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Study the Influence of Impact on the Filled Tube of Aluminum 6082-T6 Alloy by Consideration of Temperature using FEM

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ABSTRACT

In this study, a numerical analysis of the impact behavior of a hollow tube made of aluminum 6082-T6 alloy in accordance with ISO 13314-2011 was conducted using FEM. ANSYS was utilized to execute the simulation procedure utilizing the Explicit Dynamic tool. The geometry of the present study consists of a 900 mm-long tube with a diameter of 60 x 2 mm, which was designed using SpaceClaim in Ansys. The model has meshed with a sweep-type mesh utilizing local coordinates. As a result, quadratic elements were utilized to simulate every impactor effect. The convergence of the mesh was determined in accordance with the equivalent strain analysis. The scope of the inquiry is limited to the mechanical behavior and energy conservation that occurs after the impact technique. The energy that is responsible for each and every sort of energy has been recognized. Instability was observed in both the internal and kinetic energies, with the latter reaching a maximum value of three electro-megajoules. Within each of the three axes, the directional deformation of the tube has been outlined. For a period of forty millimeters, the parallel axis of the impactor has undergone the greatest degree of maximum deformation that it has ever encountered. The equivalent stress, also known as von Mises, was measured in combination with the length of the tube, and it was discovered that it reached its highest point at 450 millimeters at the site of impact with 950 megapascal stresses.

1. Introduction

Due to its outstanding machinability, high recyclability, and appealing appearance, aluminum alloy constructions have recently garnered a lot of interest from mechanical and civil engineers. This phenomenon may be attributed to the elements. This is due to the fact that they are very simple candidates for recycling. In addition, the density of the aluminum alloy is just one-third that of steel, and the surface alumina provides it with a high level of resistance to corrosion for [1]. Aluminum alloy is thus finding widespread application in the construction sector, notably for the construction of

