In-Vehicle Strain Monitoring for Control Arms in Dynamic Loading

Overview

A team of Luna Applications Engineers set up tests on a vehicle in real-world driving conditions to illustrate how HD-FOS can provide high-density data on dynamic loading conditions on components within a completed design.

To put the HD-FOS system to the test, sensors were instrumented on both forward control arms of a vehicle and monitored using Luna's ODiSI 6000 System during increasingly dynamic driving conditions. Forward control arms support the front wheels and suspension system in many vehicles, so whether turning, braking or just going over bumps, they are at the center of the action when a vehicle is in motion.

Test Set Up

A fiber optic sensor comprises a series of densely spaced virtual strain gages. Fiber sensors are ideal for measuring load on control arms because they can be bonded to a structure's surface in a similar fashion to traditional strain gages but have the flexibility to be routed around curves.

Two 5 m strain fiber optic sensors were used to cover the inner curvature of each control arm and the main support beam connecting the arms. The surfaces of the components were sanded and cleaned to ensure quality bonding with AE-10 epoxy. After curing, the fiber path was then protected with a layer of RTV to prevent damage in case of impact from debris during driving.

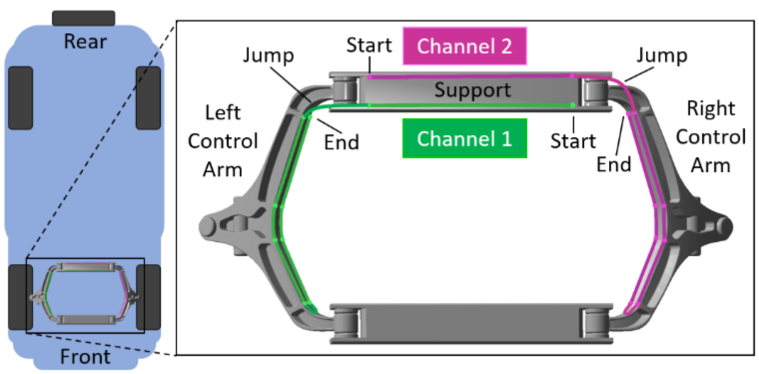

Figure 1. Instrumentation location underneath the vehicle. Two sensors were used to monitor the support beam and control arms on both sides of the vehicle. Channel 1 and 2 were instrumented in opposite directions on the support beam but identically on the control arms.

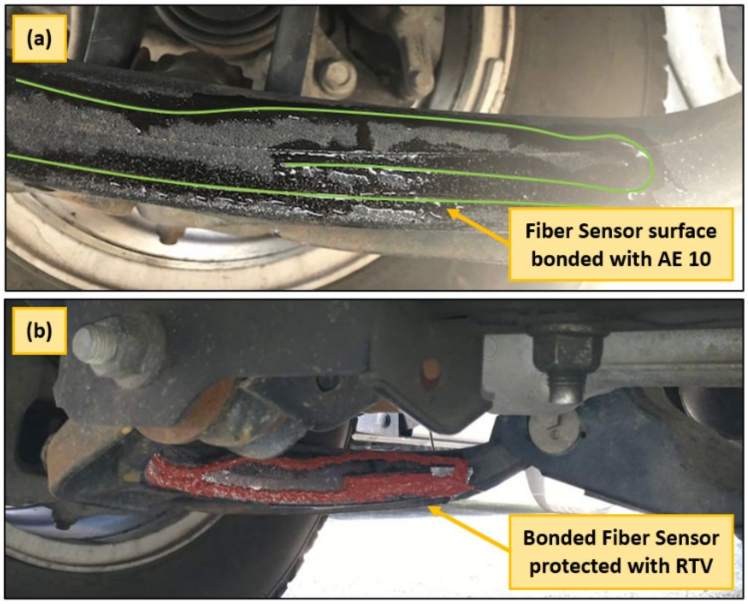

Figure 2. Bonding method for sensor instrumentation. The fiber makes two passes on its control arm, at the top and bottom of the inner curved surface.

