DYNAMIC ANALYSIS OF AIRCRAFT LANDING GEAR

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To my beloved mother and father

The brightest lights in my darkest nights

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ABSTRACT

Landing gear dynamics, especially shimmy and break-induced vibrations, is one of the problems faced today by the aircraft community. Landing gear vibration may lead to fatal accidents due to excessive wear; it can also shorten the gear life, and affect comfort to the pilot and passengers. Among the most important reasons for landing gear vibrations are unsuitable combination of structural stiffness, damping, and pneumatic tire characteristics furthermore an unlucky combination of brake system design with the tire physics can produce a serious vibration problem. Many available computer-aided engineering tools and software have made it possible to test some of the problems in the design phase by simulating the landing gear impact and ground maneuvers. In this study, it has been conducted to simulate the simplified model of aircraft Eagle-150 in MSC. ADAMS software and work on the simulation of such an unstable and complex phenomenon during landing position and also aircraft ground maneuver in order to detect vibrations in aircraft landing gear. It has also been tried to study the effect of important parameters that may affect the instability and comfort a simple simulated model of aircraft and its landing gear was prepared using ADAMS for this purpose. An adequate model of aircraft and landing gear is an important aspect of analysis in order to understand the behavior of an aircraft during landing and ground maneuver. Effect of various parameters on landing gear vibration is also one the purposes of this study.

ABSTRAK

Dinamik gear pendaratan, terutama *'Shimmy'* dan getaran berpaca dari brek, adalah salah satu masalah yang dihadapi oleh kebanyakan pesawat hari ini. Getaran gear pendaratan boleh membawa kepada kemalangan maut akibat kehausan melampau, selain boleh memendekkan hayat gear, getaran pada gear pendaratan juga menjejaskan keselesaan kepada juruterbang dan penumpang. Salah gatu sebab-sebab yang paling penting untuk getaran gear pendaratan adalah gabungan yang tidak sesuai di antara kekukuhan struktur, redaman dan ciri-ciri tayar pneumatic. Seterusnya, gabungan rekabentuk sistem brek dengan fizik tayar boleh menghasilkan masalah getaran yang serius. Terdapat banyak alat bantuan komputer kejuruteraan dan perisian telah dibuat untuk menguji beberapa masalah dalam fasa reka bentuk melalui simulasi kesan pendaratan gear dan gerakan di atas landasan. Dalam kajian ini, model ringkas pesawat Eagle-150 telah disimulasikan di perisian MSC. ADAMS. Kerja simulasi mengambil kira fenomena yang tidak stabil dan kompleks semasa kedudukan pendaratan dan juga manuver pesawat di atas landasan untuk mengesan getaran dalam gear pendaratan pesawat. Ia juga telah disimulasikan untuk mengkaji kesan parameter penting yang boleh menjejaskan ketidakstabilan model simulasi pesawat dan gear pendaratan. Satu model lenakap gear pesawat dan gear pendaratan adalah aspek penting dalam analisis untuk memahami tingkah laku pesawat semasa pendaratan dan manuver diatas landasan. Kesan parameter pelbagai getaran gear pendaratan juga merupakan salah satu tujuan bagi kajian ini.

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LIST OF SYMBOLS

SYMBOL	DESCRIPTION
Q	Connecting point of the upper end of the oleo pneumatic shock absorber
V	Velocity
B	Projection of point Q
X	variable distance with respect to the point (Q)
ϕ	shimmy angle
A	Geometric center of the wheel
F	Lateral force
m	Mass of the landing gear
I	Moment of inertia about landing gear gravity center
θ_1	Rotationary angle of the left front wheel about the king pin
θ_2	Rotationary angle of the right front wheel about the king pin
ψ	Rolling angle of the structures above the suspension
Y	Lateral displacement of the vehicle
p	Pressure
γ	Side slip angle
F_s	Spring force
P_0	Precharge pressure
P_b	Ambient pressure
V_0	Initial air volume
Δl	Shock absorber deflection

n	polytrophic coefficient
Δp	pressure drop across the orifice
C_d	orifice discharge coefficient
a	orifice area
ρ	mass density of the hydraulic oil
e	mechanical trail
M_z	Applied moment at the wheel axle center
F_w	Friction force
F_n	Normal friction
l_b	Overlap
r_b	radius of the bearing

