EFFECT OF RUBBER DAMPER STIFFNESS AND TIRE PRESSURE TO REDUCE GROUND REACTION LOAD FACTOR ON MAIN LANDING GEAR USING MULTI-BODY SIMULATION (MBS) RIGID MODEL (PENGARUH KEKAKUAN KARET PEREDAM DAN TEKANAN BAN UNTUK MENGURANGI GROUND REACTION LOAD FACTOR PADA MAIN LANDING GEAR MENGGUNAKAN MULTI-BODY SIMULATION (MBS) RIGID MODEL)

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ABSTRACT

Landing Gear Drop Test (LGDT) utilizes the apparatus requiring a substantial time and cost. Virtual LGDT (vLGDT) using MSC ADAMS software is one of the solutions for initial stage to testing landing gear. From simulation with v_{sink} 1.7 m/s and load 22000 N obtained contact/impact force that ensue in MSC ADAMS was 73650 N, while from experimental was 73612 N. The difference between vLGDT and LGDT result is 0.05 %. To obtain ground reaction load factor below 3 in v_{sink} = 3.05 m/s, the rubber damper should have stiffness in the range of 1900 - 2100 N/mm and for the tire pressure of 60 - 65 psi.

Keywords: *Contact/impact force, landing gear, drop test, multi-body simulation, rigid body*

ABSTRAK

Pengujian eksperimental Landing Gear Drop Test (LGDT) membutuhkan waktu dan biaya yang besar. Simulasi LGDT menggunakan perangkat lunak MSC ADAMS merupakan solusi awal untuk menguji landing gear. Dari simulasi dengan kecepatan jatuh v_{sink} 1,7 m/s dan beban 22000 N diperoleh gaya kontak/impak sebesar 73650 N, sedangkan dari eksperimental sebesar 73612 N. Perbedaan antara hasil simulasi LGDT dan pengujian eksperimental LGDT adalah 0,05%. Untuk mendapatkan ground load factor di bawah 3 pada kecepatan jatuh v_{sink} = 3,05 m/s, karet peredam harus memiliki kekakuan pada kisaran 1900 - 2100 N/mm dan tekanan ban 60 - 65 psi.

Kata kunci: *Contact/impact force, landing gear, drop test, multi-body simulation, rigid body*

1 INTRODUCTION

Loads that ensure in the Main Landing Gear (MLG) when touch down impact is a function of the aircraft Maximum Landing Weight (MLW) multiplied by the ground reaction load factor. The aircraft MLW about 6940 kg. In Civil Aviation Safety Regulation (CASR) Part 23.473 (Ground Load Conditions and Assumptions) states that the worth of ground reaction load factor is between 2 to 2.67 and should be evidented by LGDT (Kemenhub, 2001).

Computer Aided Engineering (CAE) has be expanded summarily in recent decades, one of them is the Multi-Body Simulation (MBS). Many MBS programs adequate to automatic generation and integration of the differential equations of motion have been developed, namely MSC ADAMS, COMPAMM, DAP and SIMPACK (Machado, Moreira, Flores, & Lankarani, 2012).

Hidayat et al (Hidayat, Istiyanto, & Sumarsono, 2018) have compared the simulated results of LGDT using MSC ADAMS and Solidworks Motion Analysis, The diversity between MSC ADAMS and Solidworks Motion Analysis is 3.08%. Leo et al (Leo, Fenza, Barile, & Lecce, 2014) has spreaded a methodology for simulating LGDT using MSC ADAMS and comparing simulation with experimental testing. Krason and Malachowski (Krason & Malachowski, 2015) familiarized a methodology for evaluating several landing gear models and numerical research on a complete landing gear system. Fu et al (Fu, Zhang, Li, & Li, 2013) modeled a LGDT using the SimMechanics module oncoming on Matlab/Simulink.

Various research have been established to create a simulated LGDT utilize a MBS approach. However, the effect of tire pressure and damper stiffness on ground reaction load factor has not been researched intensively. Therefore, research on the effect of tire pressure and rubber damper stiffness on MLG to reduce ground reaction load factor was conducted.

2 METHODS

The methodology for this research is both simulation using MSC ADAMS and experimental test. Experimental test of LGDT was performed based on regulation from Ministry of Transportation which refers to Civil Aviation Safety Regulation (CASR) Part 23 (Kemenhub, 2001). The LGDT testing prerequisites follow the regulations in CASR 23.473, CASR 23723, CASR 23725, CASR 23726 and CASR 23.727 (PTDI, 2014).

