Finite Element Analysis of the Engineered Material Arresting System: A Calibration Study Based on the Hollywood Burbank Airport Incident

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ABSTRACT

The latest innovation in airport safety features is an aircraft braking system made of porous concrete, known as the Engineered Material Arresting System (EMAS). This system was created with the intention of mitigating the damage caused by accidents during aircraft landing and takeoff. This paper presents the calibration of a computational model of this system using the finite element method using the LS-DYNA software. The study is based on the incident that occurred at Hollywood Burbank Airport in 2018, in which a Boeing 737-700 overran the runway and was effectively stopped by EMAS. From the modeling of the system and the simulation of the impact based on real data, it was possible to adjust the density of the material until the simulated stopping distance approached the observed value. The calibrated model showed a difference of only 7% in relation to the real distance, demonstrating the reliability of the method and its applicability in the analysis of the EMAS performance.

Keywords: EMAS, finite elements, LS-DYNA, airport safety, calibration.

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GENERATIVE AI USAGE STATEMENT

The authors declare that the use of generative AI tools was restricted to technical support activities, without compromising the originality, analysis, and conclusions presented in the work. All information obtained through these resources was carefully evaluated and integrated into the study, ensuring methodological rigor and academic integrity. Tool ChatGPT was used to review the text.

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FINITE ELEMENT ANALYSIS OF THE ENGINEERED MATERIAL ARRESTING SYSTEM (EMAS): A CALIBRATION STUDY BASED ON THE HOLLYWOOD BURBANK AIRPORT INCIDENT

1 INTRODUCTION

Aiming to enhance airport safety, the Federal Aviation Administration (FAA, 2012) established specific requirements for the runway end safety area (RESA). This area must, under dry conditions, support the passage of an aircraft overrunning the runway without causing structural damage to the aircraft or injury to its occupants.

This requirement directly influences the RESA's dimensions, which, according to the FAA (2024), may vary between 120 m and 300 m depending on the type and basic length of the runway, following an inversely proportional relationship. However, these conditions were only standardized in the 1980s (FAA, 2023).

As a result, many airports were built before the adoption of this standard, leading to safety areas smaller than required, mainly due to natural obstacles, environmental restrictions, or surrounding urban development, as in the case of Hollywood Burbank Airport.

To address such cases, the FAA partnered with the Engineered Arresting Systems Corporation (ESCO) and the Port Authority of New York and New Jersey (PANY&NJ) to develop an alternative solution. The result was the creation of the Engineered Material Arresting System (EMAS), which consists of low-density cellular concrete blocks with graded compressive strength. These blocks are installed at the end of the runway, within the RESA, and are designed to decelerate overrunning aircraft by absorbing their kinetic energy in a reduced space, smaller than that required for a conventional RESA (HO; ROMERO, 2009).

EMAS features a characteristic shape and composition that help absorb the aircraft's motion energy once it overruns the runway. The deceleration begins as the landing gear enters the arresting material, which crushes and shears through the concrete blocks.

It is important to note that the material used in EMAS was patented by ESCO, and in 2020, Runway Safe acquired the EMASMAX product line. Runway Safe is currently the only manufacturer of these elements, which comply with the FAA Advisory Circular standards (FAA, 2012). Within this context arises the motivation to analyze the Engineered Material Arresting System.

Therefore, the main objective of this study is to calibrate a computational model based on the finite element method to simulate the behavior of the EMAS and enable its analysis. The calibration was carried out using data from the Hollywood Burbank Airport incident, due to the availability of detailed information on the aircraft's entry conditions into the system and the distance traveled during the deceleration process.

2 CASE STUDY

The importance of the EMAS can be understood by observing the surroundings of Hollywood Burbank Airport, which has an 1,859-meter-long runway and is in a densely urbanized area, as shown in Figure 1. This highlights the severity of a potential runway overrun accident and the critical need for proper EMAS design, using the basic layout illustrated in Figure 2, while considering the specific characteristics of each airport.

Figure 1: Aerial view of Hollywood Burbank Airport. Source: Google Earth (2025).

