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Contents

Articles

A Review on Deliberations to Evaluate Stress Concentration Factor for a Plate with Different Cutouts using Various Methods 01-13
Bhaveshkumar P. Patel

Acoustic Feature-Based Alzheimer's Disease Detection using Machine Learning: A Comprehensive Approach 14-23
Himanshu Patel, Kalpana Adarkhi

Estimation of Inter-Layer Deposition Delay for Improved FDM Part Quality Using Thermal Analysis 24-30
Trivedi Achyut, Hirava Mamtora, Harshil Panchal

6G-Enabled Intelligent Healthcare: Technologies, Challenges, and Transformative Applications 31-43
Aniket Patel, Bhavesh Chavda, Rohit Patel

Digital Twins for Smart Hospitals: Architecture, Applications, and Intelligent Patient Monitoring 44-59
Mayur Mistry, Aniket Patel, Rohit Patel

Assessment of State-of-the-Art Deep Neural Networks on a Multi-Era, Cross-Domain Dataset of Indian Cinema 60-72
Khushi Modi, Dr. Devang Pandya, Rachana Modi, Ketan Sarvakar

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A Review on Deliberations to Evaluate Stress Concentration Factor for a Plate with Different Cutouts using Various Methods

Bhaveshkumar P. Patel
Professor, Department of Mechanical Engineering
Ganpat University- U V Patel College of Engineering

Abstract

Plates featuring geometric openings, often referred to as perforated plates, are frequently utilized in various engineering applications including aerospace, mechanical, and civil domains due to their ability to reduce weight, improve structural efficiency, and facilitate maintenance access or functional integration. The presence of openings disrupts the uniform distribution of stress across the plate, leading to localized intensification of stress, commonly known as stress concentration, which can significantly compromise the structural integrity and load-carrying capacity of the component. In modern engineering practice, structurally intricate components are increasingly employed across diverse applications to fulfil stringent performance, functionality, and design optimization criteria. Hence, a comprehensive investigation of analytical, numerical, and experimental approaches is essential to gain insights into stress distribution behavior and to accurately compute the stress concentration factor (SCF) in structural elements. The present study offers an in-depth review aimed at highlighting the advantages and drawbacks of the methodologies adopted by various researchers in their investigations. This review aims to guide researchers in recognizing prior contributions and selecting appropriate methodologies based on the specific nature of the problems they intend to address.

Keywords: Analytical, Complex variable, Cutout, Finite plate, Finite Element Method, Photoelasticity, Perforated plates, Stress Concentration Factor.

1. Introduction

Plates with various polygonal holes are often used in different mechanical, aerospace, civil engineering, mining engineering and offshore structures. Different polygonal shaped holes in structural elements are required to reduce the weight of the structure or provide access to other parts of the structure as mentioned by Kumar M. M. et. al (2013). The presence of polygonal shape in the plate behaves as a discontinuity and effect on the stress distribution within the plate subjected to diverse loading conditions. The effect of stress concentration can be evaluated using stress concentration factor. The stress concentration factor is defined as the ratio of maximum stress to nominal stress as stated by Kadam M. et al. (2014). The polygonal shaped holes in the plate becomes the stress risers for particular structure and it works as weakening agent for the structure or machine. Ultimately different polygonal shaped holes generate different effect of stress concentration, which directly effects on the life of the structure according to Makwana A. B. et al. (2014). Therefore,

Corresponding Author E-mail Address
bpp01@ganpatuniversity.ac.in

understanding of the effect of polygonal shaped holes presence in the plate on the load bearing capacity and stress concentration is very essential in designing of structures. Stress concentration factor helps to identify the best suitable hole/cutout for the structural member without affecting its strength under known loading conditions for different industrial applications.

Many researchers like (Ashokan K. 2009), (Woo Jinho, 2011), (Kawadkar D. B. et al., 2012), (Kumar M. M. et. al, 2013), (Kalita K., 2014), (Kadam M., 2014), (Watsar S. D, 2015) have carried out their research work on evaluation of stress concentration factor and stress distribution under different loading conditions and approaches for finite plates and (Sharma D. S., 2011), (Sharma D. S., 2012), (Makwana A. B. et al., 2014) have studied on infinite plates.

