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Numerical Simulation of Drop Test of the C27J aircraft landing gear system taking into account the test rig flexibility

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ABSTRACT

The present work shows the multi-body simulation activity performed on the landing gear of C27J aircraft to study the drop test. In order to correlate correctly the test results with the theoretical ones, and to verify that the total energy spread during the drop test, is being absorbed by landing gear only and not by the test-rig, it was necessary to introduce the flexibility of rig in the ADAMS numerical model. All dynamic characteristics of both landing gear components and test rig was determined with Nastran code and traduced to ADAMS Modal Neutral File format using "Component Mode Synthesis" theory.

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GENERAL

This paper describes a study performed within drop test activity in order to understand the influence of test setup flexibility on landing gear drop results.
The tested landing gear system is the one installed on C27J Aircraft with tactical capability and qualified for operations on semiprepared/unprepared airfields.
This aircraft will have a new nose and main landing gear system respect to its old version named G222. Both gears was submitted to the relevant test in order to obtain the Civil Certification following JAR25 change 14 rules.
The purpose of this study was to understand if the drop test machine, during the test, endures deformation absorbing an amount of the impact energy. For this reason a finite element model of test setup has been built calculating the proper modes of this structure and integrating it with the multibody models of landing gears and simulating the drop phases.

C27J AIRCRAFT

The C27J is a military transport turbopropeller aircraft derived from G222 with new propulsion system, new landing gear system and other modifications. This aircraft has the capability to operate on semiprepared airfields up to a Maximum Take Off Weight of 30500 kg and a Maximum Landing Weight equal to 27500 kg.

MATHEMATICAL MODEL - SUMMARY

The purpose of this study is to verify the influence of set up flexibility on drop test of landing gear system of C27J Aircraft. A multibody model in A.D.A.M.S. environment was developed taking into account geometrical, inertial and cinematic characteristics of entire test equipment. Furthermore these characteristic have been considered also:

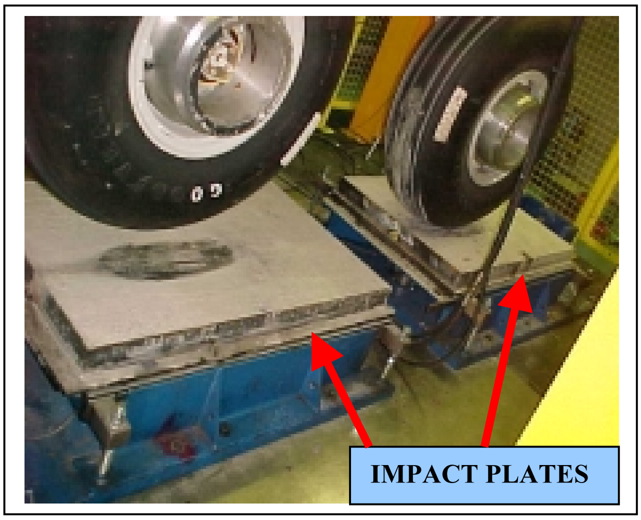
- Test-rig flexibility
- Contact between fixed parts and moving ones
- Contact between tyre and measurement impact plate
- Landing gear flexibility
- Shock absorbers gas curves
- Oil damping of shock absorbers

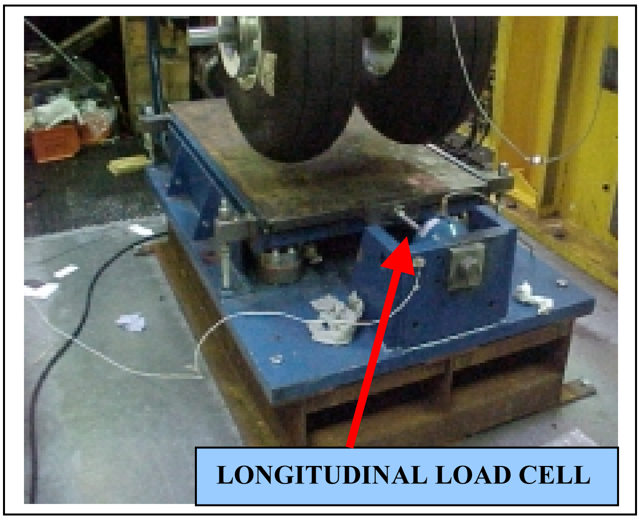
TEST EQUIPMENT DESCRIPTION

The test equipment is a steel structure with beams with double T sections, various shapes of sheet metals and other parts properly connected by means of bolt and welded unions.
The figures 1 and 2 show some structural details:

FIG.1 **FIG. 2**

The structure is jointed to floor in the down side with a base and jointed to the building on the upper side with a steel beam. As showed in the above figures, the test rig has a moving part on which the landing gear (and possible ballast) is installed. The cinematic joint, that allows the motion between fixed and moving part, is composed of four groups of three steel tires that run along lateral tracks derived on the beams; following their position, these tires allow the vertical displacement only of the moving part, unless of possible gaps that can be there in the coupling tires-track.
The base of equipment includes a steel plate on which the landing gear is dropped during the test. This plate has a longitudinal degree of freedom in order to transmit the load to a load cell that measures the longitudinal loads deriving by complete stop of the tyre initially at a defined spin velocity. The figures 3 and 4 show details above described:





A finite element model of this structure has been performed with Nastran code. Subsequently detailed model of entire structure has been performed in A.D.A.M.S. environment.

TEST RIG – FEM MODEL

This model has been built with Nastran code using beams and shell elements. The first model issue included the support structure and moving sledge. This model has been analyzed calculating the vibration proper modes.

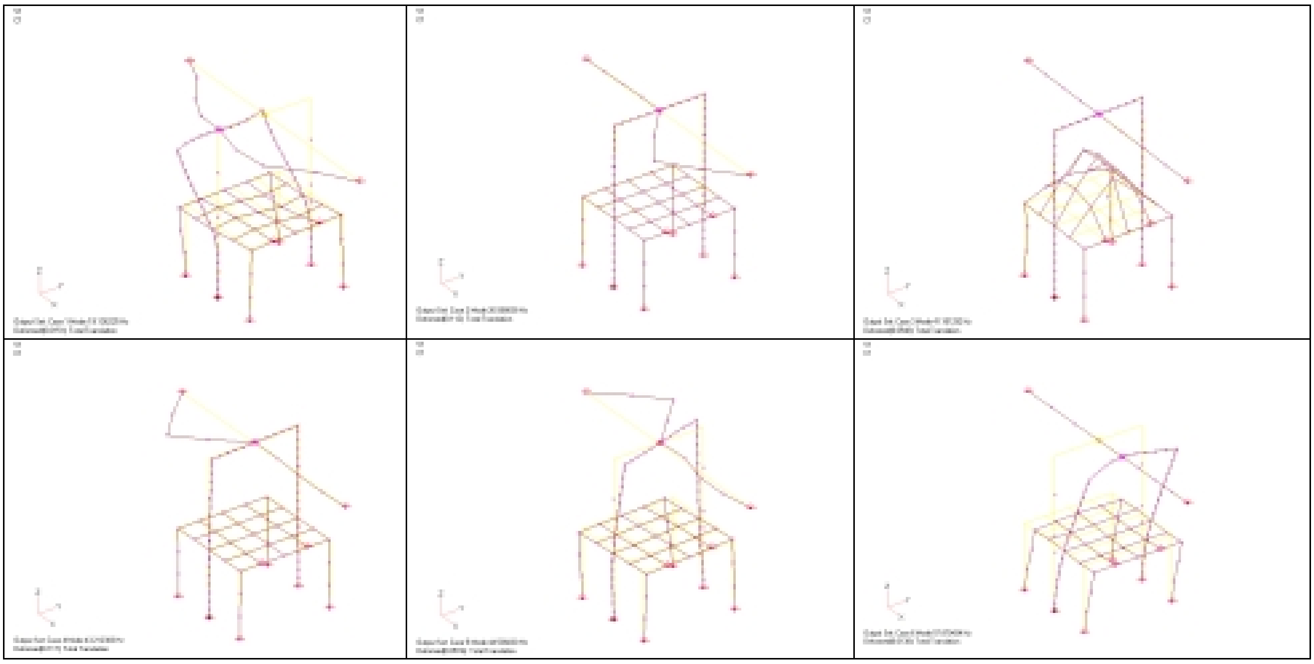


FIG. 5

In order to import in A.D.A.M.S. this F.E.M. model, the sledge has been removed because it has been simulated directly in A.D.A.M.S. environment.

