Instability Analysis of Landing Gear During Ground Maneauring

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Abstract—Landing gears are the connecting members between aircraft and the ground. They act as the load bearing members between the fuselage and the ground. Landing gear dynamics, especially shimmy and gear walk vibrations, is one of the problems faced today by the aircraft community. In this paper the effect of runway profile on gear walk instability is studied. Later a single beam landing gear model is developed to analyse gear walk phenomena as a result of ABS braking.

Keywords— instabilities; gear walk; equivalent model;

I. INTRODUCTION

Landing gears are the connecting members between aircraft and the ground .They act as the load bearing members between the fuselage and the ground [1,2,3]. The term landing gear indicates one of the main functions of the gear, namely the containment of the landing impact but it fails to describe the other main functions, namely the provision of means for the aircraft to maneuver on the ground, taxi and take off. The predominant task of an airplane is to fly with the best performance achievable. It must not be forgotten, however, that it will spend a good part of its life on the ground. Landing gear dynamics, especially shimmy and gear walk vibrations, is one of the problems faced today by the aircraft community. Though they are not catastrophic, can lead to fatal accidents due to excessive wear. Both instabilities are low frequency vibrations and can also shorten the gear life and cause discomfort to the pilot and passengers. The main reasons are slender fuselages that frequently arise from the stretching of existing aircraft and the use of new, light-weight structures and materials that influence the vibrational properties of fuselage and wings. Not only unsuitable combination of structural stiffness, damping, and pneumatic tire characteristics but also an unlucky combination of brake system design with the tire physics can produce a serious vibration problem. Mainly there are two types of instabilities. They are low frequency and high frequency vibrations (fig.1).High frequency vibrations include squeal and chatter. Low frequency vibrations include gear walk and shimmy, incorporating the applicable criteria that follow.
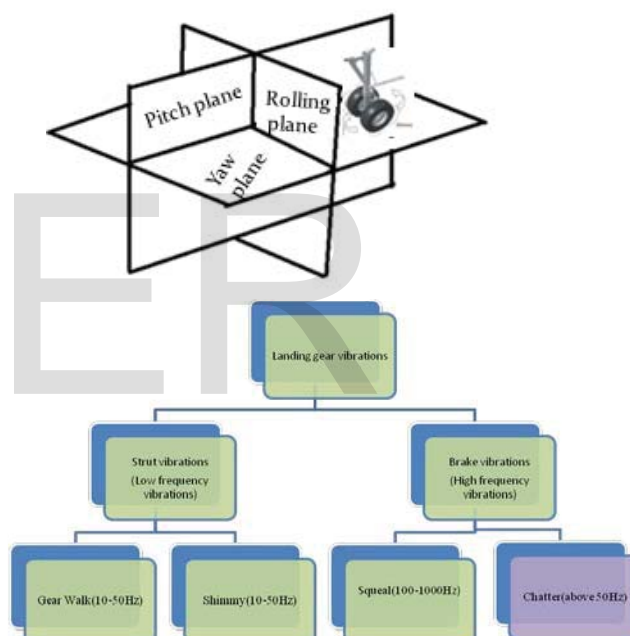

Fig. 1: Instabilities of landing gear

This paper deals with the instability known as "gear walk", a self-sustaining fore-and-aft low frequency vibration of the LG, primarily due to the coupling of the brake anti-skid system with the leg structural dynamics. Basically, as the brakes are applied and the horizontal ground load develops, the leg flexes rearwards; when an incipient skid is detected by the anti-lock system, the brakes are released and the leg springs forwards. This accelerates the wheel rapidly, tricking the anti-skid system into applying the brake pressure again, and the cycle repeats itself [5].The frequency range of the phenomenon can be placed within a range between 10 and 50 Hz [5]. While well-known instabilities, such as shimmy, have been extensively investigated through the years [9] the vibration phenomena such as gear walk, chatter and squeal, are only recently being addressed [4, 5, 6, 7, 8, 10, and 11].

Availability of simplified equivalent models of complex landing gears can reduce the modeling cost and time required for modeling. This can provide enough freedom for the designers to analyse more number of models. The runway profiles may have an important role in occurrence of gear walk. The first objective of the paper is thus to study the effect of runway profile on the gear walk instability during taxing by simulating actual taxing of a braked aircraft on a runway of having cosine profile and observing the to and fro oscillations on the pitch plane when the aircraft passes through the cosine dip. Initially the mode of braking considered is not Anti Lock Braking System (ABS).Further a single beam equivalent model is developed for analyzing gear walk instability due to tire braking which is applicable to both ABS braking and ordinary dynamic braking.