Testing was conducted under several conditions as well as several assumptions:

A. Friction at apparatus components is very small and negligible.

B. Aerodynamic drag force during the test is very small and can be ignored

The experimental test utilizes MLG (Main Landing Gear) roll out article, drop high 200 mm from the static condition and load 2200 kg. The initial condition of simulations employing MSC ADAMS comply to experimental testing conditions (PTDI, 2014). The results of simulation is thereafter compared with the results of the experimental tests. The next stage simulation uses the DRO (Design Requirement and Obejctive) condition of the 19 passenger commuter plane. Simulation conditions (vLGDT) are represented in Table 1.

Tabel 1: SIMULATION CONDITION OF LGDT (PTDI, 2014)

No.	Conditions	Load (kg)	v_{sink} (m/s)	High estimation (mm)
1	Experimental	2200	1.74	200
2	DRO	3470	3.05	470

Simulation input for contact is stiffness (k), force exponent (e), damping (c_{max}) and penetration depth (d). While simulation input for rubber damper only stiffness coefficient and damping coefficient. Time step simulation for this case is 0.001 seconds.

3 RESULTS AND DISCUSSIONS

The effect of rubber damper and tire on ground reaction load factor has been determined by means of a simulated with 3D rigid model approach.

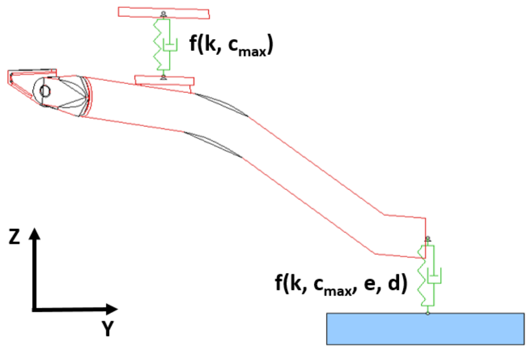

Figure 1: 3D rigid model apporoach (Hidayat et al., 2018)

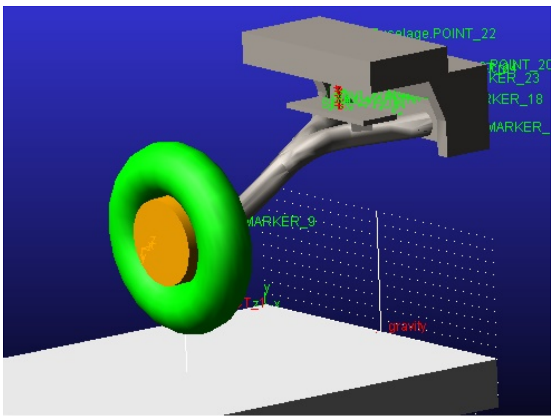

Figure 2: vLGDT uses MSC ADAMS (Hidayat et al., 2018)

Rubber damper on MLG is a function of stiffness (k) and damping (c_{max}), whereas the tire is a function of stiffness (k), damping (c_{max}), force exponent (e) and penetration depth (d) as shown in Figure. 1 above. 3D models built using CAD software afterward exported to MSC ADAMS as shown in Figure 2.

Rubber damper stiffness (k) at 12312 N/mm is measured in the compression test (Hidayat & Abdurohman, 2017), whilst the damping (c_{max}) is 1% of the stiffness value (Giesbers, 2012). For tire stiffness parameters are taken from Dunlop tire manufacturer (Dunlop, 1989), force exponent (e) for rubber ≈ 1.1 and penetration depth (d) = 1.0e-4 m (MSC.Software, 2010).

Figure 3: Landing gear drop test apparatus (Hidayat, Istiyanto, Sumarsono, & Marta, 2017)

V_{sink} in experimental testing is at 1.74 m/s while simulation using MSC ADAMS of 1.69 m/s. The comparison of vsink between experimental (LGDT) and simulation (vLGDT) is represented in Figure 4.

The contact/impact force that occurs in LGDT was 73612 N. In the simulation using MSC ADAMS, contact/impact force achieved at 73650 N. The difference between experimental with MSC ADAMS of 0.05%. Comparison of experimental and simulation results performed by Romeo et al (Leo et al., 2014) with a drop high of 250 mm was 11.1%. Ground reaction load factor from experintal was 3.41, while Romeo et al (Leo et al., 2014) was 2.90. To reduce the ground reaction load factor on main landing gear by decreasing the stiffness of rubber damper.

