Effect of Side Incubator Padding on Unrestrained Child Crash Dummy under Negative Acceleration

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1 Abstract

Nearly 20 million low birth weight and premature infants are born each year in developing countries, 4 million die within their first month due to unavailability of incubators and neonatal intensive care. Neonates and infants that require an inter-hospital transfer or ambulance/vehicle transfer in an incubator could potentially face fatal and catastrophic events, once subjected to negative acceleration. The main factor affecting the applied force due to the harsh braking or collisional accidents to the neonate/infant is the configuration of the restraining system. By eliminating the restraining system or having low residual strength seat belts the neonate or infant can experience lifelong injuries or even death. The interior of an incubator in case the restraining system fails must be designed to protect the occupant. In this paper, the effect of the paddings on the incubator wall against the unpadded wall is studied on a crash dummy using LS-DYNA software. The deceleration pulse, velocity, and displacement are validated by a sled test at Cranfield Impact Centre (CIC).

Keywords: LS-DYNA, Crash Dummy, Incubator, Neonate, Sled Test, Deceleration.

2 Introduction

Each year on European roads, 80,000 children are injured and 700 are killed [1] and there are more than 1 million preventable neonatal deaths every year in developing countries [2]. In ambulances [3], there are various restraining systems inside of the incubator. The most common type is a five-point seat belt restraint configuration that protects the infant. This method is very effective, although as there are limited data available on newborn's dynamic response on crash acceleration pulse, further analysis is required to determine the effects of the belts on the ribcage and other internal organs.

In general positioning of the infant, the infant's head is towards the driver with the feet facing the rear of the vehicle. In this configuration, with acceleration/deceleration the blood rushes towards the head or towards the feet. In the worst-case scenario, in frontal crash accelerations generate head inertial loads that put the neck in distraction. If the infant was facing the other direction, the head facing the rear of the vehicle and the feet facing the driver, the frontal crash accelerations generate head inertial load that causes compression/flexion in the neck. However, newborns are vulnerable to cervical distraction injury subjected to high loads due to severe frontal crashes.

In Europe and in the UK, the European Committee for Standardisation (Comite Europeen de Normalisation, CEN) has produced standards for securing all items and persons in road ambulances BS EN 1789:2007 [4], which is also required to apply to transport incubator systems, BS EN 13976-1:2018 [5].

The five-point restraining system is manually tightened to suit most infants. However, failing to ensure it has been fully adjusted could potentially cause the restraining system to fail and disengage in a frontal or oblique accident(s) [3]. In this paper, the effect of padded walls on unrestrained infant dummy is studied to find a feasible solution for restraining system failure.

3 Numerical Setup

The numerical setup complies with BS EN 1789, that requires acceleration/deceleration pulse to be within the maximum and minimum acceleration against time. The maximum is 12 g for 0.9 seconds followed by a constant relaxation of 0.75 seconds, in total 0.15 seconds. The minimum is 8 g, it initiates from 0 at 0.01 seconds, ramping up to 8 g for 0.05 seconds and a constant relaxation to 0.08 seconds (see Figure 1). The velocity is set to 8.6 metre per seconds [4].