F.E.M. MODEL TRANSLATION IN A.D.A.M.S.

The test-rig model has been imported in A.D.A.M.S. using Component Mode Sinthesys. This method provides a modal characterization of test rig which takes into account the free modes of the jointed structure and the static correction modes in the attachment point with external structure. The figure 6 shows some modal forms of the structure after translation in A.D.A.M.S.:

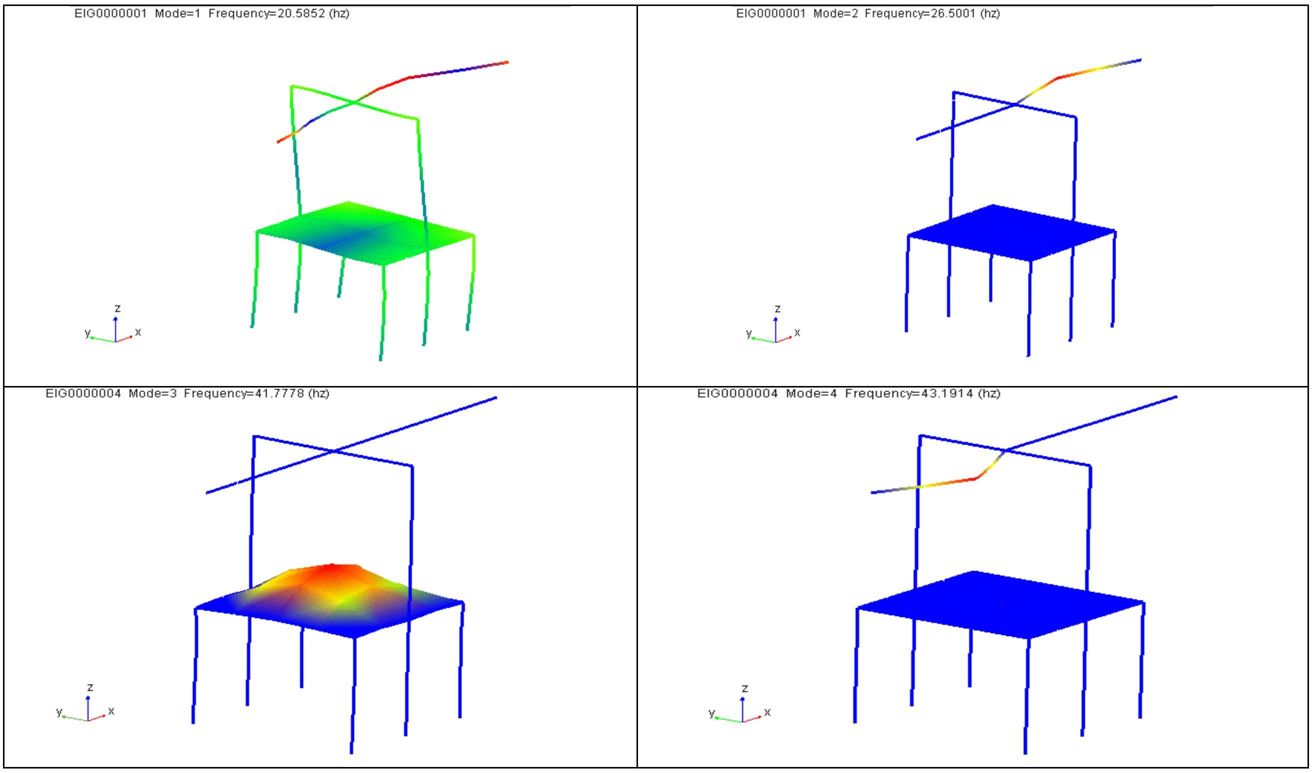


FIG. 6

A.D.A.M.S. MODEL OF TEST RIG

As soon as the F.E.M. model of fixed part of test rig has been completed, the remaining part has been built directly in A.D.A.M.S. This part includes:

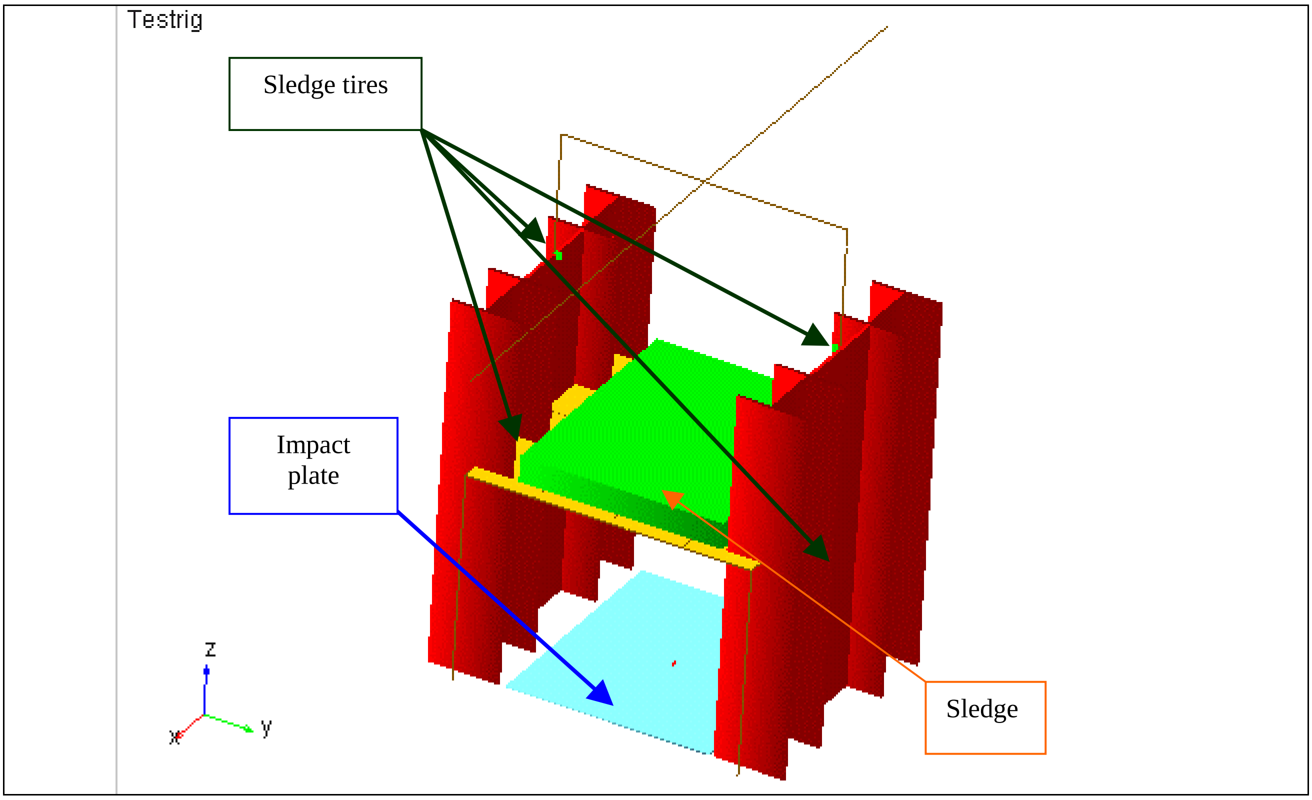
1. Joints of fixed part of test rig which reproduce the real joints configuration.

