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Dynamic Response of AL 2024-T3 Aluminium Plates Impacted by Projectile Using Small and Medium Scale of Cluster Parallel Computing

Adip Kamel Abdul Ghani[1], **Mohd Norihan Ibrahim**[1*]

[1]Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering,
University of Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Deformation processes of structures under ballistic impact have been investigated both experimentally and by simulation for many years now. The high complexity of impact problem is caused by the large number of factors like relative velocity of projectile and target, relative stiffness and masses, shape of colliding object, surface of contact, material characteristics and geometry and boundary conditions. Materials under ballistic impacts show highly nonlinear and dynamic behaviour including strain and strain rate hardening, thermal softening and fracture. Most of the analysis and investigation related to ballistic impact carried out by comparing the experimental results and numerical simulation. Experimental testing provides an important source of data that can be used to test the validity of theoretical approach provides a wealth of information into the mechanical and material properties as well as forms the basis for empirical study. The simulation is run by applying parallel computing approach. The study of impact is conducted by using ABAQUS simulation software.

Keywords: Ballistic Impact, Strain Rate Hardening, Abaqus

1. Introduction

Simulation approach has been widely used by researcher to get corresponding results. The said experiment such as ballistic impact, tensile testing, crack propagation and also fatigue.[1]. This method ease the researcher to obtain data without using a high cost of budget. But, as the processing data is time consuming because of the size of the preprocessing data is huge, parallel computing is introduced to speed up the processing phase of simulation. The cluster of parallel computing is classified into three category, which is small, medium and big cluster of parallel computing.

The subject material is AL 2024-T3, which is used by defence application. In the simulation it emphasize the perforation of the plate after impact by bullet. However the crack propagation after the impact is not conducted. In this proposed research, a conventional approach in employing a single high-end physical computer for high speed impact application will be replaced by parallel low-end computers

*Corresponding author: norihan@uthm.edu.my

on small and medium cluster environment. The conventional non-linear material constitutive laws that have been implemented nowadays would not be suitable on cluster parallel computers. The distribution of finite elements in every processor should be followed by the non-linearity of the material.The parallel computing approach should be applied in the ballistic impact simulation. This is to reduce the time of processing the simulation. ABAQUS simulation software supports parallel computing approach whether it is small or medium cluster. The purpose of this is to analyze and compare which cluster gives best result in term of time reduction.

Ballistic impact is known as impact caused by small mass material in high-speed velocity manner [2]. The name ballistic itself is related to projectiles such as guns, rockets. Which means term ballistic impact only can be used as this scenario; a bullet-sized material is thrust into material when applying high velocity of speed. In this research, the material of the plate is AL2024-T3, which is subjected to the ballistic impact itself. When speaking about the alloy aluminium, it is always linked with outer body part of jet, airplanes, rockets, and any flying vehicles which offers their high strength characteristics with low density and weight. The other term of the characteristics is high strength to weight ratio. Though, the AL2024-T3 [3] has more other characteristics than its special lightweight such as corrosion resistance to acidic liquid. But in this research paper the aluminium alloy characteristics is focused only on high strength, high resistance to fatigue. This AL2024-T3 has outstanding ultimate tensile strength of 400-430 MPa, also yield strength at least 265 - 275 MPa. With above mentioned characteristics, the AL 2024-T3 is suitable used as jet or flying vehicle body. In defence mechanism, the aluminium alloy should prevent cracking after ballistic impact is applied to the material. Further cracking can cause torn to the airplane body thus making the plane will crash.

The variety of dynamic response [4] of metal plate when subjected to ballistic impact always cause a problem when obtaining data from real life experiments. This is because external factors should be taken into account when shooting bullets to the metal plate such as angle of impact during penetration of bullets into plate [5]. The hard control of speed of bullets and aiming also make the experiments troublesome, as well the cost of experiments. This is the reason why the experiments is suitably conducted by using simulation software to study the response of metal plate when subjected to ballistic impact through computational model [6]. The well-known simulation software suitable for this research is ABAQUS and ANSYS.

As a conclusion, ballistic impact experiment can be simulated by using a suitable finite simulation program such as ABAQUS and ANSYS. This is because both of the simulation suite can simulate explicit dynamic simulation. The simulation suite also has a configuration to set the mechanical properties of AL-2024 as the impacting plate. After the processing phase, the simulation suite offers a variety of the results such as crack propagation, the after impact velocity or known as the residual velocity and also Von Mises stress of the plate after the impact. With all the supported statement stated above, it can be concluded that the dynamic response of the AL-2024 aluminium can be run through simulation.

2. **Research Design and Methodology**

As mentioned earlier, this research is mainly conducted by using simulation of ABAQUS simulation software and only using real life experiment result only just to verification purposes. The flowchart of the methodology for this research is shown in Figure 1.