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bridges and other spatial constructions that have enormous spans. The fact that these buildings are made of aluminum alloy makes them susceptible to accidental hits, which represent a serious risk to the safety of individuals, the protection of property, and the stability of society [2]. As a result, it is preferable to employ a lightweight material that has a high energy absorption capacity as a filler for the aluminum alloy tubes [3]. This is because usage of such a material can strengthen the impact resistance of the aluminum building structure. Instead of loading the whole member, the impact just loads the member that is located in the immediate vicinity [4]. The fact that the impact is often lateral in direction is something that should be taken into consideration. The member's border condition is often evaluated whenever an impact takes place, which is still another advantage. As a consequence of this, the primary focus of this researcher's research is on the dynamic response of composite tubes that are totally clamped and are subjected to external lateral impact stress. The dynamic behavior of building structural parts that have been struck from the side by tiny items has been investigated by a great number of academic practitioners [5]. The work by Jabidi and Mahmudin [6] offers a description of empirical methods that may be used to measure the length of the plastic deformation zone as well as the lateral impact force. Following the completion of lateral impact testing on circular tubes constructed of Q235 steel, these processes were further enhanced. Additionally, as demonstrated by Li *et al.,* [7], axial compression resulted in a considerable reduction in the resistance to lateral impacts. In the experiments and computer modeling that were conducted by Barua *et al.,* [8], the beams that were used were made of mild steel and had an H-section. The extent to which different material models influence the precision of the computational findings was one of the aspects that they looked into doing research on. For the aim of this investigation, the results of the examinations were analyzed. Raju *et al.,* [9] and Sharaf *et al.,* [10] examined the dynamic response of H-shaped mild steel columns after they had been subjected to axially pre-compressive treatment. The columns were then subjected to local lateral impact. In order to gain a clear picture of the columns' capacity for residual bearing, we carried out this procedure. At the time when the columns were being designed, the H-section was selected for them. After conducting lateral impact testing on 6082-T6 and 6061-T6 aluminum alloy circular tubes, Aslam *et al.,* [11] were able to determine the components' capacity for energy absorption and their dynamic behavior during the whole impact process. According to the findings of Barua *et al.,* [8], while employing circular tubes manufactured of ultra-high strength steel, the mid-span deflection and residual deformation were significantly reduced when compared to the usage of mild steel, which is the material that is most typically employed [12]. This was found by analyzing the outcomes of lateral impact tests that were carried out on the tubes while they were moving at a very slow pace. The impact energy, thickness-to-diameter ratio, axial compression ratio, axial force direction, and hammerhead form are all factors that have been shown to have an effect on the dynamic behavior of high-strength steel tubes, as demonstrated by numerical studies and lateral impact tests carried out on axially preloaded circular tubes [13]. In order to gain an understanding of how these tubes respond when subjected to dynamic situations, several tests were conducted. According to the current body of literature on construction-related themes, such as bridge structures that are subjected to lateral impacts and large-span spatial structures, there is a deficiency in study on the dynamic response of composite tubes that are formed of aluminum alloy and filled with aluminum foam [14]. Considering that it has a low density, a high porosity, and a high energy absorption capability, this material is frequently utilized as a filler in protective constructions [15,16]. The quasi-static and dynamic axial crushing capabilities of metallic tubes filled with aluminum foam have been the subject of a significant amount of study. More specifically, individuals with square sections and circular sections have focused their attention on these capabilities [17,18]. The axial crush response of tubes filled with aluminum foam are, in many instances, superior to that of tubes that are empty. Interfacial friction between the wall of the tube and the foam, as well as the force that the foam applies to keep the tube from folding, are the factors that result in the outcome. The capabilities of the aluminum foam-filled tube as an energy absorber were also evaluated, and they were tested for bending and lateral loading [19,20]. Aluminum foam filling has been found to improve the crashworthiness of tubes under lateral impacts, increase energy absorption, and improve bending response, according to extensive research that has been conducted in theory, numerical models, and experimental settings [21]. There has been a significant amount of study conducted on the bending performance and dynamic lateral crush behavior of circular tubes filled with aluminum foam. However, the majority of this research has been on the ship-building, automotive, and aerospace industries. These studies on the application of composite tubes in construction still have a few shortcomings, including the following problems, which are outlined below: Rather than being confined to that particular region, the composite tube is subjected to lateral impact forces that are distributed uniformly along its length. Secondly, the boundary condition of the tube is hinged so that dynamic bending tests may be performed on it [22]. When compared to the length of the aluminum alloy component that is connected to construction, the length of the studied member, which ranges from 40 to 300 millimeters, is much shorter. The dynamic reaction and energy absorption of tubes that have been impacted laterally have been the subject of much research in recent times [23]. The focus of these research has been on cutting-edge materials and cross-sectional forms. Glass fiber reinforced plastic (GFRP) and improving pore morphology foam are two examples of these types of materials [24,25]. These novel components, on the other hand, are not well suited for usage in the construction sector because of their complicated design, high prices, and lengthy production processes [26]. There is a possibility that the components of long-span space constructions and bridges might be rectangular tubes with a broad span that are filled with aluminum foam [27]. The impact resistance of the composite tubes is going to be evaluated with the help of this. Guo *et al.,* [28] make use of numerical models and impact experiments that involve components that have fixed ends in order to determine how well these tubes are able to withstand localized lateral impact. The process of doing so lays the groundwork for the real engineering application of the components and improves their structural protection capabilities [29]. This is accomplished by comprehensively addressing the positive impacts that the aluminum foam filling has on the impact resistance performance of the components [30].

In this study, we numerically investigated the impact behaviour of hollow tube 6082-T6 alloy using the finite element method (FEM) in accordance with ISO 13314-2011. Analytical software from SYSTEM has been used to accurately reproduce the impact process.

2. Methodology

2.1 Meshing and Geometry

As part of this scientific investigation, the hollow shaft of the 6082-T6 aluminum alloy that is based on ISO 13314-2011 has been created with the aid of the SpaceClaim tool that is a component of the Ansys software. This was done in order to fulfill the requirements of the investigation. Through the use of the workspace, we have imported the geometry of the hollow shaft in accordance with the parameters that were provided. The transitional structure that was generated by the ansys tool has been utilized in order to construct a mesh, as has been established by the findings of the investigation, as shown in Figure 1. For the purpose of determining the dimensions of the tube's surface, it has been decided that a portion of the element that is two millimeters in length will be utilized. In order to provide a description of the contact zone that exists between the contactor and the tube, the rough form of connection was utilized at that particular stage. In order to achieve the objective of simulating the significant deflection that occurs as a consequence of the impact process, the sweep type of mesh has been chosen as the type of mesh that will be utilized. Additionally, the element type has been selected to be the quad type in order to facilitate the process of convergence to be carried out in a more straightforward manner.