There are several methods adopted by different researchers to determine the stress concentration factor for different kind of plates having different discontinuities. Digital photoelasticity (Ashokan K. et al., 2009), FEA (Woo Jinho et al. (2011); Sharma D. S. (2012); Kawadkar D. B. et al. (2012); Kumar M. M. et al. (2013); Kalita K. et al. (2014); Kadam M. et al. (2014); Watsar S. D. et al. (2015); Makwana A. B. et al. (2014); Kadam M. et al. (2015); Jafari M. et al. (2016); Ozkan m. T. et al. (2016); Dongarwar P. D. et al. (2016); Sayyad S. M. et al. (2017); Sahu R. (2017); Fesharaki J. J. et al. (2017); Roy A. et al. (2017); Khechaia A. et al. (2018); Bakhshi N. et al. (2019); Devaraj E. et al. (2019); Mahadik S. C. (2020)), MATLAB codes (Sharma D. S. (2011); Makwana A. B. et al. (2014)), Photoelasticity test (Kawadkar D. B. et al. (2012); Watsar S. D. et al. (2015); Dongarwar P. D. et al. (2016)), empirical model (Ozkan m. T. et al. (2016)), regression analysis (Ozkan m. T. et al. (2016)), artificial neural network (Ozkan m. T. et al. (2016)), analytical methods (elasticity theory) (Ozkan m. T. et al. (2016)) (complex variable theory) (Yang Q. Q. et al. (2017); Chawla K. et al. (2018); Guan Y. et al. (2018); Liu K. et al. (2019)) (classical laminated plate theory) (Khechai A. et al. (2018)) (Tan's analytical method) (Bakhshi N. et al. (2019)), strain gauges (Ozkan m. T. et al. (2016); Sayyad S. M. et al. (2017); Fesharaki J. J. et al. (2017); Roy A. et al. (2017); Khechaia A. et al. (2018).

The review depict that the majority of work has been carried out by researchers using Finite Element Analysis and very limited attempts have been made by experimental and analytical methods to determine the stress distribution around the discontinuity presence in the plate and stress concentration factor for different shapes and loading conditions. It shows that there is a scope that the use of experimental technique is to be proposed to determine the stress concentration factor.

2. Review on Methods Used

The literature review reflects that the different methods and techniques have been adopted by researchers to evaluate the stress concentration and stress distribution around the discontinuities presents in the finite and infinite plate under different boundary and loading conditions. Certain methods like Experimental (i.e., Photoelasticity and strain gauges), empirical method, regression analysis, artificial neural network, analytical methods (i.e., elasticity theory, Tan's method and complex variable method), and classical laminated plate theory used by researchers which are very familiar to evaluate the stress concentration factor and stress distribution. Below is the detail review carried out to identify the various method used by peoples for their research work as per the literature referred for this review article.

Digital photoelasticity is an experimental technique that provides information on principal stress difference and direction at every point in a model domain. It was used by K. Ashokan et al. (2009) for stress separation using a simple raster scanning approach. Finite Element Analysis was used by Woo Jinho et al. (2011) to analyze stress concentration patterns in perforated plates with different cutouts, considering factors like shape, boundary conditions, bluntness, and rotation. Results showed that these parameters significantly influenced stress concentration.

Sharma D. S. (2011) used Muskhelishvili's complex variable method to study stress concentration in laminated composite infinite plates, revealing that corner radius, fiber orientation, and loading angle significantly influence stress concentration. The effect of the hole geometry and loading pattern on the stress concentration factor was also studied by Sharma D. S. (2012) finite element method. The study found that controlling the corner radius of a polygonal hole can limit stress concentration, but as corner radii approach zero, it approaches infinity. Kawadkar D. B. et al. (2012) conducted an experimental photoelastic test on an Araldite model, considering bluntness and cutout orientation, and found that stress concentrations were in close agreement with FE results.

