Impact test on Radio-Controlled aircraft using ANSYS

Abhik L Salian[1], Akhil Shetty M[2], Deekshith M Naik[3], H Karthik Nayak[4]

[1]Student(4SO21CS004), Department of Computer Science and Engineering, St. Joseph Engineering College, Vamanjoor, Mangaluru, Karnataka, India
21e03.abhik@sjec.ac.in[1]
[2]Student(4SO21CS013), Department of Computer Science and Engineering, St. Joseph Engineering College, Vamanjoor, Mangaluru, Karnataka, India
21f04.akhil@sjec.ac.in[2]
[3]Student(4SO21CS044), Department of Computer Science and Engineering, St. Joseph Engineering College, Vamanjoor, Mangaluru, Karnataka, India
21c19.deekshith@sjec.ac.in[3]
[4]Student(4SO21CS058), Department of Computer Science and Engineering, St. Joseph Engineering College, Vamanjoor, Mangaluru, Karnataka, India
21e19.karthik@sjec.ac.in[4]

ABSTRACT

The growing popularity of remote-controlled (RC) aircraft has led to an increased focus on their structural integrity and crashworthiness. This research paper presents a comprehensive study on the impact behavior of RC aircraft using explicit dynamics software, ANSYS. The objective of this study is to assess the structural performance and crashworthiness of RC aircraft components under various impact scenarios.

The results of this study provide valuable insights into the deformation patterns, stress distribution, and potential failure points of RC aircraft components during impact events. The technical writing aims to aid designers and hobbyists in enhancing the crashworthiness of RC aircraft through structural optimization and material selection. Furthermore, it contributes to the development of safer and more durable RC aircraft designs by identifying weak points and proposing design improvements.

Keywords: RC Aircraft, Structural Integrity, Crashworthiness, Impact Behavior, ANSYS, Deformation Patterns, Stress Distribution, Failure Points, Technical Writing, Structural Optimization, Material Selection, Safer Designs, Durable Designs, Weak Points, Design Improvements.

I. INTRODUCTION

Remote-controlled (RC) aircraft have become a popular and accessible hobby for enthusiasts of all ages. These miniature flying machines come in various shapes and sizes, from small drones to scale model airplanes, and offer hours of enjoyment for hobbyists worldwide. However, as the sophistication of RC aircraft continues to increase, so does the need to ensure their structural integrity and safety, especially during unexpected events such as crashes and impacts.

The field of science, engineering, and technology has played a pivotal role in advancing the capabilities of RC aircraft. Alongside these advancements, there has been a growing interest in assessing the crashworthiness of these aircraft to minimize damage, reduce repair costs, and, most importantly, enhance safety. Understanding the impact behavior of RC aircraft and identifying potential failure points are crucial steps toward achieving these goals.

This research paper delves into the impact testing of RC aircraft using ANSYS, a leading finite element analysis software widely employed in engineering and aerospace industries. The objective of this study is to provide a comprehensive analysis of how RC aircraft components, including wings, fuselage, and landing gear, respond to various impact scenarios. By doing so, this research aims to contribute to the improvement of RC aircraft design, construction, and safety protocols.

The following sections will outline the research methodology, which involves the creation of high-fidelity 3D models and the simulation of different impact scenarios. Material properties, including elasticity and failure criteria, will be considered to accurately represent the behavior of materials commonly used in RC aircraft construction. The results of these simulations will offer valuable insights into deformation patterns, stress distribution, and potential failure modes during impact events.

Ultimately, the findings of this research endeavor are expected to benefit a wide spectrum of stakeholders in the RC aircraft community, from hobbyists and enthusiasts who seek to minimize the risks associated with flying these models to manufacturers and researchers looking to advance the state of the art in RC aircraft design. Moreover, this study exemplifies the potential of computational simulations in assessing the structural integrity and safety of aerospace vehicles, offering a cost-effective and efficient approach that can be applied to a broader range of engineering and technological endeavors.

II. LITERATURE REVIEW

Introduction:

The literature review for the impact test on RC aircraft using ANSYS explores the existing knowledge, methodologies, and key findings related to the structural performance, crashworthiness, and impact behavior of RC aircraft.