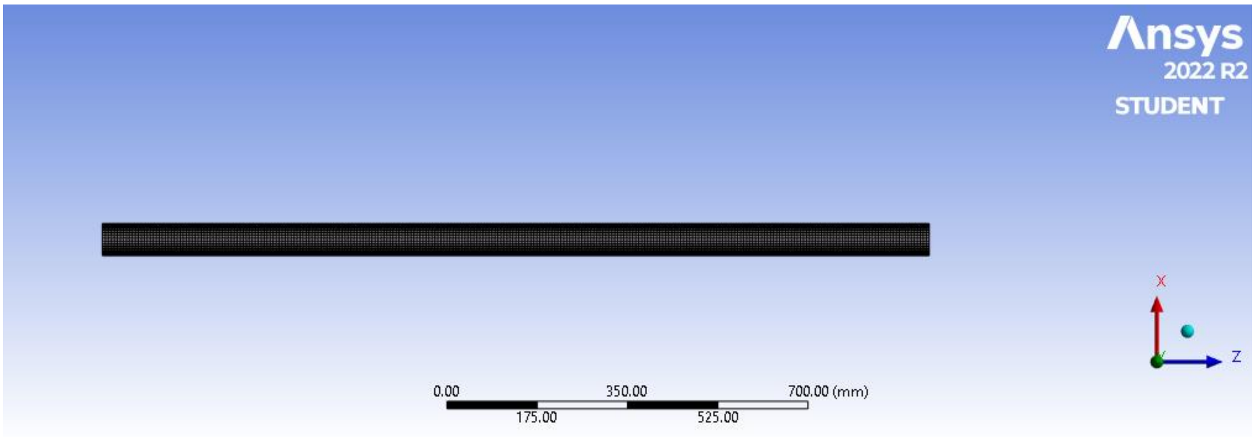

Fig. 1. Meshed of aluminium 6082-T6

2.2 Material Properties

A determination must be made in the engineering data of Ansys on the mechanical properties of the model that is being utilized for analysis. A reference to the Modulus of elasticity of the alloy has been made in this analysis, which was based on the prior scientific study [31]. In addition, the ansys program has already been established and executed with the alloy of aluminum 6082-T6, which has previously been designed. The results of the simulation technique are presented in Table 1, which include the data that was acquired.

Table 1
General properties of aluminum 6082-T6

Material	E (MPA)	Passion ratio	Density (kg/m^3)
Aluminum 6082-T6	70	0.30	271

2.3 Convergence Process

In order to converge and regulate the election that was brought about by the application of the dynamic load to the time, a convergence test has been carried out in the ansys mechanical of the current model. In accordance with the criteria that are now in place, the convergence status has only been attained in two of the solutions . Upon completion of this solution, every geometry will converge in the appropriate manner. For the Convergence process, the equivalent elastic strain has been selected as the appropriate parameter. As can be seen in Figure 2, the maximum strain has been attained, which is 1.63e-5 (mm/mm) for the convergence.