2. Sledge model: realized as rigid body with its real geometrical and inertial properties

3. Model of contact between sledge tires with the tracks: since it's not possible to build in A.D.A.M.S. environment with a standard procedure the contact on flexible elements and the run of each tire is limited, this contact has been built adding four fictitious parts, of negligible mass, connected with fixed joints to the points in the which the connection MPC between sledge and fixed structure is realized. These additional parts have the same geometrical properties of lateral tracks and are connected to the sledge part with cinematic joint which avoid the longitudinal degree of freedom of the sledge. Furthermore the contact forces simulating the sledge tires action on lateral tracks has been introduced. The configuration of these elements has allowed a correct representation of joints set existing between fixed structure and the sledge.

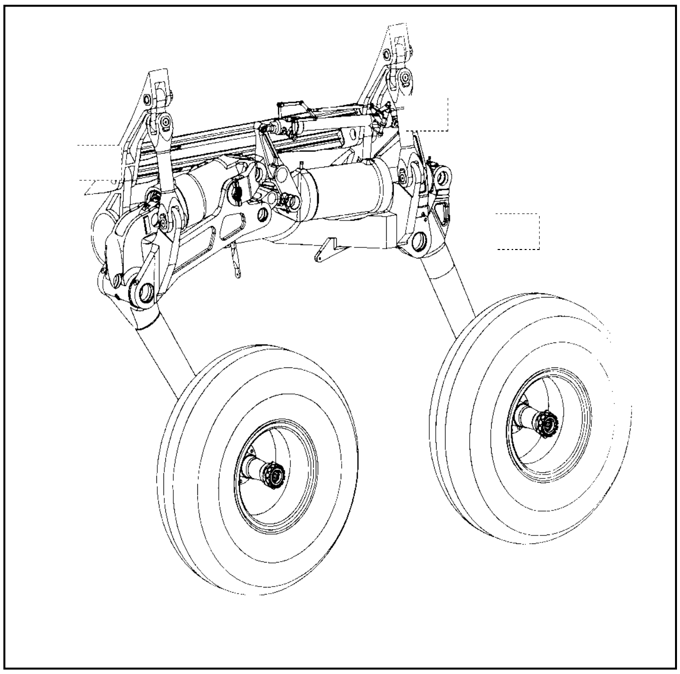
4. Impact plate model: it has been realized with a rigid part connected to the absolute reference system with a cinematic joint which allows the vertical movement only; in this direction a spring with the stiffness equal to the one of the load cell has been added.

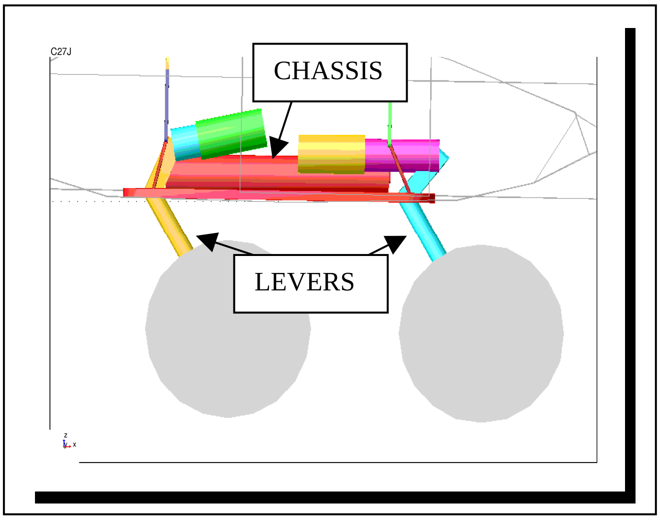
The next figure shows the entire test-rig model:



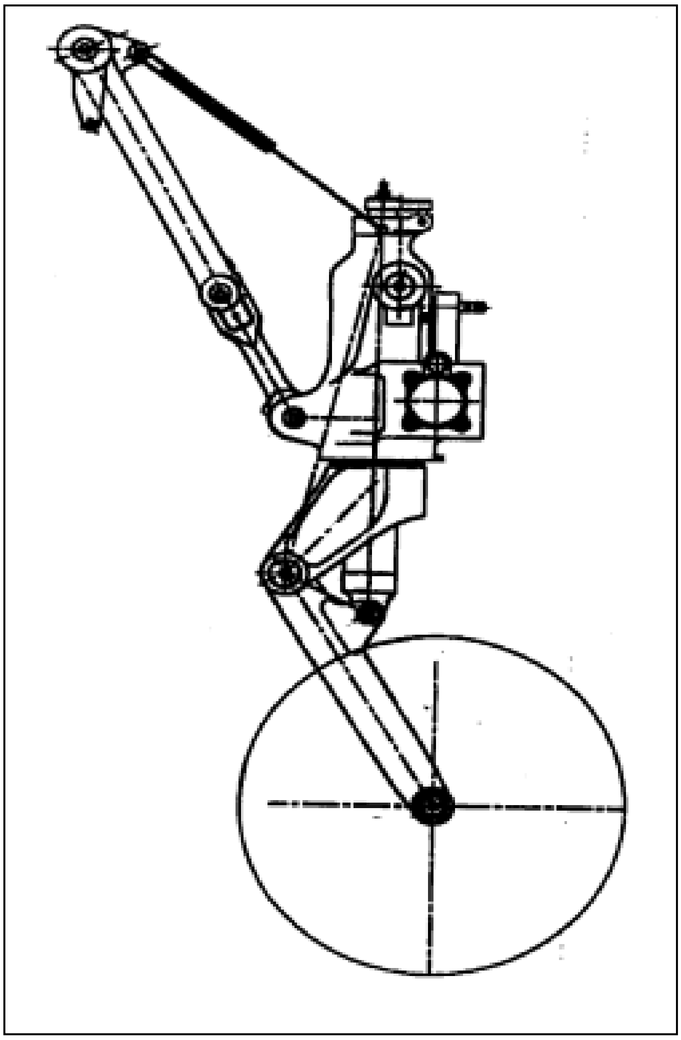
LANDING GEAR MODEL

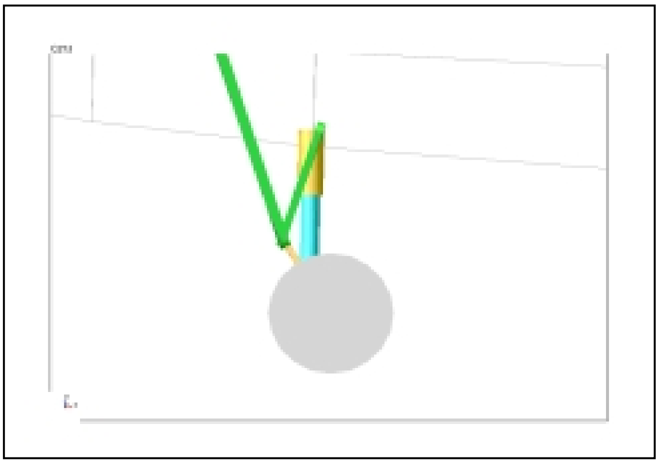
Both nose and main landing gear have been modeled.





