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Experimental Investigation and Analysis of Circular Tile Cutter Using FEA and FFT

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ABSTRACT

Cutting system play very important role in the marble cutting industry. Circular tile cutters with uniform radial cracks are mostly used in the cutting processes. Cutters are used to cut respective material to a required size or shape. They come in a number of different forms, from basic manual devices to complex attachments for power tools. Unwanted noise, vibration and accidental failure associated with the cutting process have become an important economic and technological aspect in the industry. The knowledge of natural frequencies of components is of great interest in the study of the response of structures to various excitations. In this study, natural frequencies will be evaluated in desired frequency ranges of cutter mechanism. Mode shapes at various natural frequencies will be evaluated using FEA and FFT results, CATIA V5 software will be used to design various existing blades and modification will be carried out as per results. Optimization to minimize the weight of circular tile cutter and thereby reducing the material cost. Optimised model is further verified by FFT and thermal analysis. Conclusion and future scope will be suggested.

Keywords: Tile cutter, Frequency, Mass, Vibrations.

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 the same sample, cutters are selected with respect to different changes so that we comment on vibration and natural frequency. There many parameters required to consider for minimize vibration in tile cutter. Which contain the increase in no. radial crack, increase the length of the radial crack, slot end whole diameter, the geometry of cutter tooth, material selection, adding damping material, enlargement of stress concentration holes, applying mass concentration. The primary purpose of modification of such tile cutter beside from minimization of vibration is to allow thermal expansion during the cutting process without the 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. The further modern trend to manufacturer tile cutter with a computer aided laser. Also, examine the usefulness of various Laser cut slot pattern including radial slots. Also by applying rotational velocity stress distribution known at the center is high around the cutter hole which will minimizes outwards and at the outer edge again maximum.

L. Cheng et.al. [1] tried to discover the relationship between parameter variations (eccentricity, hole size, boundary condition) and vibration modes, and to find the vibration behavior around the eccentric hole. To our knowledge, these results are new and give guidance for the modal analysis and damage detection and the effects of the eccentricity, whole size and boundary conditions on DMSs are investigated systematically.

Chi-Hung Huang [2] has investigated that the dynamic characteristics of the vibrating plate are affected by cracks. The combination of the field of vibration analysis and fracture mechanics makes such a problem complicated. In this study, an optical system named as the AF-ESPI method with the out-of-plane displacement measurement is used to investigate the vibration characteristics of a free circular plate with a radial crack emanating from the edge. The boundary conditions along the circular edge are free. As compared with the "lm recording and optical reconstruction procedures used for holographic interferometry, the interferometric fringes of AF-ESPI are produced instantly by a video recording system.

Based on the fact that clear fringe patterns will appear only at resonant frequencies, both resonant frequencies and corresponding mode shapes can be obtained experimentally at the same time by the proposed AF-ESPI method. Numerical finite element calculations are also performed and the results are compared with the experimental measurements. Good agreements are obtained for both results. The vibrating mode shapes obtained in this study can be classified into two types, symmetric and antisymmetric modes based on the crack line. The influence of crack length on resonant frequencies is also found in terms of the dimensionless frequency parameter (j2) versus crack length ratio (a/D). crack face displacement of out of phase, produces the antisymmetric type, a large value of stress intensity factor may be induced and the cracked circular plate will be dangerous, from the fracture mechanics point of view. However, there are some resonant frequencies for which the crack face displacements are completely in phase, i.e., the symmetric type, which yields a zero stress intensity factor and the cracked plate will be safe.

W.M. Lee et.al. [3] has studied an analytical formulation to describe the free vibration of a circular flexural plate with multiple circular holes by using the null field integral formulation, the addition theorem, and complex Fourier series. Owing to the addition theorem, all kernel functions are represented in the degenerate form and further transformed into the same polar coordinates centered at one of the circles, where the boundary conditions are specified. Thus, not only the computation of the principal value for integrals is avoided but also the calculation of higher-order derivatives in the flexural plate problem can be easily determined. By matching the specified boundary conditions, a coupled infinite system of simultaneous linear algebraic equations is derived as an analytical model for the title problem. According to the direct searching approach, natural frequencies are numerically determined through the singular value decomposition (SVD) in the truncated finite system. After determining the unknown Fourier coefficients, the corresponding mode shapes are obtained by using the direct boundary integral formulations for the domain points. Several numerical results are presented. In addition, the inherent problem of spurious eigenvalue using the integral formulation is investigated and the SVD updating technique is adopted to suppress the occurrence of spurious eigenvalues. Excellent accuracy, fast rate of convergence and high computational efficiency are advantages of the present method thanks to its analytical features.

