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A Review Paper on: Containment Test and Impeller Burst Simulation using Explicit Dynamics

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Abstract: Containment test is done for ensuring the safety of turbocharger by checking the ability of the turbine and compressor housing to retain all the fragments within it, in case of wheel burst. For inducing impeller burst, an impeller with purposely provided slot on the back face of the impeller is assembled in turbocharger and operated at target speed. Experimental testing involves various iterations to be performed for successful burst to occur i.e. to obtain correct slot dimensions of the impeller to burst at target speed, resulting in expensive and time consuming test. Thus, to avoid the experimental iterations of containment testing, Finite Element simulation method can be used. This paper presents the literature survey on containment testing, methodology used for simulating containment test and impeller burst. Based on literature survey, various parameters can be considered to develop a methodology to simulate impeller burst.
Keywords: Containment testing, Impeller burst, Weakening slot, Successful burst, Explicit Dynamics

I. INTRODUCTION

A. Containment Test

Various tests are performed on turbocharger to check its capability for usage before it is delivered to the customer. Containment test is used for checking the ability of the compressor and turbine housing individually for containing the debris within it, if wheel burst occurs.

Pranita Kesare et.al. [1] explains certain operating conditions that may lead to the failure of turbocharger and its components. High pressure turbine disk failure of CF6-80A engine at Los Angeles International airport in 2006 and turbine disk incident at Qantas A3380 engine are few of the examples illustrated.

Burst and Containment by Garett et.al. [2] explains the wheel burst as the failure of turbine or compressor wheel when they are unable to hold as a single piece against the centrifugal forces. Wheel burst can occur in two ways: 1. Blade burst – where the blades get detached from the wheel 2. Hub burst – the extreme case where hub region reaches beyond its ultimate limit and bursts into pieces. This phenomenon occurs at very high temperature and high-speed range. Containment test is described as an ability of the turbine and compressor housing to absorb the energy released during burst and contains all the debris within it. Impellers have higher probability to fail through burst as the material used for manufacturing impeller is Aluminium, which has lower strength than the Inconel material used for turbine wheels. Some of the other factors are low cycle fatigue, foreign object damage etc. For validating a new wheel or impeller design, tests are carried out with the turbocharger assembled with speed and temperature sensors. After this, the instrumented turbocharger is installed on containment stand where hot air fuel gas mixture is introduced on turbine wheel to drive the test according to actual operating conditions. After dwelling the turbocharger at some speed and temperature, its speed is intentionally increased and operated at speed more than design speed.

Simon Barrans et.al. [3] explains the use of turbochargers in engine to meet the Euro VI norms. Development in turbocharging technology, its methods and limitations for future development are also proposed in this paper. In most of the countries, the taxes on passenger cars are linked with the amount of carbon dioxide that is generated in standard duty cycle, therefore demanding the turbochargers to reduce the emissions of carbon dioxide. The turbochargers are also expected to deliver various peak powers, help in downsizing the engine etc. This increases various structural problems in turbocharger. There are several other reasons contributing to turbocharger failure such as external load on turbine side (thermal expansion and vibration of components) and compressor side (vibration load due to air filter etc.), internal load due to rotating systems and high temperatures on turbine side. The highest load that turbine housing or compressor housing will be experiencing are those resulting from the failure of turbine wheel and impeller through burst. The reason for turbine wheel or an impeller to burst is low cycle and high cycle fatigue. Low cycle fatigue (LCF) is seen when the material is loaded beyond its elastic limit. To avoid this, author concludes with a suggestion to manufacture by

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milling the compressor wheel from strong aluminium billet and not by casting. High cycle fatigue is observed when material is subjected to cyclic loading within the material's elastic limit. To safeguard the turbocharger and other components around, from the damage due to turbine or impeller burst, manufacturers design the turbocharger such that they contain all the burst fragments and validate the same by carrying out containments tests. For containment testing the turbocharger wheels are purposely induced to burst at speed higher than maximum design speed. Two types of tests are performed to depict wheel burst are 1. Hub burst 2. Blade off. Work is further required to relate the actual material properties of wheel to predict the turbine wheel or impeller burst using Finite Element Analysis.

