DESIGN AND SIMULATION OF KINEMATIC LINKAGES OF A LAUNCHER FOR WEAPON CARRIAGE AND RELEASE FROM FIGHTER AIRCRAFT

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Abstract: Fighter aircraft carries and releases weapons with the help of launchers. The launcher consists of suspension mechanism, pneumatic system, locking mechanism and pyro mechanism. There is need to develop kinematic linkage for the design and development of the launcher. Kinematic system consists of different number of parts. These parts need to be designed, modelled and simulated in simulation software like ADAMS.
There is an existing launcher of capacity 500kg. The objective is to enhance the capacity to 2000kg. For that there is a need to model existing components in software like CATIA. Then the system needs to be simulated in simulation software like ADAMS. From ADAMS, we can get the necessary boundary conditions required for finite element analysis of components. Once boundary conditions are obtained, the finite element analysis of components is carried out and hence critical points where components can break for 2000kg missile are highlighted.

Index Terms: Launcher, Fighter aircraft, CATIA, ADAMS, finite element analysis.

I. INTRODUCTION

Present day missiles or stores are often thin skinned, winged objects which must be launched from an aircraft under a wide variety of speeds and flying conditions. In launching such objects it is important to get the missile or store safely away from the aircraft so that it does not subsequently collide with the aircraft or become diverted by reason of the flow of air passing the aircraft. In addition, it is important to launch the missile with sufficient velocity to free itself from the aircraft and its influence while at the same time preventing the missile from being damaged by the launching apparatus. This report relates to a launcher for missiles or stores which are released from aircraft.

With present day aircraft, and particularly military aircraft the missiles may be launched at speeds varying from the subsonic through transonic and into the high supersonic. In addition, the missiles may be launched at elevations in excess of 70,000 feet. Each of these conditions imposes certain forces upon the missile which affect its performance during the launch.

The missile launcher itself, in order to be practical, must in addition to directing the missile provide a minimum amount of drag before and after the release of the missile. There must be an instant and positive retraction of the launcher after a release and the missile or store must be under positive mechanical control of the launcher at all times so that a successful launch can be achieved in the presence of the many forces acting upon the missile.
Guided missile launchers provide suspension for carriage and launch of guided missiles from an aircraft. They provide the mechanical and electrical interface between the aircraft and the air-launched missile. Guided missile launchers are categorized as either ejection type or rail type launchers. Ejection type launchers utilize gas pressure generated by cartridges fired in the launcher breeches to physically separate the missile from the aircraft. The missile motor is then ignited at a pre-determined distance below the aircraft. Rail launchers are normally carried on the wing stations. Rail launchers enable the missile motor to be activated while the missile is still attached to the launcher. After motor fire, the thrust generated by the motor overcomes the missile restraining device and the missile separates from the aircraft. The tube launcher is a variant of the rail launcher. Tube type launchers contain the missile in launcher tubes until the missile motor is ignited. The missile then fires from the tube in a manner similar to firing aircraft-mounted rockets.

II. CONSTRUCTION AND WORKING

The main function of a launcher is to hold, suspend and eject the store. Therefore launcher should mainly consists of following,

- A non-moving strong body with units fastening to it
- An ejection mechanism for forced suspension of missile from launcher before starting the engine of missile
- Locking mechanism for holding exit levers of ejection mechanism in starting position. Actuator intended for forced withdrawal of missile
- Power drive designed for forced separation of article.
- An existing model of launcher having capacity of 500Kg article load is modelled in CATIA software. The modelled parts of the launcher and their function are as given below.

BODY-

Body is power carrying part of a launcher and is meant for fastening and positioning all components inside it. It also has provision to fasten the launcher to aircraft.

Body consists of separate units, fabricated from steel and welded between them in single beam of box-like section. From front side, the body is closed with fairing, which is fastened to body with screws. In tail part, the body is closed with rear fairing.