M. Haterbouch et.al. [4] has studied nonlinear free axis symmetric vibration of simply supported isotropic circular plates is investigated by using the energy method and a multimode approach. In-plane deformation is included in the formulation. Lagrange's equations are used to derive the governing equation of motion. Using the harmonic balance method, the equation of motion is converted into a nonlinear algebraic form. The numerical iterative method of the solution adopted here is the so-called linearized updated mode method, which permits the authors to obtain accurate results for vibration amplitudes up to three times the plate thickness. The percentage of participation of each out-of-plane basic function to the deflection shape and to the bending stress at the plate center and of each in-plane basic function to the membrane stress at the center are calculated in order to determine the minimum number of in- and out-of-plane basic functions to be used in order to achieve a good accuracy of the model. The nonlinear frequency, the nonlinear fundamental mode shape and their associated nonlinear bending and membrane stresses are determined at large amplitudes of vibration. The numerical results obtained here are presented and compared with available published results, based on various approaches and with the single-mode solution. The limit of validity of the single-mode approach is also investigated.

D.V. Bambill et.al. [5] have investigated arose from the practical necessity of placing a centrifugal pump rigidly attached to a thin, circular cover plate of a water tank in a medium size ocean vessel. Due to lack of space, it was necessary to locate the system off—center of the circular configuration. The first part of the present study is concerned with the determination of the fundamental frequency of vibration of a circular plate carrying a concentrated mass at an arbitrary position, using a vibrational approach. An experimental investigation is also performed in the case of clamped plates. Based on the results for solid circular plates, the fundamental frequency of annular plates with a free inner edge and a concentrated mass is also obtained. Circular plates are fundamental structural elements in ocean engineering applications: from off-shore platforms to underwater acoustic transducers. In a great variety of circumstances, they must carry operational systems in an eccentric fashion. Since the dynamic performance is always of interest, one must know at least some of the basic dynamic parameters.

Sasank SekharHota et.al. [6] have investigated that amalgamation of a sub parametric triangular plate bending element with first-order shear deformation has occurred for the first time with an approach that maintains uniform mesh sizes and shapes even while dealing with cutouts of arbitrary shapes. This is a distinct improvement over the existing practices of cutout modeling. Further, the formulation is based on the sub parametric element has the advantage of achieving matching modes, which enables the model to deal problems of very thin plates without even going for reduced integration. Numerical examples on free vibration of plates with cutouts have been analyzed and the results presented together with those available in published literature.

W T Norris, et al. [7] have studied about revisitation of the commutation of the resonant frequencies of an annular disc fixed at its edge and free at its outer edge. This paper intends to clarify differences and gives computation using MATLAB, ANSYS, and Mathematic. The minimum frequency is given in terms of poisons ratio and the ratio of diameters.

II.OBJECTIVES

1) To study and perform Experimental modal analysis on Circular tile cutter
2) To propose an optimized model which will have better or same performance.
3) To achieve cost effectiveness by reduced weight.
4) To do thermal analysis of optimized model

III. METHODOLOGY

1) The modal analysis and mass optimization is Done on an existing circular tile cutter model by using FEA tool
2) Check the any results for frequencies and maximum Equivalent stress and make sure they are within yield Limit of tile cutter.
3) Experimental analysis: by making an optimized geometry, FFT is done for optimized model and verifying the test and analytical results.