B. *Explicit Dynamics*

Ashish Jaiswal et.al. [4] explains the capabilities of ANSYS to solve structural dynamics problems. Various disciplines available and their algorithms available in ANSYS are explained. Transient dynamics analysis is used for determining the time response of structure for forces varying with time. To solve these problems, time integration is performed. Implicit and Explicit are the time integration methods available. Implicit uses Newmark method, it is unconditionally stable. This method solves linear equation for each time step and the stiffness matrix is inverted for each increment, which is computationally expensive. Explicit method used Central Difference method which is conditionally stable. It also solves linear equations for each time step but it does not perform any inversion. Thus, Explicit method is preferred to provide solution for nonlinear problems involving large deformation, impact problems, short duration problems etc.

Czeslaw Bajer et.al. [5] describes various types of time integration methods used through this paper. Newmark and Central Difference method are most commonly used for structural dynamics analysis problems. Various other methods such as the Bossak and Hilber Hughes Taylor methods are also studied, which are considered as an alternative to Newmark method. Implicit methods provide infinite speed of information which is considered to be very important for wave propagation problem. But, in Explicit methods, the speed of information flow is limited to diagonal of mesh.

Pranita Kesare et.al. [1] studied the steps followed for solving problems using Explicit method. The state of system at later time is calculated using state of system at current time in Explicit method. Smaller time steps are used which ensures proper stability and accuracy of solution. No convergence check is needed as the equations are uncoupled. No inversion of stiffness matrix is needed to avoid iterations. They have considered wheel burst analysis for light duty turbine wheel application, for the speed varying from 150 krpm to 200 krpm. ANSYS AUTODYN has been used for simulating wheel burst.

Suman Anand et.al. [6] states that Explicit Dynamics is used to model high velocity impact problems. Explicit Dynamics makes it easy to simulate highly non-linear problems involving high strain rate, material failure, large deformation etc. Explicit Dynamics is used to simulate problems which last for few milliseconds or less than that. To solve Finite Element problems, user starts with discretising the model after the addition of material properties defined by material models. Further, the application of loads and constraints are provided for solving.

L Wang et.al. [7] explains the reason to use Explicit Dynamics for simulating wheel burst. Finite Element (FE) methods are resolved into Implicit and Explicit method. The Implicit method performs iterations to find approximate static equilibrium after each loading increments. It uses convergence condition for controlling the increment. For problem involving high non-linearity, many iterations are performed to find the equilibrium. Hence, this method is expensive and requires high memory. The Explicit method solves the problem by advancing the state from one to next time increment without performing iterations. It does not require any convergence criteria, thus solves nonlinear, complex problems efficiently. Thus, Explicit FE Analysis is selected to simulate wheel burst and containment test.

Badita et.al. [8] explains the Explicit Dynamics solution strategy. Dynamic response of any structure or nonlinear problems can be determined by using Explicit Dynamics. Various steps are followed while solving problems using Explicit Dynamics like discretising the model, assigning material properties, meshing, providing initial boundary conditions and loadings. After this, pre-processing the time will be integrated which will produce motion at node points in mesh. This motion produces deformation in elements which results in change in volume. The strain rate is derived with the help of rate of deformation using various elemental formulations. External forces are calculated from the given boundary conditions, loads and contacts. For calculating nodal acceleration, nodal forces are divided by nodal mass. The accelerations are integrated in time to determine nodal velocities and the velocities are further integrated in time to calculate new nodal positions. The advantage of using Explicit Dynamics for nonlinear is, no iterations are required while performing time integration. No convergence criteria and no inversion of stiffness matrix are required. There was also a car crash test simulated using the same. The Model is prepared in ANSA and simulation is done using ANSYS Explicit Dynamics. Thus, car crash simulation results are determined without any actual hardware destruction.