MAIN LANDING GEAR



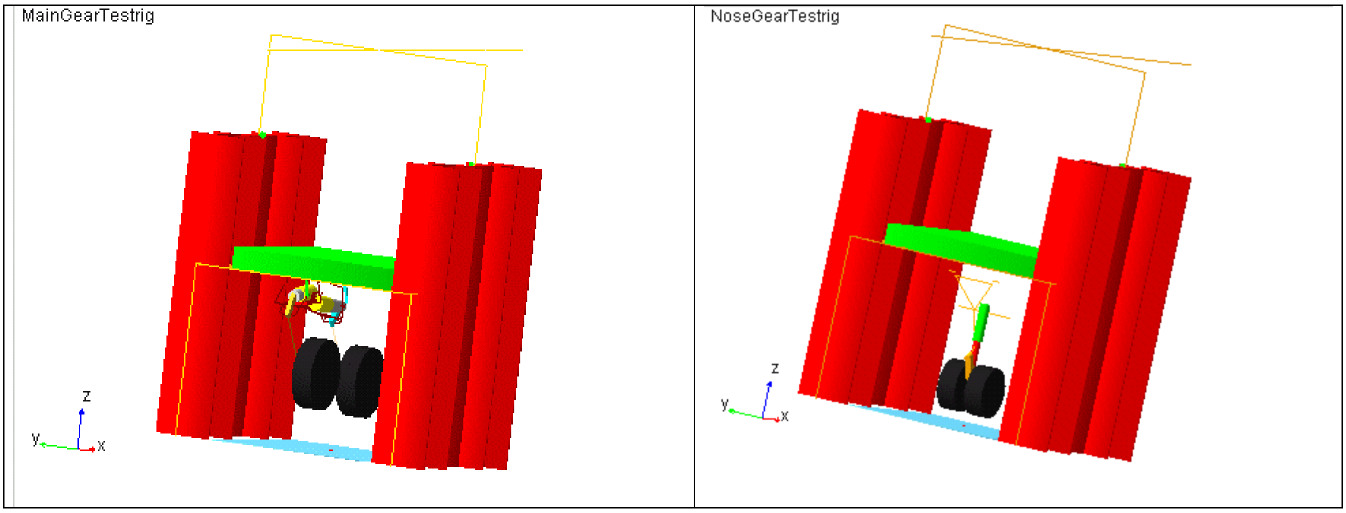


NOSE LANDING GEAR

To build this model, the following items has been taken into account:

- flexibility of chassis
- flexibility of levers
- shock absorbers properties (gas spring curve, oleo damping)
- no linear tire (realized with external subroutine)

The tire has been developed using an external subroutine in order to take into account the no linearity of vertical deformation and the fact that the impact is on a moving plate and not on ground. In particular, the A.D.A.M.S. tire model considers the contact with the ground (fixed respect to absolute reference system). This method can provide no correct results in the case the impact surface is moving (in our case the impact plate); in fact the slip ratio, utilized for the ground loads calculation, is evaluated respect to absolute reference system and not respect to plate reference system which is moving. This is not acceptable for this case study.
To solve this problem, a fortran routine has been developed; it calculates the slip ratio respect to impact plate reference system.
In any case the tire contact force is acting between ground part and tire; therefore, even if the slip ratio is calculated respect to the exact reference system, the impact plate doesn't emerge under tire forces. This problem has been solved adding an external force which, acting between plate and ground, transfers on the plate the resultants of the tires contact forces. Also this problem has been solved with an external fortran routine.
FIG. 8 shows the entire models of landing gear with test-rig:



DYNAMIC SIMULATIONS

As above mentioned, the purpose of this work is to verify the influence of test-rig on ground loads and, more in general, on behavior of landing gear.
With the model described in the previous paragraphs, dynamic simulations of drop test with both (main and nose) landing gear has been performed with rigid test setup and subsequently considering the flexibility of test-rig. The comparison of results allows to understand as the test setup flexibility affects general behavior of landing gear.
The drop height is that one realizes a vertical speed of 10 ft/sec following Civil Certification rules.
The tires have a initial spin.

RESULTS

Next figures show ground loads calculated for simulation drops of landing gear.