CHAPTER 1

INTRODUCTION TO THE RESEARCH

1.1 Background of the research

The wheel is one of the most important inventions and breakthrough of our civilization. The pneumatic tire plays the considerable and determining part in vehicle dynamics. Shimmy vibrations can be caused by the interaction between the landing gear of aircraft and tire dynamic behavior. Landing gear is an important and complex system. It should be free from excessive vibrations and dynamical instabilities particularly shimmy vibrations.

Shimmy is the self-excited oscillatory motion of a wheel about (an almost) vertical steering axis. Such type of unstable motion about vertical steering axis is usually designated as the wheel shimmy oscillation. Shimmy is a violent and possibly dangerous vibration. This phenomenon does not only occur on aircraft but has also been encountered on the steerable wheels of cars, trucks, and motorcycles and on the caster wheelchairs too. The vehicle forward motion kinetic energy is transferred to self-excitation energy through the road to tire side force and aligning moment. Figure 1.1 illustrates the motion of shimmy vibration.

Fig 1.1: Lateral/ Yaw vibration

Figure 1.2 shows an accident of an airplane caused by shimmy vibration suffering a nose wheel vibration.

Fig 1.2: A B-24 Liberator, shown after suffering a nose wheel failure at a base in North Africa. Nose wheel shimmy was a serious enough problem that all the Halpro aircraft carried a spare nose wheel when they left Florida.

1.2 Introduction to vibration

1.2.1 Types of vibration

Vibration is oscillating, responding, or any other periodic motion of a rigid or elastic body forced from a position or state of equilibrium. If the frequency and magnitude of vibration are constant, the vibration is said to be harmonic. The vibration is random when the frequency and magnitude vary with time. Buffet is a form of vibration usually caused by aerodynamic excitation. It is commonly associated with separated airflow. For example, buffet may be felt during the extension of speed brakes or during air turbulence.

Flutter is an unstable condition in which unsteady aerodynamics excite the natural frequencies of the structure over which the air flows. The resulting vibrations can grow to a magnitude that causes the structure to fail. *Noise* is a vibration that excites the air and can be heard. When the vibration is random, the noise is unpleasant or confused. When the vibration is harmonic, the result is a tone like that produced by a musical instrument. It may sound like the whistling of a drain or a slight leak in a door.

1.2.2 Cause of airplane vibration

Normal and abnormal vibrations occur due to several reasons. Mechanical malfunctions, aerodynamics, and external factors such as atmospheric turbulence can cause airplane vibration. All vibrations have associated frequencies and magnitudes that might be readily noticed or barely noticeable to the flight crew and passengers. For some vibrations, such as those associated with engine operation, the flight crew has dedicated instrumentation to measure magnitude. Other vibrations are detected by sight, sound, or feel and may depend on flight crew experience for analysis.

Each aircraft has a unique signature of normal vibration. This is due to mass distribution and structural stiffness that result in vibration modes at certain frequencies. When external forces act on the airplane, such as normal airflow over the surfaces, very-low-level vibrations result. Characteristically, this is perceived as background noise. More noticeable, but also normal, is the reaction of the airplane to turbulent air, in which the magnitude of the vibration may be larger and thus clearly visible and felt. Engine operation at some spool speeds may result in increased vibration because spool imbalance excites the engine and transmits this vibration throughout the airframe. Finally, the operation of some mechanical components, such as pumps, may be associated with normal noise and vibration. Most flight crews recognize these normal events, which become the experience base from which flight crews detect abnormal vibration events.