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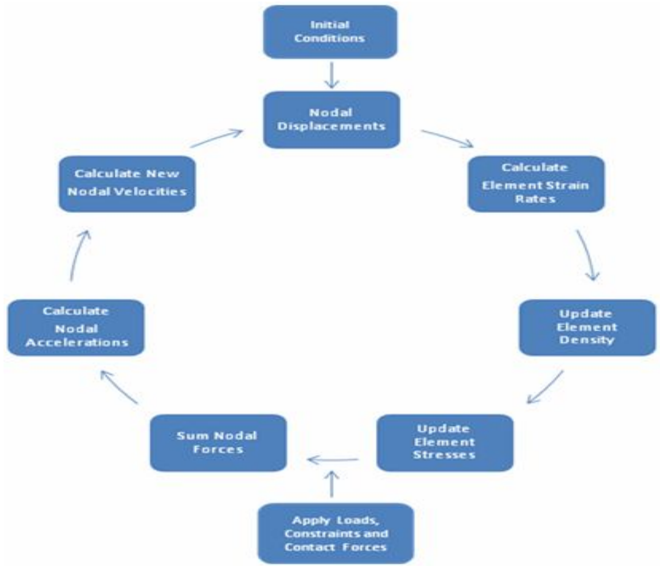

Fig 1: Explicit Dynamics methodology [8]

J S Sun et.al. [9] explained a performance comparison between Implicit and Explicit methods for impact test of an elastic bar and cylindrical disk on rigid wall. The author has described Implicit method to be unconditionally stable but faces issue while solving complex problems. The reason is that, for complicated problems the time increment reduces, the computational cost of tangent stiffness matrix increases and equilibrium is difficult to achieve.

C. Material Models For Ductile Materials

There are various material models used for defining the behaviour of ductile material under dynamic loadings. Johnson Cook is one of the material model which covers strain rate effect, high temperature and thermal softening effects.

Ying Li et.al. [10] studied different strength and fracture models used for simulation of ductile material. To validate these models Taylor test is performed in which the flat nosed cylinder is impacted against fixed wall. Finite Element Analysis software AUTODYN is used for predicting the failure modes of the test through simulation. Maximum principal stress, equivalent plastic strain, maximum principal strain, Johnson Cook fracture model's parameters are obtained by conducting tensile test at high temperature. Johnson Cook material model is selected to reduce the complexity. According to the results of the test conducted, it is concluded that Johnson Cook fracture criteria is accurate for ductile fracture in dynamics problems.

Len Schwer et.al. [11] differentiated the Johnson Cook (JC) model from traditional plastic models. JC model can model material responses such as strain hardening, strain rate effect and thermal softening effect. According to the author JC model is considered as linear in logarithm of strain rate. JC constitutive model is given as below. Johnson Cook later expanded the idea of this model for fracture criteria.

$$\sigma_Y = \left[A + B\left(\varepsilon_{eff}^{p}\right)^{N} \right]\left(1 + C\ln\dot{\varepsilon}\right)\left[1 - \left(T_H\right)^{M}\right]$$

Fig 2: Johnson Cook material model equation [11]

A V Sobolev et.al. [12] studied difference observed in the results calculated with plasticity given by Johnson Cook material model. Most of the models do not consider the phenomena of kinematic strength and effect of strain intensity on yield strength. Johnson Cook material model is mostly used as it considers both kinematic strength phenomenon and adiabatic heating of the material which is under strain. The equation of Johnson Cook material model shown in fig 2, defines a material's strain curve. The A parameter is the yield strength of material for low stress rate. Parameter B and n represent isotropic strengthening during the strains. C considers the kinematic strengthening. Plastic properties of materials are tabulated. Simulation is run using LS Dyna and Johnson Cook material model. Test and analysis results are compared, and it is seen that plastic strain tabulated model disagree with the test data with 20% indent depth and 13% indent diameter. It is assumed that the disagreement may be because of the test data that doesn't include any description of how indent diameter and depth are measured.