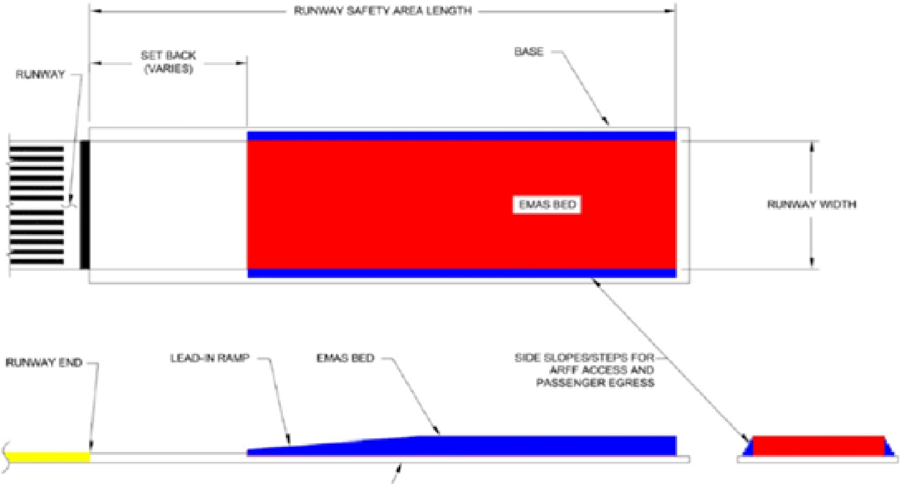


Figure 2: Schematic representation of the EMAS design in plan and elevation views, illustrating its layout. Source: FAA (2012).

Thus, there are several approaches that, when used together, enable a technical study of the EMAS. Initially, the finite element theory with dynamic analysis and an explicit method is suitable for the element under study. The LS-DYNA software is based on this theory and allows both modeling and the static and dynamic analysis of stress and strain in structures under various loading conditions (ANSYS, 2023), which is essential when evaluating situations such as an aircraft landing or takeoff and the corresponding reaction of the impacted material.

In addition, a crucial element for the analysis of EMAS is a real-world event in which the system was deployed following a runway excursion and successfully fulfilled its intended function.

A suitable case study is the incident that occurred on December 6, 2018, involving a Boeing 737-700 that departed from Oakland, California, en route to Hollywood Burbank Airport. During the final approach to Runway 8, the aircraft encountered adverse weather conditions and overran the end of the runway. According to the NTSB (2020), all 112 passengers and 5 crew members were unharmed, and the aircraft sustained no significant damage.

To achieve the proposed objective, the first step was to obtain the computational model of the EMAS.

The software used in this study to construct the model was LS-DYNA. It is necessary to select a set of characteristics to properly represent the main elements involved: the EMAS structure, the aircraft tire, the aircraft wheel, and the contact interactions among them. The model developed in this study is shown in Figure 3.

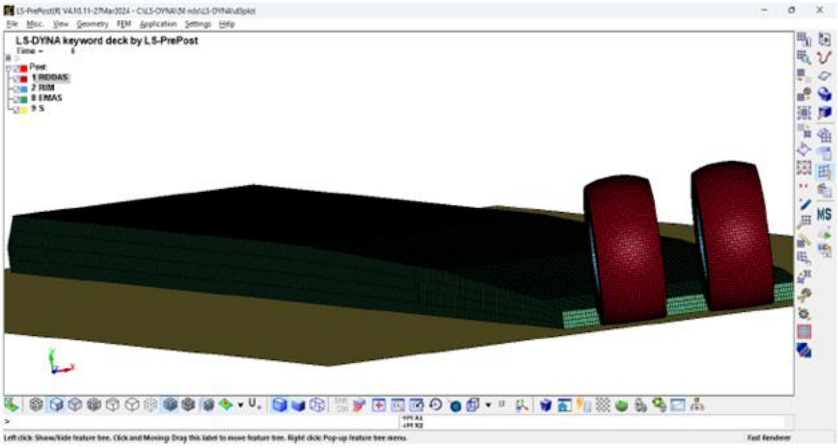


Figure 3: Finite element modeling of the EMAS, including aircraft tires, developed in LS-DYNA

These elements were initially treated using finite element theory with explicit dynamic modeling, which allows a continuous structure to be represented by dividing it into small volumes with finite dimensions. Each of these elements is bounded by discrete points known as nodes. The response of each element to an applied load is described by its own set of equations, and the combination of these individual responses enables the determination of the global structural behavior (FILHO, 2000).

Accordingly, a mesh with nodes was created for each of the three components, and the number of nodes was determined through mesh refinement, using an iterative process to obtain the best result considering both simulation quality and computational effort. The final EMAS model was 2 meters wide, with 101 segments, and 72 meters long, with 201 segments, and a variable thickness that reflects real-world conditions.

Dynamic analysis, in turn, makes it possible to evaluate the behavior of the structure when subjected to time-dependent loads, which generate significant accelerations in the model components. Since the elements of the structure possess mass, these accelerations result in inertial forces, as established by Newton’s second law (FILHO, 2008). This process directly represents the aircraft's deceleration as it enters the EMAS.

The aircraft wheel was modeled according to the dimensions shown in Table 1 below.