IV. MODELING AND ANALYTICAL TOOLS USED

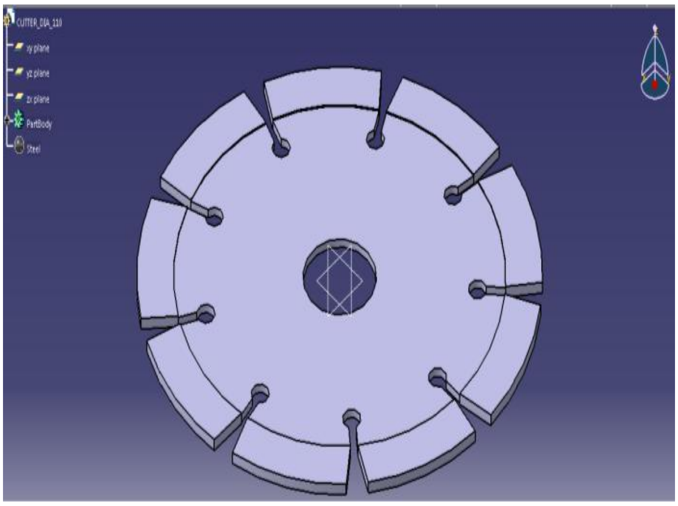
1) Solid modeling of the circular tile cutter is made by Using CATIA V5 R20
2) Ansys 17.0 is used for finite element modeling and analysis.

V.CIRCULAR TILE CUTTER USED FOR EXPERIMENTATION AND COMMON MATERIAL USED FOR IT

Commonly used material for circular tile cutter is steel, High Carbon steel

Fig 1 circular tile cutter

VI. SOLID MODELING AND DRAFTING OF CIRCULAR TILE CUTTER



MASS= 111 gm

Fig.2. Solid model of circular tile cutter by using CATIA V5

R20.

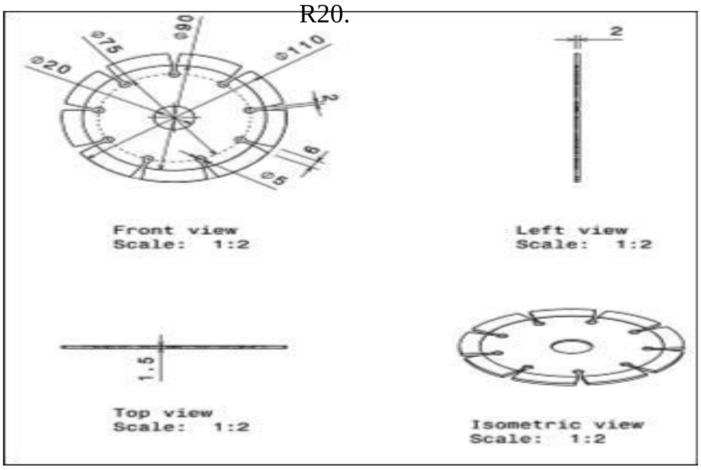


Fig.3. Drafting of circular tile cutter

VIII. DISCRETIZATION AND FEA ANALYSIS OF CIRCULAR TILE CUTTER

Finite element analysis is a type of computer program which uses the finite element method to analyse the object and find how applied stresses will affect the design. FEA can help to determine the points of weakness in a design before it is manufactured. Below are the steps for finite element analysis

1) First, define the geometry of the problem.
2) Then discretize the model by meshing.
3) Define the element types to be used.
4) Then define the material properties of the elements.
5) Define the boundary conditions (physical constraints).
6) Do Modal Analysis
7) Get solution for the analytical problem.
8) Finally the result evaluation.

Elements Details:

- Element Type : Tetrahedron
- Element Order: First Order

- Mesh Method : Solid
- Node Population count : 39263
- Element Population count : 2078

Fig.5. the solid meshing of circular tile cutter

IX. MATERIAL PROPERTIES

The material used for circular tile cutter is steel.
Modulus of Elasticity: 200GPa
Poisson's ratio : 0.30
Density : 7.85e-6 kg/mm^3
Yield Strength : 520 Mpa

X.BOUNDARY CONDITIONS

The cutter is fixed at its inner edge and free at its outer edge with its dynamic response

XI. OPTIMISATION

Optimization is a process to make the component possibly perfect, based on an objective function and design constraints. The function allows comparison of the different choices to decide which might be "best." Some Common Applications: Minimal cost, maximal profit, minimal error, optimal design.

