Tire-struts suspension

Development Report

This article aims to demonstrate the level of detail in DCS when it comes to modeling various physical systems, the challenges encountered in the process, and the frequent necessity of working with conflicting reference data.

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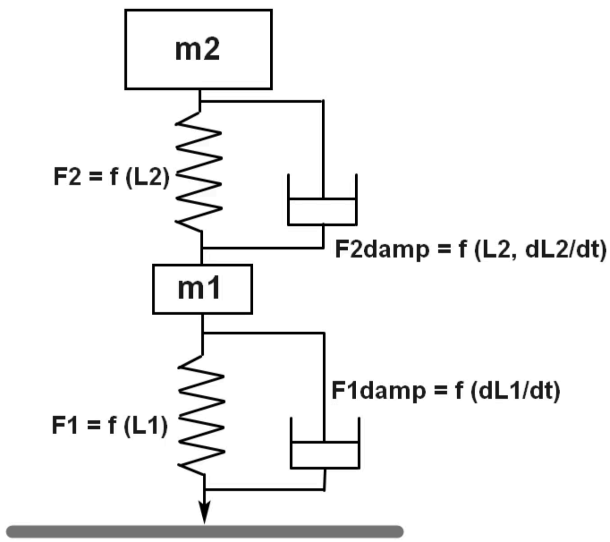
The development of the new suspension model was a relatively long journey before its implementation into our flight model. Our previous version used a single-component mechanical system with one non-linear spring element and one damper. This model represented a typical response for two interconnected oscillatory systems: tires and shock absorbers. For a wide class of aircraft undercarriages, it provided satisfactory results. However, as we added new aircraft to DCS, we encountered difficulties adjusting the model, as the single-component system could not accurately represent pronounced non-linear components. For instance, an aircraft might have relatively soft tires but very rigid struts.



The new model adopts a two-component system, consisting of a strut and a tire in series. This is a classical model, but the main challenge is that it requires numerically solving a second-order nonlinear differential equation. This type of equation involves displacement, velocity, and acceleration (the first and second derivatives).

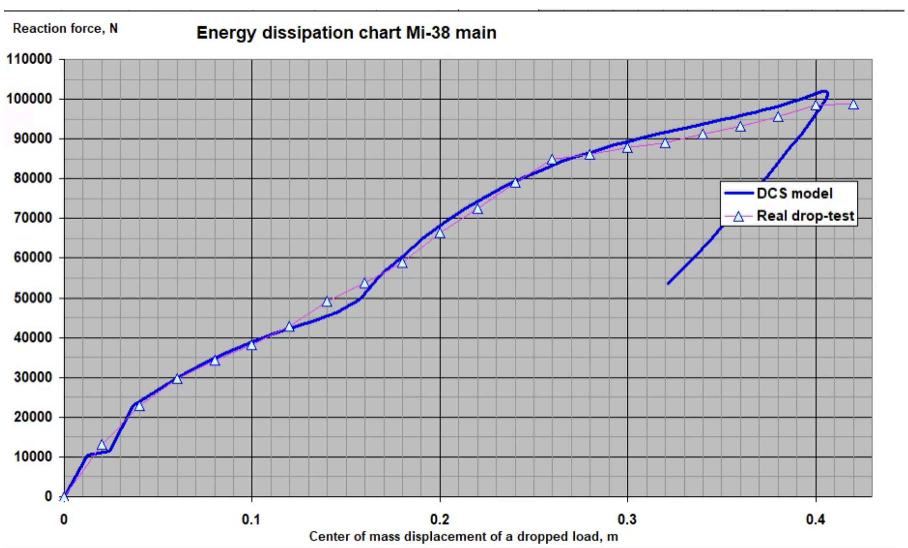
As the main solver was optimized, various types of struts were added, each with distinct characteristics for spring force and damping, as modeled from real-world cases. Our new model can now handle oleo-pneumatic asymmetric damping struts, rubber stack suspensions (such as those used on the Mosquito), spring-oleo suspensions (used in cars, tanks, etc.), and even two-stage oleo-pneumatic struts. The damping factor for oleo struts can also depend on strut displacement, similar to their real-world counterparts, increasing the effectiveness of the strut. Each type shows distinct force dependencies related to compression and velocity.