Michal Grazka et.al. [13] presents how laboratory experiments and numerical simulation results are connected. Taylor impact test is used for calculating the dynamic parameters of a material. Johnson Cook model is used for simulation as it shows relation of deformation with strain rate. The A, B, C, n, and m constant in the equation of Johnson Cook model shown in fig 2, are used to calculate dynamics response of material undergoing plastic deformation. This material model is used as it is easy to apply and only 5 constants are required to describe it. For simulation, speed of sample hitting the wall is considered as $130ms^{-1}$. For Taylor impact test, impact velocity and final shape of the sample after its deformation on rigid wall is used for determining the dynamic properties of material. Copper Cu-ETP samples has been used. Coordinate measuring technique is used to measure the shape after the test. The fault value after comparing the curves obtained is about 3.8%. Thus, it's concluded that the method followed (Taylor test) can be used as an alternative to Hopkinson pressure bar test for calculating the Johnson Cook parameters.

I S Boldyrev et.al. [14] studied the effect of material model parameters and the failure criteria on cutting forces that arise during the Finite Element simulation of the cutting process of Al 6061-T6. Finite Element method is chosen for analysis using Langrangian approach and element erosion with 0.5 failure strain. For analysis, isotropic, kinematic hardening and Johnson Cook material models are selected. The developed model predicts the cutting forces, continuous chip morphology in accordance with experimental data. From the simulation results, it is observed that Johnson-Cook constitutive model and the failure criteria used gives more accurate results as compared to kinematic and isotropic hardening.

D. Containment Simulation

Experimental containment testing involves number of iterations to be performed for successful burst to occur i.e. to achieve impeller burst at target speed. To avoid the iterations in testing, containment test is simulated using Explicit Dynamics. Simulation provides an initial guess of weakening slot that is required for successful burst to occur, thus saving time and with minimum cost.

L Wang et.al. [7] used ANSYS Autodyn method to simulate the containment test. During simulation, steady state thermal analysis, in which the temperature effects are considered first then Transient Explicit Dynamics analysis, where wheel burst and turbine housing containment simulation is performed. Later, the target speed is applied to the weakened wheel. To model the plastic behaviour of housing material, Johnson Cook strength model is used as it models high temperature, large strain and high strain rate. For ductile failure of wheel burst and housing simulation, plastic strain is applied as material failure criterion. This simulation is applied to other case studies and good correlation between test and simulation results is observed. Also, this simulation technique of wheel burst is used for simulating impeller burst and it shows good results. Thus, this paper presents the methodology to optimize the design of weakening slot for bursting turbine wheel at any specific speed.

J M Ramamoorthy et.al. [15] performed the simulation of containment test of both the compressor and turbine housing and validated it with the test results. Wheel burst occurs when the centrifugal forces exceeds the internal binding forces. Hub burst condition is considered, where the hoop stress is a major concern. Burst speed of wheel is estimated using area weighted mean hoop stress (AWMHS) method. The containment test has been simulated by defining the strength and damage model. For impeller burst no temperature effects are considered. The duration of simulation showed considerable reduction in kinetic energy of impeller. For wheel burst, steady state thermal analysis has performed considering the thermal effects. Simulation results have been validated with several rig tests and they show less than 2% deviation in burst speed.

Thomas Winter et.al. [16] described the containment test as the ability of turbocharger housing to contain the fractures of rotating parts inside the housing during wheel burst. The containment test is expensive and time consuming. Therefore, the author has suggested to simulate the test using Explicit Finite Element method.

E. Meshing algorithms/Mesh sensitivity

Meshing is an important factor affecting the simulation results. Use of different meshing algorithms, mesh sizes leads to variation in result. Thus, mesh sensitivity study is required before running the simulation.

Maruti BH et.al. [17] developed a Finite Element method to predict the burst margin limit. The parameters used for meshing the model are stated in this paper. The Finite Element model developed consists of 12,534 nodes of PLANE 42 type of elements. The mesh model has around 1000 first order elements for one half of disc thickness. 4 noded axis symmetric PLANE 42 elements have been chosen as they possessed the capability of modelling plasticity and large strain effects. Each node has 2 degrees of freedom (DOF) along x and y axis accordingly and the angular velocity is given about y axis.

