

Analysing helicopter landing gear



**ASSIGN
BUSTER**

The Landing gear, an important part of a helicopter, assists the helicopter to land. So, when the helicopter is in land condition, the landing gear should withstand the whole weight of the helicopter. Apart from this, it should also withstand the thrust while landing operation is on.

The landing gear of a helicopter can be of three types:

Skid type

Wheel type

The skid type landing gear is the simplest one and cheaper to manufacture. Some skids allow the helicopter to land even on water. If the helicopter need to land on hard surfaces (like runway) regularly, then some special kinds of “shoe” need to be attached to the skid. The shoe can be replaced upon wearing. The most commercial helicopter has the skid type landing gear.

The wheel type landing gear is little complicated and costlier as compared to the skid types but the wheel type landing gear gives easier ground handling and advantageous while rough and crush landing.

In our case, we have to design a landing gear suitable for landing on an aircraft carrier. The landing condition can become really bad due to the vertical motion of the aircraft carrier. Considering this severe landing condition I have chosen to go ahead with the wheel type landing gear for this assignment.

I have used ADAMS/View for creating the design models, ADAMS/Vibration for running the vibration analysis and ADAMS post processing for analyzing and plotting the results.

Design of Landing Gear Mechanism

Research on Existing Landing Gear

From the earlier days of the aviation history, many concepts of the landing gears are used. I will explain few of them here:

Landing gear with leaf springs: The uses of aluminum leaf springs are possible for the very light weight helicopter (around 300kg). The design looks attractive.

Fig. 1: Showing the concept of aluminum spring landing gear

The concept of the heavy duty composite leaf spring is being experimented by some of the commercial aircraft manufacturer including AIRBUS. The main advantage of leaf spring concept is its reduced part count.

Landing gear with shock absorber: Most commercial applications use shock absorbers for the design of the landing gears.

Fig. 2: Showing a typical shock absorber based landing gear design

Based on the numbers and the positions of the tires, this type of landing gears are typically classified in nine configurations as shown in the below figure (fig. 3).

Fig. 3: Showing classifications of shock based landing gear

I have used the “Twin” configuration of tires for each of the landing gears and used total of three landing gears in my final design. However, before selecting the final design, I have studied one concept with two twin configuration landing gears at rear and one single configuration landing gear at front as well.

Design Inputs

Few of the design inputs were given along with the assignment and for others, either I googled out from the manufacturer’s specifications or assumed. All together I have used the following design inputs:

Weight of the helicopter = 5126 Kg

Length of the helicopter = 15.16 m

Spacing between the two rear landing gear = 2.5 m

Spacing between the front and the rear landing gear = 5 m

Young’s modulus of steel = 2.7×10^{11} N/m²

Density of steel = 7801 kg/m³

Poisson’s ratio of steel = 0.29

Young’s modulus of rubber = 5×10^6 N/m²

Density of steel = 1100 kg/m³

Poisson’s ratio of steel = 0.3

Possible design options

After doing the preliminary study of the existing available designs, two aspects had come to my mind before proceeding further: one, covering all the assignment tasks and two, simplicity. I was looking for coming out few design concepts, which are good enough to cover all the assignment tasks and simple enough to finish the assignment in time. And I came out with the following two concepts:

Design option -1: In this concept, I have used two twin-configured rear landing gears and one single-configured front landing gear.

Fig. 4: Showing a real life example of the Design option-1

The three landing gears (one front and two rears) are connected to a triangular top frame made up of steel. The top steel frame in turn is bolted with the fuselage.

Design option-2: In the second concept, I have used three twin landing gears. One, in front and two are at rear. Please not that I have used two wheels (twin) in front (in design option-1, I have used a single nose wheel in front). The three landing gears are connected with the triangular top frame. The top frame is bolted with the fuselage.

Creations of the ADAM models

ADAMS is a tool, develop by MSC and used extensively for simulating different types of mechanisms. It has different modules, out of which I have used the ADAMS/View here. I also used the ADAMS Vibration plug-in for simulating the action of the ocean waves on the stationary helicopter on the aircraft carrier.

I have used the “ block” option for creating the base (aircraft carrier platform), “ torus” option for creating the wheels , the “ link” option to create the axels, “ cylinder” option to create the top frame (which will be bolted to the fuselage) and the “ spring” option for creating the shock absorber springs . Also, I have made used of the options like “ point”, “ contacts”, “ joint”, “ force”, “ input channel” and “ output channel”. How? I will explain in details little later, while explaining each of the design concepts separately.

Fig. 5: Showing MSC ADAMS tools

ADAMS model for the design option-1

Start ADAMS/View.

In the main toolbox right click the “ Rigid body” and click the “ Point” to create the points each at the wheel centers, at the three vertex of the frame, at the top left corner of the base.

Again in the main tool box, right click the “ Rigid body” bar and click the “ Box” to create the base.

Click on the “ Torus” of the “ Rigid Body” bar to create all the five wheels.

Click on the “ Link” of the “ rigid body” bar to create the three axels.

Click on the “ Cylinder” of the “ Rigid body” bar to create all the three sides of the top frame.

Use the “ Merge two bodies” of the “ rigid body” bar to merge all the three sides of the top frame into one.