Finite element analyses conducted by Kumar M. M. et al. (2013) to evaluate stress concentration for perforated aluminum plates with various shaped cut-outs and studied the effect of different boundary conditions, bluntness and cut-out orientations on stress concentration. Kalita K. et al. (2014) utilized Finite Element Analysis to investigate the impact of symmetric and asymmetric auxiliary holes in a plate with a central hole on stress concentration and stress distribution. Kadam M. et al. (2014) studied stress concentration for a plate with circular and square openings with different boundary conditions for tensile and compression loading using analytical and FEA approach. Watsar S. D. et al. (2015) conducted stress analysis on finite plates with triangular, square, and rectangular cut outs using numerical method and experimental photoelasticity. Results showed square cut out has lower Stress Concentration Factor. Makwana et al. (2014) utilized Muskhelishvili's complex variable method to study stress concentration in a composite infinite plate, obtained general solutions using MATLAB coding and compared them with FEA.

Finite Element Analysis carried out by Kadam M. et al. (2015) for a plate having central hole under uni-axial and bi-axial loading and evaluated the stress concentration factor. Jafari M. et al. (2016) used Muskhelishvili's complex variable method to study stress distribution around holes in finite metallic plates. They obtained unknown stress function coefficients and investigated the influence of parameters like bluntness and hole size. Ozkan m. T. et al. (2016) et al. studied stress concentration factor in a plate with circular hole under axial tension stresses, and compared empirical results with analytical, regression, and ANN models. The best results were obtained using ANN model. Using a computational approach, Dongarwar P. D. et al. (2016) studied the impact of elliptical and circular stress raisers in tensioned plates; the results were compared with those of photo-elasticity tests. Sayyad S. M. et al. (2017) studied stress distribution and stress-compression factor (SCF) on a perforated plate under uni-axial tensile loading using FEA method and electrical strain gauge method. Based on theory of the complex variable functions, the analysis of stress concentration in a homogeneous plate with an arbitrary shape hole coated by a functionally graded layer was presented by Yang Q. Q. et al. (2017).

Sahu R. (2017) applied tensile force to a perforated square steel plate with various hole shapes, and evaluated stress concentration factor using Finite Element Analysis. Fesharaki J. J. et al. (2017) conducted Finite Element Analysis using ABAQUS software to evaluate stress concentration factors on a functionally graded material plate, verified through strain-gauge-based experimental tests. Roy A. et al. (2017) studied heat treatment processes on stress concentration factor (Kt) of a plate with a circular hole. They found quenching had higher SCF values than normalizing and annealing, and both had lower values compared to room temperature mild steel specimens.

Khechaia A. et al. (2018) studied the stress concentration factor (SCF), failure process, delamination, and tensile strength degradation of aluminum and E-glass laminated plates using analytical, experimental, and numerical methods. They used Digital Image Correlation to measure surface strain in notched specimens with different fiber orientations and open hole sizes. A comparison for SCF obtained from three different methods studied is presented in table 1 with reference to fiber orientation as mentioned in.

Table 1. Comparison of SCF obtained from different methods

Materials	Fiber Orientation	Analytical	FEM	Experimental
Aluminum	-	3.000	3.117	3.695
E-Glass/Epoxy	0°	3.939	4.047	4.224
	45°	2.827	2.776	3.184
	-45°	2.827	2.776	3.358
	90°	3.047	3.151	1.655

Chawla K. et al. (2018) conducted a systematic study using complex variable theory and Finite Element Analysis to understand the impact of various parameters on stress concentration in a composite plate. Khechai A. et al. (2018) studied stress concentration factor in isotropic and laminated composite plates under uniaxial tensile force, evaluating both analytically and numerically. Guan Y. et al. (2018) utilized the complex variable method to analyze the impact of the FG layer on shear stress distributions in holes, revealing that optimal material variation design can significantly reduce stress concentration factor. The influence of plate length on the stress distribution around the hole was studied by Bakhshi N. et al. (2019) using numerical method and the SCF obtained from the Tan's model was tested through numerical method.