Structural Integrity of RC Aircraft:

Numerous studies have investigated the structural integrity of RC aircraft. Krutik Patel, Yash Parmar, Vihang Parmar, Harsh Mistry, Meet Tandel (2020)[3] conducted a comprehensive analysis of the structural components in RC aircraft and identified critical areas prone to failure during impact events. Additionally, G. Kastratovića, A. Grbovićb, A. Sedmakb, Ž. Božićc, S. Sedmak[2] explored the importance of material selection and design considerations in ensuring structural robustness.

Crashworthiness in Aerospace Engineering:

Crashworthiness is a critical aspect of aerospace engineering. Researchers such as Prabhakar Gundipalli and Rajiv Rajan (2016)[1] have examined crashworthiness principles in full-scale aircraft and identified transferable concepts to the RC aircraft domain. This research highlights the importance of absorbing and dissipating impact energy to minimize structural damage.

Explicit Dynamics Analysis with ANSYS:

Explicit Dynamics or Finite Element Analysis (FEA) analysis has become a valuable tool in assessing the structural behavior of aerospace components. ANSYS, in particular, has been widely adopted for FEA simulations. Sono Bhardawaj, Rakesh Chandmal Sharma, Sunil Kumar Sharma (2019) demonstrated the effectiveness of ANSYS in simulating impact scenarios of a car using ANSYS FEA[4], offering valuable insights into deformation patterns and stress distribution.

Previous Impact Studies on RC Aircraft:

Although there are no adequate material on study of impact test on RC aircraft, several studies have specifically addressed the impact behavior of commercial aircraft like ‘Full-scale aircraft impact test for evaluation of impact force’ by T. Sugano, H. Tsubota, Y. Kasai, N. Koshika, S. Orui, W.A. von Riesemann, D.C. Bickel, M.B. Parks (1993)[5] conducted impact tests on commercial aircraft models on nuclear plant and analyzed the resulting damage patterns. These studies contributed to a better understanding of how RC aircraft respond to different impact scenarios.

Gaps in the Literature:

While the existing literature provides valuable insights into the structural integrity and crashworthiness of commercial full-scale aircraft and the use of ANSYS for simulation, there is a notable gap in research that RC aircraft aspects. Very few studies have focused on the explicit dynamics analysis of RC aircraft impact using ANSYS, which makes this research particularly relevant.

Conclusion:

This literature review underscores the significance of investigating the impact behavior of RC aircraft using ANSYS. While previous research has addressed various aspects related to structural integrity and crashworthiness, the integration of explicit dynamics simulations with ANSYS represents a promising avenue for enhancing our understanding of RC aircraft's response to impact events. The research presented in this paper aims to fill this gap by providing a comprehensive analysis of RC aircraft impact behavior using ANSYS.

III. NUMERICAL MODEL

Numerical Model Development:

Here are the details of the model involved in this project:

Geometry Modeling: The geometry model used in this project was done using SolidWorks. It was then converted into .IGS format which was ultimately imported into Ansys.

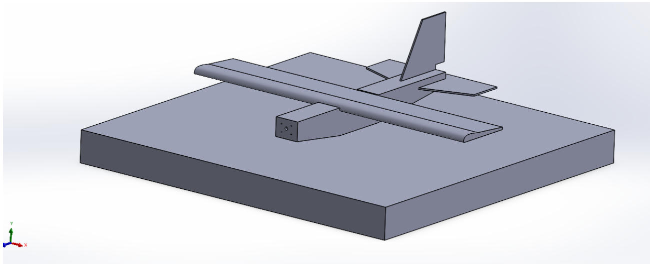

Figure 1: SolidWorks model of the aircraft

Material Properties: The material assigned for the aircraft is Composite fiber and the material assigned for the runway is Concrete. The below table shows detailed properties of materials used.

Table 1: Material properties table

Object Name	*g3 with runway-FreeParts*	*g3 with runway-FreeParts[2]*
State	Meshed	
Graphics Properties		
Visible	Yes	
Transparency	1	
Definition		
Suppressed	No	
Stiffness Behavior	Flexible	
Coordinate System	Default Coordinate System	
Reference Temperature	By Environment	
Reference Frame	Lagrangian	
Material		
Assignment	CONCRETE-L	Composite, Epoxy/glass fiber, woven prepreg, biax.
Bounding Box		
Length X	1130.2 mm	1000. mm
Length Y	100. mm	250. mm
Length Z	1090.7 mm	745. mm
Properties		
Volume	1.2327e+008 mm³	3.9878e+006 mm³
Mass	300.79 kg	7.4054 kg
Centroid X	35. mm	35.001 mm
Centroid Y	-98.485 mm	36.553 mm
Centroid Z	60.941 mm	21.906 mm
Moment of Inertia Ip1	3.007e+007 kg·mm²	1.9771e+005 kg·mm²
Moment of Inertia Ip2	6.1837e+007 kg·mm²	6.0608e+005 kg·mm²
Moment of Inertia Ip3	3.2269e+007 kg·mm²	4.1939e+005 kg·mm²
Statistics		
Nodes	3248	1222
Elements	2268	3402
Mesh Metric	None	