For circular tile cutter optimization, we chose mass optimization and vibration optimization as it is more suitable to apply design constraints as we needed. We have taken four parameters for optimization

1. Stress concentration holes
2. No of stress concentration holes
3. Shape of stress concentration holes

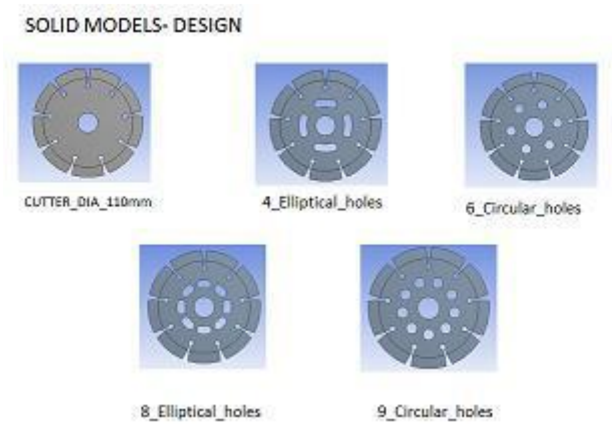


Fig 6 Solid models for optimization

For above five models, we do modal analysis and the result
For frequencies are tabulated as shown below we observe that all cutter model gives frequencies more than the basic frequency of cutter so vibrations will get optimized . The things are elliptical eight holes give maximum weight reduction that is 8.2 % but according to manufacturing constraints, it will not economical. So we have taken circular nine holes for mass reduction of tile cutter.