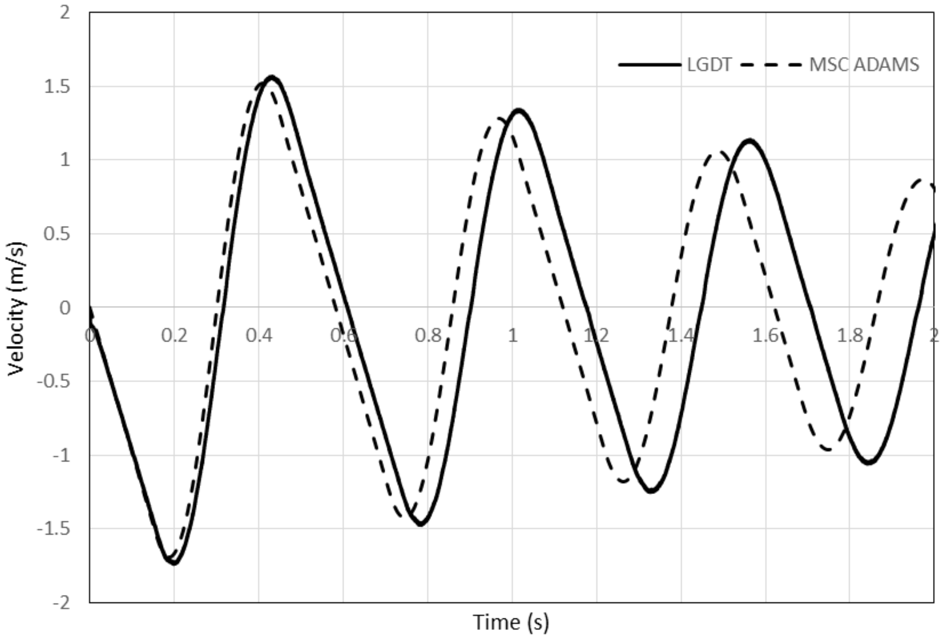

Figure 4: Comparison of v_{sink} simulation and experimental (LGDT)

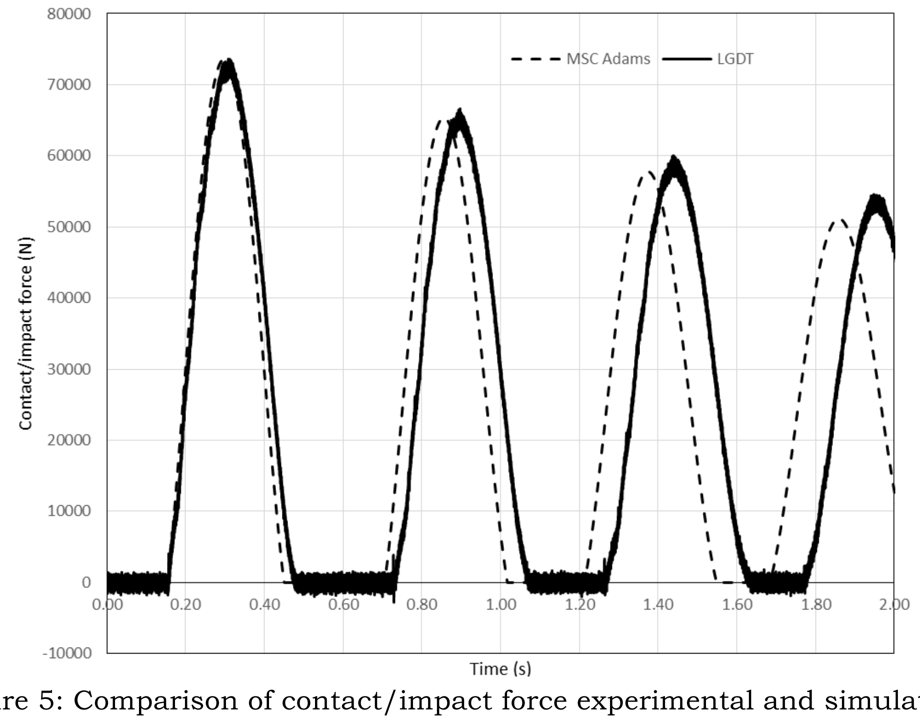

Figure 5: Comparison of contact/impact force experimental and simulations

Regulation stated v_{sink} equal 3.05 m/s and the load given in accordance with MTOW. The estimate of height (h) to get v_{sink} = 3.05 m/s is 470 mm and the load retained by one main landing gear is 3470 kg. From simulation that has been conducted using MSC ADAMS, to obtain ground reaction load factor under 3, then the stiffness of rubber damper ranged from 1900 N/mm to 2100 N/mm and tire pressure between 60 psi to 65 psi as represented in Figure 6. Through the figure also gained that the stiffness of rubber damper has non linear function to ground reaction load factor. Significant changes take place in the stiffness of rubber damper 2000 N/mm to 3000 N/mm. Stiffness function upon 2200 N/mm trend to linear, but the worth of ground reaction load factor is over 5.