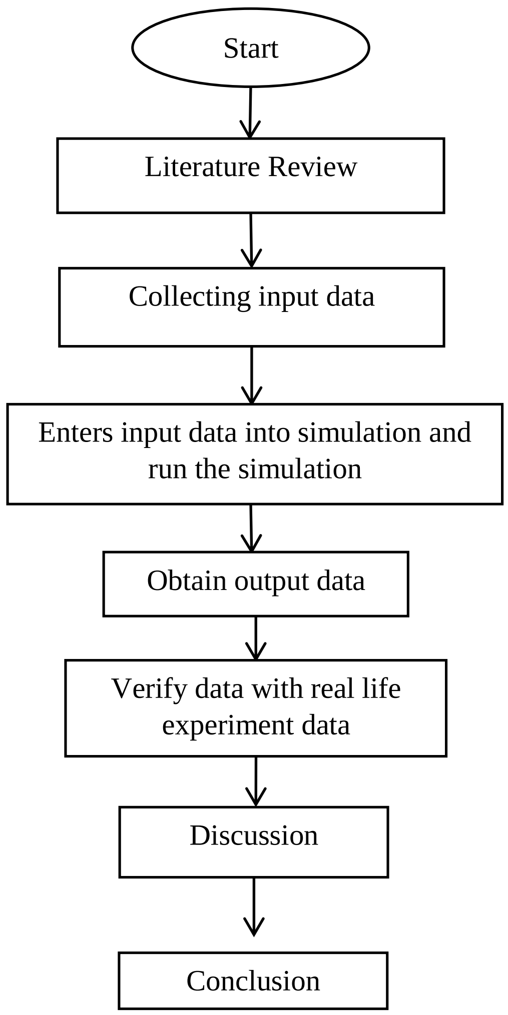

Figure 1: Flow chart of research methodology

3. Result and Discussion

In this research, a specific non-linear material computational model with a distribution parallel capability will be searched and developed to be implemented in cluster system. This will be a better and faster solution for low and high speed impact application. Small parallel personal computers can be arranged and to become a high-performance parallel computer system. On completion of this research, an effective platform in cost effective cluster parallel computing can be established. This system can be transformed to general engineering applications. This will be a potential commercialization of the developed system. This brings a new platform in the implementation of finite element methods cluster system that possibly extended to world-wide grid network computing. The run time of the simulation with different usage of internal processor is observable but not too significant and it shows that the higher the number of internal processor used, the lower the run time of the simulation. Figure 2 shows the deformation profile of Al2024 T3 plate when subjected to blunt nose projectile impact while Table 1 shows that the decrements of running time ballistic impact of blunt nosed bullet simulation when applying the multiple processor.

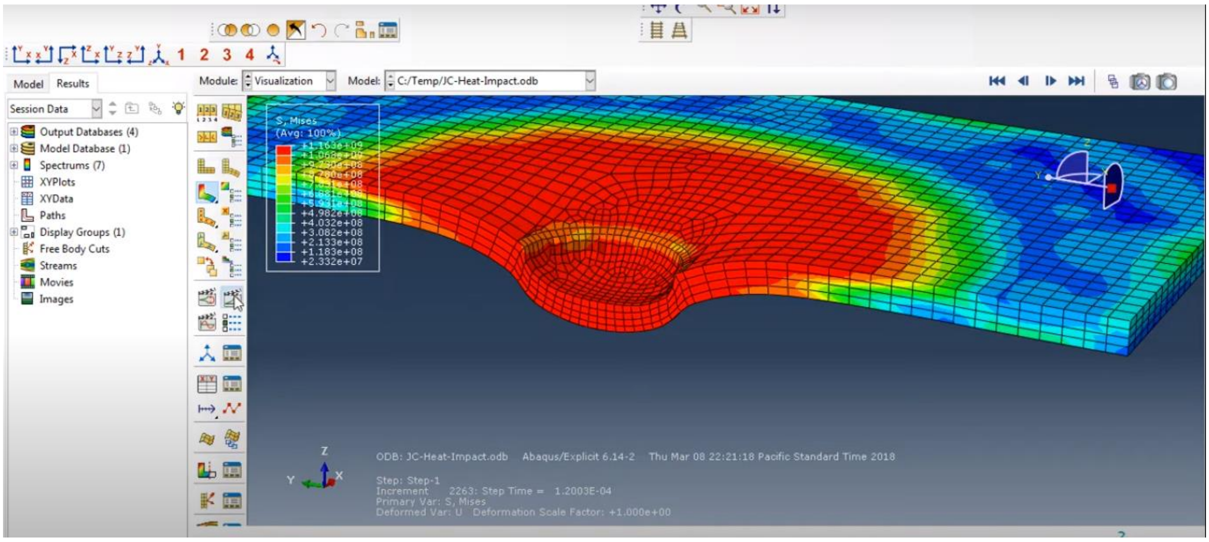

Figure 2: Simulation of plate when subjected ballistic impact

Table 1: Processing time of blunt nosed bullet simulation with different number of processor

Impact Velocity (m/s)	Simulation Run Time (s)			
	2 Processors	4 Processors	6 Processors	8 Processors
450	21	20.88	20.67	20.58
290	20.72	20.62	20.72	20.59
270	20.66	20.64	20.37	20.56
240	20.46	20.33	20.67	20.73
160	20.50	20.50	20.45	20.65
125	20.90	20.62	20.50	20.54
82	20.76	20.72	20.44	20.57
68.2	20.50	20.33	20.43	20.27
64	20.54	20.29	20.47	20.02
59.4	20.70	20.12	20.18	19.88
57.4	20.67	20.08	20.27	20.21
50.5	21.07	20.00	20.27	20.26
45.7	20.74	20.30	20.53	20.27
43.7	20.74	20.29	20.32	20.20

4. Conclusion

Normal impact of projectile towards single layered AL2024 T3 aluminum target plate has been studied numerically where the simulation was carried out by using ABAQUS explicit finite element code. The single plate of target plate was impacted by blunt nosed projectile and based on the study which has been implemented it is shown that the mode and contour of failure found on the impacted target plate has tremendously influenced by the projectile nose shape and the range of velocity. The preliminary results and finding can be used as part of initial phase of deformation study before extending to further investigation in non-linear material computational model with a distribution parallel capability in cluster system. This will be a better and faster solution for low and high speed impact application.

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