Under Joint bar, select Revolute to connect the wheels with the respective axels.

Under Forces bar, select Translational Spring-Damper to connect the axels and the respective vertices of the triangular top frame.

Create sliding joints between the base and back ground and between the top frame and back ground.

Under Forces bar, select Contact to create the contact between the wheels and base.

Finally, the design option-1 ADAMS model should look like below:

Fig. 6: showing the ADAMS model of design option-1

ADAMS model for the design option-2

Following the similar procedure as described for creating the ADAMS model for design option-1, I have created the Design option-2 (with twin in front).

The ADAMS model of the design option-2 looks like below:

Fig. 7: Showing the ADAMS model of design option-2

Comparisons of the design options

After finishing the ADAMS model for both the design concepts, I run the “ Normal landing” analysis on both design option models. The data used for the “ Normal landing” analysis for both the design options are as below:

Vertical descent speed of the top frame = 0. 5 m/sec

Vertical upward speed of the base = 0 m/sec

Spring Stiffness coefficient= 30 N/mm

Spring damping coefficient = 1 Ns/mm

Spring preload = 17000 N

I got the following results:

Fig. 8: Showing the acceleration plot of the top triangular frame for Design option-1 and the Design option-2.

The above plot (fig. 8) is showing that the acceleration of the top frame for the design option-1 is higher than that for the design option-2.

Fig. 9: Showing the Z-direction reaction force plot of the joint between the top frame and the back ground (space) for Design option-1 and the Design option-2.

The above plot (fig. 9) is showing that the design concept-1 is producing lots of Z- direction force, the force that can affect the stability of the helicopter.

So, on the basis of the above analysis, I have chosen the Design option-2 for further study.

Results and Calculations

Spring Calculations

Sprung mass = 5126 kg

Maximum acceptable acceleration = 0.3 m/s²

Preload on each spring = $5126 \times (9.81 + 0.3) / 3 = 17274 \text{ N}$

Dynamic Analysis Results

Normal landing

Normal landing analysis is performed based on the following conditions:

Vertical descent speed of the top frame = 0.5 m/sec

Vertical upward speed of the base = 0 m/sec

Spring Stiffness coefficient = 30 N/mm, 50 N/mm, 70 N/mm

Spring damping coefficient = 1 Ns/mm

Spring preload = 17274 N

Fig. 10: Showing normal landing analysis of the design option-2 for different spring rate

Hard landing

Hard landing analysis is performed based on the following conditions:

Vertical descent speed of the top frame = 3 m/sec

Vertical upward speed of the base = 3 m/sec

Spring Stiffness coefficient = 30 N/mm, 50 N/mm, 70 N/mm

Spring damping coefficient = 1 Ns/mm

Spring preload = 17274 N

Fig. 11: Showing hard landing analysis of the design option-2 for different spring rate**Crush landing**

Crush landing analysis is performed based on the following conditions:

Vertical approach speed of the top frame = 15 m/sec

Vertical upward speed of the base = 0 m/sec

Spring Stiffness coefficient= 30 N/mm, 50 N/mm, 70 N/mm

Spring damping coefficient = 1 Ns/mm

Spring preload = 17274 N

Fig. 12: Showing crush landing analysis of the design option-2 for different spring rate

The acceptance criteria of the above analysis are as follow:

Normal landing: Minimum acceleration

Hard landing: 50 m/sec²

Crush landing: 300 m/sec²

In order to fulfill all the acceptance criteria, I have chosen the spring stiffness as 30 N/mm and proceed further for the vibration analysis.

Vibration Analysis Results

Fig. 13: Showing frequency response of the design option-2

The pick of the frequency response curve is indicating the resonance frequency, which is around 2.5 Hz for our case.

Fig. 14: Showing PSD plot of the design option-2

The above plot is showing the transmitted power from all the inputs used in the analysis as a function of the frequency. Again, the pick (2.5 Hz) is showing the resonating frequency here.

Discussion

Task 1

For the Task-1, I have developed two design options (as shown in section 3.1 and 3.2) and compare the two design options on the basis of normal landing analysis (section 3.3). The result has shown that the design option-2 is better in terms of acceleration and z-direction reaction force. Hence I have selected the design option-2 for the further study.

Task 2

For the task-2, I have run the normal, hard and crush landing analysis (section 4.2) on the design option-2 for different spring stiffness and choose the best spring stiffness to ensure that all the acceptance criteria is met.

Task 3

For Task-3, I run the vibration analysis for the design option-2 (section-4.3) and find out the resonating frequency for the mechanism on response to the sea wave.

Task 4

For the task-4, I have discussed (section 3) how I have used the ADAMS/View for creating the ADAMS model and also, I have discussed how I simulate the mechanism.

Conclusion

The emphasis is given to come out with a simple but reasonably good landing gear mechanism, which will be able to pass all the test conditions specified in the assignment. The hand calculations are used for selecting the spring preload however, the selection of the spring stiffness is done on the basis of hit and trial.

ADAMS/View and ADAMS Vibration plug-in are used for the whole analysis for getting the quick and easily interpretable results.

I believe that the design of the mechanism can be further improved by incorporating the torsion springs along with the compression springs.