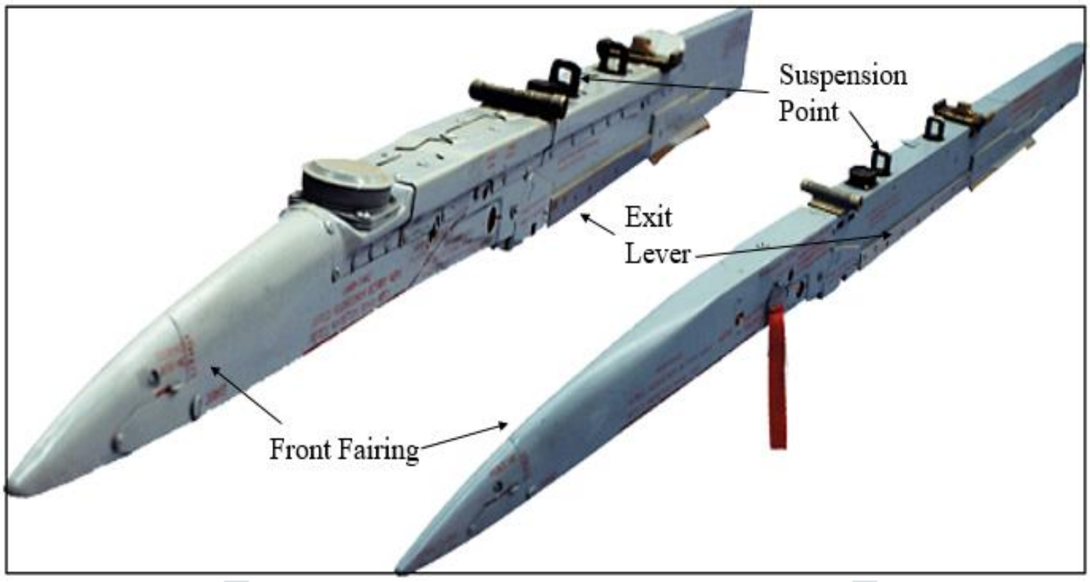

Figure 1. Body of a launcher

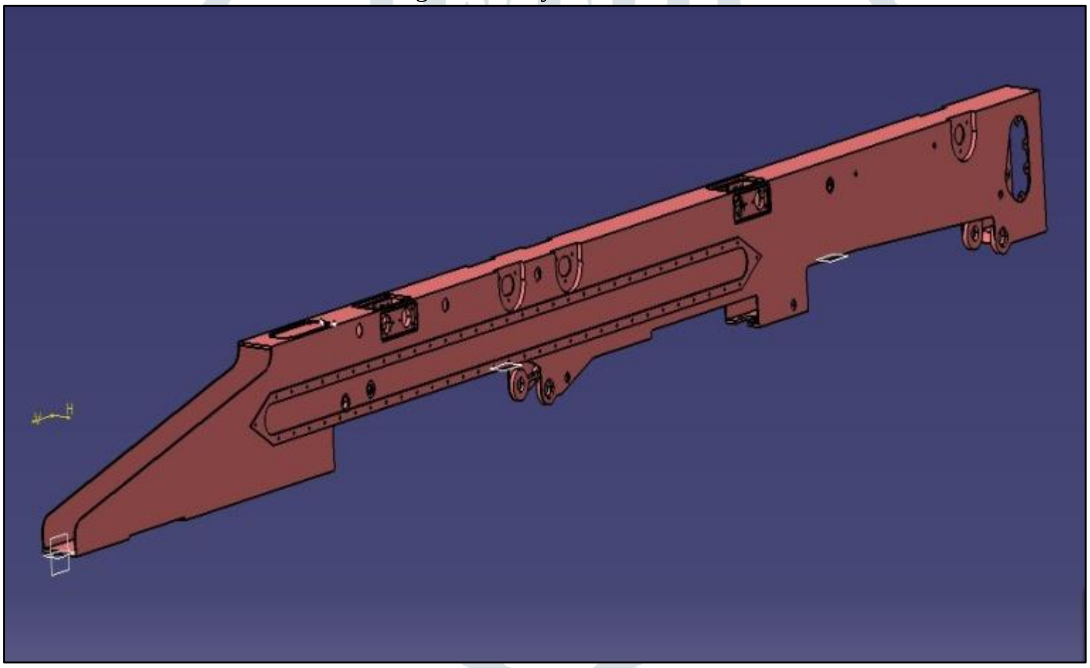

Figure 2. CATIA model of body of launcher

LOKING MECHANISM-

The functions of locking mechanism are as follows

- To hold the jettison levers in their initial position prior to jettisoning.
- To release the jettison levers at jettisoning.
- To hold the jettison levers after they return to their initial position.
- To control operation of item cooling system valves.
- To control the mechanism which serves to couple and uncouple external electrical connectors.

The locking mechanism consists of front and rear item-carrying hooks, front and rear stoppers and a rod. Carrying hooks are installed in axles. These axles are secured in the device casing with nuts and suspended from the springs which are installed in spring holders. Both spring holders are hinged to the body with the help of clamps. The carrying hooks serve to hold jettison levers in their initial position. The function of the springs installed in spring holders is to hold the carrying hooks in the open position during the entire period of jettisoning until the jettison levers are returned to their initial position.

Front stopper is coupled through a shaft with control rod of valves that are installed for cooling system and the coupling and uncoupling mechanism of external electrical connectors. At the initial instant of jettisoning, this roller is actuated by the force transmitted from operating rod of the front pneumatic cylinder.