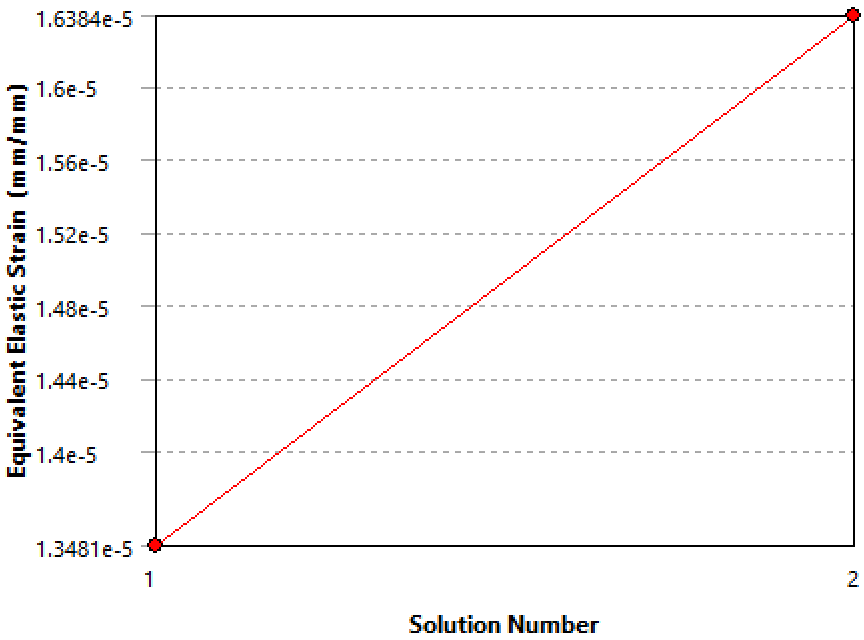

Fig. 2. Convergence analysis

2.4 Primary Boundary Conditions

In order to accomplish the goals of this inquiry, the scenario that has been taken into account is that of an impact test being carried out on a hollow tube that is built of aluminum alloy [32]. The length of the tube is 900 mm, and it is equipped with supports that might be attached from either side. As a result of its flat shape, this type of hammer is referred to as an impactor. It is designed to make touch with the middle of the tube at a speed of four metres per second because it is its ultimate destination. The amount of force that is being exerted is equal to 54 kilonewtons. The configuration of the program has been carried out with the assistance of an explicit dynamic tool in order to conform to the specification. It has been 0.01% of a second since the strike has arrived at its conclusion. An approach that takes into consideration significant deflections has been triggered in order to compute all of the deflections.

3. Results and Discussion

3.1 Behavior of Energy Conservation

The numerical analysis that was performed on this specific instance revealed that there are four different kinds of energy: contact energies, kinetic energies, hourglass energies, and internal energies. It has been concluded, on the basis of the data, that the first two energies, contact and hourglass, remain constant during the entirety of the impact phase. There are considerable adjustments that take place throughout the course of time with regard to the energy that is contained inside, with the highest energy reaching 3.8e-3 Mj. These movements involve the energy that is contained within. It is possible to compare the shape that the interior assumes in Figure 3 to that of a sin wave, which contains peaks at both the top and the bottom of the wave. Only four peaks were seen, and they were derived from the starting and ending times of the impact process. These peaks were the only ones that were observed.

The behaviour of energy is not stable with a sin wave shape when it comes to kinetic energy being the subject of discussion. Several variables are responsible for this result. The energy reaches its peak point with a value of 1.e-3 Mj, which is its maximum value. The curve that was seen and seen during the impact process of the impact test that was carried out on the aluminium tube had seven peaks. These peaks were seen and observed throughout the whole procedure. The contact energy and the hourglass energy, which are the other two, are both connected with a linear relationship with time. Together, they make up the other two. In the entirety of the process, from the very beginning to the very end, their values were entirely intact.