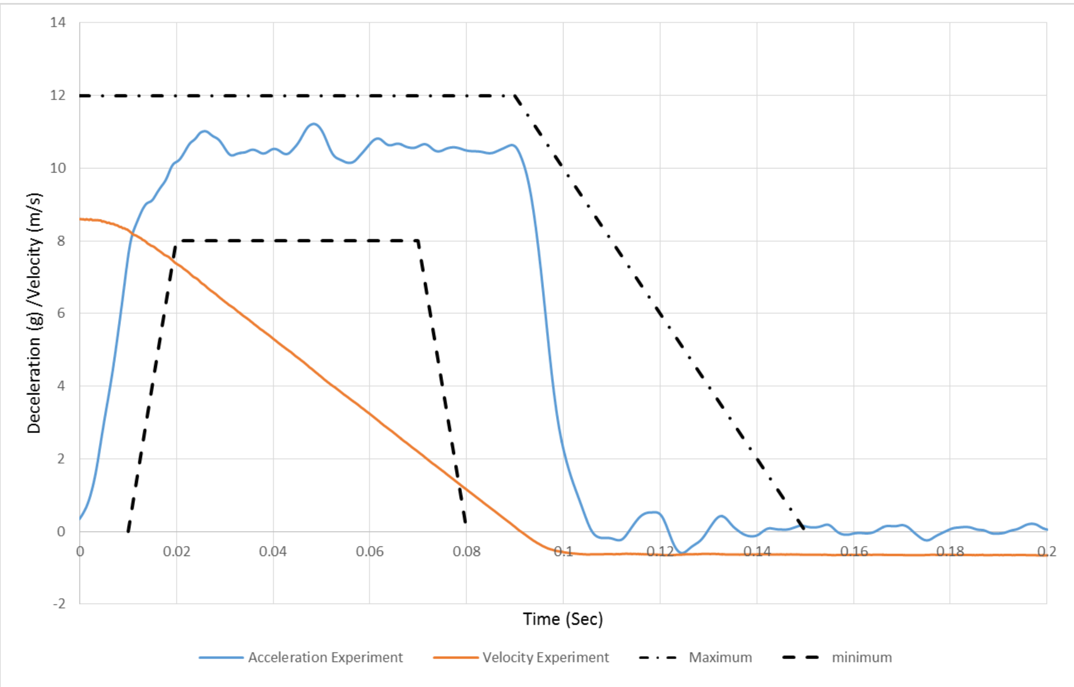

Fig.1: Acceleration (g) and velocity (m/s) against time obtained experimentally, maximum and minimum acceleration (g) against time in comply with BS EN 1789 [4]

The acceleration was remapped and used in the model. The Model consists of two mattresses, one beneath the dummy and one which is standard mattress used on the stretcher (for road ambulances), an incubator shell and two main restraining belts that pins the incubator down to the sled (see Figure 2). The properties of the two mattresses were obtained experimentally.

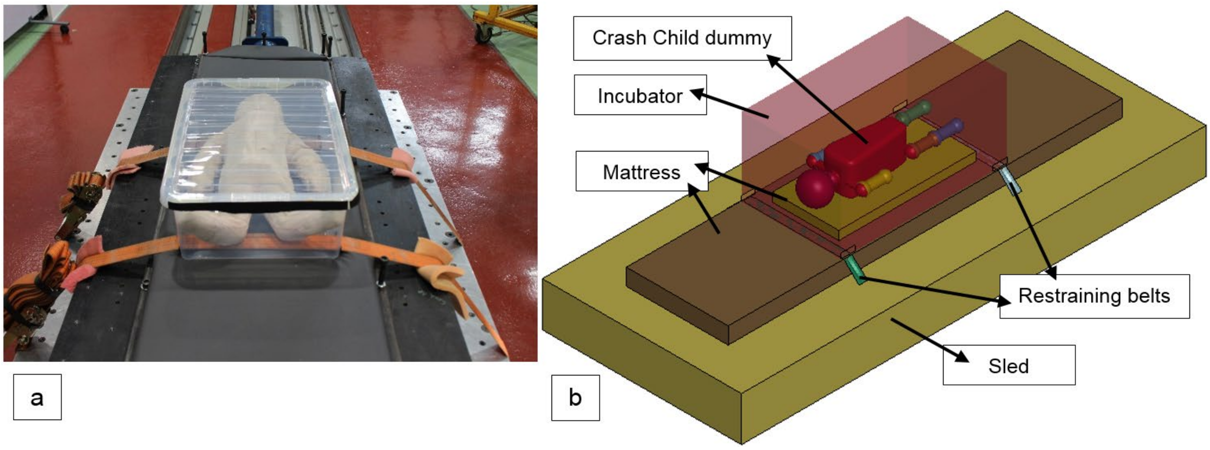

Fig.2: Acceleration (g) and velocity (m/s) against time obtained experimentally, maximum and minimum acceleration (g) against time in comply with BS EN 1789 [4]

In frontal deceleration, the initial velocity is applied to all nodes in the model and the deceleration curve is applied to the sled. In this case, the response of the dummy can be studied. A padding mattress is added to the model as shown in Figure 3 and the differences between the acceleration that the dummy experiences with and without the wall padding is studied.
The deceleration is applied using Boundary_Prescribed_Motion_Set assigned to the sled in X direction. Dynamic relaxation was added to determine the prestress caused by gravitational acceleration, which was modeled using Load_Body_Z.