Rear stopper is mounted on an axle secured in the casing and suspended on the springs installed in spring holders. These spring holders are hinged to the launcher’s casing. One arm of the rear stopper serves to lock carrying hook while other one is coupled with interconnecting rod whose opposite end is connected to front stopper so as to synchronize the motion of both the stoppers.

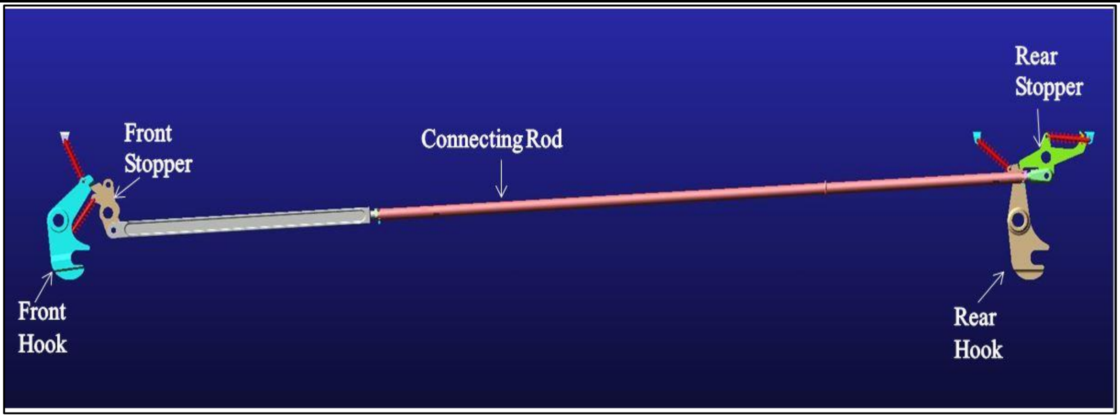

Figure 3. Locking mechanism

EJECTION DEVICE-

Ejection device is intended for suspensions of article and its forced separation from launcher before starting engine of article. It consists of front and rear exit levers, two interconnecting rods and a bell crank.

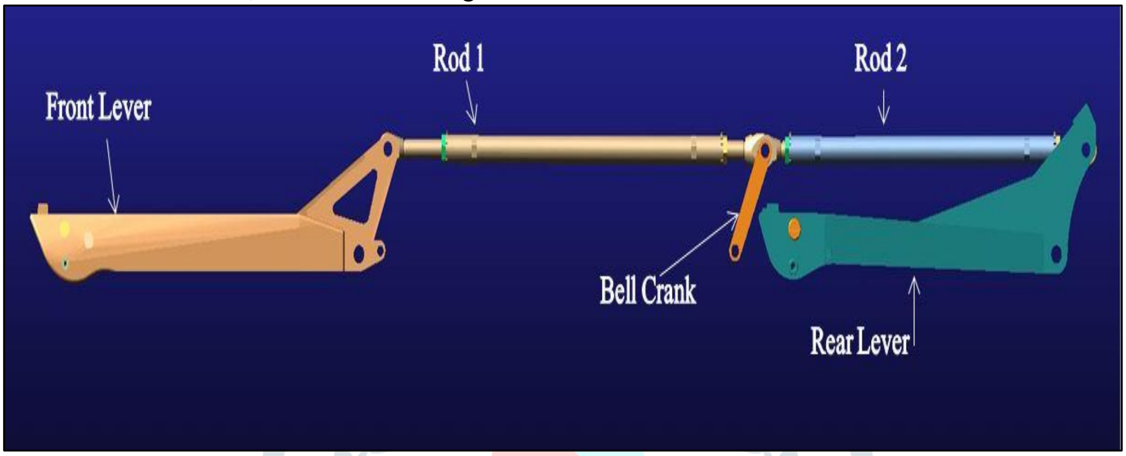

Figure 4. Ejection device

POWER DRIVE-

The power drive is designed for forced deflection of front and rear lever together with the article suspended from them and for return of these levers to their initial position after the article is launched.