Table 1 – Aircraft Tire Dimensions – B737-700

Parameters	Dimensions (mm)
Outer diameter	1117.54
Inner diameter	697.90
Tire width	500.00
Axle distance between dual rear wheels	930.00

In this approach, the structure is interpreted as a system with infinite degrees of freedom, and discretization allows stiffness and inertia effects to be evaluated at each of these degrees, contributing to the accuracy of the simulation (FILHO, 2008). Accordingly, it was also necessary to define in the software the directions in which each element has movement constraints, as identified in Table 2.

Finally, the explicit method is suitable for simulating nonlinear dynamic problems, such as those involving wave propagation, collisions, and high-intensity impacts. In these situations, the structure may undergo permanent deformations, requiring a modeling approach that accounts for the nonlinear behavior of materials. This occurs because, under plastic regimes, the material response changes throughout the loading process (FILHO, 2012). This also applies to the present case, as the impact between the aircraft tire and the EMAS causes the arresting material to "fracture" in a manner similar to tearing.

2.1.1. MODEL CALIBRATION

With the model created, it can be brought closer to real-world conditions through calibration, that is, by comparing the EMAS's response during aircraft deceleration in a real incident with the response obtained from a simulation under the same boundary conditions. This is followed by adjustments to align both responses, allowing for the estimation of material properties and, consequently, enabling further analysis.

The calibration parameters used are detailed in Table 2. These correspond to the aircraft characteristics and the behavior of the arresting material from the incident previously mentioned in Section 1 (Introduction).

Table 2 – Calibration Parameters

Parameters	EMAS Surface	Wheel	Tire
Material	MAT_CRUSHABLE_FOAM	MAT_RIGID	MAT_HYPERE-LASTIC_RUBBER
Pressure (GPa)	–	–	0.0014134
Density (kg/mm³)	*	0.0027	0.0012
Poisson's ratio	0.1	0.3	0.49
Elastic modulus (GPa)	0.22	200	–
Gravity (m/s²)	9.81	9.81	9.81
Displacement constraint	Base: all directions	Horizontal	Horizontal
Rotational behavior	–	Around own axis	Around own axis

* EMAS material density to be defined

With these data incorporated into the model, the calibration process began. The first step involved extracting the boundary conditions from the analysis of the incident at Hollywood Burbank Airport, which were as follows:

In the study conducted by Hradecky (2018), it was reported that the Boeing 737-700 entered the EMAS at a speed between 5.0 and 7.7 m/s during the initial deceleration phase. For calibration, the upper limit of 7.7 m/s was adopted, as it represents the most critical overrun condition and ensures a conservative modeling approach. According to the same author, the nose landing gear traveled approximately 21.6 meters into the EMAS before the aircraft came to a complete stop. This distance is fundamental for model calibration, as it is directly related to the braking efficiency of the system and the properties of the arresting material used.

However, since the numerical model considered the main (rear) landing gear — positioned 12.6 meters behind the nose gear, as shown in Figure 4 — the effective distance used for comparison with the real-case data was 9.0 meters.

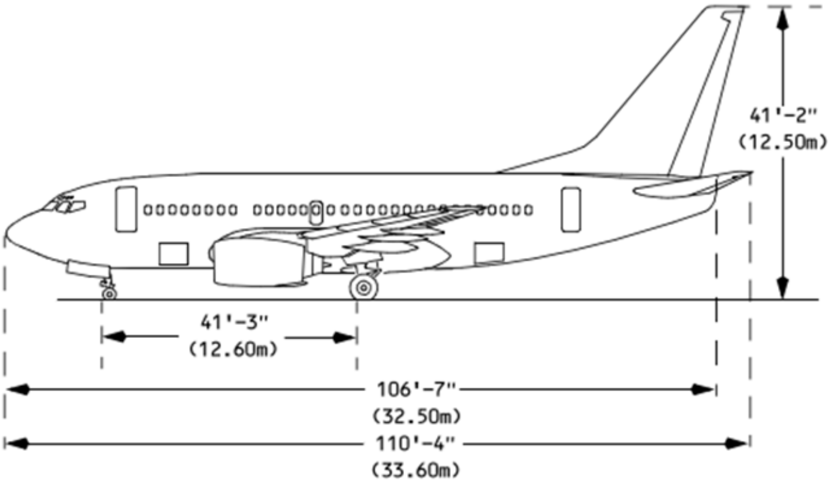


Figure 4: B737-700 technical drawing. Source: The Boeing Company (1997).