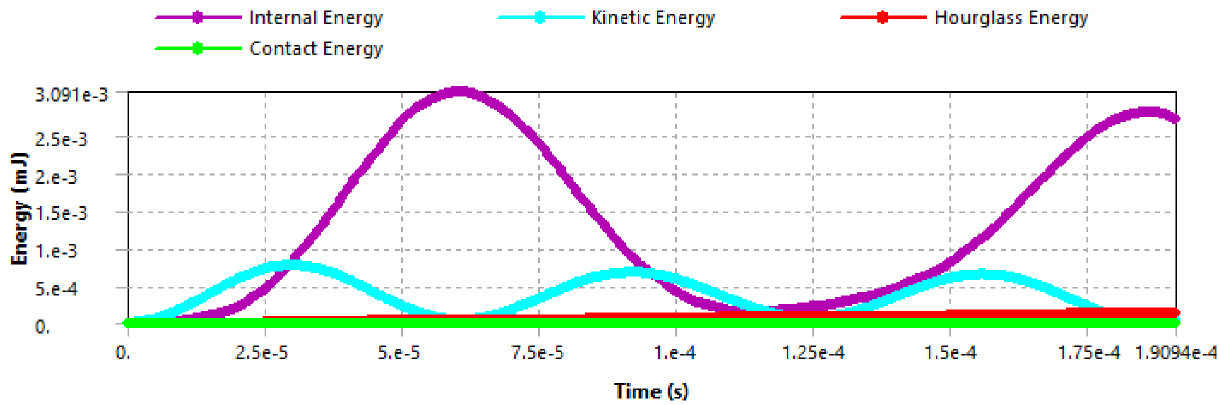

Fig. 3. Results of the energy conservation

This is seen in Figure 4, which depicts the concertation of energy distribution along the tube made of aluminum alloy. A numerical finding demonstrates that the middle of the tube was the location where the overall amount of energy was at its highest. The placement of the impactor is the rationale behind the large concentration of energy that may be found at this particular area. It is anticipated that the region will be in direct contact with the impactor. 3.1 J was the largest amount of energy that was measured at 450 mm, according to the findings. As can be seen in Figure 4, the energy steadily diminishes as one moves further out from the centre of the tube until it approaches zero at the margins of the tube.

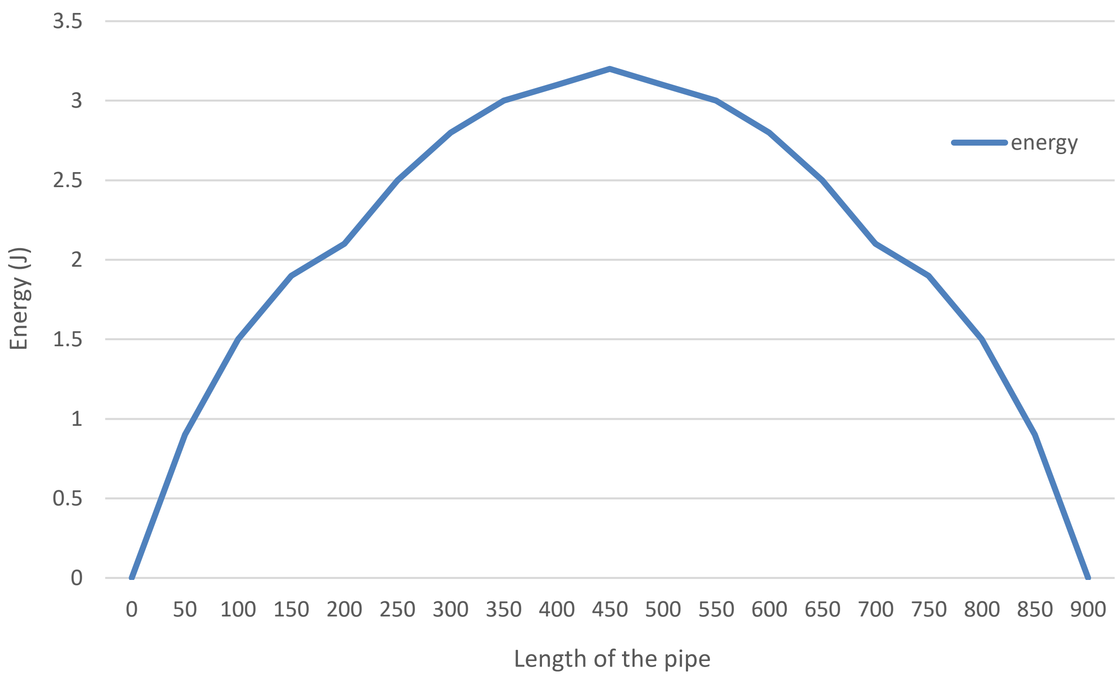

Fig. 4. Total energy with a length of the tube

3.2 Equivalent Elastic Stress

After being made out of aluminum alloy, the tube was put through an impact test in order to ensure that it complied with the international standard. The numerical studies have demonstrated that the equivalent elastic stress achieves its highest value in the middle distances of the tube, which happens at 450 millimeters. This is the point at which the tube is at its most middle distance. It was via the analysis of the data that we arrived at this conclusion. Nine hundred eighty megapascals was the highest achievable value that was achieved. Just as the energy behavior lowers over time, the von Mises stress steadily decreases as it comes closer to the boundary. This is similar to how the energy behavior diminishes with time. According to Figure 5, the magnitude of the stress that is distributed over the whole length of the tube is 240 megapascals (Mpa). This can be observed by looking at the figure. At the edge of the tube, where it is disseminated, stress is spread out and distributed. In terms of the stress distribution, it is not feasible to create a linear link between the length of the tube and the stress distribution. This is because the stress distribution differs from tube to tube. The impact effect that took place at specific spots inside the tube caused the mechanical properties of the aluminum alloy to be altered after the tube had been impacted. This was due to the fact that the tube had been affected itself. The tube was impacted as a result of this particular cause.