The model includes numerous parameters that can be fine-tuned with high precision when drop-test data is available for a specific suspension, whether for static or dynamic loads.

To support this, a specialized workbench was developed internally to simulate drop tests. This tool allows the model to be adjusted using either available drop-test data or when designing a new strut/tire system with only a few known parameters, such as tire size and full strut travel.

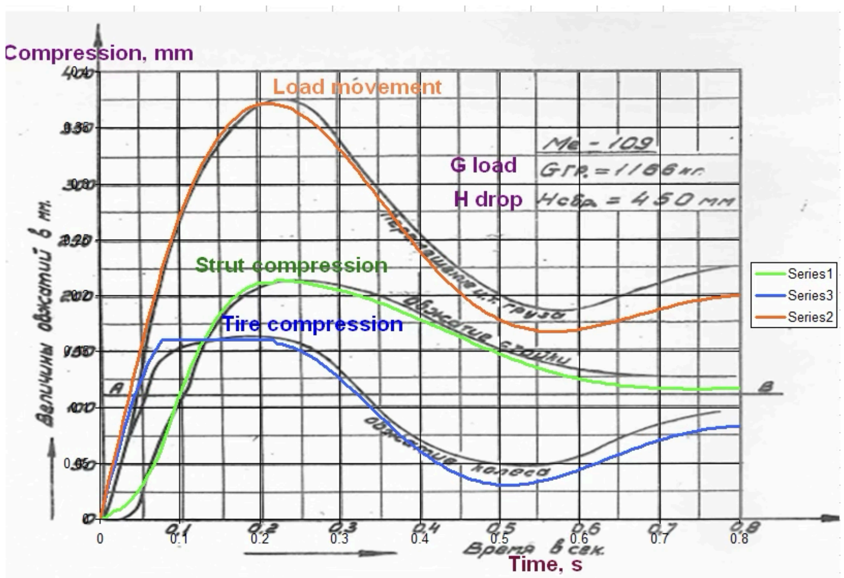
Different drop tests yield various results, such as the time history of tire and strut displacement, overall force versus overall displacement (energy absorption charts), and more.

As an example of the model's accuracy, the main wheel of the Mi-38 (a variant of the Mi-8) was taken as a reference.