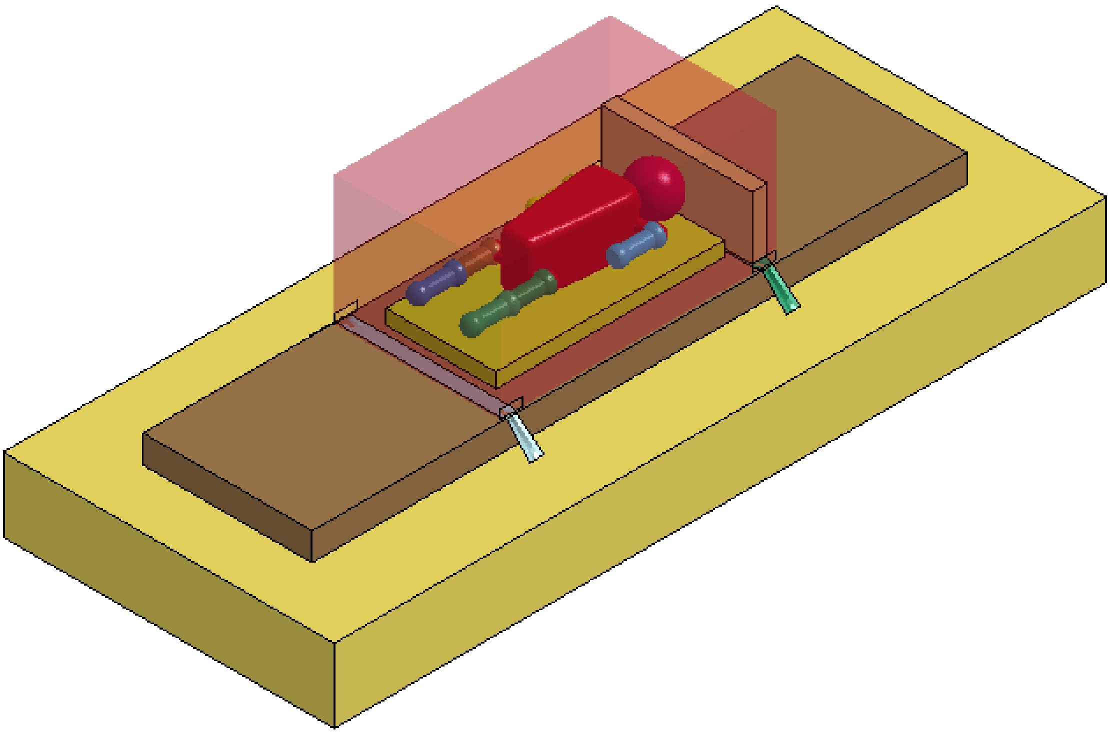

Fig.3: Wall padding added to the model

3.1 Mechanical Properties and Contact Definition

The mechanical properties are shown in Table 1. The load curves (stress-strain curves) used to model the mattress are also shown in Figure 4.

3.1.1 Mechanical properties

Component	**Mass (Kg)**	**material Model**	**Young's Modulus (EA) (Pa)**	**Young's Modulus (EB) (Pa)**	**Minor Poisson's ratio**	**Major Poisson's ratio**
Main Mattress	2.72	Mat_57	2.5e10			
Dummy Mattress	0.4	Mat_57	2.5e10			
Seat Belts	0.5	Mat_34	4e8	4e8	0.3	0.3
Sled	1000	Mat_20	2.07e11			0.3
Incubator	15	Mat_24	3.1e9			0.3

Component		**Shear Modulus (ab) (Pa)**	**Shear Modulus (ab) (Pa)**	**Damp**	**Yield Stress (%)**	**Tangent modulus (Pa)**	**Load Curve**
Main Mattress				0.1			**Yes**
Dummy Mattress				0.1			**Yes**
Seat Belts		1.54e8		0.1			
Sled							
Incubator					0.2	**2.e9**	

