SHIMMY ANALYSIS OF A LANDING GEAR SYSTEM

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ABSTRACT

Shimmy of a Landing Gear System is a violent self-excited oscillation driven by the interaction between tire and the ground and this motion interacts with the landing gear structure. Shimmy can occur during taxiing, take-off and landing and the effect could be detrimental to the Landing Gear structure and/or the Aircraft. The stability of Landing Gear is not only a function of the Landing Gear Structure. The Landing Gear attachment conditions, aircraft wheels, tires and brakes, runway conditions, are also contributing factors affecting Landing Gear Stability. This paper presents a general method of determining Landing Gear System stability by using ADAMS.

BACKGROUND

In traditional Landing Gear Design process FEA "Stick Models" are used to determine Stiffness, Load Path, Internal and Unit Loads for Strength, Fatigue, DTA and Dynamic analyses. With the addition of Mass and Inertia properties to these models, Modal Analyses are also performed to determine the Modal characteristics of the Landing Gear Structure. Both the Stiffness and Modal models are modeled with the Landing Gear free hanged (tires clear off ground) with or without the Landing Gear Attachment conditions. For various Shock Absorber Closures, the Kinematics of the movable parts is calculated to determined their corresponding FEA Joints(Grids) coordinates and re-define the connectivities of the components of the Model

Model

The best Mathematical Flexible Body Dynamic model should be created by transforming the FEA Modal Model into a mechanism. This transformation can be accomplished by using one of ADAMS' features named ADAMS/FEA. It allows transformation of FEA information into MSA (ADAMS) model.
A typical Landing Gear Structure consists of a Cylinder, Piston, Upper and Lower Torque Links and Side Brace as shown on figure 1. Each of these Parts is transformed into Superelements from the FEA model by using ADAMS/FEA. These Superelements in ADAMS are created with their own PART, MASS, CG, stiffness(NFORCE) and coordinates to represent the Flexible Bodies. These parts are manually joined together by using the ADAMS/JOINT to represent the connectivities between each Superelement. Various linear and non-linear components such as Landing Gear Attachment Stiffness, Shock Strut internal Forces, Shimmy Damper Force element and joint tolerances can be included by using various ADAMS utilities. A typical Shimmy Model is shown on figure 2. The tire force element is then added to the axle to represent the tire and ground interaction. The tire force and moment play an important role in Landing Gear System Shimmy Analysis. The Shimmy tire models with Finite-area contact, Stretch String type (Dr. Pacejka or B. Von Schlippe-Dietrich) and a Point contact type (Moreland) are mostly used and accepted by the current Aerospace Industries.

Basically, only one ADAMS Landing Gear Model is used to perform Stiffness, Modal and Transient Shimmy analyses. Since this model is a mechanism, it is relatively easy to evaluate the Landing Gear for various shock strut closures. In this Shimmy Model, Landing simulation and Shimmy Analysis can be performed simultaneously. Due to the current computer power limitations and time consuming analysis, especially with the non-linear elements such as free play, it is not economical to perform Shimmy Analysis and Landing simulation at the same time. This combination of analysis shall only be used as a spot check to ensure the Stability of the Landing Gear System.