The most easily identified abnormal vibration is that which has a sudden onset and may be accompanied by noise. The vibration may be intermittent or steady with a distinct frequency, or it may be a more random buffet type. When the onset of abnormal vibration can be associated with a previous action or event, the source may be obvious. However, some vibrations initially are rather subtle and require diagnostic procedures to determine their probable causes.

Abnormal vibration usually is related to one or more of the following causes: malfunction of mechanical equipment, engine rotor imbalance, and airflow disturbances acting over doors or control surfaces that are misrigged or misfaired or that have excessive wear or free play. Abnormal vibration hardly is caused by a structural failure or an unstable power control system.

In this project the main focus is on a destructive phenomenon called shimmy vibration which is an unwanted oscillation occurred on the aircrafts. The frequency of this phenomenon is typically in the range of 10 to 30 Hz. The degree of instability may vary from annoying vibrations up to structural damage or even a collapse of the landing gear. This phenomenon can occur on both nose and tail wheels. In Figure 1.3 the marks on runway indicates that the aircraft had shimmy oscillation during taxi motion.

Fig 1.3: Tire marks on the runway

Shimmy may be caused by a number of conditions such as:

- Low torsional stiffness of landing gear
- Excessive free-play in the gears
- Wheel imbalance
- Uneven tire pressure
- Etc.

In order to avoid this phenomenon from happening there are several design which are known as anti-shimmy designs including: using twin wheels, Mastrand tire, and shimmy damper for both light and large aircrafts.

Mastrand tire is a single tire used on nose wheels. It has a double contact area which helps to eliminate shimmy. These tires can be used until the center section starts to contact the ground.

Some popular configurations of landing gears as illustrated in Figure 1.4:

- Twin wheeled cantilevered main landing gears may experience shimmy stability problems.

- Bogie landing gears and levered suspension configurations are generally not sensitive to shimmy.

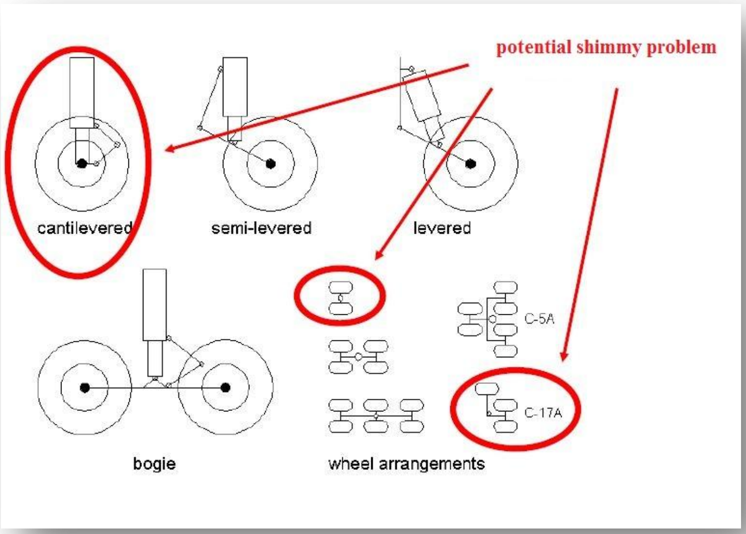

Fig. 1.4: Landing gear configurations

1.3 Objectives of the study

This research is focused on dynamic analysis of aircraft Eagle 150 landing gear and investigation of unwanted vibration called shimmy which typically occurs to this kind of light aircraft. Objectives of this research are mentioned in the following:

- To study the dynamic behavior of landing gears during landing position using MSC. ADAMS software.
- To improve and develop the model in order to reduce shimmy problem using available software.

1.4 Scopes of the study

The scopes of this study will be focused on:

- To develop a simplified model of airplane ‘Eagle 150’ in MSC. ADAMS.
- To validate the developed model with experimental or published results.
- To study the effects of stiffness ‘k’, damping coefficient ‘c’, mass ‘m’, etc. on shimmy phenomenon.
- To improve the model in the form of implementing different damping coefficient, mass, stiffness, and configuration of the aircraft in order to reduce shimmy vibration.

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