Table 1: Mechanical properties

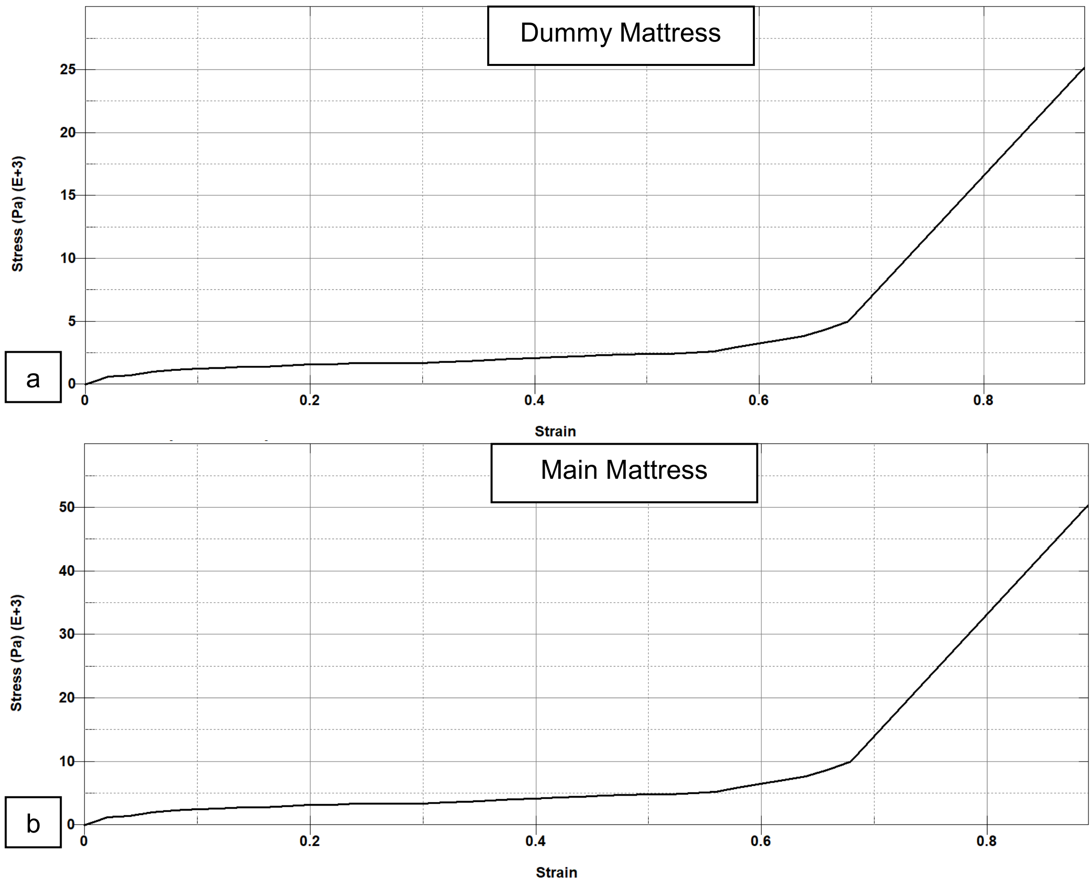

Fig.4: a) Dummy Mattress and b) main mattress load curves (stress-strain curves)

3.1.2 Contact definition

Tied_Surface_To_surface contact card was defined for the sled and the mattress, and for incubator and the dummy mattress. Tied_Nodes_To_surface contact card was defined for the belt end nodes to the sled. Automatic_Surface_To_Surface contact card was defined for the main mattress and the incubator with 0.3 and 0.2 static and dynamic coefficient of friction respectively. Automatic_Surface_To_Surface contact card was defined between the mattress and the two belts with 0.3 and 0.2 static and dynamic coefficient of friction respectively. Automatic_Surface_To_Surface contact card was defined for the torso, upper right arm, upper right leg, upper left arm, upper left leg, head, lower left leg, lower right leg to the mattress and the incubator with 0.45 and 0.25 static and dynamic coefficient of friction respectively.

4 Results

The results were obtained using Part_Acceleration of the torso. The model with no padding shows forces up to 75 g for 0.012 seconds followed by another 40 g peak for a duration of 0.014 seconds (see Figure 5). This indicates that the infant subjected to harsh braking or collisional accident can instantly experience fatal/severe injuries and possibly death in case of five-point restraining system failure. However, in the padded wall model, the dummy experiences at most 23 g for 0.008 seconds followed by a controlled relaxation of acceleration force. In this case, even though the infant experiences high values of g force at the beginning for 0.008 second, in the duration of the deceleration, the infant has higher survivability chances with minor injuries and no long-term effect.