The major components of the power drive are,

- Air and squib operated unit
- Compressed air (Nitrogen) bottle
- Front and rear pneumatic cylinders
- Connecting pipelines

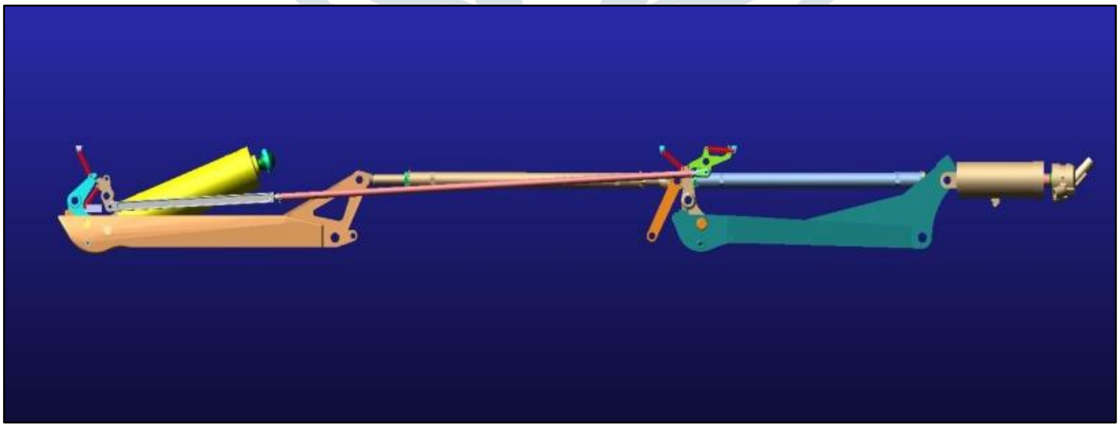

Figure 5. Assembled model of launcher without body

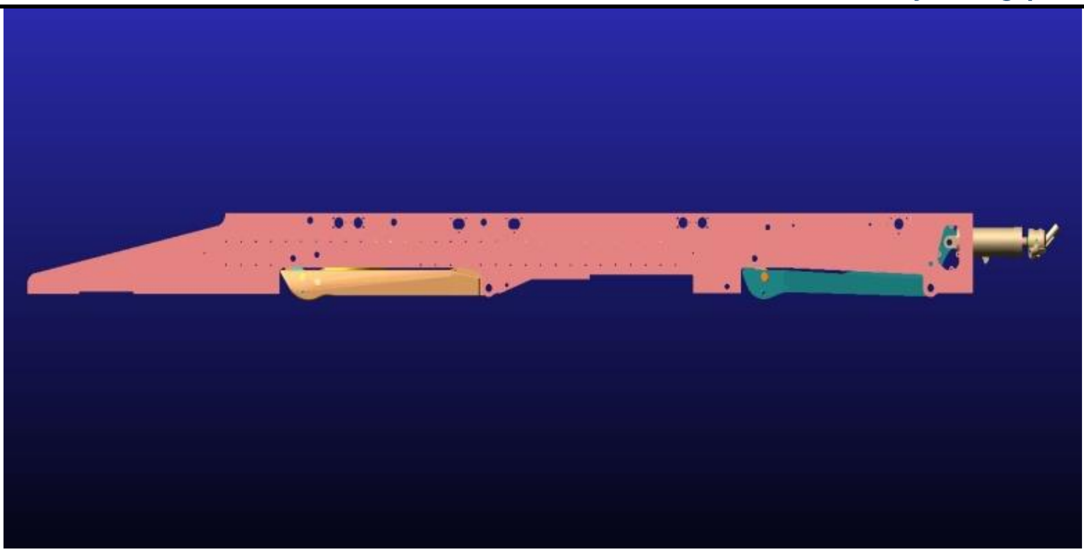

Figure 6. Assembled model of launcher

III. MATHEMATICAL CALCULATIONS

FRONT HOOK-

R_A - Reaction coming on front hook due to shaft that rests in front lever
R_{BH} - Horizontal component of reaction force that comes on the axle of front hook
R_{BV} - Vertical component of reaction force that comes on the axle of front hook
R_C- Force exerted by spring of holder on front hook
R_D- Reaction force coming on front hook due to contact with front stopper
R_E- Reaction force coming on front hook due to retraction spring of front stopper