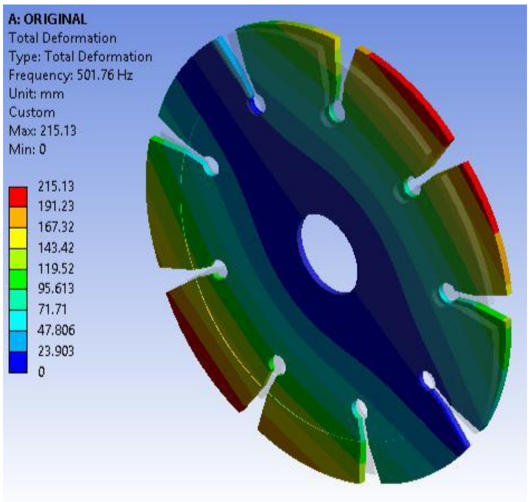


Fig 7 1st mode shape for original cutter

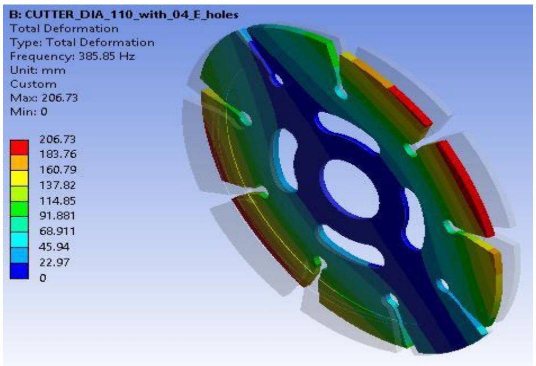


Fig 8 1st mode shape for elliptical four holes

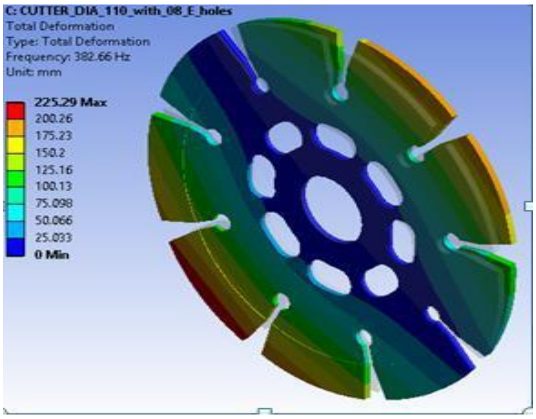


Fig 9 1st mode shape for elliptical eight holes

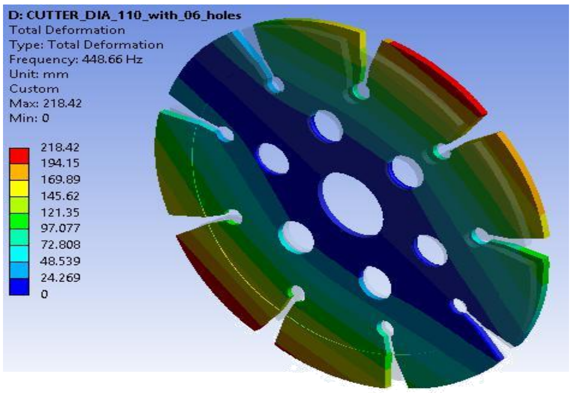


Fig 10 1st mode shape for circular six holes

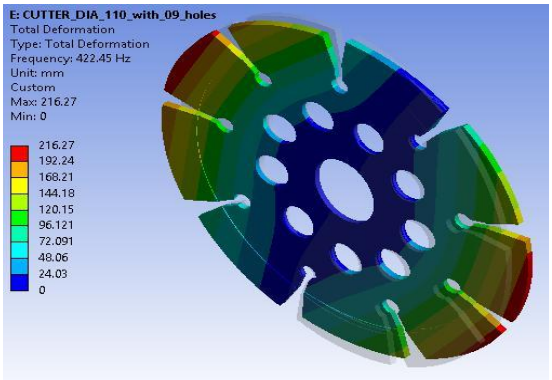


Fig 11 1st mode shape for circular nine holes

MODE-NO	ORIGINAL	Eliptical 4 holes	Eliptical 8 holes	Circular six holes	Circular nine holes
1	501.76	385.85	382.66	448.66	422.45
2	501.95	385.94	382.74	448.76	422.6
3	526.28	399.79	394.63	460.56	432.41
4	588.68	486.97	493.58	546.7	523.37
5	588.77	510.63	493.78	546.75	523.44
6	898.03	833.53	826.31	849.25	834.98
7	898.28	833.85	826.51	860.49	835.03
8	1181.5	1148.8	1147.1	1154.7	1144.9
9	1181.7	1152.2	1148.4	1155.3	1145.1
10	2215	2116.6	2110.4	2139.7	2109.1
Weight	111.72 g	103.59g	102.45g	106.17g	103.4g
		7.2%red	8.2% red	4.9%red	7.4% red
Highest RPM range of cutter blade	14500 rpm	241.66Hz (Basic Freq)			