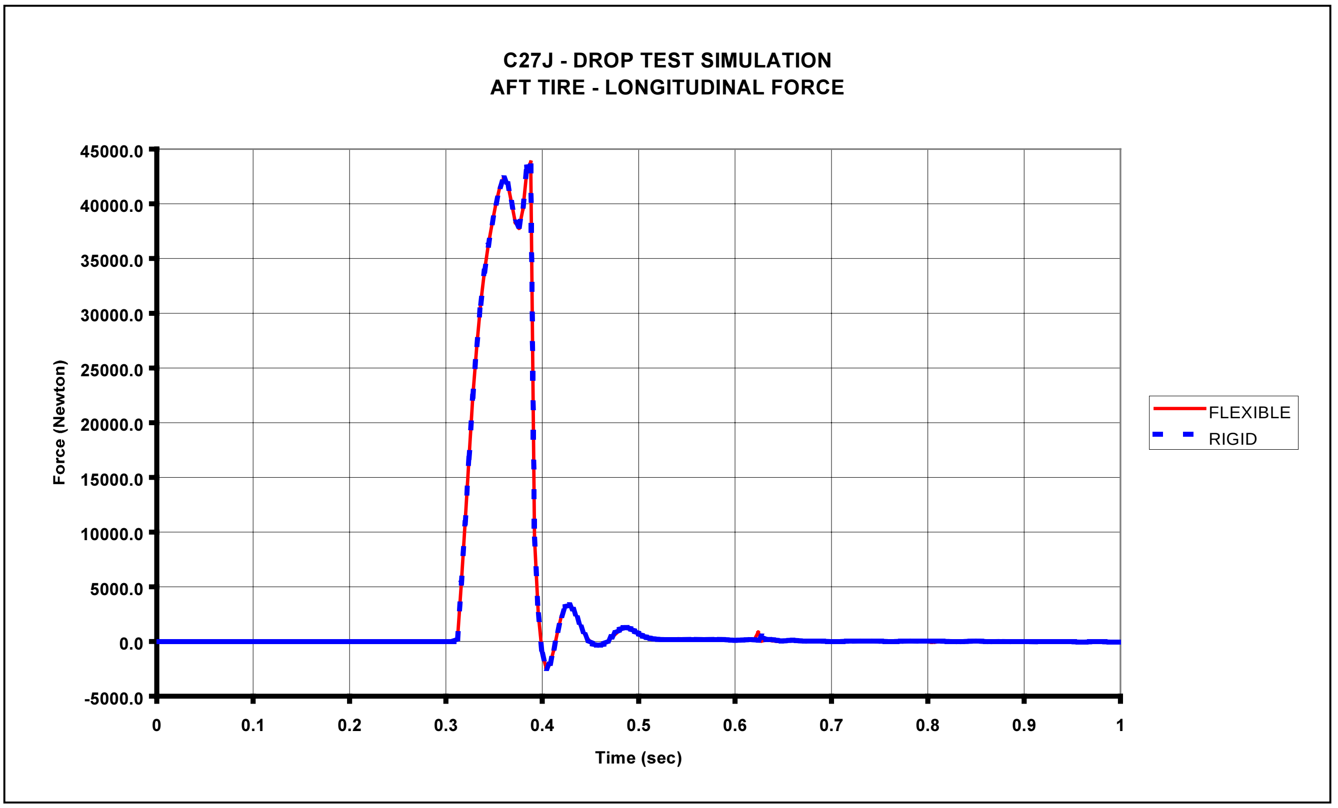


FIG. 9

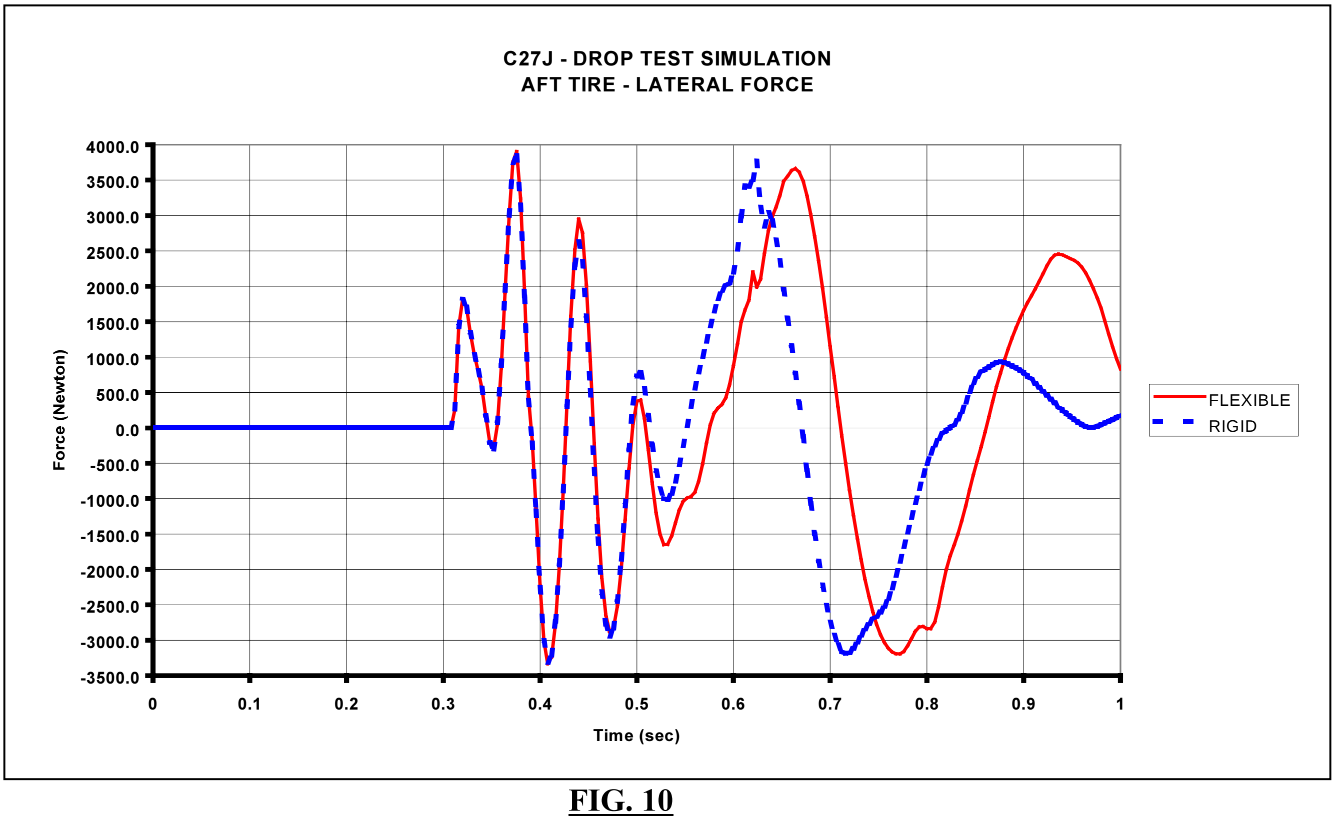


FIG. 10

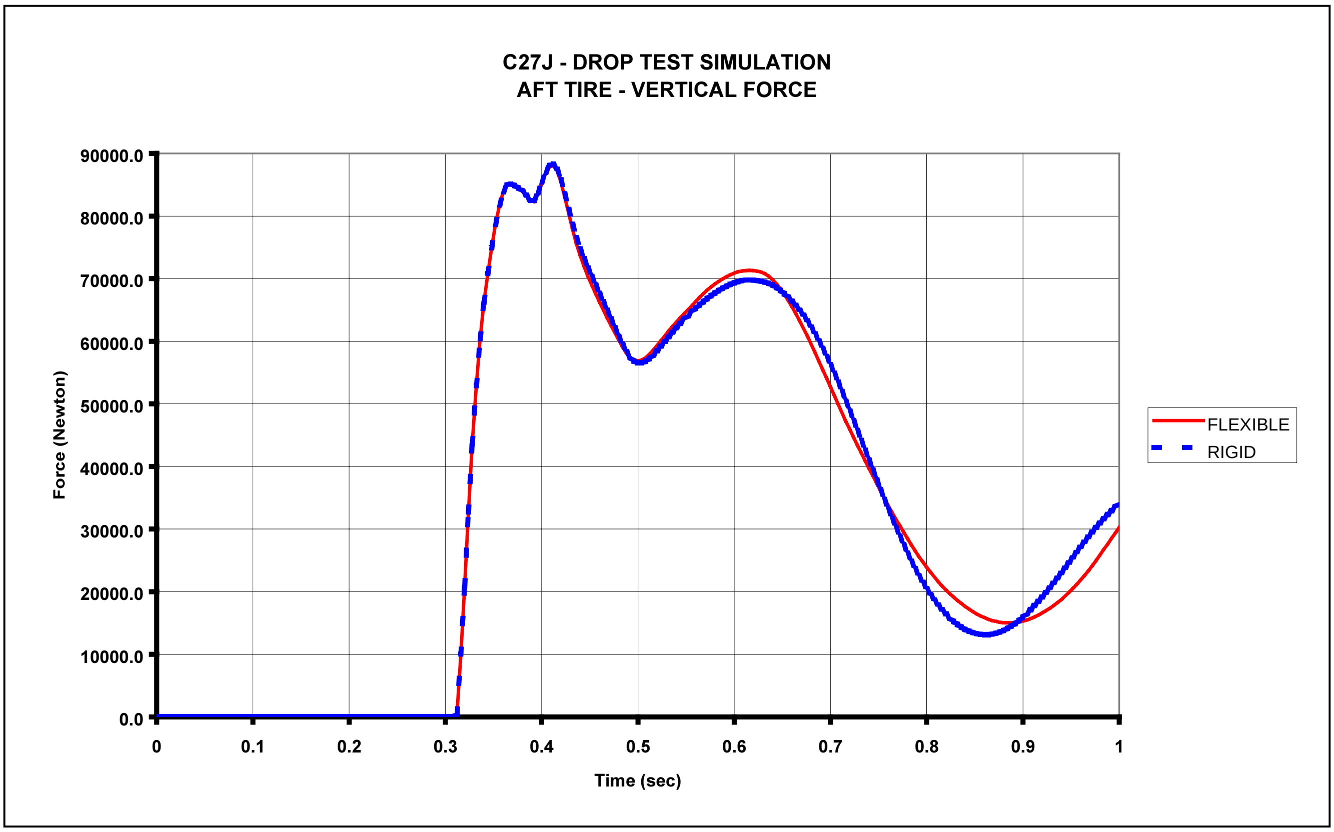

C27J - DROP TEST SIMULATION
AFT TIRE - VERTICAL FORCE
Force (Newton)
90000.0
80000.0
70000.0
60000.0
50000.0
40000.0
30000.0
20000.0
10000.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (sec)
FLEXIBLE
RIGID