LANDING GEAR WITH TIRES

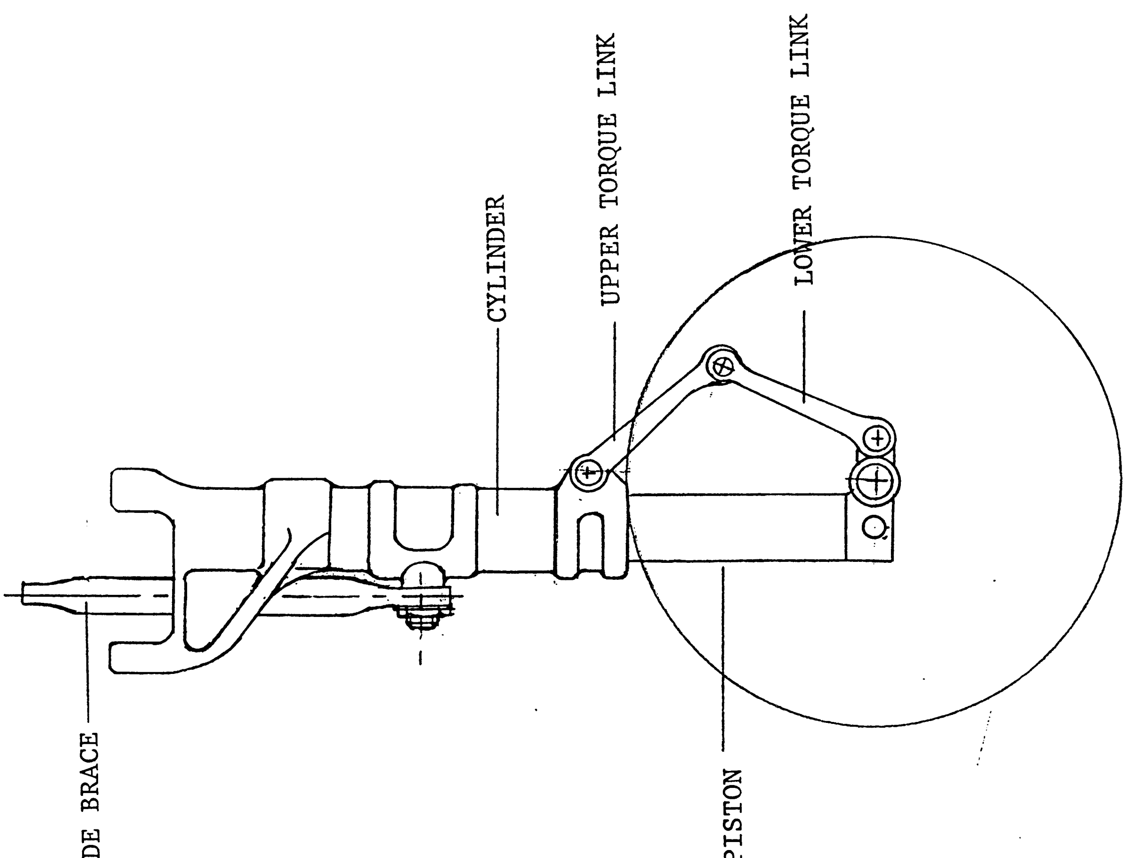

FIG. 1

SHIMMY MODEL

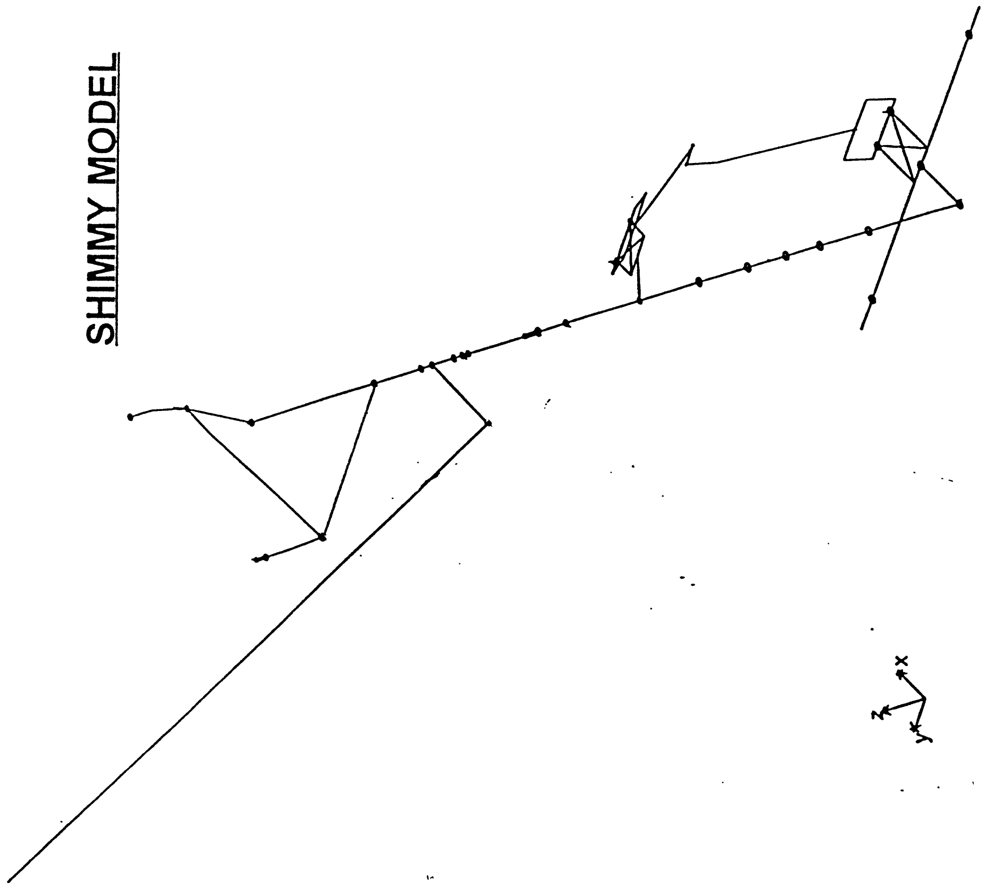

FIG.2

Validation of the Shimmy Model

To validate the Shimmy Model, Modal and Stiffness Analyses are performed with the free hanged Landing Gear System. The analysis results are compared with the FEA Modal and Stiffness Analyses results, and the Modal and Stiffness Test results which are performed under the same conditions. The Modal Analysis is performed by using ADAMS/LINEAR and the Stiffness Analysis is performed with forces and moments applied to the Landing Gear through the axle that results in a deflected Landing Gear. Analysis results of Mode Shapes of a Landing Gear System are shown on figure 3.
Shimmy Testing can be performed with the Landing Gear System in contact with a very large rotating drum to represent the forward rolling motion of the aircraft or using the actual aircraft as a test bed. These tests are expensive but necessary to ensure safe operation of the aircraft.

Shimmy Analysis

A static analysis is performed before a transient dynamic analysis. The static analysis determines the equilibrium condition with part of the Aircraft weight resting on the Shock Strut and the tires. The Shock Strut spring force and vertical tire force components will react to the weights of the Landing Gear and the partial aircraft weight which rest on the Landing Gear System. This static analysis will determine the corresponding tires and Shock Strut deflections. A transient dynamic analysis begins with rolling tires and an external or internal disturbance to excite the Landing Gear System. These disturbances can arise from simulating a brake pulse, running over an obstruction or applying a step input to the Landing Gear System. The Dynamics of the Landing Gear System and the tire force and moment will interact together and result in the oscillations of the axle, mainly in the lateral and torsional directions.
If the oscillation is converging, the Landing Gear System is said to be stable. If the oscillation is diverging, the Landing Gear System is said to be unstable and it is under Shimmy condition. Some shimmy analysis results of the axle displacement and Apex Damper force and its linear velocity are shown on figures 4 to 7. Figures 4 and 5 show an unstable Landing Gear System with an Apex Damper which is not tuned to the Landing Gear System. Figures 6 and 7 show the same Landing Gear System can become stable if the Apex Damper is tuned to the Landing Gear System.