Pranita Kesare et.al. [1] studied the impact force generated by turbine wheel blade detachment. The author has used Johnson Cook material model for modelling the ductile INCONEL turbine wheel material. For meshing, they have used linear tetrahedral elements to capture the geometry accurately. Also, the critical regions have been meshed finely based on mesh sensitivity study. Around 1 lakh elements and 2 lakh nodes are generated on the wheel model.

L Wang et.al. [7] simulated the turbine housing containment. Due to geometry complexity, tetrahedral elements of first order have been used for meshing. About 1.8 million elements are generated after meshing.

S S Borikar et.al. [18] stated that at high temperature and high velocity of exhaust gases, internal bonds of the materials start breaking w.r.t. high centrifugal forces. Wheel burst can occur in two failure modes, hub burst and wheel detachment. Explicit Dynamics has been used for simulation. To model the ductile behaviour of turbine wheel material, Johnson Cook model has been used. Circumferential groove has been considered for blade detachment. In simulations, wheel burst resulted in an unequal number of fragments due to non-uniform mesh density over the regions of the turbine wheel. Hence, the turbine model is meshed with different type of meshing algorithms, mesh sizes such as Tet mesh, Hex dominant, pattern meshing etc. Using the Pugh matrix, pattern instance method is selected for meshing.

Thomas Winter et.al. [16] used axial flow turbocharger of 5100 kW consisting of radial compressor. The compressor wheel sample is notched at three positions with 120 deg apart. For simulation, the model consisted of brick, shell and beam elements are used. Shell elements are used in regions of less importance. Beam elements are used at the connection of two different parts. The body of compressor wheel had three parts, which consisted hexahedron elements mostly and pentahedron elements in small number. MAT_PIECEWISE_LINEAR_PLASTICITY material type is used in model. Plastic strain of 35% to 40% is considered for realistic failure. The simulation lasted about 2 to 2.5 milliseconds. Using LINUX-cluster with four CPUs, simulation ran for about 20 hours. The parts of compressor wheel are on the shaft at beginning of simulation, later the fragments intruded the housing within 1.2 milliseconds. For validation, test is carried out. High stressed region and cracks seen on the compressor wheel during the test are well predicted by simulation. Good correlation is identified between test and simulation.

D Ruta et.al. [19] presented the mesh sensitivity study that is carried out on compact tension specimen which is dynamically loaded. In experimental testing, it's observed that the resistance increases as the loading rate increases. And the crack tends to incline with respect to the loading direction. To validate the experiment results, analysis with three different mesh sizes are done with h = 5, 10, 15mm. 8 noded linear strain elements and 4 noded constant strain elements are used for meshing the model. It is observed that even though the mesh and finite elements are different, there is no significant difference on response. The crack propagation is observed to be perpendicular to loading direction as expected from experiment.

R A Claudio et.al. [20] performed analysis on gas turbine disk. For meshing the sector model, 20 node isoparametric elements are used, as they showed good results. Different types of mesh are used for analysis: coarse mesh with 11886 DOF, medium mesh size with 20387 DOF and fine mesh with 67938 DOF. The simulated results predicted the life of the component.

F. Burst Margin Determination Using Static Analysis

Simulating containment testing or burst phenomenon using Explicit Dynamics involves high run time. Even simulation requires a good guess of slot depth value to be provided in order to avoid many iterations and achieve burst at target in few instances. To reduces the time involved for simulation using Explicit Dynamics and provide right guess of slot depth value for simulation, static analysis has been proposed as one of the method.

Hasan Calhoglu et.al. [21] investigated analytically the elastic plastic stress analysis of curvilinear orthotropic rotating disc for strain hardening material. The disc has been produced by compression moulding of aluminium metal which has matrix reinforced curvilinear steel fibers. From the solution, it is seen that radial stress component is always tension and along the radial section it is zero. Also, the circumferential stress component is highest at inner surface and low at outer surface. The circumferential stress magnitude is found to be higher than the radial stress component.