According to estimates presented by Hradecky (2018), the aircraft's weight at the time of landing was approximately 53,070 kg, corresponding to the maximum zero-fuel weight. This parameter is crucial for the simulation, as it directly influences the generation of inertial forces involved in the braking process: the greater the weight, the higher the kinetic energy to be dissipated by the EMAS, and consequently, the longer the distance required for the aircraft to come to a complete stop.

The author also noted that, during the first 17 seconds after touchdown, the aircraft experienced a deceleration between 0.3 and 0.4 G, related to conventional braking and before the EMAS engagement. For the simulation, 0.3 G was adopted to reproduce the conventional braking phase while ensuring physical plausibility and compliance with aeronautical safety standards, considering that ACRP Report 50 establishes 2.0 G as the maximum tolerable limit for aircraft occupants.

With the data gathered, they were then entered into the LS-DYNA software, creating a scenario very similar to the incident that occurred at the California airport. The only missing parameter was the material density, as it is not publicly disclosed and only that it is classified as low density, according to Ho and Romero (2009). Therefore, the simulation was run multiple times, as shown in Figure 5, adjusting the density values until the stopping distance closely matched the theoretical value adopted.

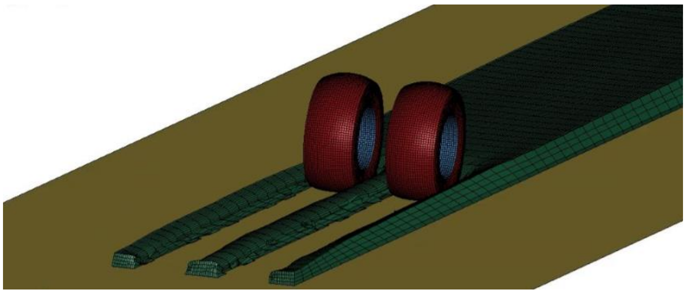
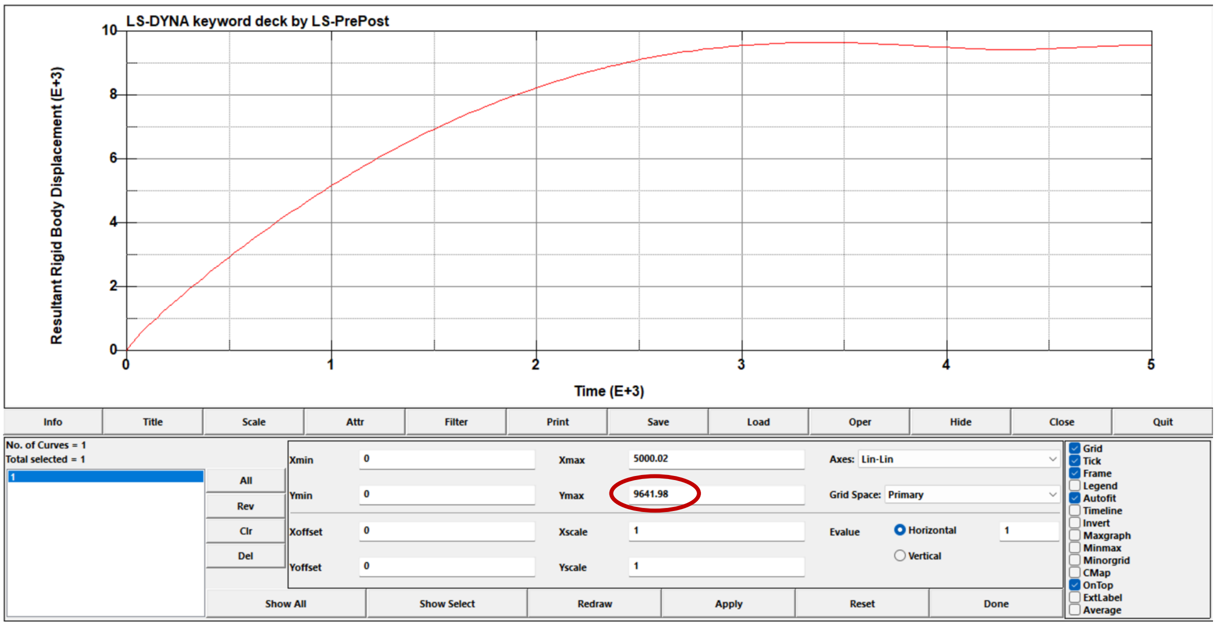


Figure 5: Simulation performed at a speed of 15 knots (7.7 m/s).

3 RESULTS

The simulation showed the highest correlation with the real event when the distance traveled by the aircraft matched the value observed in the actual incident, as illustrated in the graph in Figure 6.