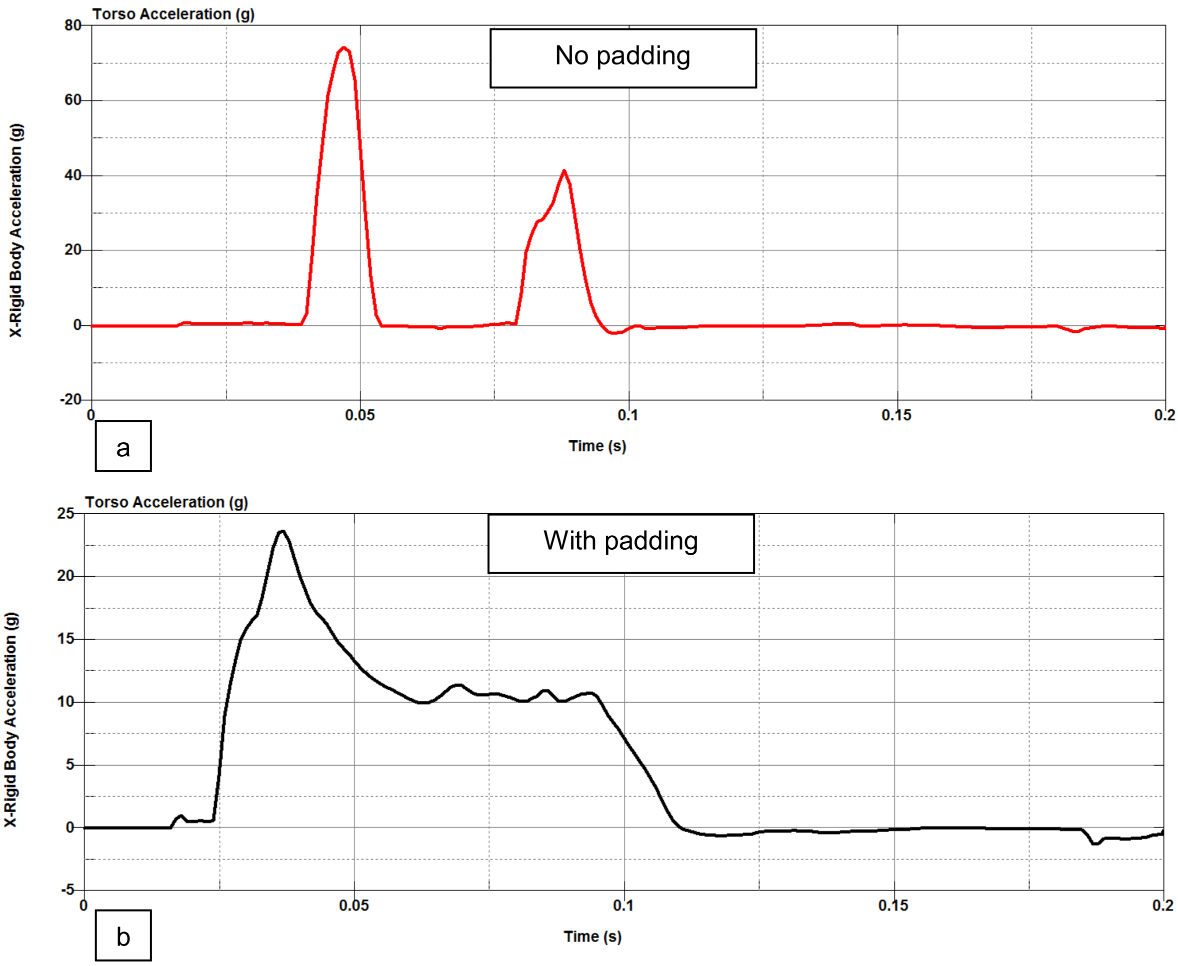

Fig.5: Torso acceleration (g), a) no padding b) with padding

Figure 6 illustrates the stages of the simulation from time = 0 to time = 0.2. the stages of also indicate that the oscillation of the acceleration in Y and Z direction is severe in the model without padding, due to the dummy separating from the mattress as it strikes the incubator.