FIG. 11

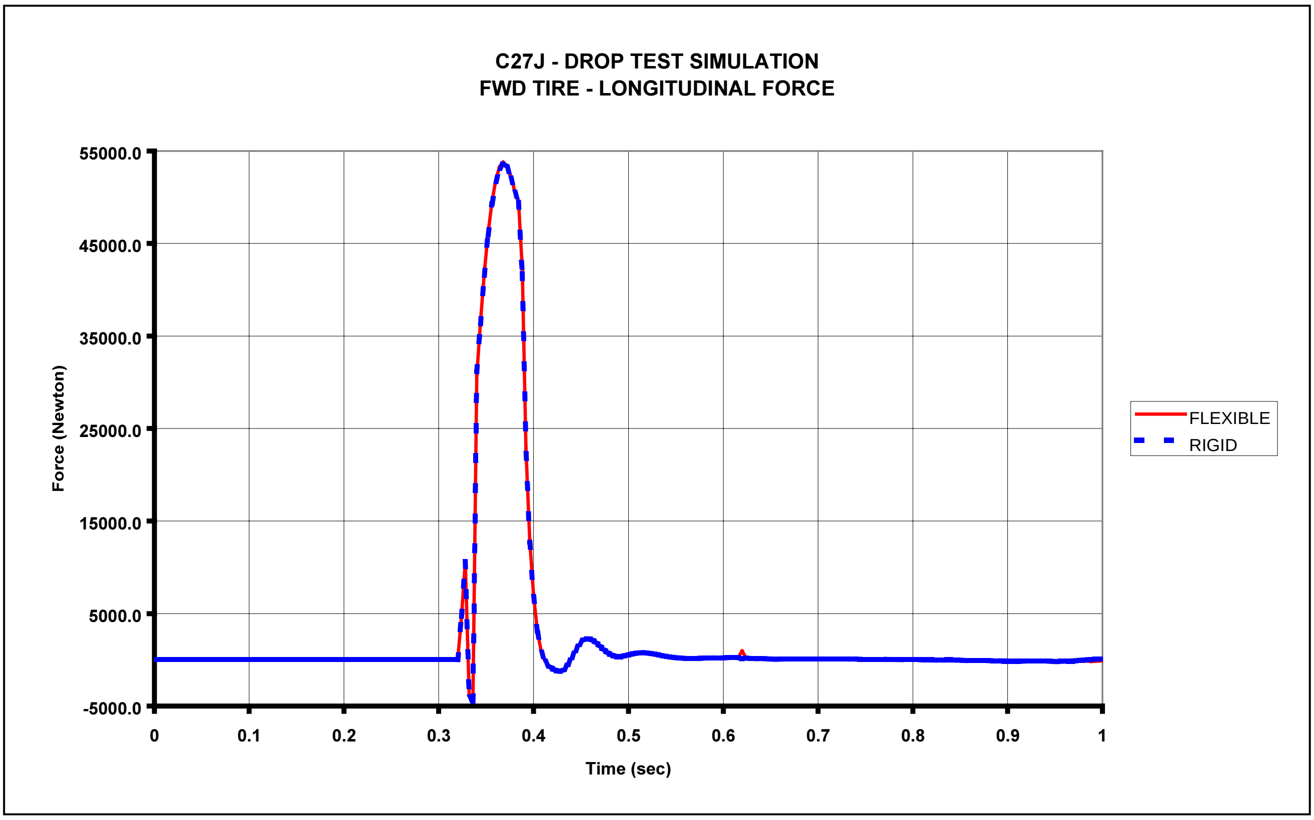

C27J - DROP TEST SIMULATION
FWD TIRE - LONGITUDINAL FORCE
Force (Newton)
55000.0
45000.0
35000.0
25000.0
15000.0
5000.0
-5000.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (sec)
FLEXIBLE
RIGID

FIG.12

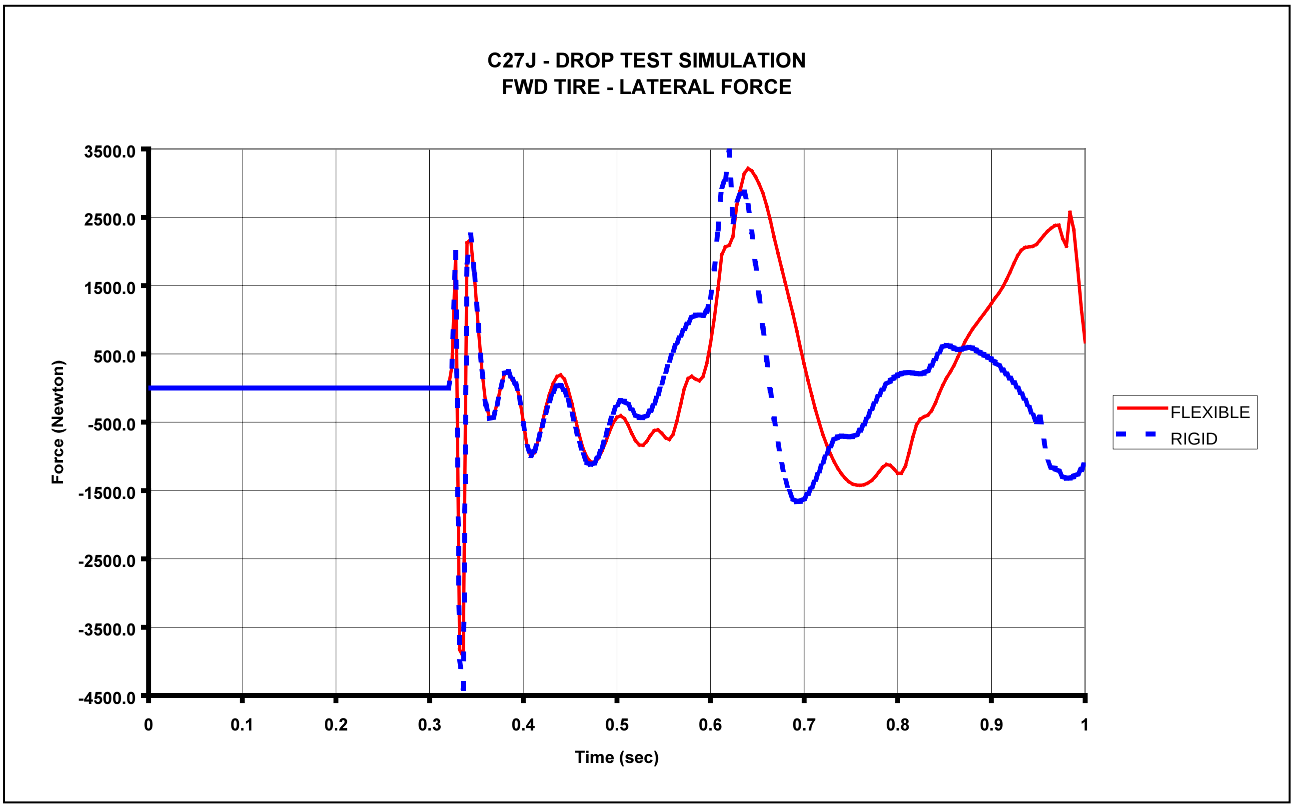

C27J - DROP TEST SIMULATION
FWD TIRE - LATERAL FORCE
3500.0
2500.0
1500.0
500.0
-500.0
-1500.0
-2500.0
-3500.0
-4500.0
Force (Newton)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (sec)
FLEXIBLE
RIGID