If compared to the recent works regarding gear walk [4, 5, 6, 7, 8, 10, and 11] this paper presents a simple equivalent single beam model instead of complex landing gear strut to predict the gear walk instability. In this work the effect of runway profile on the gear walk instability is also investigated

II. GEAR WALK INSTABILITY

A. Taxing simulation through a runway with cosine profile

The taxing simulation in this work is implemented by using MSC Adams/Aircraft2005 which is specialized software for the dynamic analysis of aircrafts and landing gears. An aircraft with tricycle landing gear arrangement is considered for the simulation (fig.2).Braking of the aircraft is not an ABS braking. Considered weight of the aircraft is 2250kg and the taxing speed is applied as 100knots.The runway profile is given as a flat road having a cosine curve shaped dip. Oscillations on pitch plane about the strut centerline are expected for the landing gear during the dip encounter.
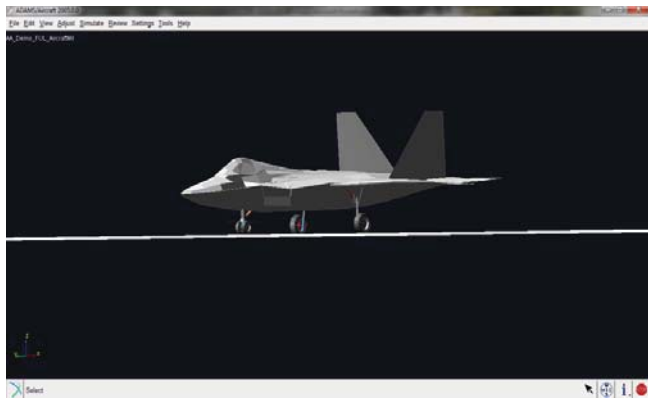

Fig. 2: Aircraft with tricycle landing gear

B. Gear walk analysis using Abaqus CAE

As the part of simplifying the landing gear model an equivalent single beam model can be developed based on some assumptions. Table .1 shows the material properties of the landing gear. It is assumed that during braking no change in length occurs for the landing gear or constant stroke is assumed during braking. Since there is no change in length

during braking the whole structure can be considered as a single beam model. Assumptions are
1. Normal landing conditions are considered
2. Lateral slip conditions are ignored.
3. Longitudinal vibrations are considered.
4. Landing strut considered as continuous DOF cantilever beam.
5. Arbitrary stroke position is considered to simulate gear walk.
6. Drag strut is not considered for analysis.

Table 1: Material Properties

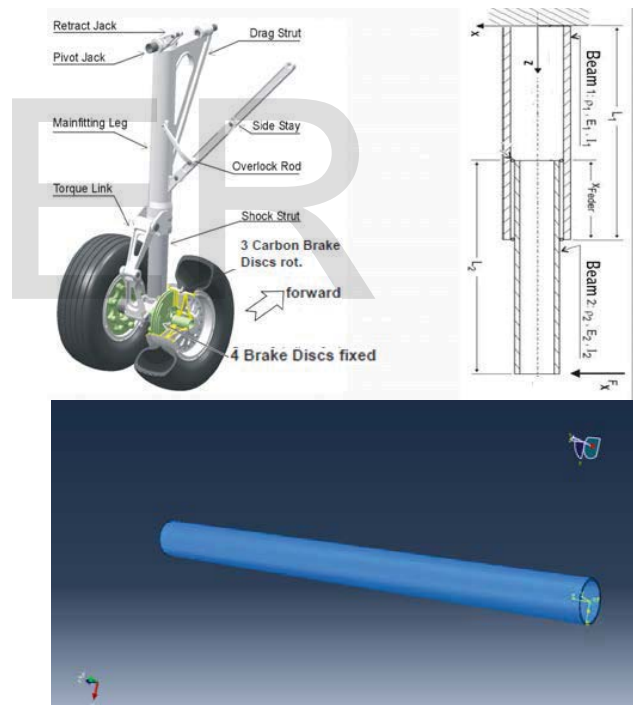| Parameter	Beam1	Beam2
$D_{1,2}$	$0.15\ m$	$0.13\ m$
$L_{1,2}$	$1.469\ m$	$1.188\ m$
$t_{1,2}$	$0.005\ m$	$0.004\ m$
$E_{1,2}$	$2.1E+11\ Pa$	$2.1E+11\ Pa$
$\rho_{1,2}$	$7895\ Kg/m^3$	$7895\ Kg/m^3$