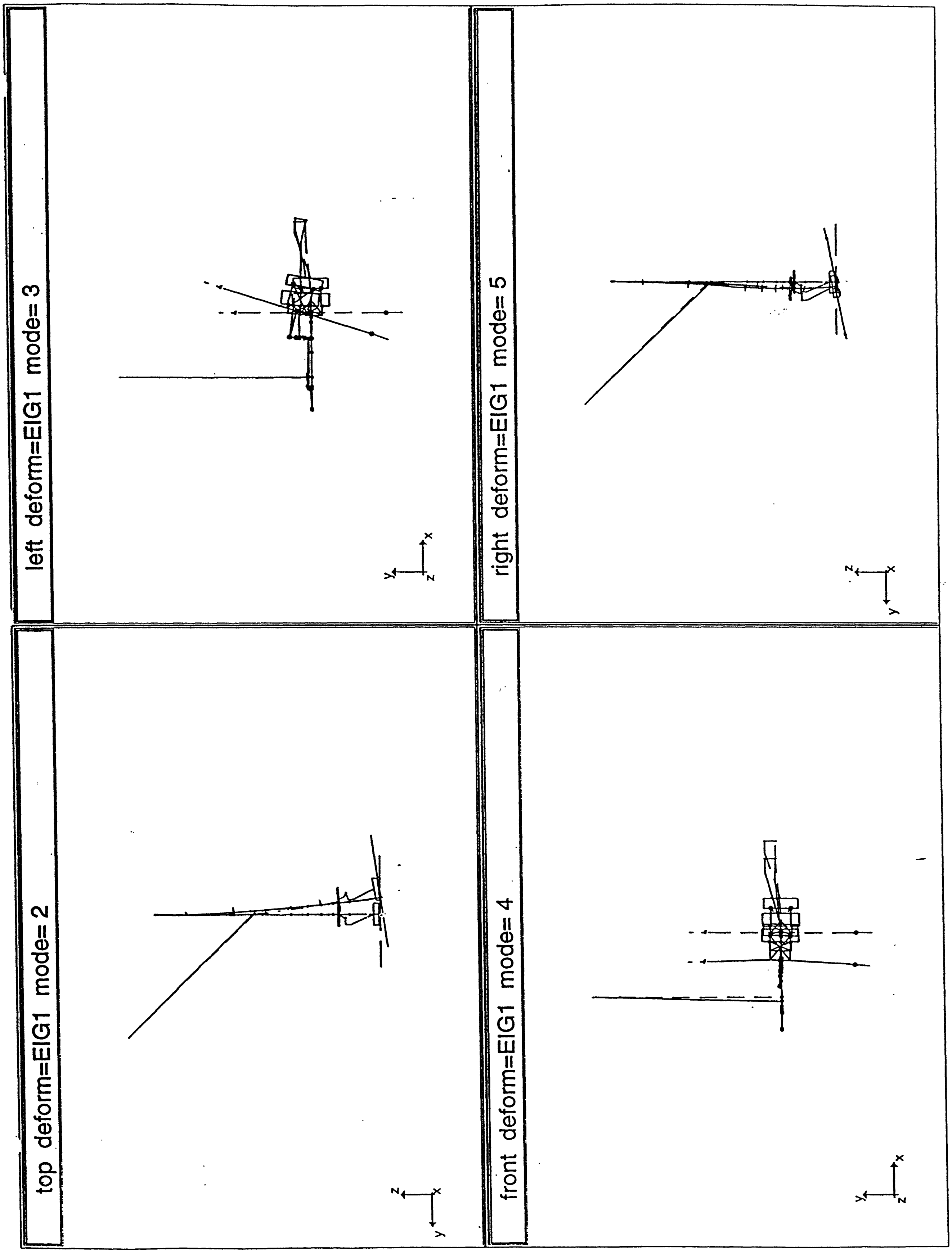
left deform=EIG1 mode= 3
right deform=EIG1 mode= 5
top deform=EIG1 mode= 2
front deform=EIG1 mode= 4

FIG. 3

MLG SHIMMY MODEL

stretch string, sd & sd spring, mu=0.03, Cq- , Ksat-STRTQ, Attach Stiff, Axle yaw