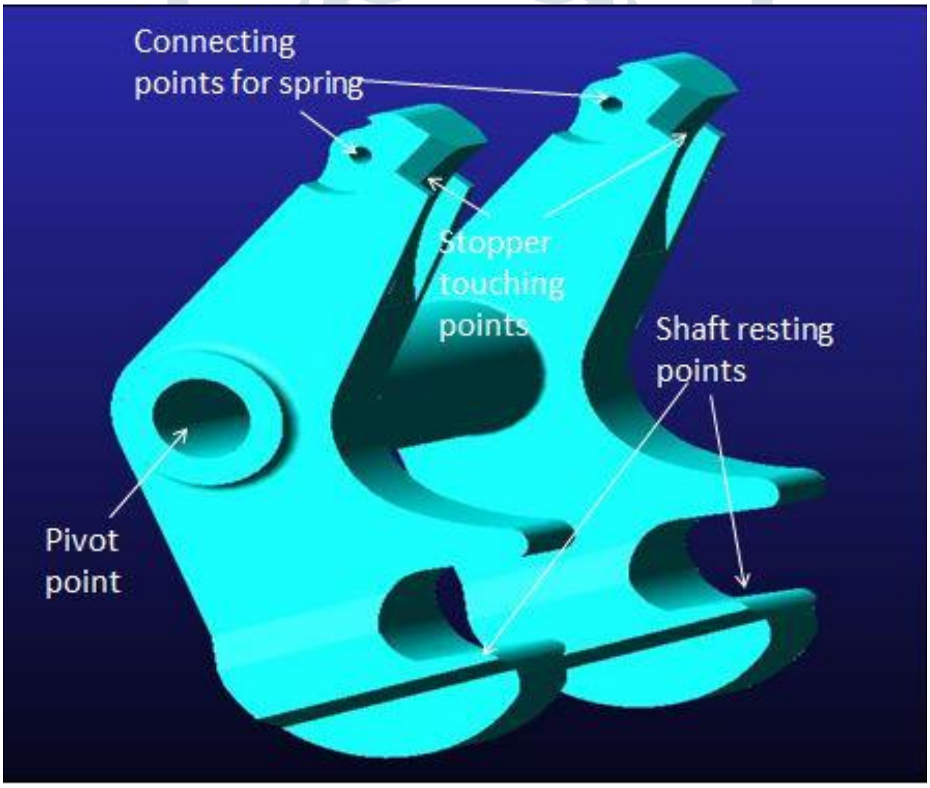

Figure 7. Front Hook

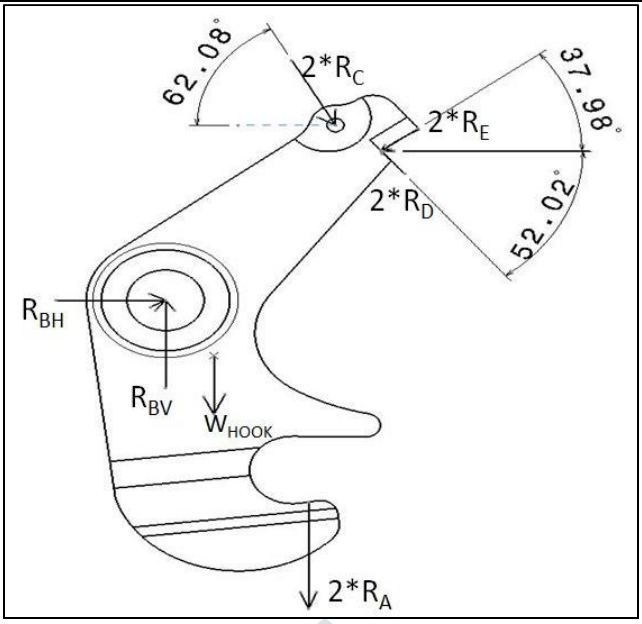

Figure 8. Free body diagram of Front hook

The missile is held on position with the help of front lever and rear lever. The levers are held in position with the help of hooks and stoppers. So the load coming on levers is ultimately transferred to hooks and stoppers.
The load of missile was given as 2000kg and calculations of front lever was carried out. From front lever, load is transferred to front stopper. Using simple equilibrium equations, the reactions were calculated. The answer of mathematical calculations are tabled below.

Part	Point	Unknown	Reaction (N)
Front Hook	A	R_A	4952
	B	R_{BX}	2751
		R_{BY}	6314
	C	R_C	77
	D	R_D	2457
	E	R_E	109

Table 1. Reactions on front hook

Similar calculations were carried out for rear hook. Following results are obtained.
REAR HOOK-