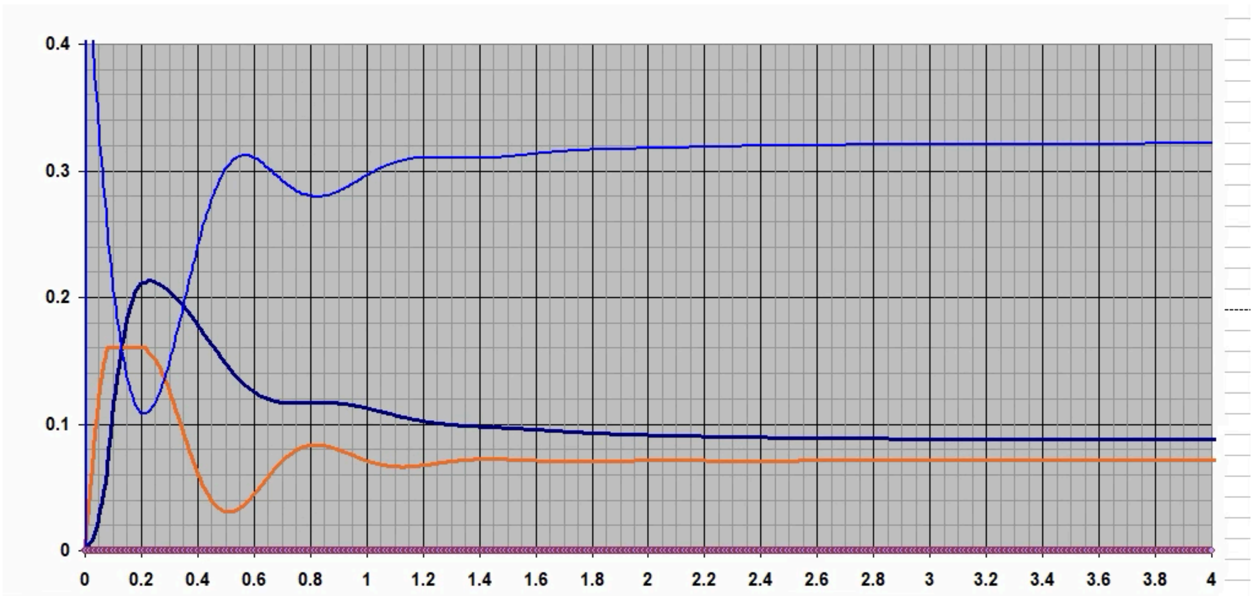


In this test of a two-stage oleo-pneumatic strut, the load mass, initial velocity, and unload factor were known, so a virtual drop-test was conducted under the same conditions.

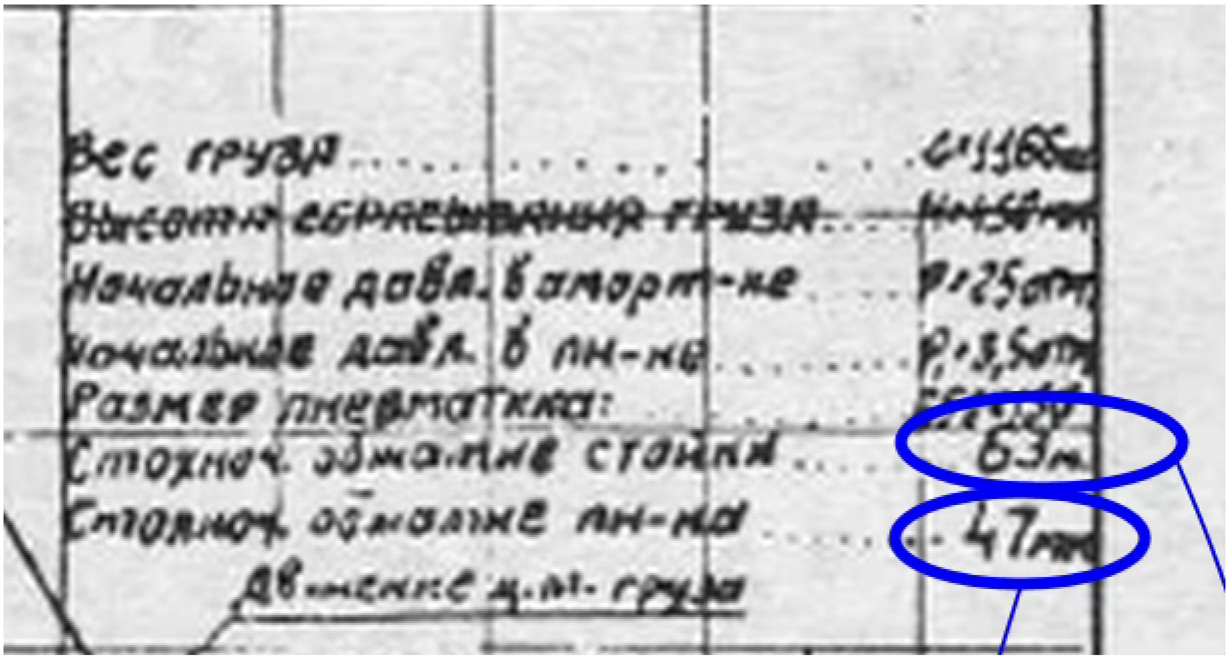
The next benchmark was a Soviet WWII-era test of the Bf-109E undercarriage. Although this report contains seemingly conflicting data in the graphs and text regarding the static compression of the tire and shock absorber, it can still be used to demonstrate the model's tuning potential.