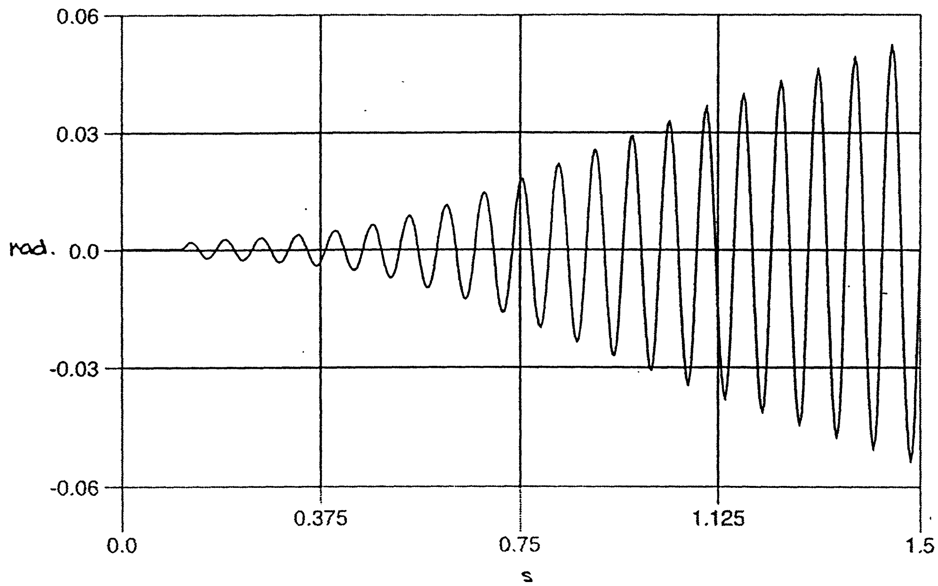

FIG. 4

MLG SHIMMY MODEL

stretch string, sd & sd spring, mull=.03, Cq , Ksat-STRTQ, Fapex vs Vapex

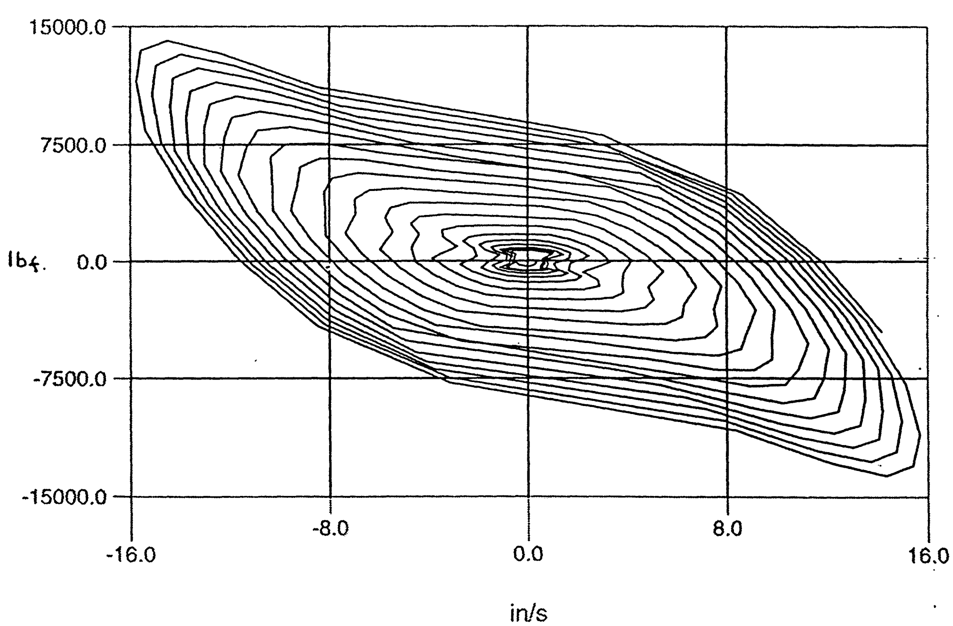

FIG. 5

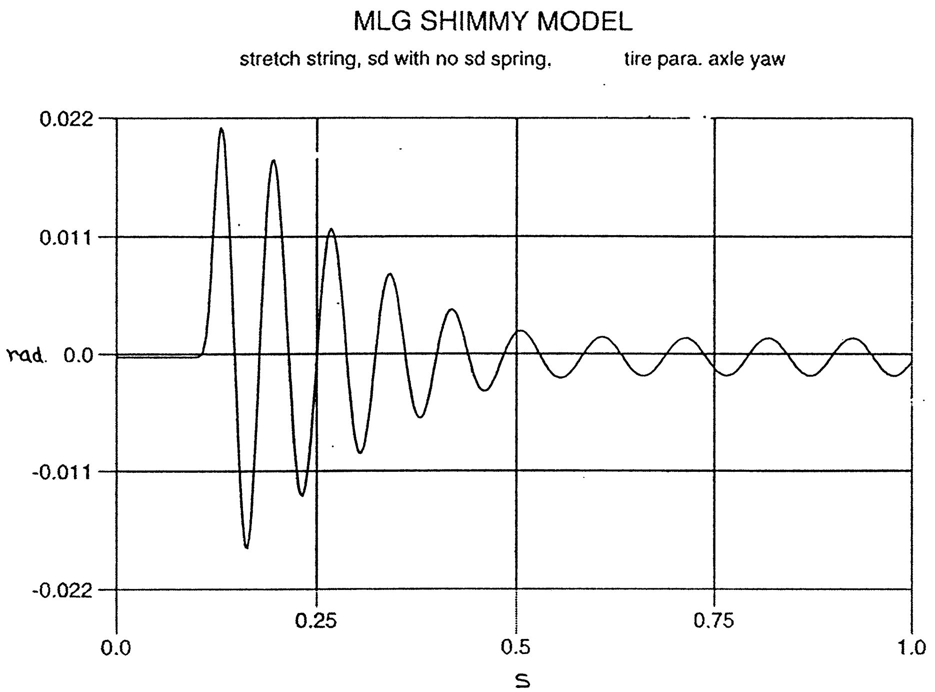
MLG SHIMMY MODEL
stretch string, sd with no sd spring, tire para. axle yaw
0.022
0.011
rad. 0.0
-0.011
-0.022
0.0
0.25
0.5
0.75
1.0
S