Table 1 Comparison between models for designed solid model

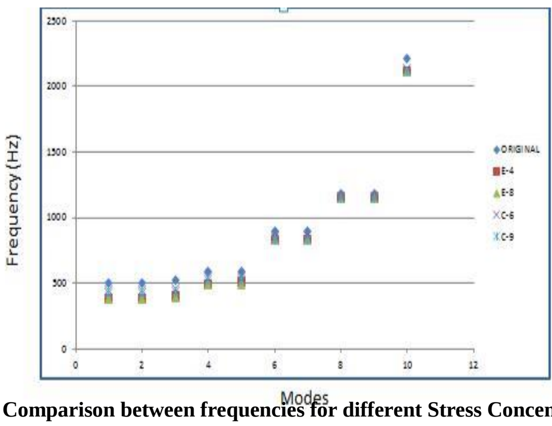


Fig 12. Comparison between frequencies for different Stress Concentration Holes

XII. OPTIMIZED PART ANALYSIS

Circular holes are cut by using laser cutting machining

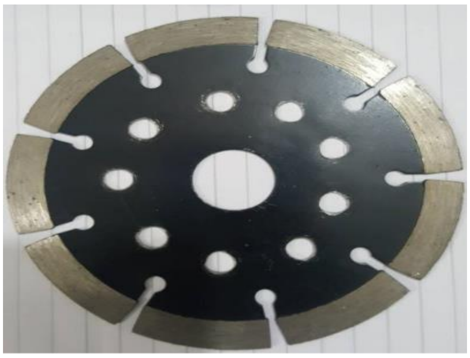


Fig 12 Optimised tile cutter

XIII. TESTING AND VALIDATION

FFT analyzer is used for validation of optimized circular tile cutter

Fig 13 experimental setup

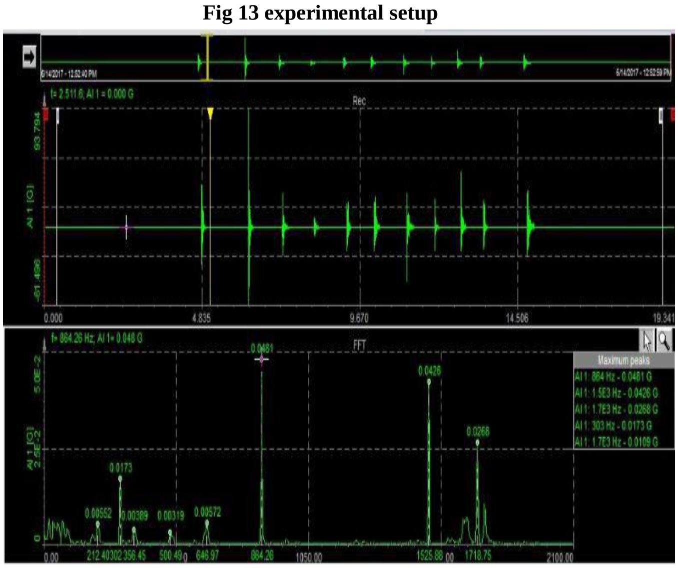


Fig14 Modal frequency obtained by FFT analyzer

Modal

Here experimental frequency obtained by FFT is 864 Hz which is approximately matching to the 6 mode frequency of analytical results which is 834 Hz.

XIV THERMAL ANALYSIS OF OPTIMISED TILE CUTTER

Fig 15 Temperature of tile cutter in working condition

We have measured the temperature of optimised circular tile cutter in operating condition with the help of temperature gun. It is about 37.9-degree celsius.by taking this temperature as boundary condition we did a thermal analysis of circular tile cutter.

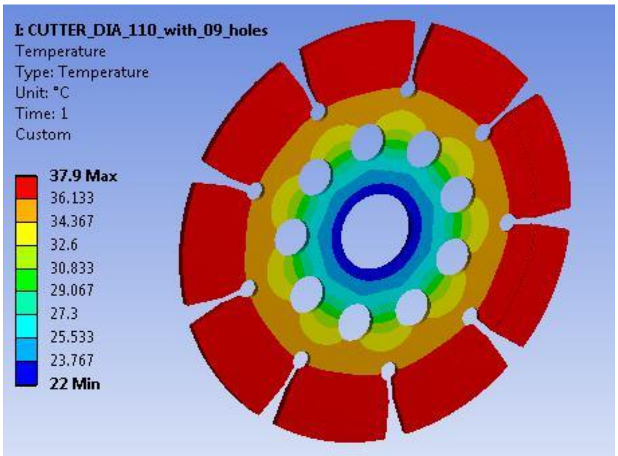


Fig 16 Temperature plot for C-9 holes

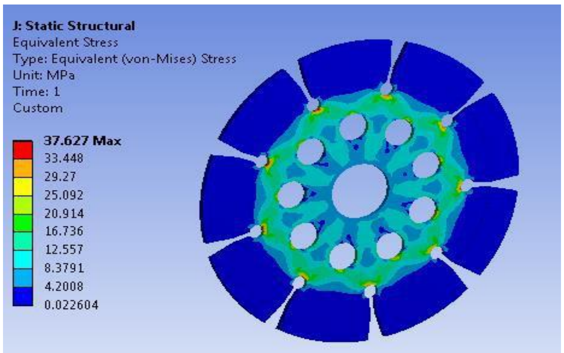


Fig 17 Equivalent stress plot for C-9 holes (37.627 MPa)

CONCLUSION

Optimization of the circular tile cutter is carried out and below are the conclusions from the analysis and testing:

1) Initially, FEA result shows that there is the scope of optimization.
2) Also, the static analysis result of the optimized modeL shows that the stresses are within the yield limit of the material, which proves that the new steering arm design could be used instead of the current one for high duty vehicle.
3) Percentage reduction in mass is 7.4 %.
4) 9_Circular_holes design is safe and economical design i.e stress is within yield limit of material 37 Mpa and also drilling holes is simple as compared to elliptical holes suggested which makes design economical

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