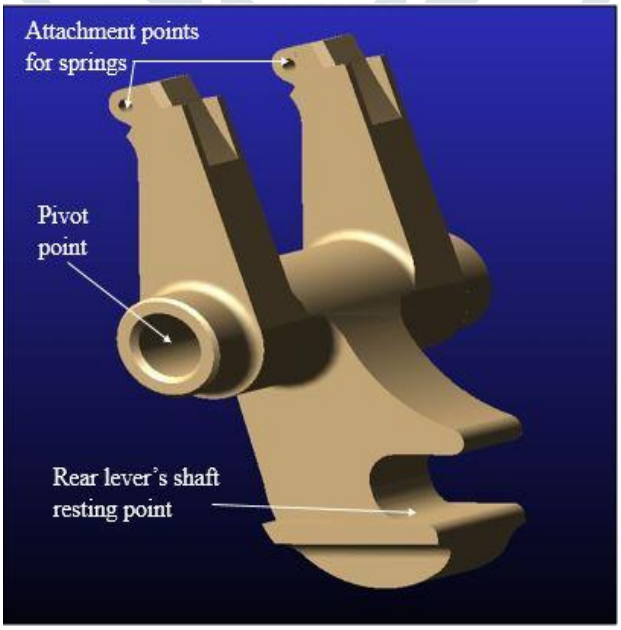

Figure 9. Rear Hook

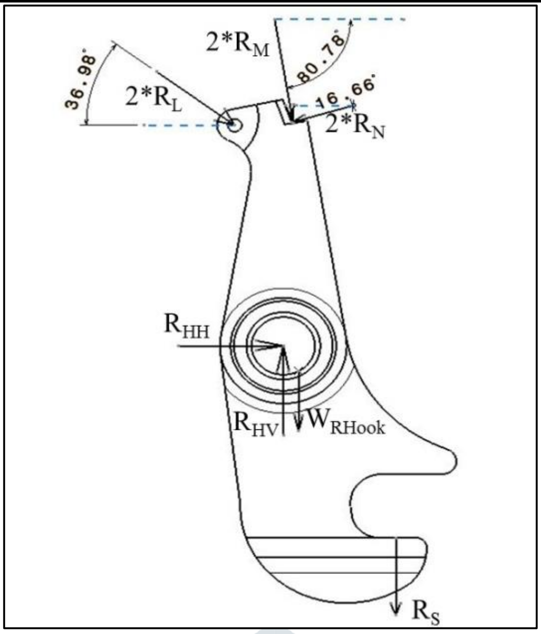

Figure 10. Free body diagram of rear hook

R_{HH} - Horizontal component of reaction force that comes on the axle of rear hook

R_{HV} - Vertical component of reaction force that comes on the axle of rear hook

R_L - Force exerted by spring of holder on rear hook

R_M - Reaction force coming on rear hook due to extension spring of rear stopper

R_N - Reaction force coming on rear hook due to contact with rear stopper

R_S - Reaction coming on rear hook due to shaft that rests in rear lever

Part	Point	Unknown	Reaction (N)
Rear Hook	S	R_S	9865
	H	R_{HX}	4513
		R_{HY}	11772
	L	R_L	82
	M	R_M	201
	N	R_N	2457

Table 2. Reactions on rear hook

IV. ADAMS RESULTS AND DISCUSSION

After modelling, the components were assembled in CATIA software. After that the assembly was imported in ADAMS simulation software. Material properties were defined for each component of the system. Then proper connections were provided between the components by keeping in mind that system should not get over constrained. The reactions at some points were checked and compared with the mathematical results.

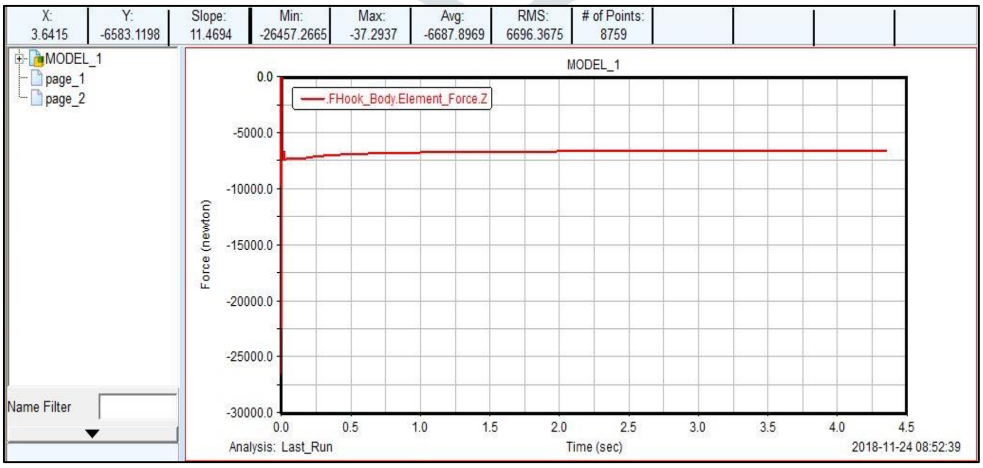

Figure 11. ADAMS result of reaction R_{BY}

The average value of the R_{BV} comes out to be 6583.12 N. The value that is obtained from the calculation is 6313.59 N.