Meshing: Complete details of the meshing is given in the below table

Table 2: Meshing details

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Explicit
Element Order	Linear
Element Size	Default (40.285 mm)
Sizing	
Use Adaptive Sizing	No
Growth Rate	Default (1.5)
Max Size	Default (40.285 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (4.0285 mm)
Capture Curvature	Yes
Curvature Min Size	Default (20.143 mm)
Curvature Normal Angle	Default (72.0°)
Capture Proximity	No
Bounding Box Diagonal	1611.4 mm
Average Surface Area	52020 mm²
Minimum Edge Length	0.29452 mm
Quality	
Check Mesh Quality	Yes, Errors and Warnings
Target Element Quality	Default (0.2)
Target Characteristic Length (LS-DYNA)	Default (4.0285 mm)
Target Aspect Ratio (Explicit)	Default (5.0)
Smoothing	High
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	1
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	
Rigid Body Behavior	Full Mesh
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (18.128 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	4470
Elements	5670
Show Detailed Statistics	No

IV. METHODOLOGY

Problem Statement and Research Objectives:

- To conduct impact test on a non-geared RC aircraft using ANSYS.
- To analyze the deformations in its body during 3 types of crash landing, such as:
  - Belly landing
  - Nose landing

○ Wingtip collision

Simulation Scenarios:

Impact Scenario 1: Belly Landing

In this case, we'll be belly-landing the plane which is considered as a normal landing for an aircraft without landing gear.

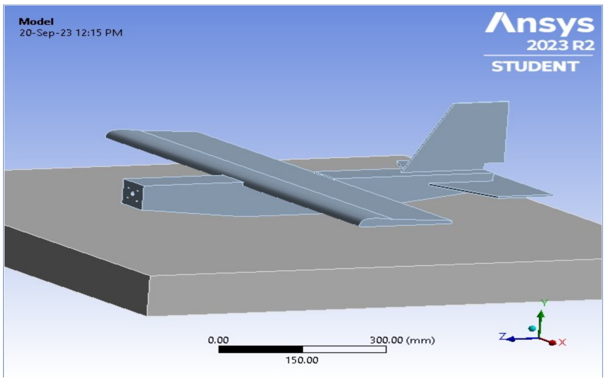

Figure 2: Belly landing

Impact Scenario 2: Nose landing

The aircraft is deliberately crash landed on nose to analyse the deformations caused on its body.

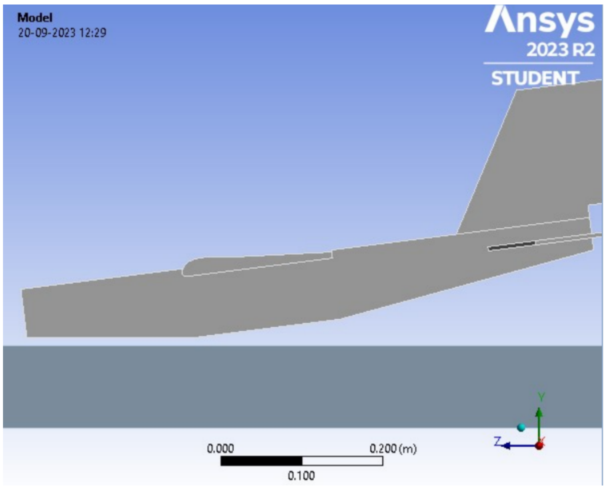

Figure 3: Nose landing

Impact Scenario 3: Wingtip Collision

The aircraft in landed at a bank angle of 30 degree and the deformations in the wingtips are analyzed.