Masahiro Shikida et.al. [22] studied spin tests for both the notched and unnotched disks made of the mild steel under simple loading test. Bursting of disk has been achieved by air turbine which provides high speed rotation. Vacuum pump maintains the test chamber's pressure less than 5mmHg. Digital tachometer is used for recording the rotating speed of air turbine. SS41 mild steel has been used as spin burst test material. The notched length on notched disk varies from 5 to 40mm in 5 intervals. One side of the surface is polished with emery paper. The strain components in disk include radial, tangential and axial stresses. The Tangential strain affects the fracture mostly. In experimentation it is seen that, deformation started at 26000 rpm and later the tangential strain reached 17% on the inner diameter before it finally burst. And the deformation at outer side is not more than 1.5%. The difference between the x and y component of tangential strains are small, hence no deformation of anisotropy material was tested. In unnotched disk it was seen that a warp of 3.8mm on edge of the bore at 28000rpm and gradually decreases to plane surface before it burst. The wrap is due to severe strain concentration around bore.

Nelli N Alexandrova et.al. [23] studied the plane state of stress in an elastic perfectly plastic isotropic rotating annular disk mounted on a rigid shaft. The analysis is based on Mises yield criterion and its flow rule. Analytical method is used for solving the plane stress conditions as much as possible and further solving them numerically. The plastic deformation is seen near disk's inner radius and the outer radius is never seen to be plastic completely.

Maruti B H et.al. [17] performed thermal and mechanical analysis on high speed aero-engine turbine wheel for determining the over speed and limit for burst. They developed a parametric model as per the real object. The combinations of thermal and centrifugal loads are calculated by FE calculation after knowing the axis of symmetry, speed and blade material and disc. For analysis, 10000 to 22000 rpm is applied as turbine speed. Thermal load of 450 deg at bore and 600 deg at rim of disc is considered. The blade load is distributed on nodes. INCONEL 718 is used as turbine disc material. Bilinear material parameters are considered for temperature variation from the bore to rim. To understand the effect of various load acting on the disc, individual sensitivity analysis is done. The results showed hoop stress distribution is a function of disc radius. It is maximum on inner rim side and minimum on outer surface. Experimental test is simulated for the burst margin on the disc and for all the loading conditions. After the finding the stress for each radial station, the burst margin is calculated using empirical formula. It is concluded that, all the three loads (thermal load, centrifugal load and blade load) together affect the stresses and burst margin.

Sai Prashanth R C et.al. [24] described that amount of stress acting on compressor disc which is necessary to prevent the failure of an aero engine's compressor. Rotating components release energy on bursting. 2D model of compressor disc is created and used for analysing over speed burst margin. Titanium Ti 6Al 4V is considered as compressor disc material. Disc rotational velocity of 14000 and 15000 rpm is applied. For simulation, and the body motion is constrained in y direction. Snippet commands are used for calculating hoop stress e.g. SSUM. The average hoop stress values are obtained for 14000 and 15000 rpm cases. Case 7 of both 14000rpm and for 15000 rpm gave best results in terms of burst margin. It is seen that burst margin increases with decrease of average mean hoop stress.

Rudresh et.al. [25] in this paper established the failure analysis of turbine disk for an air engine. To determine the stresses on the turbine disc, a model is developed with the help of CATIA software. Model is meshed using hypermesh tool. INCONEL 718 is used as turbine disk material. It is observed that using 18000rpm as angular velocity, the hoop stress and von misses stress increase and the radial stress decrease as a result of increase in radial distance from bore to outer rim.

Harinath SP et.al. [26] carried out a methodology for the estimation of aero engine disc's safety margin and LCF number of duty cycles. According to ASTM INCONEL 718 material is considered for aero engine disc. ANSYS software is used for simulation, as experimental way for obtaining safety margin is time consuming and expensive. The geometry is optimized considering the design, behavioural and topological constraints using a design of experiments (DOE) approach. Later static analysis is performed on the optimized geometry on which various loads act such as centrifugal, thermal loads. It is seen that the hoop stress which is maximum at bore decreases as the length of the disc increases from the bore region to rim. The radial stresses are minimum at bore portion. As hoop stress is dominant at bore portion, which is a major factor for disc failure.