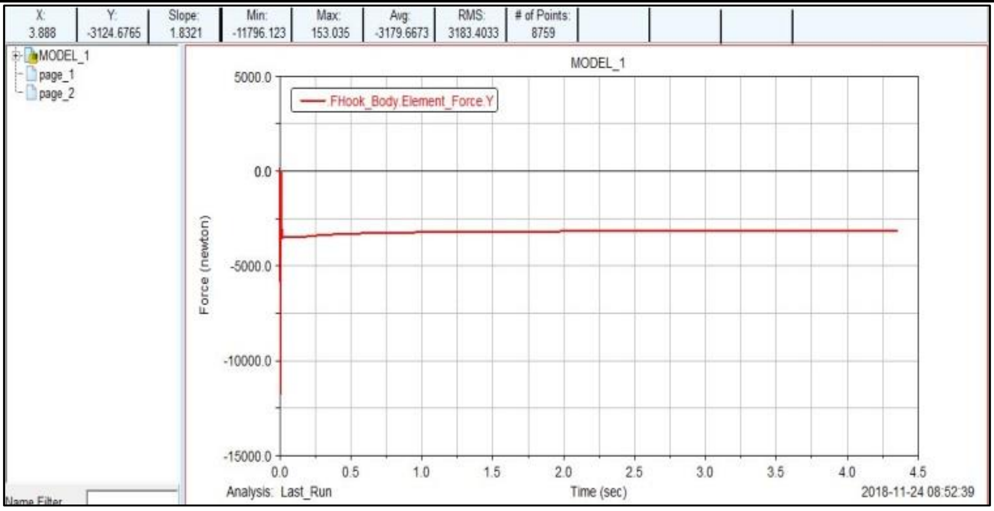

Figure 12. ADAMS result of reaction R_{BX}

The value of R_{BX} obtained from ADAMS software is 3124.68 N whereas the value obtained by mathematical calculation is 2761.35 N.

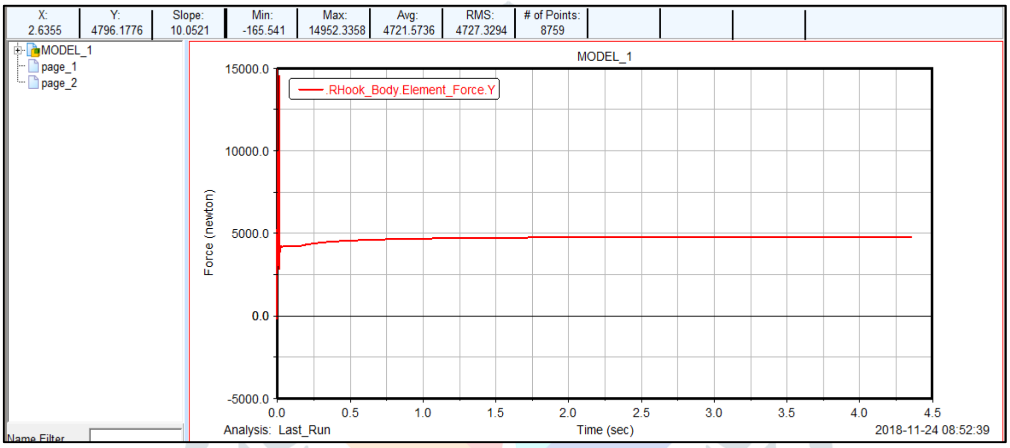

Figure 13. ADAMS result of reaction R_{HX}

The average value of the R_{HX} comes out to be 4727.33 N. The value obtained from the Calculation is 4513.37 N.

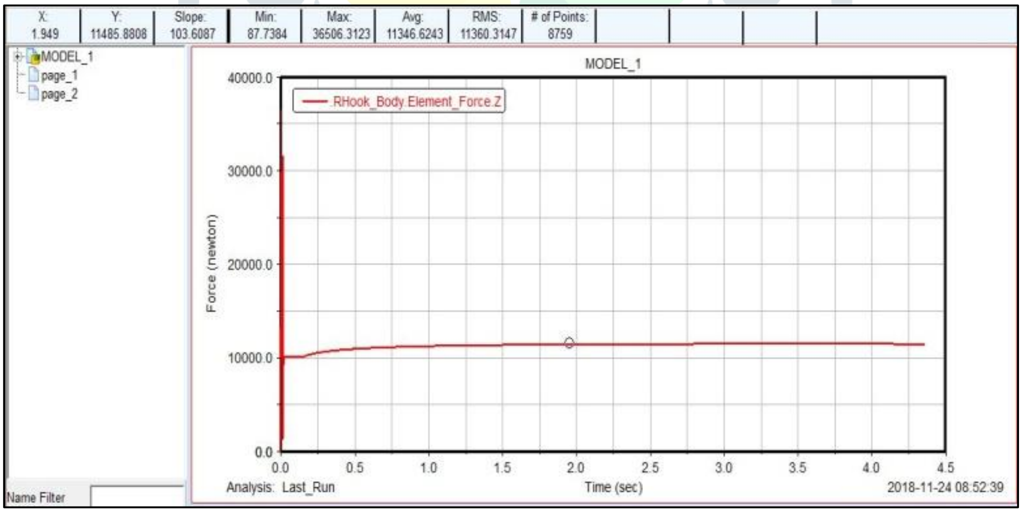

Figure 14. ADAMS result of reaction R_{HY}

The average value of the R_{HY} comes out to be 11346.62 N. The value obtained from the calculation is 11772.51 N.