Stage One: Evaluating Strain from Loading – Braking and Turning

The first stage of testing involved the vehicle making simple forward and reverse braking tests to observe the strain due to changes in load on the control arms. This was thought to be a good starting point as it is one of the simplest maneuvers a vehicle can perform. Areas of high strain occurred at several locations shown in Figure 3.A. Depending on the direction of the brake event, these areas would see compression in one direction and tension in the other. These high-strain areas appeared to correspond to the hollowed sections of the control arms, whereas the reinforced sections experienced lower strains. The similar loading caused while braking lead to symmetrical loading strain profiles for both the left and right control arms.

Turn testing added a new layer of complexity. High strain occurred again at the hollowed areas but instead of mirrored behavior between the two control arms, they experienced inverse strain profiles shown in Figure 3.B. When leading a turn, the control arm would experience tension but when trailing the turn, it would experience compression. This could be explained by the increase in load as more weight is shifted to the leading wheel and load is removed from the trailing wheel.

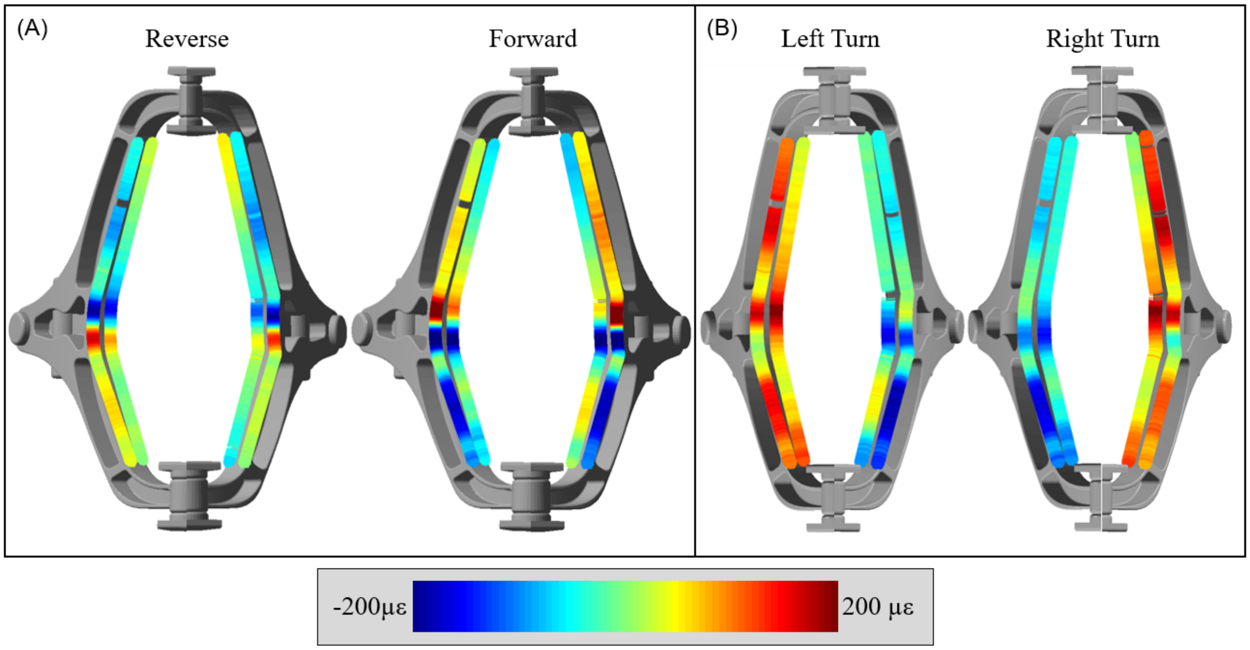

Figure 3. CAD of left and right control arms braking (A) and turning (B) with strain map overlay.

Stage Two: Evaluating Strain from Loading – Highway and Gravel Road

For the second test, the vehicle was driven normally in highway and dirt road environments to cover a full range of vehicle operation conditions. Vibration became greater concern in these test conditions. For many strain measurement devices, vibration can cause increased noise or data loss to such an extent that measurements become unreliable or nonexistent. This could be due to degradation in signal quality or system failure of the measurement device in high vibration conditions. To quantify the intensity of the dynamic driving conditions, an accelerometer was attached to the ODiSI System to monitor the G forces experienced while driving. At points on the gravel road, the system saw acceleration spikes of nearly -14 g when the vehicle passed over potholes. However, the ODiSI System never experienced any hardware failure or sensor damage.