Fig. 3: .Equivalent Single Beam Model

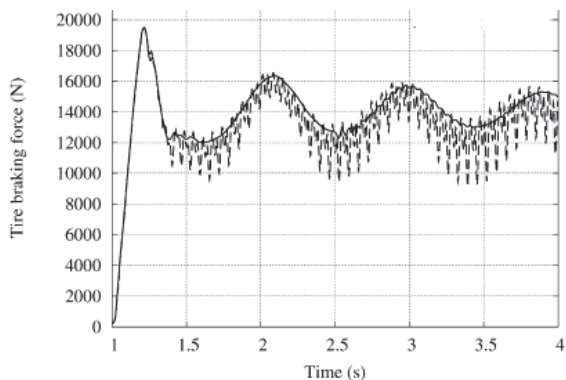The tire braking force given as a timely varying force which represent Anti Lock Braking System (ABS).

Fig. 4: Tire braking force

III. RESULTS AND DISCUSSION

A. Taxing simulation of an aircraft bump encounter

Taxing simulation of the braked aircraft through a cosine shaped runway proves the effect of runway profile on the gear walk instability (fig.6).During the bump encounter, the aircraft landing gear shows some vibrations on the pitch plane .Those to and fro vibrations on the pitch plane can be classified as gear walk.
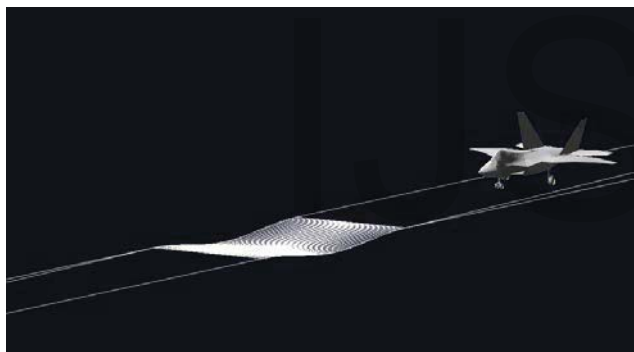

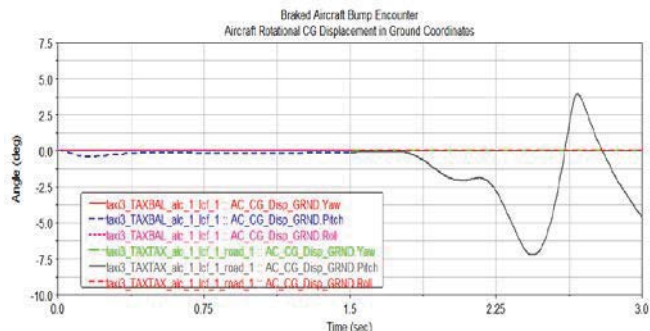Fig. 5: Aircraft on a cosine profile runway

Fig. 6: Aircraft CG displacement along the pitch plane

It is very evident to state the influence of the runway profile on gear walk instability of an aircraft to which tip back design conditions are not considered (fig.6).This data should be very useful for designers of landing gears for emergency landing, rejected take off landing and landing on surfaces other than prescribed runways.

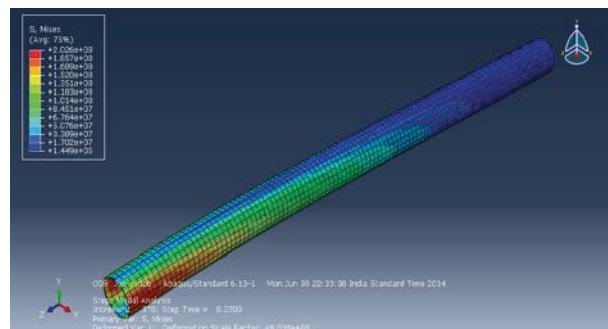### B. Gear walk analysis due to ABS brake gear interaction
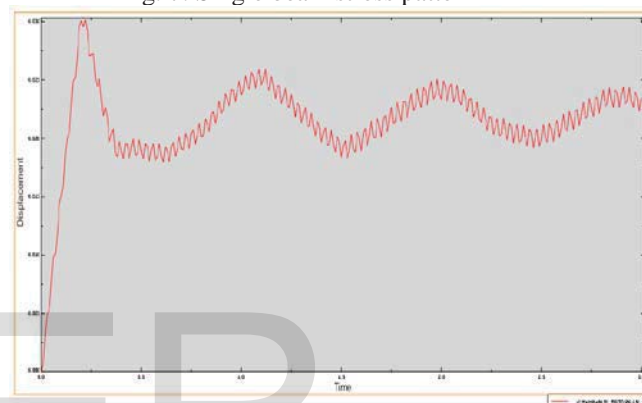