Harinath SP et.al. [26] also performed static analysis for evaluating safety margin and LCF life. They obtained the radial and hoop stress from the analysis performed. Several criteria and theories state the procedure to obtain the rotational speed at which the disc will fail. Robinson and Hallinan's criteria are used as these are widely used theories for finding burst margin of rotating disc. Using linear approach for evaluating safety margin, it assumes ultimate stress to be within the elastic limit region and the yield is not there. But this assumption is not real thus they concluded it as invalid. Later isotropic hardening is also considered but they concluded it to be unacceptable as real material behaviour i.e. stress in tension and compression loading not same. Finally, kinematic approach is selected as it modelled the material behaviour as it behaves during testing. The burst margin is evaluated using Robinson's and Hallinan criteria for 3 different cases.

R A Claudio et.al. [20] explained the procedure followed for predicting fatigue life of a gas turbine disk. Sector model is used for finite element analysis. Nickel alloy IN718 is defined as turbine disk material. Null displacement is given in Z direction of the mounting flange and θ direction. Temperature of 600 deg and speed of 15,000rpm is given as loading conditions. 3D as well as 2D analysis is performed with and without crack on turbine disk. Initially stress analysis is performed. The stress results has good conformance in simulation and analytically results. In 3D analysis, it is observed that maximum principal stress value is close to tangential stress value.

Srinivas Murthy et.al. [27] illustrated how the gas turbine disc is designed at speed of 12000rpm and operating temperature of 500 degC. Centrifugal loads and thermo mechanical loads are major loads which act on turbine blades. A sector model of cyclic symmetry for an integrated disk assembly is considered. The model having 3 blades with 18 deg disk sector. For analysis, higher order elements are considered. They have also considered three loading conditions: centrifugal force only, combination of centrifugal and blade pressure, and at last considering all three loads. It is observed, that hoop stress is maximum at disc bore and it decreases as length of the disc increases from the bore region to rim. As a part of over burst evaluation, two criteria are used: Robinson's criteria and Hallinan's Criteria.

Ranjan Kumar et.al. [28] explained, how they found the burst margin for a gas turbine disc using finite element method for different wheel speeds. They have also explained the burst margin as safety limits of speed within that region are no failure of disc will be seen. 2D model of the disc is considered due to complex geometry. IN718 is used as turbine disc material. A temperature of 481.5deg at bore and 510deg at rim of disc is applied. Static analysis is run for uniform thickness of the disc and the results are compared with the analytical results. Hoop stress is determined to calculate the burst margin. For burst margin of 122%, the allowable speed is 18000rpm for disc with variable thickness and 17800rpm for disc with uniform thickness.

Anton N Servetnik et.al. [29] studied methods used for determining limiting burst speed of disks of gas turbine engine (GTE). Limit equation method is the traditional method used for assessing the disk load carrying capacity. In this equation stress concentration effect is not considered and also the effect of mating part and thermal field of the disk. The calculative values and the experimental data are distinct by 20% in some of the cases. Further finite element method is used as it takes into account the structural and loading peculiarities. For this, energy based fracture criterion is selected which states that fracture will occur at instant when the strain energy density reaches its critical value in most stresses point of the disk. To determine the plastic strain distribution on disk during loading, incremental plasticity theory with isotropic hardening is used. The simulation and experimental results using energy fracture criterion fit within less than 2%. The Tresca yield condition proved to be more reliable than the Von Mises yield condition.

II. CONCLUSIONS

Based on the literature survey done, it can be concluded that there are various methods to solve dynamic problems but Explicit Dynamics analysis seems to be widely used to solve such problems. To carry out impeller burst simulation, various parameters are to be considered important. As per literature survey carried out, some of the important parameters used in different research for containment test simulation can be considered to be standard. Such as for defining ductile behavior of the impeller material, Johnson Cook material model can be selected. Uniform meshing option can be selected to capture results accurately in the slot region. Equivalent plastic strain can be selected as failure criteria. Also, burst margin criteria can be studied for providing initial guess for slot depth during testing.