Some critical flight cases were taken for force calculations. Using ADAMS, forces coming on front hook and rear hook were noted down. Using those forces, FEA analysis of both components were carried out.

V. FEA ANALYSIS RESULTS

The results of FEA analysis of front hook and rear hook are as follows,

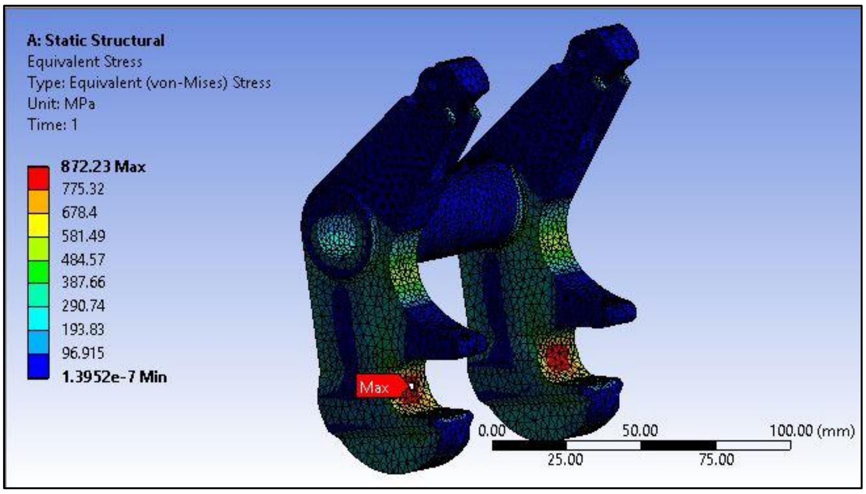

Figure 15. FEA analysis of front hook

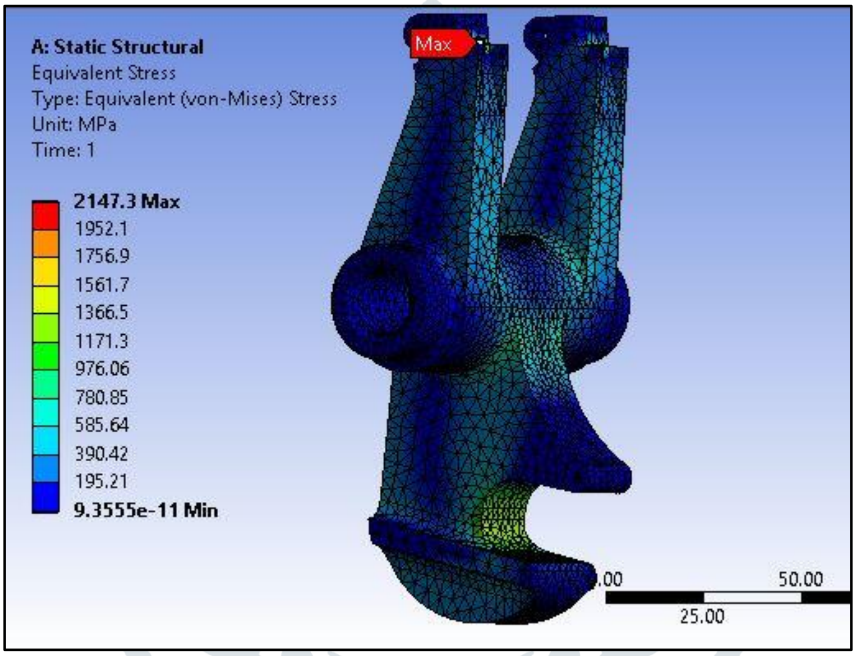

Figure 16. FEA analysis of rear hook

VI. CONCLUSION

The boundary conditions given were four times as that of existing launcher. The maximum stress observed in front hook is also four times of its yield strength. The hook is more likely to fail for 2000Kg missile load. To avoid it corrective actions are required to take. The maximum stress observed in rear hook is about 2100 MPa which is too high. So rear hook will fail prior to front hook. So first of all rear hook needs to made safe.

VII. ACKNOWLEDGMENT

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