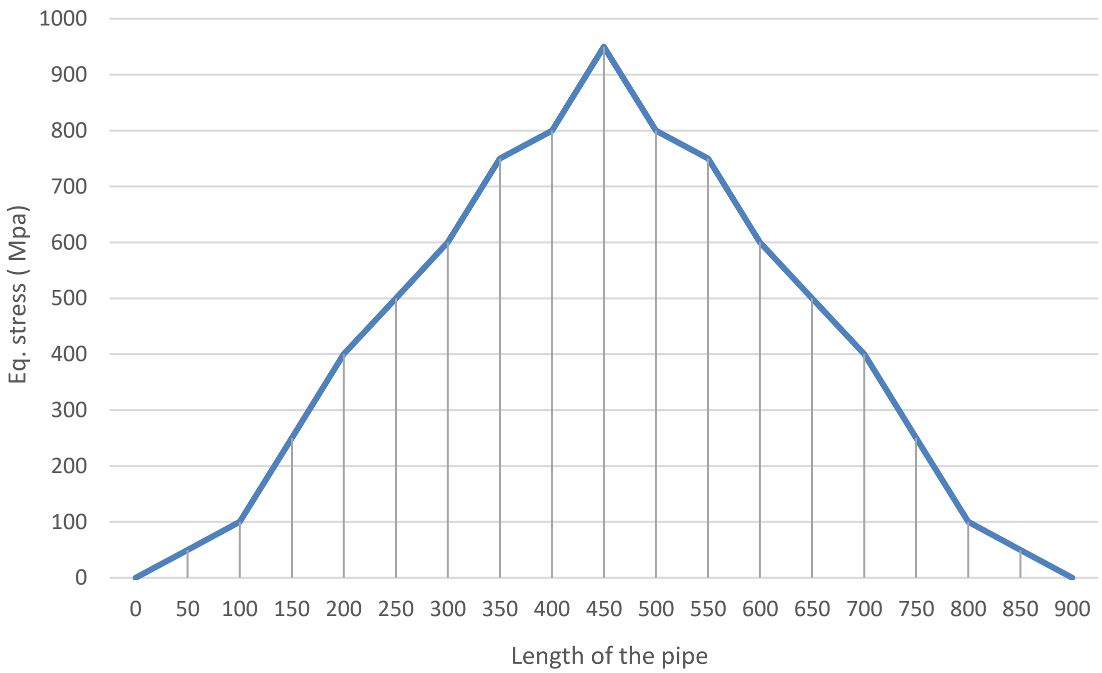

Fig. 5. Equivalent elastic stress

As can be seen in Figure 6, the simulation method generates the visual effect of impact on the aluminium tube, complete with a caption that distributes the magnitude of the stress at each place. As a result of the impactor, the damaged portion is visible, and it is possible to annotate it appropriately.

