Geometry Creation-Geometry is created using CATIA V5 CAD Tool.

1) Material Data-Apply material property as per specification. Boundary Condition-The material properties are assigned and boundary conditions are defined. The all degrees of freedom on surface are taken.
2) Mesh of Finite Elements-Mesh on the beam is generated automatically by ANSYS, while is used the tetrahedral elements.
3) Analysis-We can influence computational time of the analysis, when a range of frequencies or number of mode shapes is specified. The type of solver and the solution method in program ANSYS is selected automatically. For this modal analysis the direct solver method is used.

1) Major steps

1) ANSYS → Workbench 15.0 → Modal → Engg.data (material property) Geometry → Import geometry → Model
2) Model → Mesh update → Statistics Nodes → Element →
3) Solution → Insert → Analysis Setting Boundary condition (first fixed support and second rotational velocity) → Deformation

4) Model → Set up → Solution
For meshing, triangle surface mesh used in which minimum 1 mm and maximum 6 mm size required. Also tetrahedral elements are selected. Total 24595 nodes and 12331 elements are used, for meshing simple steps are,

Mesh → Insert → Sizing (load control patch conforming)

3. Analysis Procedure

The procedure for a typical ANSYS analysis can be divided into three distinct steps

1) Build the model, applying boundary condition (Pre-processor)
2) Processing or solution (Solver)
3) Review the results (Post-processor)

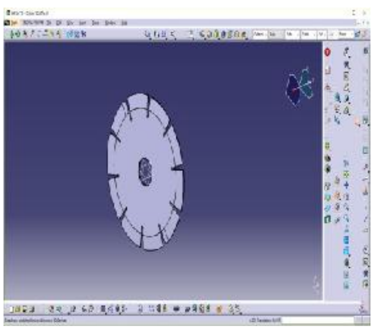

Figure 2. CUTTER (1)

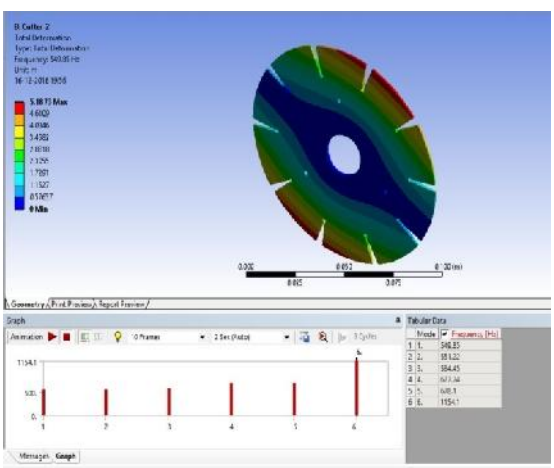

Figure 3. Natural frequency &Deformation plot in ANSYS for Tile cutter 1

4. Manufacturing

Different changes in tile cutter

All different changes in tile cutter like stress concentration holes are made by using laser and wire cutting. By considering all cutter impact test is done.

Laser and Wire cutting

In laser and wire cutting tile cutter location shown below fig. which will gives complete fixture with respect to foundation fixture and by using laser rays there is formation of slots, holes and increase in diameter like changes are formed. There is computational data program exist only applying three dimensions at three direction X,Y &Z. we will get different changes in tile cutter.

Figure 4. Tile cutter locations in wire cutting

5. Testing

Instrumentation Used for Modal Analysis

a) FFT analyzer b) Accelerometer c) Impact Hammer

Fast Fourier Transform

FFT is a popular computer program to convert data from time domain to frequency domain (PSD) or vice versa. With Fourier transform any random loading signal can also be represented as a sine wave functions each having a unique set of values for amplitude. A spectrum analyzer is an electronic device that is capable of taking the time waveform of a given signal and converting it into its frequency domain. Importance of spectrum analyzer by J. B. Fourier mathematician showed that it is possible to represent any time waveform (the plot of a signal whose amplitude varies with time) by a series of sins and cosines of particular frequencies and amplitudes. A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument.

Accelerometer

The benefit to use accelerometers is that they do not require a calibration program to ensure accuracy. From the accelerometer record, the velocity and displacement are obtained.. Most are constructed of polycrystalline ceramic piezoelectric materials because of their ease of manufacture, high piezoelectric sensitivity, and excellent time and temperature stability.

Impact Hammer

It is a built up force transducer in its head..The shape of frequency response is dependent on the mass and stiffness of the hammer and structure. The impact force caused by impact hammer, which is nearly proportional to the mass of the hammer head and the impact velocity. It can be found from the force transducer embedded in the structure at an impulse is composed of excitation at each of the natural frequencies of the structure. The impact hammer is simple portable, inexpensive.

Circular Tile Cutter structure Model

In analysis, circular tile cutter structure is used for investigating the tile cutter's bending modes. The structure is axi-symmetric and formed of an isotropic homogeneous elastic material. Three dimensional parameters represents the cutter inner radius (b),outer radius(a) and thickness (h) respectively.

Test Specimen

Total fifteen circular tile cutter specimen of Spring Steel are chosen with variation in b/a ratio i.e. aspect ratio (Inner to outer radius ratio).Following are the material properties for the specimen tile cutters.