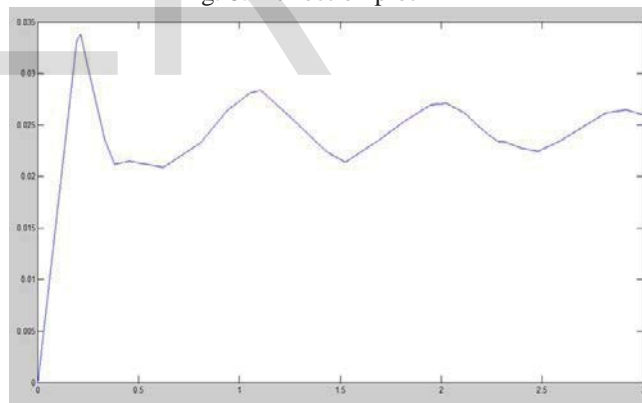Fig. 7: Single beam stress pattern

Fig. 8: Deflection plot

Fig. 9: Deflection plot obtained from mat lab

Table 2: Comparison

Single beam model	Max.Amplitude(m)
Using Abaqus CAE	0.03
Using Mat lab	0.035
Reference [8]	0.035

It becomes much easier to analyse gear walk instability by using equivalent models. Two beam models can be used to predict the gear walk well, but for a particular stroke using single beam models can reduce modeling time and overall cost of the analysis. It seems that the single beam model gives gear walk analysis results matching well with that of two beam analysis results. It is shown in Table.3 Single beam model can be proposed as a model for predicting gear walk instability accurately for a particular stroke.

Table 3: Comparison between two beam and single beam models

	Frequency	Max.Amplitude	Stress
Two Beam	29 Hz	0.025m	236 Mpa
Single Beam	30.198 Hz	0.03m	202Mpa

C. Response at different Strokes

It can be seen that the displacement response of single beam model matches well with standard results. It can be suggested to use single beam model for analyzing gear walk for a particular stroke value. It is also possible to use the same model to analyse gear walk at different strokes just by changing the length of the beam (Fig.10).
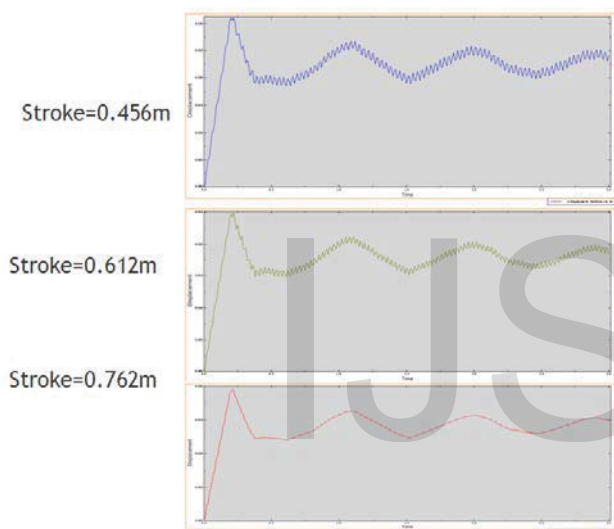

Fig. 10: Response at different strokes

Table 4: Comparison of responses

Stroke(m)	Frequency	Max. Amplitude(m)
0.456	30.198 c/s	0.03
0.612	35.160 c/s	0.025
0.762	41.167 c/s	0.02

Table.4 shows that as the stroke increases the effective length of the landing gear strut reduces and it increases the frequency and reduces the amplitude of vibrations. As this follows the general relation between the frequency and

amplitude, it further validates the suitability of the single beam model to predict the gear walk.

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