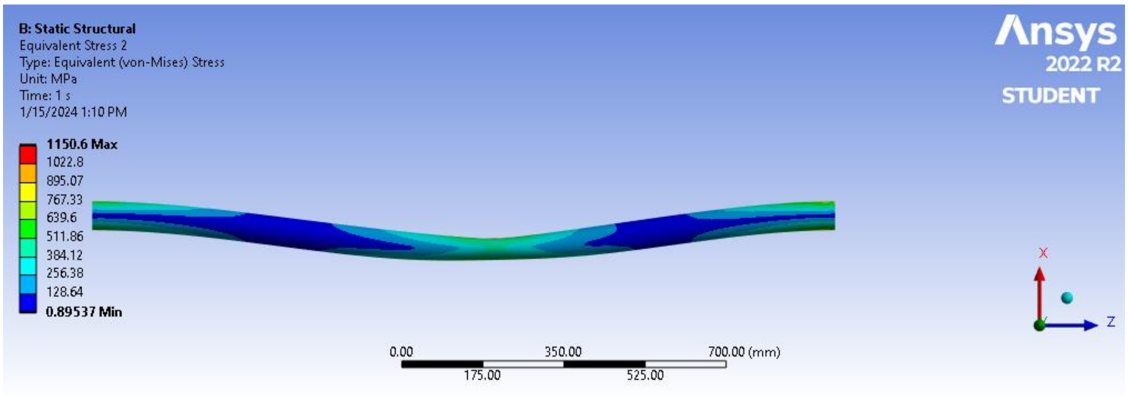

Fig. 6. Equivalent elastic stress

3.3 Investigation of Directional Deformation

Through the use of numerical analysis, it has been established that the directed deformation takes place along three axes. In light of the data obtained through numerical analysis, it has been concluded that the X axis exhibited the largest degree of displacement. Specifically, this is because it is in parallel with the hammer, which is also known as the impactor. Figure 7 illustrates the deformation that the tube exhibits along its length as demonstrated by the tube. It was proved that the largest amount of deformation happened at a distance of 450 millimetres, and the value of this deformation is forty millimetres. This deformation was measured. The degree of distortion is gradually decreasing until it approaches the end of the tube, at which point it achieves its maximum. It can be deduced from this that the deformation along the X axis is equal to zero at both of the tube's edges of the tube.

In addition, research has been carried out on the conductor alloy in order to investigate the defection that takes place along the Y axis. The amount of deflection that takes place along the y-axis is far less than what transpires along the x-axis. In this particular case, the impactor will be a predicator of the Y axis, which will result in a lesser degree of distortion. This disparity in the amount of the deformation at each axis may be related to the fact that the Y axis causes a lower degree of distortion. It was found, on the basis of the numerical findings, that the maximum value of the deformation along the y-axis is 25 millimetres, and that it gradually decreased at both of the tubes' borders. This was the conclusion that was reached.

As a result of the fact that it is located in the tangential direction of the impactor, the Z axis, which is also referred to as the tangential axis, was found to be the site where the least amount of deformation values were recorded. The greatest deformational value that this axis was capable of achieving was 12 millimetres.