Using analytical and computational techniques, Devaraj E. et al. (2019) investigated the Von-mises stresses and stress concentration that occurred in a rectangular plate with a central hole of varying sizes. Liu K. et al. (2019) used a complex variable method to study stress distribution in regular hole shapes, specifically waist holes on infinite plates. Mahadik S. C. (2020) studied stress distributions in square plates with cutouts using Finite Element Analysis and Photo Elasticity, examining shape, bluntness, loading direction, and orientations. A comparison of stress concentration factors for a thin plate with an eccentric hole using classical analytical formulas and numerical simulations carried out by Patel P. et al. (2021). The study conducted by Safaei B. et al. (2022) was numerically analyzed stress distribution around circular cutouts in sheets to evaluate stress concentration at hole edges, comparing results with analytical solutions. It established relationships between SCFs and hole dimensions based on elasticity theory. The findings confirmed the accuracy of the ANSYS-based numerical analysis.

The study conducted by Patel R. H. et al. (2023) presents a detailed finite element analysis of stress concentration in steel plates with various polygonal cutouts.

A critical review of the literature has enhanced the understanding of composite reinforcement in CHS joints for improving fatigue life carried out by Mohsin I. et al. (2024). It also highlighted key research gaps, such as combined loading conditions, optimal layup strategies, and SCF prediction models. These insights pave the way for future studies in this domain.

Table 2 shows the methods used in the research work with observations which will helpful to the reader or researcher for selection of right method for his/her proposed problem.

The study conducted by Adnan R. et al. (2024) used a finite element model combined with response surface methodology to analyze and minimize stress concentration factors (SCFs) in internal ring-reinforced KT-joints. By optimizing eight key parameters, a novel set of parametric equations was developed, and the results showed high accuracy with less than 6% deviation from FEA validation.

The study carried out by Shubhrata N. et al. (2012) presents a comparative overview of analytical, numerical, and experimental methods for analyzing and mitigating stress concentration factors around discontinuities in rectangular plates. Various techniques are tabulated and evaluated, highlighting that

no universal method fits all cases, but the study aids in selecting suitable approaches based on specific conditions.

The study conducted by Yan D. et al. (2024) investigates SCFs in SHS-CFSHS X-joints using experimental testing and finite element analysis in ANSYS, applying the hot spot stress method. A total of 64 FE models and multiple regression analysis were used to develop SCF prediction formulas, which were validated as conservative and reliable.

Table 2. Methods used in the research work with observations

Authors	Method/s used	Observations
Ashokan K. et al. (2009)	Digital Photoelasticity (i.e., Shear difference method- raster scanning approach), adaptive scanning scheme	Adaptive scanning scheme is better than the raster scanning approach.
Woo Jinho et al. (2011)	FEA	Utilizing a finite element program, stress concentration patterns were obtained. For modelling, a solid element with eight nodes is employed. The plates are modelled as a linear elastic material in order to examine stress concentration in an elastic range.
Sharma D. S. (2011)	Muskhelishvili's complex variable method	Muskhelishvili's complex variable method is used to calculate stress concentration around different cut-outs in laminated composite infinite plate under arbitrary biaxial loading at infinity.
Sharma D. S. (2012)	Muskhelishvili's complex variable method, FEM	Muskhelishvili's complex variable method yields general solutions for the stress distribution around holes in an infinite plate exposed to arbitrary biaxial in-plane loadings at infinity. Cauchy's integral is evaluated for the specified boundary conditions in order to determine the stress functions. Using FEA, the impact of the loading pattern and hole geometry on the stress concentration factor is investigated.
Kawadkar D. B. et al. (2012)	Photoelasticity, FEA	Experimental Photoelastic test on Araldite model loaded in one direction for different cut outs showed good agreement between experimentation and FEM stress concentrations.
Kumar M. M. et al. (2013)	FEA	The study analyses stress concentration in perforated panels using MSC NASTRAN and a 4-node shell element, focusing on linear elastic material in an elastic range.
Kalita K. et al. (2014)	FEA	Reduction in stress concentration with symmetric and asymmetric auxiliary holes is studied using FEA approach.