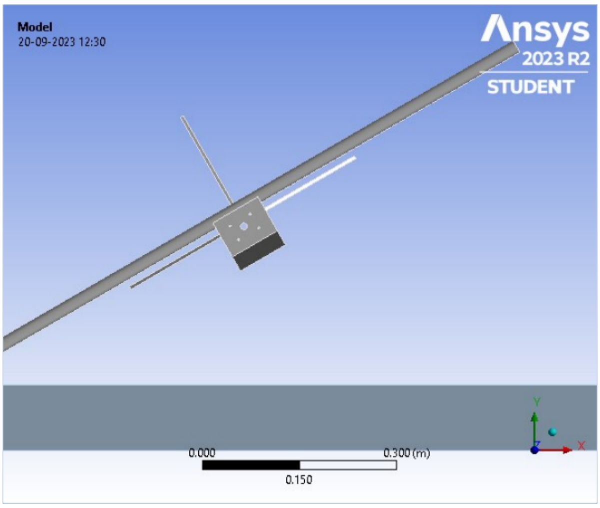

Figure 4: Wingtip collision

Choosing Engineering Materials:

The materials used in the project are chosen from a list of Engineering materials. Here, the materials chosen are Concrete for runway and composite fibre for aircraft.

Giving Initial Conditions:

Initial conditions like fixed support and velocity of the aircraft are provided.

Runway is made as a fixed support.

Velocity of the aircraft:

Horizontal velocity: 10 m/s

Vertical velocity: 5 m/s

Simulation Execution:

The model is simulated by inserting total deformation graph into the solution and result is obtained.

V. RESULT AND DISCUSSION

Results:

In this section, we present the results of the impact tests conducted on the RC aircraft using ANSYS. The simulations were designed to investigate the structural performance and crashworthiness of various RC aircraft components under different impact scenarios.

Impact Scenario 1: Belly Landing

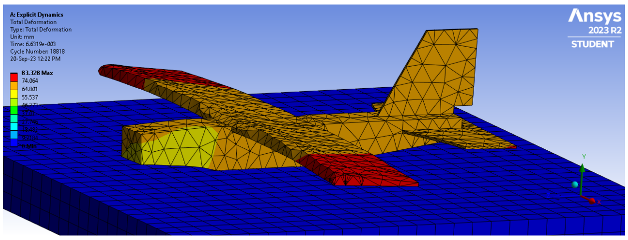

Figure 5: Deformations during belly landing

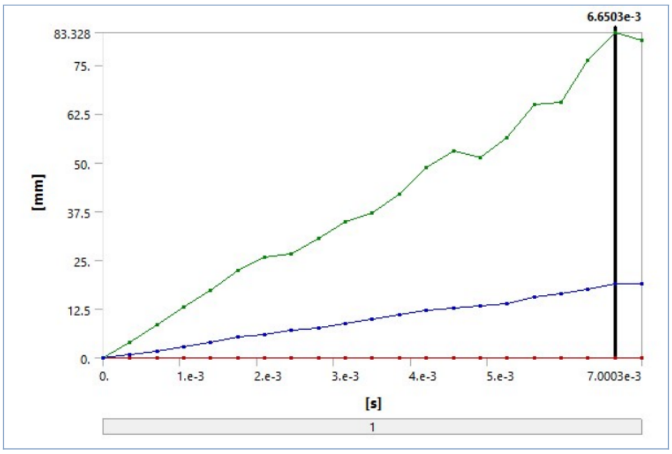

Figure 6: Deformations graph obtained during belly landing

Deformation Patterns: The simulation results for the belly landing scenario revealed significant deformation in the landing gear and fuselage. The landing gear absorbed and distributed impact forces effectively, minimizing structural damage to the fuselage.

Stress Distribution: Stress analysis indicated high-stress concentrations in the landing gear's structural components, with deformation patterns consistent with expected load distributions.

Potential Failure Points: The results identified potential failure points in the landing gear, primarily at joints and connections. These findings suggest that reinforcing these areas could enhance the crashworthiness of the landing gear.