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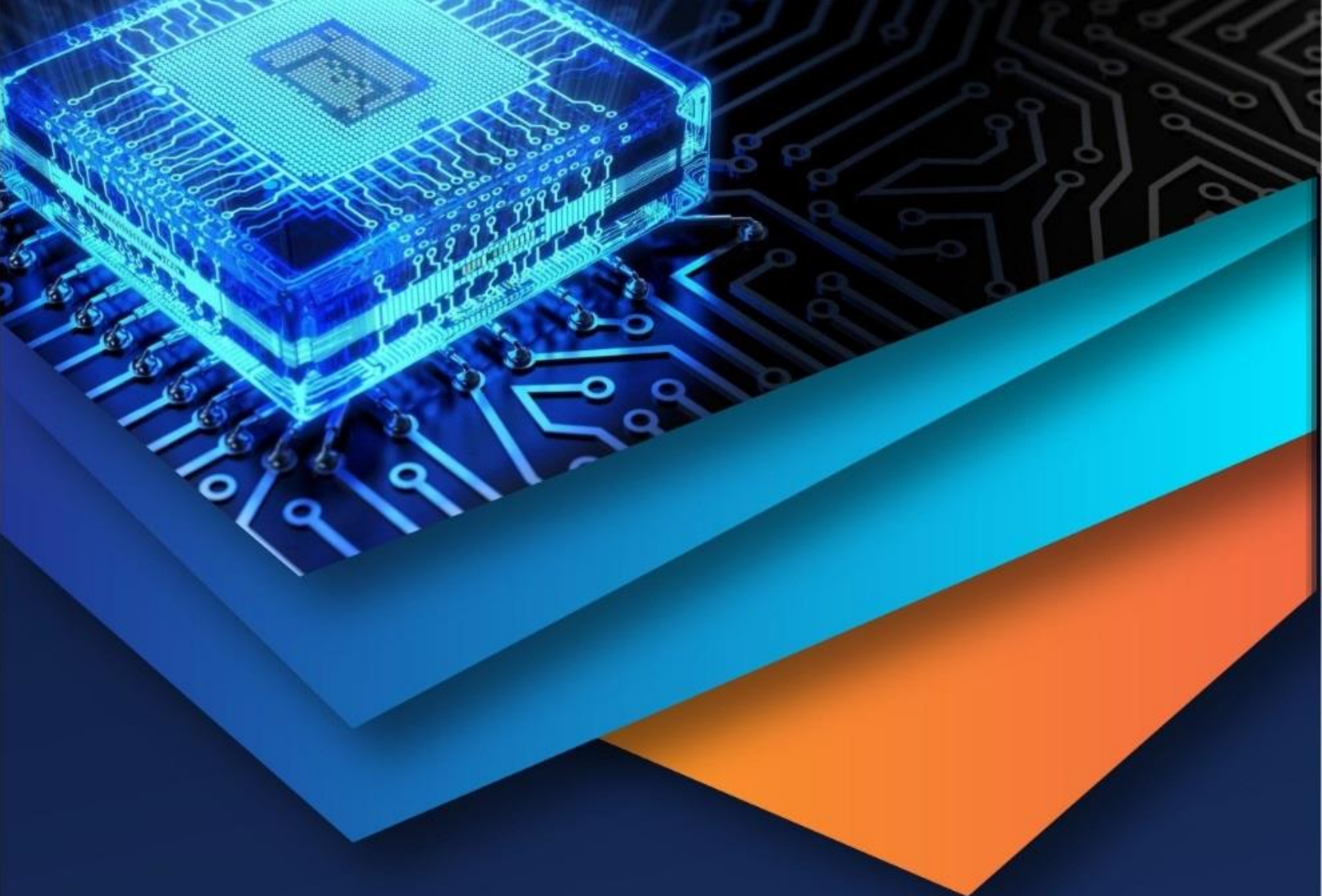

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