FIG. 6

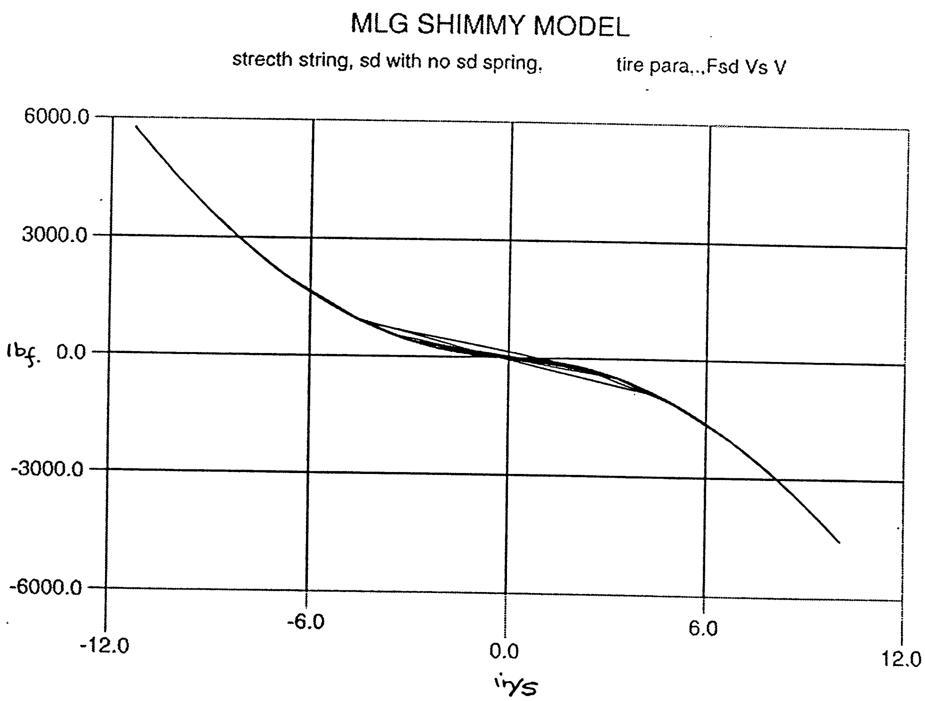
MLG SHIMMY MODEL
strecth string, sd with no sd spring, tire para.,.Fsd Vs V
6000.0
3000.0
lbf. 0.0
-3000.0
-6000.0
-12.0
-6.0
0.0
6.0
12.0
in/s

FIG. 7

CONCLUSION AND RECOMMENDATION

FEA model can be relatively easy to transform into a MSA(ADAMS) Shimmy Model. More ADAMS/BEAM shall be used to represent the Landing Gear structure to facilitate the parametric study on the Landing Gear structure stiffness. Modifying an ADAMS/BEAM is more efficient than modifying the FEA model and then transforming it to ADAMS Shimmy Model. ADAMS also allows the analyst to conduct various parametric studies on Landing Gear System stability with varying Landing Gear System parameters. However, due to some of the non-linear elements, this type of analysis could be time consuming. Another advantage of using ADAMS to perform Shimmy Analysis is that it can easily model the method of excitation in order to simulate the actual testing conditions. It allows a direct comparison between the analysis and test results.

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