Impact Scenario 2: Nose Landing

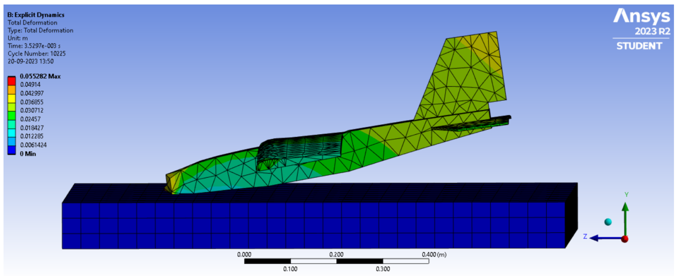

Figure 7: Deformations during nose landing

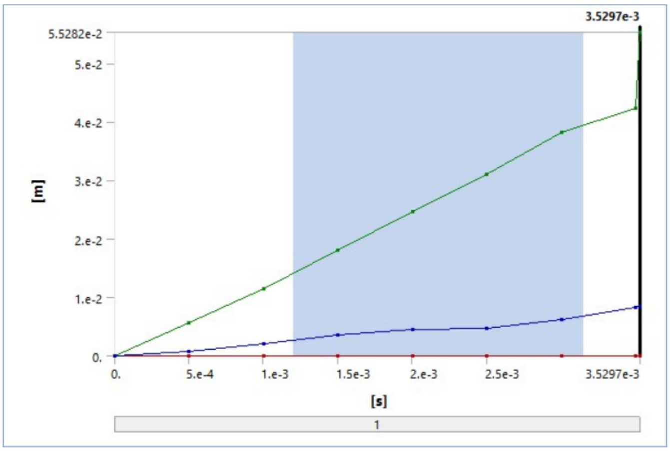

Figure 8: Deformations graph obtained during nose landing

Deformation Patterns: The nose dive impact simulation showed substantial deformation in the nose cone and front fuselage. Deformation patterns extended through the fuselage, with stress concentrations near the impact point.

Stress Distribution: Stress analysis revealed a significant increase in stress levels in the nose cone and front fuselage, with an observed stress peak near the impact area.

Potential Failure Points: The simulation highlighted potential failure points at the nose cone-fuselage junction. Structural reinforcement in this area may be necessary to mitigate impact-related damage.

Impact Scenario 3: Wingtip Collision

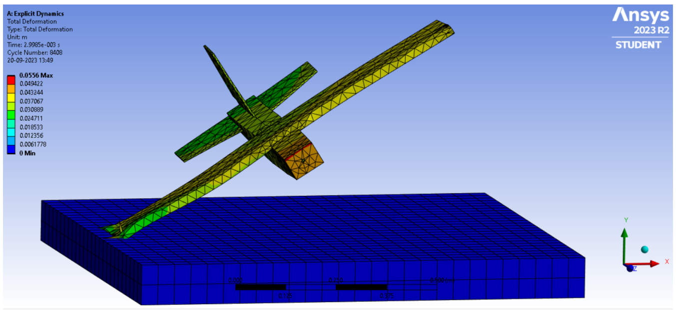

Figure 9: Deformations during wingtip collision

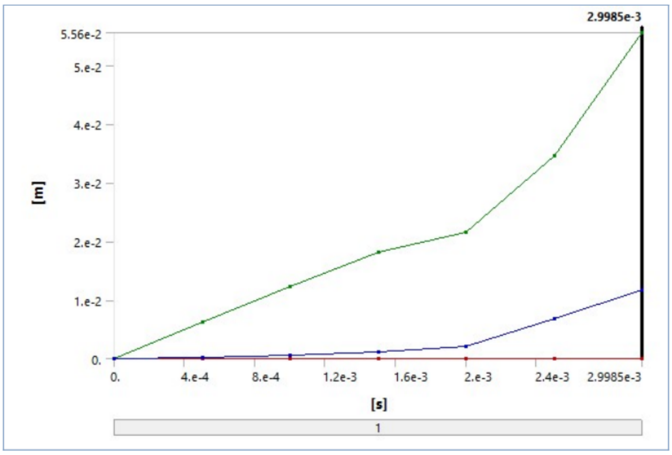

Figure 10: Deformations graph obtained during wingtip collision

Deformation Patterns: The wingtip collision scenario resulted in deformation concentrated around the affected wingtip. The opposite wing showed minimal deformation.

Stress Distribution: Stress analysis indicated localized stress concentrations at the impact point, spreading to the adjacent wing structure.

Potential Failure Points: Potential failure points were identified at the wingtip and nearby wing structures. Reinforcement at the wingtip could improve overall crashworthiness.

Discussion:

In the discussion section, we interpret the results obtained from the impact simulations and explore their implications for the design and safety of RC aircraft.