Contact/impact force simulation output utilize MSC ADAMS software in the manner of rubber damper stiffness 2000 N/mm and 65 psi pressure of tire was 94680 N as shown in Figure 7. The ground reaction load factor was 2.78.

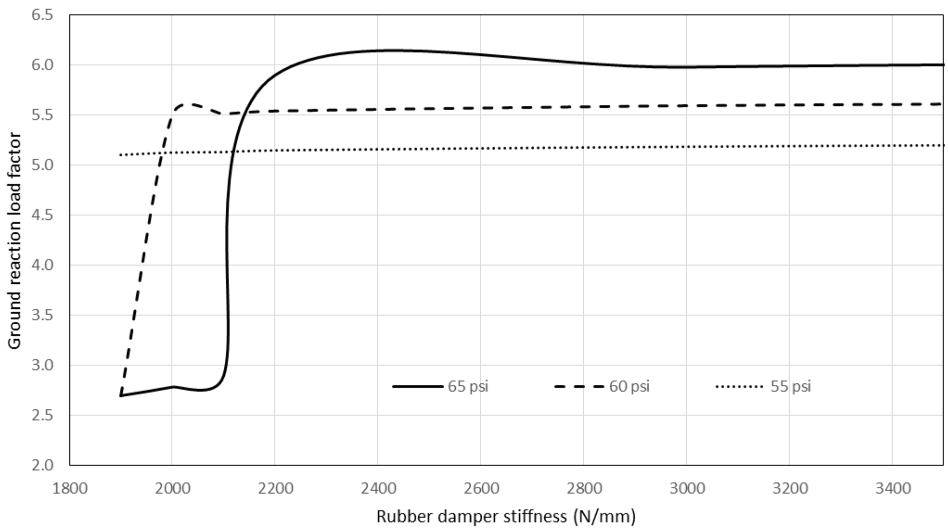

Figure 6: Effect of rubber damper stiffness on ground reaction load factor with tire pressure variant utilize MSC ADAMS

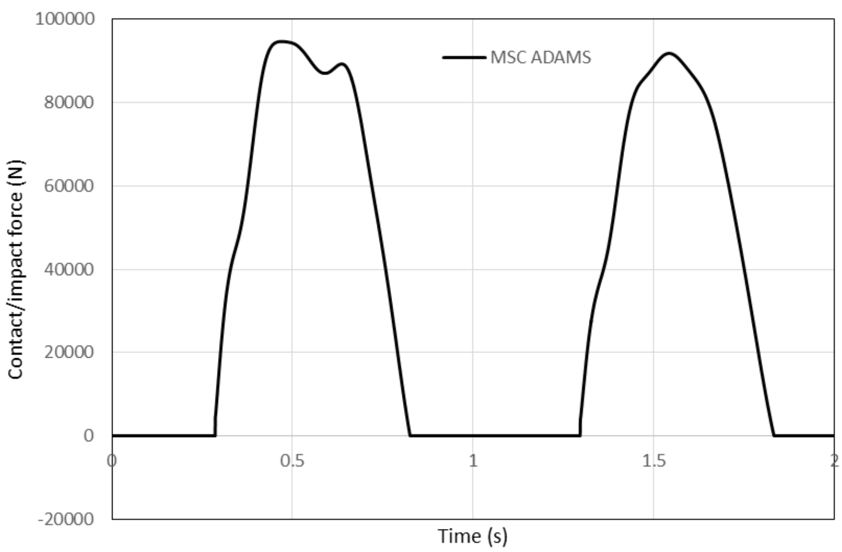

Figure 7: Contact/impact force in MSC ADAMS

4 CONCLUSION

Landing Gear Drop Test (LGDT) has been conducted and compared with virtual LGDT created using MSC ADAMS. Simulation utilize 3D oncoming with MSC ADAMS software, contact/impact force achieved of 73650 N. The difference between experimental with MSC ADAMS of 0.05%. Generally, the greater the stiffness of the rubber damper, the higher the value of the ground load reaction factor, as well as the higher wheel pressure value, the greater the value of the ground load factor. The ground reaction load factor value under 3 has been achieved by having the stiffness of rubber damper ranges from 1900 N / mm up to 2100 N / mm and 65 psi tire pressure.

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