Kadam M. et al. (2014)	Analytical (R. E. Peterson's formula), FEA	Results from the FEA approach and analytical method for circular opening are compared.
Watsar S. D. et al. (2015)	Experimental, FEA	Experimental and numerical results show that the SCF for circular cutout is less than triangular, square, and rectangular cutout, as determined by photoelasticity and Finite Element Analysis.
Makwana A. B. et al. (2014)	Muskhelishvili's Complex variable method, MATLAB code, FEA	The study uses Muskhelishvili's complex variable method to analyses stress concentration around a circular hole in a composite infinite plate, obtaining general solutions using MATLAB coding and FEA tool comparison.
Kadam M. et al. (2015)	Analytical, FEA	The study found that the SCF decreases exponentially with an increase in the d/w ratio, as determined through analytical and FEA methods.
Jafari M. et al. (2016)	Analytical (Muskhelishvili's complex variable method), Numerical (FEA)	The analytical method's stress distribution results align with numerical data from ABAQUS software and other previous research.
Ozkan m. T. et al. (2016)	Empirical (Peterson's) model, regression analysis (REGA), Artificial Neural Network (ANN), Analytical, (Roark's) model and FEA.	The best results are obtained using ANN model compared to other models.
Dongarwar P. D. et al. (2016)	Experimental (Photo Elasticity apparatus), FEM	The stress distribution results from the FE analysis are found to be in close agreement with the experimental results.
Sayyad S. M. et al. (2017)	FEA	The stress distribution and SCF were obtained using FEA, but the results were not validated using any other method.
Yang Q. Q. et al. (2017)	Complex variable method	The stress concentration analysis was conducted using the Complex variable method, but the results were not validated using any other method.
Sahu R. (2017)	FEA	The study utilized FEA through Solid Work software to examine the impact of stress concentration, but the results were not validated using other methods.
Fesharaki J. J. et al. (2017)	Experimental test (strain-gauges), Finite Element Method (EFM)	ABAQUS software was used for modelling, and a strain gauge test was conducted to verify Finite Element Method results, revealing a 4.9% variation.

Roy A. et al. (2017)	Finite Element Analysis, Universal Testing Machine, (Without heat treatment and with heat treatment)	The study utilized ABAQUS 6.13-1 for Finite Element Analysis and calculated Kt for rectangular plates with varying diameters, and generated Stress-Strain diagrams from ASTM E8 specimens. The annealed metal's Kt is low compared to other heat treatment methods, requiring high ductility and minimal toughness. The maximum Kt is observed for the quenching method having same d/D ratio. The Kt lowers as the d/D ratio rises. The Kt value decreases with annealing and normalizing for the same d/D ratio, but increases with quenching for all d/D ratios compared to other methods.
Khechaia A. et al. (2018)	Analytical (Strength prediction methods: Point Stress Criteria (PSC) and modified stress criteria (MSC)) Experimental (Universal Testing machine with strain gauges) and Numerical studies (FEA) Digital Image Correlation (DIC) technique	This research utilizes finite element modelling techniques and Digital Image Correlation to analyses surface strain measurements in notched specimens, examining their effects on SCF, failure strength, and mechanisms. Experimental data and simulation results show a 17% accuracy in predicted strength for notched laminated plates, while finite element analysis (FEA) outputs provide a good stress distribution estimation.
Chawla K. et al. (2018)	Complex variable theory	The study investigated the impact of various parameters on stress and strain concentration factors in a composite plate with a hole under uniaxial tension using complex variable method.
Khechai A. et al. (2018)	FEA, Analytical	The stress concentrations were obtained using a recent quadrilateral finite element of four nodes with 32 DOFs. The analytical results of SCF are in good agreement with the results of numerical method (FEA).
Guan Y. et al. (2018)	Complex variable theory	The study utilized piece-wise homogeneous layers and conformal mapping techniques to derive complex potentials in the FG layer, examining its influence on shear stress distributions around shaped holes.
Bakhshi N. et al. (2019)	Tan's analytical model, FEA	Tan's model's stress concentration factor accuracy is limited to plates longer than critical length and uniaxial loading. Similar approach is used to develop new model for biaxial loading plates. The proposed model and finite element analysis showed excellent agreement for plates with / >3 and −0.5≤ ≤1.