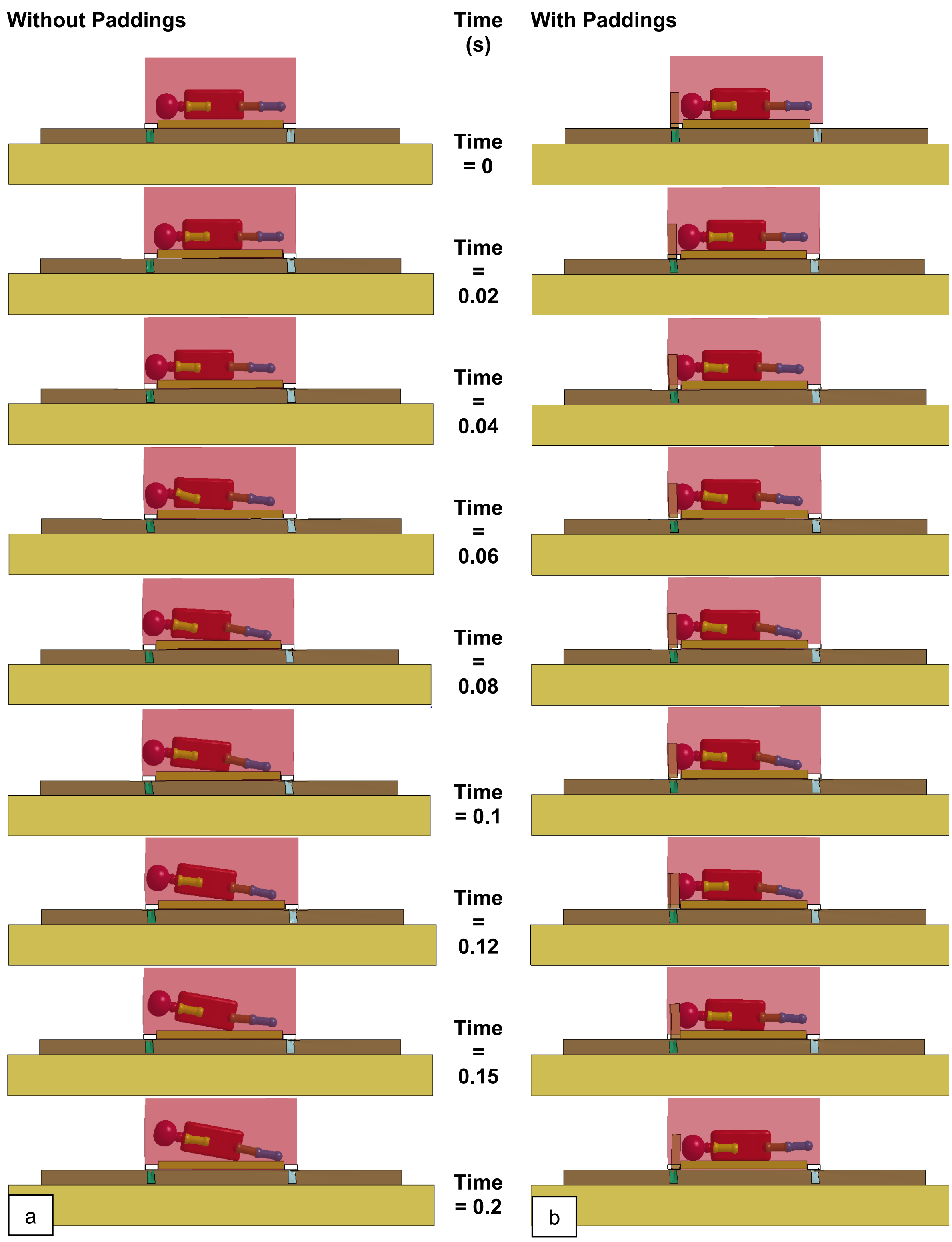

Fig.6: Dummy Mattress and main mattress load curves (stress-strain curves)

5 Conclusion

The model is validated with experimental studies including the acceleration, velocity, displacement and the dummy. The seat belts that restraint the incubator was seat belt shell elements. The mattresses are validated experimentally. Dynamic relaxation was used to apply prestress on the model. The results are indicating that adding paddings to the incubator could save the infant's life. The model without padding experienced two high fatal peaks reaching 75 g and 40 g which can be catastrophic. Adding a 0.4 kg padding to the walls could absorb the strike of the dummy and significantly improve the probability of survival in a frontal crash.

6 References

References should be given in the last paragraph of your manuscript. Please use following scheme:

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