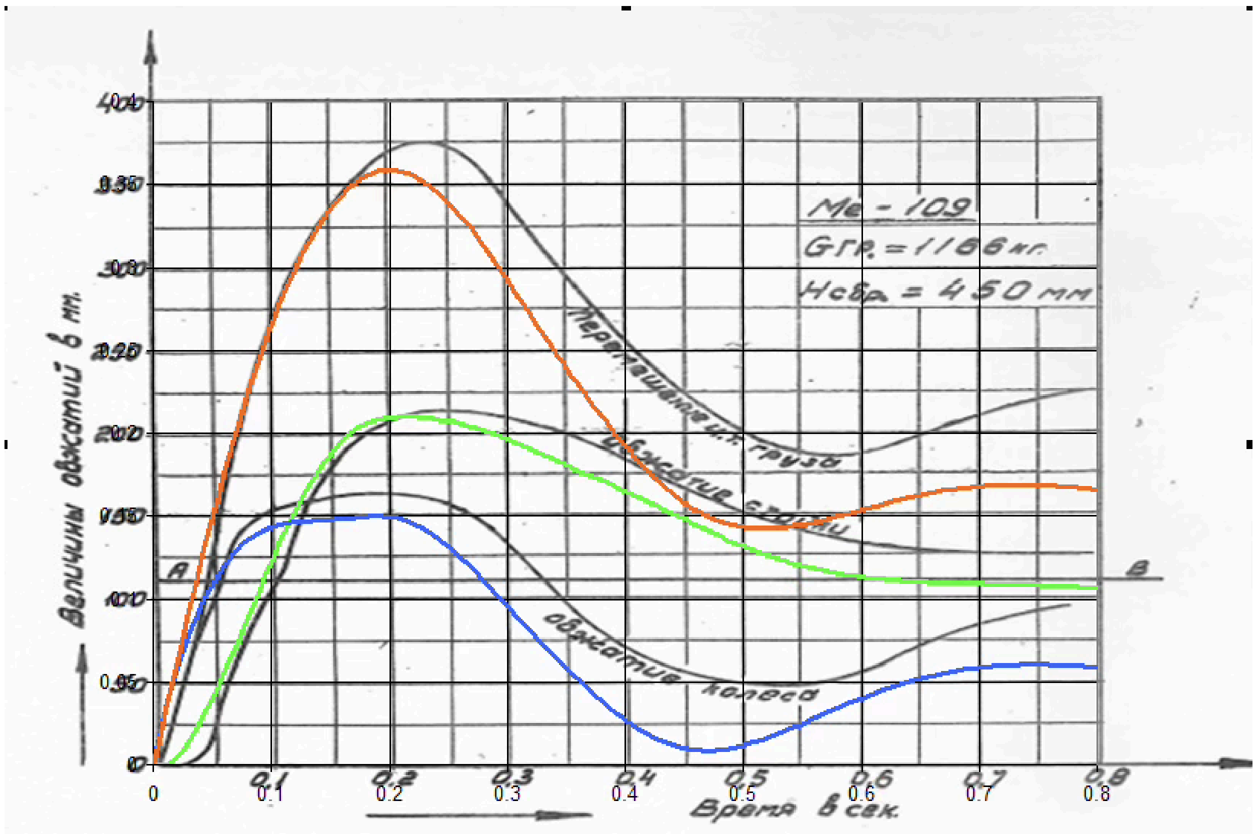
Why do these charts seem contradictory? Let's take a closer look at the extended calculated response:



Two things are notable: 1) The strut recoil time is quite long, as mentioned in the report, and the overall process is a superposition of two different transients; 2) The static tire and strut displacements derived from the transient record (tire – 71 mm, strut – 87 mm) do not match the specified on-ground values (47 mm and 63 mm).



This discrepancy cannot be fully explained, at least not until the full test report becomes available. Nevertheless, it is clear that the transient response for the quasi-linear tire cannot converge to a static displacement of 47 mm given the test data. However, by adjusting the model's dynamic parameters to match the test results, the static parameters can be modified to achieve a static compression closer to 47 mm and 63 mm.



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Although we do not have short term plans to develop the 109E, we can extrapolate these results to the 109 G/K series, considering the initial design approaches and the changes implemented for these aircraft. While detailed drop-test or static data is rarely available, we can usually find static, fully compressed, and unloaded displacements for tires and struts, which provides an excellent reference for suspension tuning in our model.