Devaraj E. et al. (2019)	Analytical, FEA	The study modelled a rectangular structural steel plate using numerical method, determining its maximum equivalent Von-Mises stress and displacement under constant force and results are validated using analytical method.
Liu K. et al. (2019)	Muskhelishvili's complex-variable method, Experimental test (Photo elastic apparatus)	The stress-concentration problem around holes was solved using complex-variable function method, and finite-element simulation results were compared to Maplesoft program analytical solution for waist-hole mapping function formula accuracy verification.
Mahadik S. C. (2020)	Finite Element Analyses	Author discusses experimental, analytical and numerical methods in brief and used the FEA to investigate stress concentration in metallic plates with special shaped cut-out and bluntness.
Patel P. et al. (2021)	Finite Element Analyses	FEA approach adopted to evaluate the SCF for a plate with different position of the hole.
Safaei B. et al. (2022)	Analytical Method Numerical method (FEA)	The distribution of stress in sheets with circular cut out was numerically investigated to study stress concentration at the edge of hole and the obtained results were compared with analytical solutions.
Patel R. H. et al. (2023)	Finite Element Method	Stress Concentration Factor (SCF) evaluated for a finite plate with different polygonal discontinuities under uniaxial compression using FEM.
Adnan R. et al. (2024)	Finite Element Method combined with response surface methodology	Employed finite element analysis and response surface methodology to optimize SCFs in ring-reinforced KT-joints.
Shubhrata N. et al. (2012)	Analytical, numerical (FEM, BEM, Mesh Free Method), and experimental (Photoelasticity, Brittle Coating Electrical Strain Gauges)	The study compares analytical, numerical, and experimental methods for reducing stress concentration in rectangular plates, aiding in method selection based on specific conditions.
Yan D. et al. (2024)	Experimental testing and finite element analysis in ANSYS, applying the hot spot stress method.	The study analyses SCFs in SHS-CFSHS X-joints through experiments and ANSYS-based FEA using the hot spot stress method, deriving validated SCF formulas via multiple regression analysis.

3. Results and Discussion

Literature review depict that the researchers used Photoelasticity test (Ashokan K. et al. (2009); Kawadkar D. B. et al. (2012); Watsar S. D. et al. (2015); Dongarwar P. D. et al. (2016); Mahadik S. C. (2020)), FEA (Woo Jinho et al. (2011); Sharma D. S. (2012); Kawadkar D. B. et al. (2012); Kumar M. M. et al. (2013); Kalita K. et al. (2014); Kadam M. et al. (2014); Watsar S. D. et al. (2015); Makwana A. B. et al. (2014); Kadam M. et al. (2015); Jafari M. et al. (2016); Ozkan m. T. et al. (2016);

Dongarwar P. D. et al. (2016); Sayyad S. M. et al. (2017); Sahu R. (2017); Fesharaki J. J. et al. (2017); Roy A. et al. (2017); Khechaia A. et al. (2018); Chawla K. et al. (2018); Khechai A. et al. (2018); Bakhshi N. et al. (2019); Devaraj E. et al. (2019); Mahadik S. C. (2020)), MATLAB codes (Sharma D. S. (2011); Makwana A. B. et al. (2014)), empirical model (Ozkan m. T. et al. (2016)), regression analysis (Ozkan m. T. et al. (2016)), artificial neural network (Ozkan m. T. et al. (2016)), analytical methods (elasticity theory) (Ozkan m. T. et al. (2016); Devaraj E. et al. (2019)), complex variable method (Sharma D. S. (2011); Jafari M. et al. (2016); Yang Q. Q. et al. (2017); Chawla K. et al. (2018); Guan Y. et al. (2018); Liu K. et al. (2019)) (classical laminated plate theory) (Khechai A. et al. (2018)) (Tan's analytical method) (Bakhshi N. et al. (2019)), strain gauges (Ozkan m. T. et al. (2016); Sayyad S. M. et al. (2017); Fesharaki J. J. et al. (2017); Roy A. et al. (2017); Khechaia A. et al. (2018)) to evaluate the stress concentration factor and stress distribution around the cut-outs.