FIG. 13

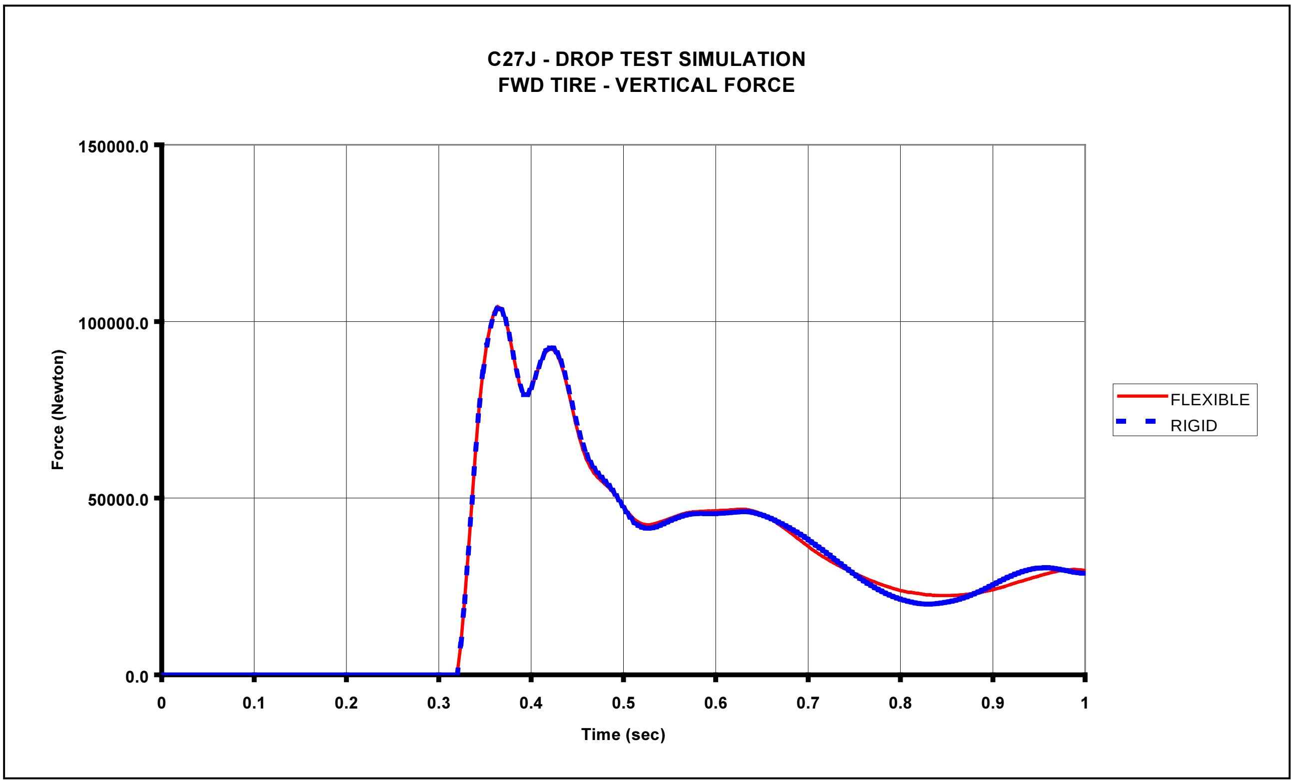

C27J - DROP TEST SIMULATION
FWD TIRE - VERTICAL FORCE
150000.0
100000.0
50000.0
0.0
Force (Newton)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (sec)
FLEXIBLE
RIGID

FIG. 14

Next figures report the ground loads for drop test of nose landing gear:

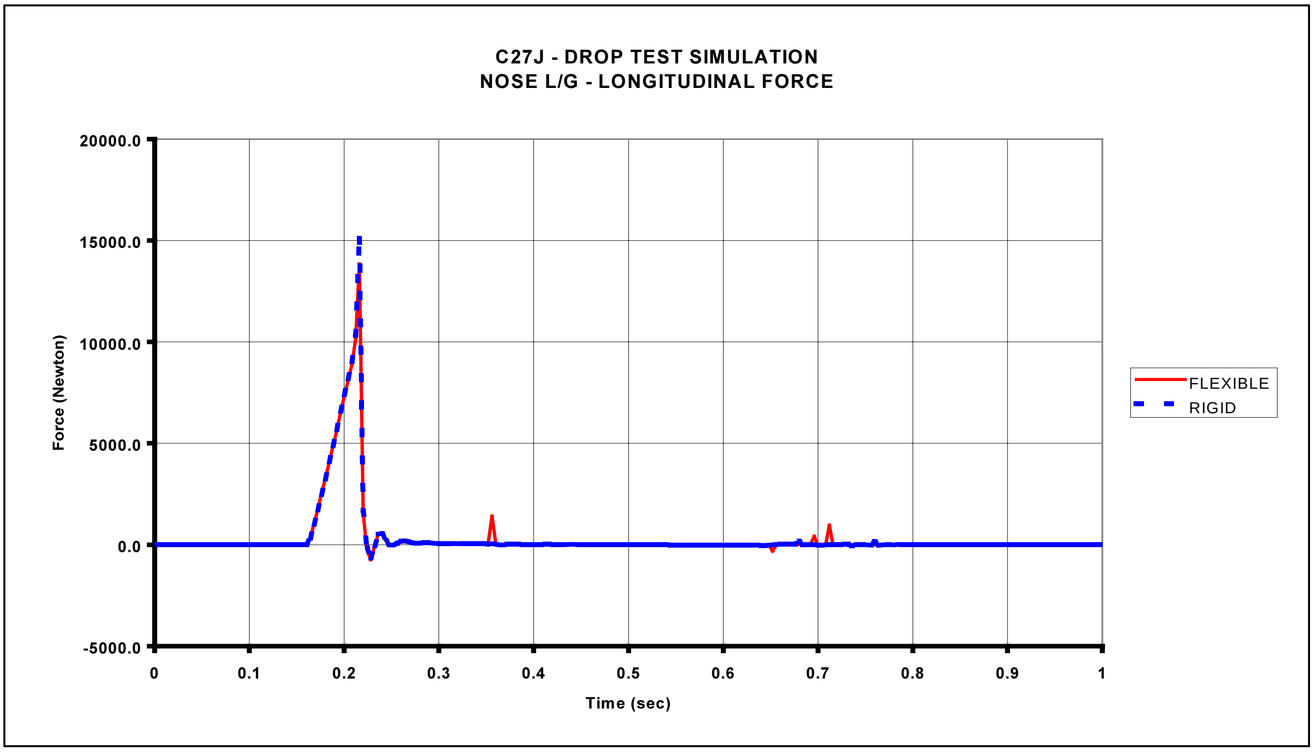


FIG. 15

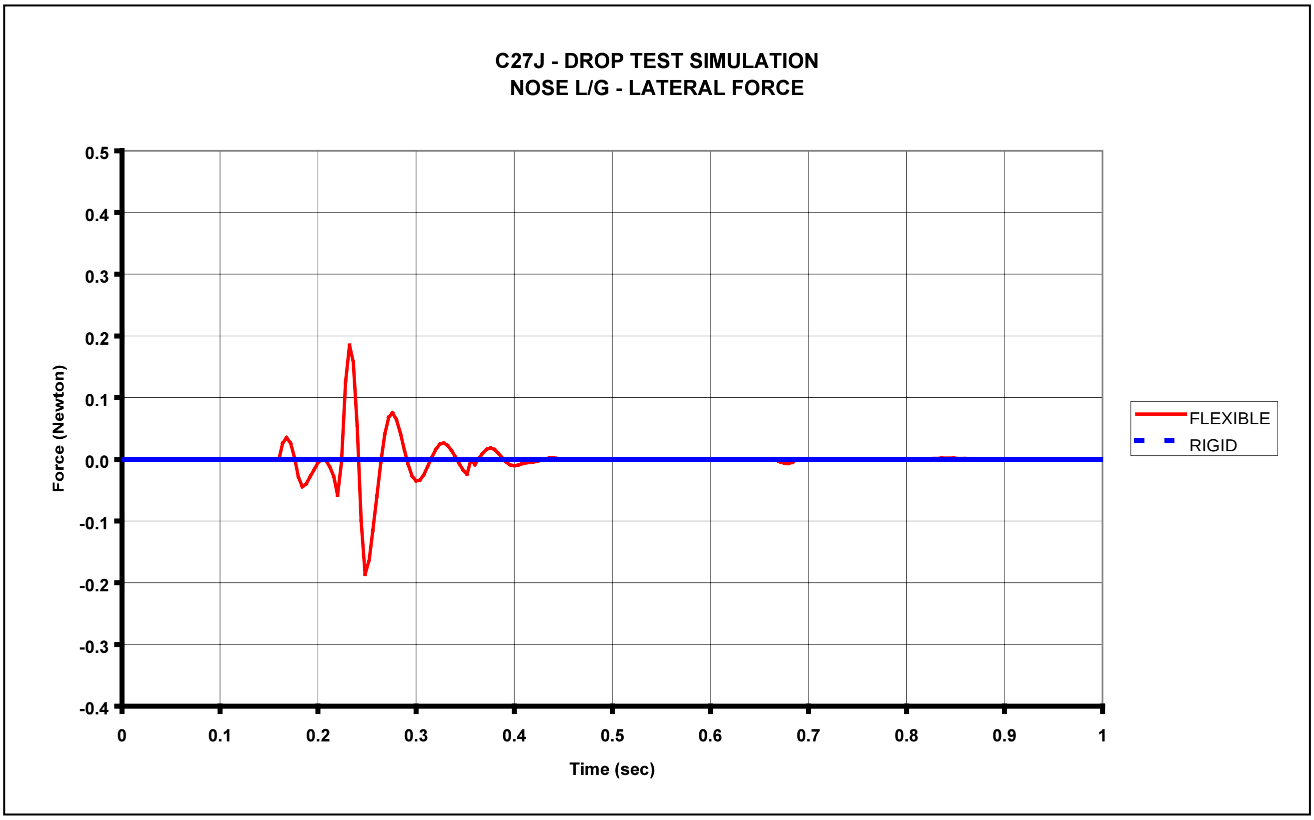


FIG. 16

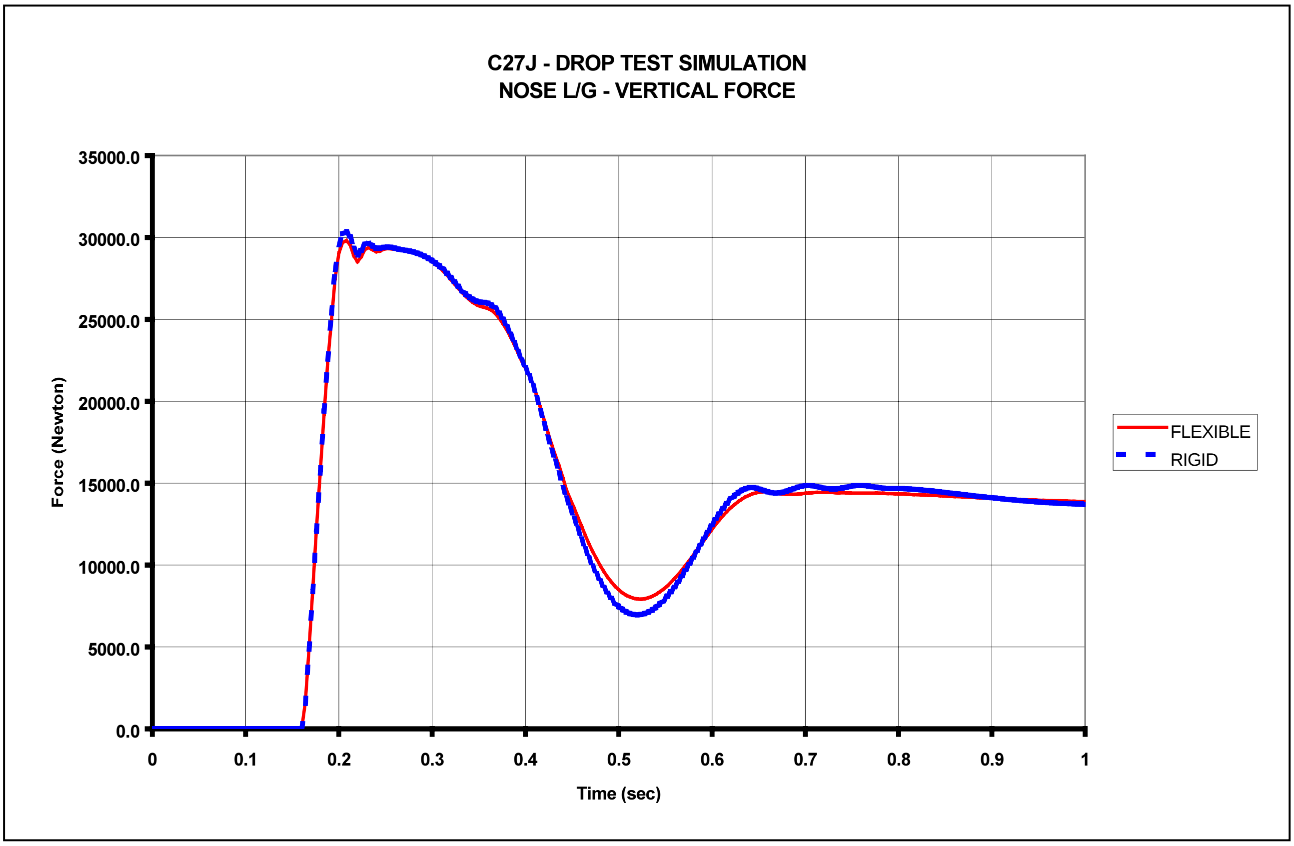


FIG. 17

CONCLUSIONS

The analysis performed in the present work shows these main results:

- the ground loads and general behavior of landing gear have not been affected by test-rig flexibility
- the test-rig does not contribute to drop energy absorption
- small differences can be noticed on lateral forces but these components are negligible if compared to vertical and longitudinal ones
- the test rig can be considered more rigid than test article; this ensures that the test results are correct.

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