Figure 5. Circular tile cutter

Young’s modulus (E)= 2.1 X 10 11 N/m2,
Poisson’s Ratio=0 .3,
Density of material (ρ) = 7800 N/m3

Inner diameter of the tile cutter is 20 mm while outer diameter is 110 mm; thickness of the tile cutter is kept 1.85 mm for specimens. These specimen sizes are chosen to facilitate the measurements by using the same fixture for all the specimen tile cutters. As boundary conditions for tile cutter specimen are inner edge fixed and outer edge free, with these boundary conditions same ratios of inner to outer radius but variable numbers and variable lengths of radial cracks. These specimens are selected one by one for experimental modal analysis.As result will analysis by using FFT and FEM with different parameter considering in tile cutter as discussed in problem definition. Here only take two points one aspect ratio and radial crack .remaining changes will require to do in tile cutter further effect on tile cutter with respect to vibration analysis. Further the FFT procedure can elaborates.

Experimental SET-UP

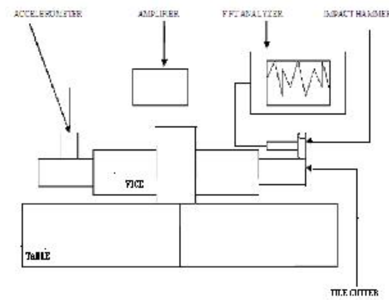

Figure 6. Experimental set up

Figure 4.3 shows schematic representation of the experimental set up to be used, both for impact hammer test to simulate the clamped end condition at the inner boundary.The inner diameter of the tile cutter is 20 mm and outer diameter is 110 mm but variable changing parameter. Specimens prepared were rigidly fixed in fixture to obtain correct boundary conditions. Analysis is done experimentally with the help of FFT analyzer, accelerometer, and impact hammer. Natural frequencies are detected by hitting the tile cutter with hammer; the response at a point of a tile cutter is measured by using an accelerometer. FFT analyzer analyzed the output of accelerometer. Also vibrations were getting by comparing acceleration in cutter.

Experimental Procedure

Figure 7. Actual experiment set-up

Processes to find out natural frequency and vibration by using FFT are as follows,

1) Arrange all instruments as require for vibration analysis like analyzer, impact hammer, display unit, vice, accelerometer as shown in experimental set up also.
2) Select 3 nodes on tile cutter such that impact is done on tile cutter by using impact hammer at thrice in each tile cutter.
3) First open FFT software and select channel set-up after that select first point acceleration and at fourth point take forces. Then select physical quantity.
4) Click on measure after that click on design and take 3 reading simultaneously at every 3 node on cutter by impacting on tile cutter. After that store reading and save that reading up to 8 cutters.
5) Thus total 24 reading taken and save in store. Then make auto scale by clicking Y-axis and select only 8 fine results for find out natural frequency and acceleration.

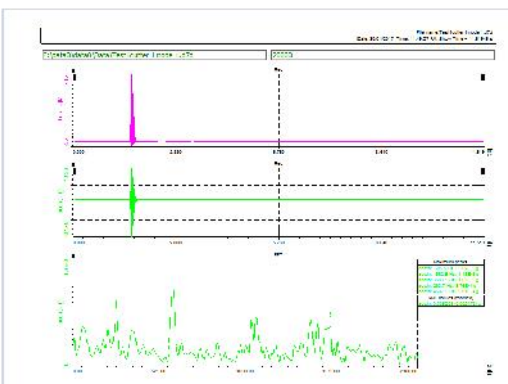

Figure 8. FFT spectrum showing Natural frequency & acceleration of Tile cutter 1

IV. RESULTS AND DISCUSSION

Comparison between Theoretical, ANSYS&FFT

We can comparing with different methods in-between 8 cutters by using following results. Parameters are selected with respect to different change in tile cutter. Also comparative graphs are plotted in below table.

Comparative graphs plotted for different tile cutter

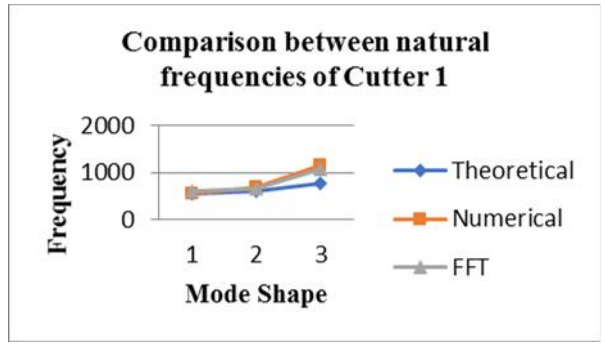

Figure 9. Comparison between natural frequencies of cutter 1

V. CONCLUSION

1. As we reduced the thickness of tile cutter, then natural frequency also was reduced. But vibrations were found to have increased. (Cutter 1&4)
2. As we increased no of cracks from 3 to 6 of same crack length (24.5 mm) natural frequency decreases with increase in vibrations. (Cutter 5 & 6)
3. As we increased length of cracks (30 mm) with same no of cracks (3 or 6) Natural frequency will decrease but vibrations observed were more. So select minimum length of crack and minimum no of crack for minimum vibration than original cutter (1) and (cutter 5, 6, 7 & 8)
4. It is found that, experimental and simulation analysis results are within the permissible limits.
5. Equivalent stresses obtained for modified tile cutters are within the permissible limits.
6. 6. From this, life of tile cutter was obtained by considering equivalent stresses. The range of Equivalent stresses obtained for modified tile cutters are found in between 48 MPa to 158 MPa

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