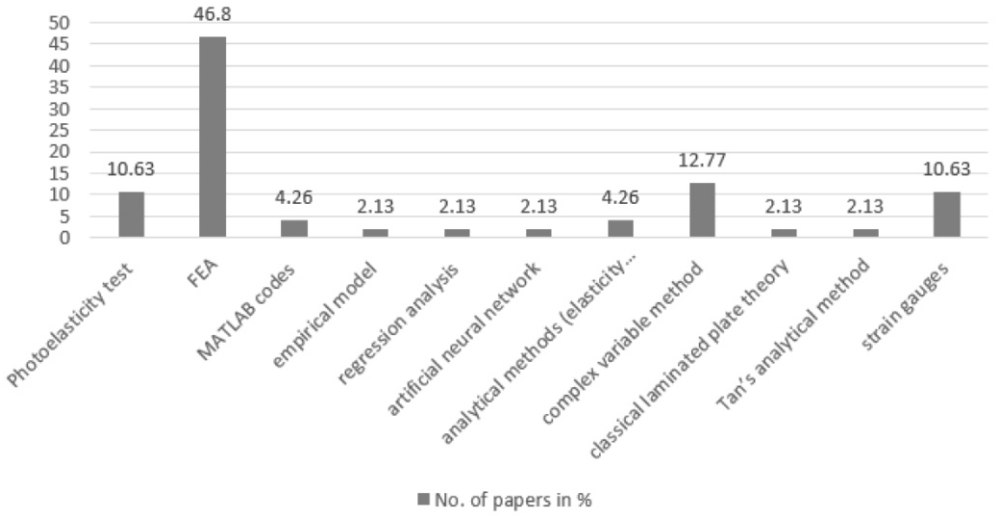


Figure 1. Kind of methods used for research work in %

The review depict that the majority of work has been carried out by researchers using Finite Element Analysis (Refer Figure 1) and very limited attempts have been made by experimental and analytical methods to determine the stress distribution around the discontinuity presence in the plate and stress concentration factor for different shapes and loading conditions. It shows that there is a scope to use appropriate method to validate the work to be proposed to determine the stress concentration factor and stress distribution in the vicinity of the cut-out or discontinuity present in the plate.

Table 3 shows the comparison of various methods along with their strengths, limitations and best for concerned problem statement or application.

Table 3. Comparison of methods

Method Type	Methods	Strengths	Limitations	Best For
Analytical	Complex variable methods (e.g., Muskhelishvili's method), Conformal mapping, Series expansion methods, Airy stress function approach	Exact, fast, benchmark solutions	Limited to simple geometries and conditions	Idealized problems, infinite plates, model verification
Numerical (FEM)	Finite Element Method (FEM), Boundary Element Method (BEM), Meshless methods (e.g., Smoothed Particle Hydrodynamics, SPH)	Versatile, handles complex geometry & materials	Needs computational resources & careful meshing	Practical engineering applications, optimization studies
Experimental	Photoelasticity, Digital Image Correlation (DIC), Strain gauges and extensometers, Moiré interferometry	Real-world validation, direct stress observation	Costly, time-consuming, needs equipment	Validation, fracture studies, complex material behavior

One can study the strengths, limitations and the method best suitable for formulated problem statement and can select the best method for their proposed study.

4. Conclusion

Study show, total 11 different methods have been used by different researchers to evaluate the stress concentration factor and stress distribution in a plate with discontinuity. Out of these, FEA used about 46.8% and experimental method used about 10.63% (Photoelasticity and strain gauges) whereas complex variable method used about 12.77%. Table 4 shows the outcome of the review study and it

Table 4. Method selection based on problem type

Problem Formulation	Recommended Method	Reason
Infinite plate with circular hole under uniaxial tension	Analytical	Availability of exact solutions
Finite plate with irregular cutouts	Numerical (FEM/BEM)	Flexibility in modeling geometry and boundary conditions
Composite laminated plate with multiple load types	Numerical (FEM with anisotropic material modeling)	Handles material complexity and layered structure
Validation of numerical model	Experimental (DIC, photoelasticity)	Provides real-world stress data for comparison
Crack or fracture behavior near discontinuities	Experimental + FEM	Captures both realistic stress states and predictive modeling

suggest the application of suitable method with reference to type of problem formulation along with reasons. Based on this study one can select appropriate method according to his or her proposed problem formulation.

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