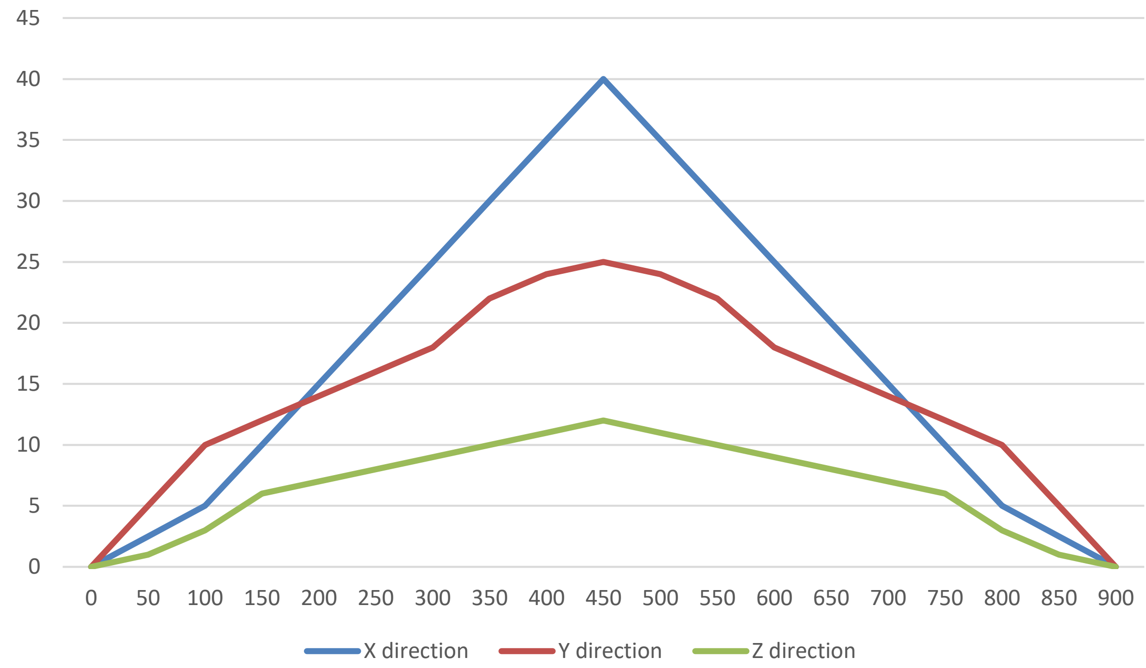

Fig. 7. Results of directional deformation

Figure 8 is a visual representation that shows the effect that the entire aluminium alloy tube deformation has. You can see this example in the image. A considerable amount of the overall deformation was attributed to the impactor in the main plate, according to the results of the modeling and simulation efforts. This proves, to within a margin of error of 40 millimetres, that the maximum distortion has been attained. At every stage of this process, the explicit dynamic has played an important role.

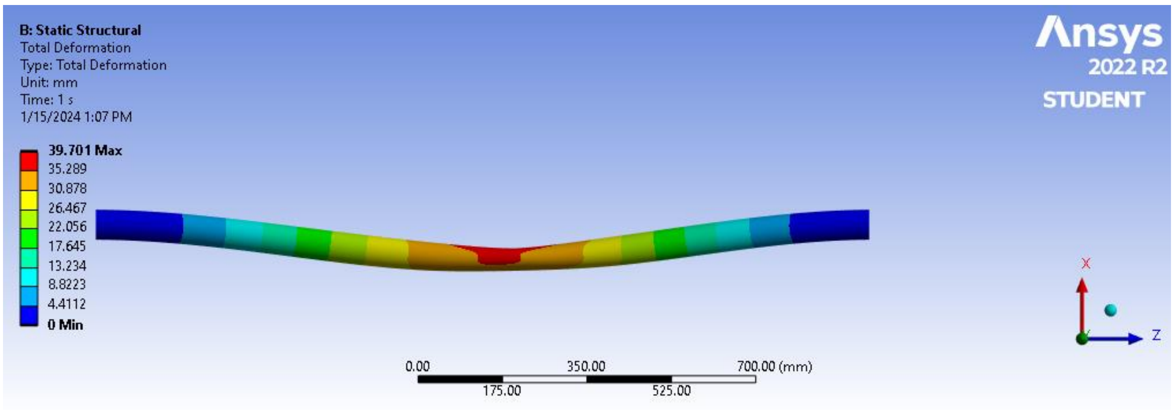

Fig. 8. Visual representation of the entire aluminum alloy tube

4. Conclusions

In conclusion, numerical research on the impact behaviour of a hollow tube made of aluminium 6082-T6 alloy based on ISO 13314-2011 has been simulated in accordance with the results of the FEM simulation. The simulation procedure was carried out with the help of ANSYS, and the Explicit Dynamic tool was utilised throughout the process. In the current investigation, the geometry consists of a tube that has a length of 900 millimetres and a diameter of 60 millimetres by 2 millimetres. This tube was developed in SpaceClaim within Ansys itself. For the purpose of meshing the model, a sweep-type mesh has been utilized, and local coordinates have been utilized as well. In order to accurately simulate all of the impactor's effects, components of the quad type have been utilized. This was done in order to ensure that the simulation is accurate. In accordance with the findings of the equivalent strain analysis, the mesh has been converged in the proper manner. Nevertheless, the conclusions are limited to the conservation of energy and the mechanical behavior that takes place after the impact process has been completed. The energy that resides beneath all types of energy has been the subject of a revelation that has happened recently. Because the internal and kinetic energy both reached a maximum value of three-eighty-three millijoules, they were unstable. This was the case for both of them. The directional distortion of the tube, which was previously unknown, has been brought to light by the three axes since their discovery. It is determined that the maximal deformation has reached its greatest level when the impactor is measured along a parallel axis across a distance of forty millimeters. A comparison was made between the equivalence stress (von Mises) and the length of the tube. The equivalence stress reached its highest level at 450 mm at the location of the impact, which was 950 Mpa. The length of the tube was also examined.

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