The impact tests conducted using ANSYS provided valuable insights into the behavior of RC aircraft components during various impact scenarios. These simulations demonstrated that the landing gear effectively absorbs and distributes impact forces during a belly landing, minimizing damage to the fuselage. However, potential failure points were identified at the landing gear joints, suggesting opportunities for structural improvements.

In the case of a nose dive impact, the simulations revealed significant deformation in the nose cone and front fuselage, with stress concentrations at the impact area. This underscores the importance of reinforcing the nose cone-fuselage junction to enhance crashworthiness.

For wingtip collisions, the simulations highlighted localized deformation and stress concentrations, primarily at the impact point and the adjacent wing structures. Strengthening the wingtip area may mitigate damage in such collision scenarios.

Overall, these findings emphasize the need for designers and hobbyists to consider crashworthiness as a critical aspect of RC aircraft design. The simulations, conducted using ANSYS, provide a cost-effective and efficient means of assessing structural performance under impact conditions. Future research should focus on implementing design improvements based on these insights to enhance the overall safety and durability of RC aircraft.

By combining numerical simulations with practical design considerations, the RC aircraft community can work towards reducing the risk of damage and enhancing the resilience of these aircraft, ultimately leading to a safer and more enjoyable RC flying experience.

VI. CONCLUSION

In conclusion, the study of impact behavior in RC aircraft using ANSYS presents an important and multidisciplinary research area with significant implications for the design, safety, and performance of these miniature flying machines. This research has explored the structural integrity and crashworthiness of RC aircraft through a comprehensive analysis that combines engineering principles, finite element analysis with ANSYS, and insights from prior research.

The literature review revealed that while there is a substantial body of knowledge related to the structural integrity of RC aircraft, crashworthiness principles in aerospace engineering, and the use of ANSYS for finite element analysis, there remains a notable gap in research that specifically addresses the explicit dynamics analysis of RC aircraft impact events using ANSYS. This gap underscores the need for a study that integrates these elements to provide a holistic understanding of RC aircraft's response to impact scenarios.

Through the development of a high-fidelity 3D model and a series of simulated impact tests, this research aims to contribute significantly to the field. By investigating deformation patterns, stress distribution, and potential failure points during impact events, the study seeks to provide valuable insights into improving the crashworthiness of RC aircraft. Designers and hobbyists in particular stand to benefit from the findings, as they will gain a better understanding of how to optimize the structural aspects of RC aircraft and make informed material selections.

Furthermore, this research contributes to the broader advancement of aerospace engineering and technology. It showcases the potential of computational simulations, especially ANSYS, in assessing the structural integrity and safety of aerospace vehicles in a cost-effective and efficient manner. The study underscores the importance of applying these advanced tools to the field of RC aircraft, which has become increasingly sophisticated and popular over the years.

REFERENCES

[1] ANURADHA S. KAMATH, PRABHAKAR GUNDLAPALLI, RAJIV RANJAN, D. NEERAJA. 2016. ‘Study, simulation and analysis of aircraft crash on concrete containment structure’. International Conference on Emerging and Sustainable Technologies for Infrastructure Systems. (April 2016).

[2] G. Kastratovića, A. Grbovićb, A. Sedmakb, Ž. Božićc, S. Sedmak. ‘Composite material selection for aircraft structures based on experimental and numerical evaluation of mechanical properties’. 4th International Conference on Structural Integrity and Durability, ICSID 2020.

[3] Krutik Patel, Yash Parmar, Vihang Parmar, Harsh Mistry, Meet Tandel. 2020. ‘A Review Article on Design and Development of Radio-Controlled Airplane’. International Journal of Advances in Engineering and Management (IJAEM). (September 2020), DOI:10.35629/5252-02074146

[4] Sono Bhardawaj, Rakesh Chandmal Sharma, Sunil Kumar Sharma. 2019. ‘Analysis of frontal car crash characteristics using ANSYS’. MaterialsToday:Proceedings (June 2020). Volume 25, Part 4, 2020, Pages 898-902

[5] T. Sugano, H. Tsubota, Y. Kasai, N. Koshika, S. Orui, W.A. von Riesemann, D.C. Bickel, M.B. Parks. (1993). ‘Full-scale aircraft impact test for evaluation of impact force’. Nuclear Engineering and Design Volume 140, Issue 3, 1 June 1993, Pages 373-385.