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Yscale 1

☑ Grid
☑ Tick
☑ Frame
☐ Legend
☑ Autofit
☐ Timeline
☐ Invert
☐ Maxgraph
☐ Minmax
☐ Minorgrid
☐ CMap
☑ OnTop
☐ ExtLabel
☐ Average

Figure 6: Distance graph obtained in LS-DYNA.

The simulation performed in LS-DYNA resulted in a stopping distance of approximately 9.6 meters, as shown in the graph in Figure 6. This value represents a 7% deviation from the reference distance of 9.0 meters, which is considered acceptable within the modeling margin of error. The graph axes are expressed in millimeters (position) and milliseconds (time), allowing for a time-based analysis of the braking process.

This result was obtained using a density of 4.01×10^{-5} kg/mm^3 for the EMAS material, a value consistent with low-density cellular concrete. The strong agreement between the simulated and observed data validates the model, demonstrating its suitability for EMAS analysis in other airport scenarios.

Ketabdari et al. (2020) also highlight the relevance of computational modeling for evaluating the performance of EMAS in overrun scenarios. The authors analyzed the interaction between aircraft tires and different arrestor bed materials through numerical simulations, considering variables such as density, compressive strength, and system thickness.

The results indicated that low-density cellular concretes, when combined with higher crushing strength, provide shorter stopping distances, whereas materials such as gravel or lightweight aggregates tend to extend braking. This approach confirms that proper material selection and characterization are decisive for system efficiency, in line with the results of this study, which also identified density as a critical parameter for model calibration and characterized the material in a similar way.

4 CONCLUSIONS

This study aimed to calibrate a computational model of the Engineered Material Arresting System (EMAS) using the finite element method within the LS-DYNA environment, based on the real incident that occurred at Hollywood Burbank Airport in 2018. Through explicit dynamic modeling, it was possible to simulate the behavior of the arresting material during the entry of a Boeing 737-700, using realistic boundary conditions extracted from the incident and adopting a material density of 4.01×10^{-5} kg/mm³ as determined in the study.

The results demonstrated that, by adjusting the material density within ranges consistent with the literature, the simulation reached a stopping distance of 9.6 meters, only a 7% deviation from the theoretical value obtained from the incident. This proximity validates the model calibration and indicates that the deformation and energy absorption processes were accurately represented in the computational environment.

Therefore, it is concluded that the proposed methodology is effective for analyzing and evaluating the performance of EMAS through simulation. The ability to estimate material behavior based on real-world data, even with limited information such as exact density, reinforces the method's potential for future applications in airport safety engineering. Further studies may expand the analysis using different input data, contributing to the optimization of EMAS design.

5 REFERENCES

American Association of Airport Executives. (2011). Improved models for risk assessment of runway safety areas (Airport Cooperative Research Program – ACRP Report 50). Washington, D.C.: Transportation Research Board. Retrieved September 20, 2025, from https://nap.nationalacademies.org/catalog/14558

Ansys. (2023). LS-DYNA® theory manual. Retrieved July 22, 2025, from https://lsdyna.ansys.com

Federal Aviation Administration. (2012). AC 150/5220-22B, Engineered Materials Arresting Systems (EMAS) for Aircraft.

Federal Aviation Administration. (2023, June 13). Engineered Material Arresting System (EMAS). Retrieved July 22, 2025, from https://www.faa.gov/newsroom/engineered-material-arresting-system-emas-0

Federal Aviation Administration. (2024). AC 150/5300-13B, Airport Design.

Filho, A. A. (2000). Elementos finitos: A base da tecnologia CAE (1st ed.). São Paulo: Érica Ltda.

Filho, A. A. (2008). Elementos finitos: A base da tecnologia CAE – Análise dinâmica. São Paulo: Érica Ltda.

Filho, A. A. (2012). Elementos finitos: A base da tecnologia CAE – Análise não linear. São Paulo: Érica Ltda.

Ho, C.-H., & Romero, P. (2009). Investigation of existing Engineered Material Arresting System at three U.S. airports. Presented at the 50th Transportation Research Forum.

Hradecky, S. (2018, December 6). Incident: Southwest B737 at Burbank on Dec 6th 2018, overran runway on landing. Retrieved July 22, 2025, from https://avherald.com/h?article=4c1378c5

Ketabdari, M., Toraldo, E., Crispino, M., Lunkar, V., 2020. Evaluating the interaction between engineered materials and aircraft tyres as arresting systems in landing overrun events. Case Studies in Construction Materials 13.

National Transportation Safety Board. (2020). Aircraft performance study – DCA10IA022. Washington, DC.

The Boeing Company. (1997). 737-600/-700/-800/-900 operations manual. The Boeing Company.