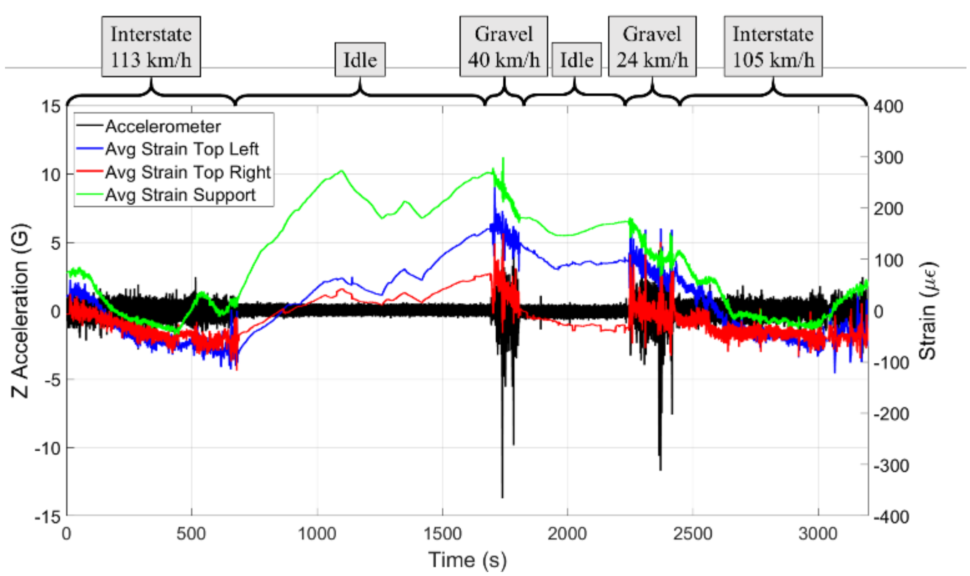

Figure 4. Accelerometer and strain measurement correlation. Z axis accelerometer data clearly shows the duration of interstate and service road conditions. The average strain for the top segments of both control arms and the support beam show corresponding times of activity. The rise in strain in between dynamic events was due to heating under the vehicle during engine idle.

HD-FOS measurements were very stable for the highway data, and turning and breaking events were distinguishable when they occurred. While driving along the gravel road and over deep pot holes, the measurements became noisier at times but always recovered. Despite the high vibration, the sensors and the system saw no damage or failures in operation.

Summary

These tests show the versatility of the [ODiSI 6000 System] and its ability to make high resolution measurements even in dynamic, real-world conditions. This capability allows for analysis of new materials and components or structural health monitoring in and outside the lab to ensure that new, lightweight parts meet needed design specifications.

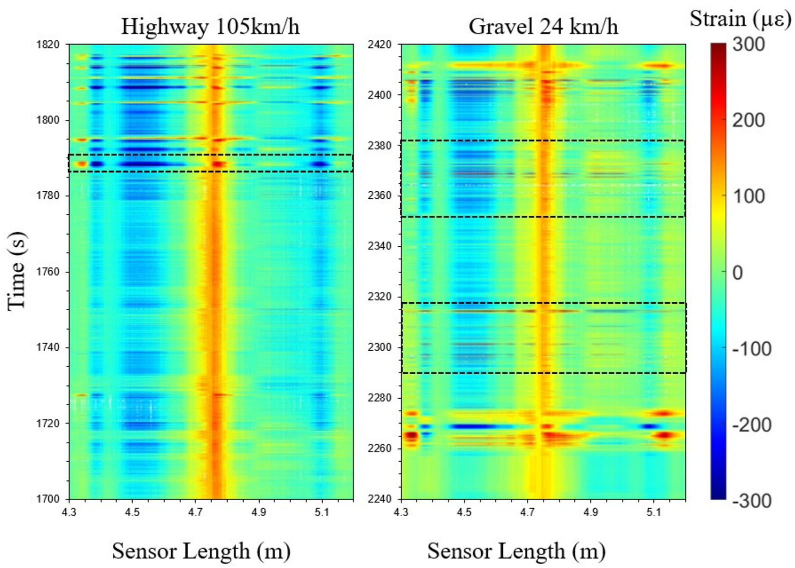

Figure 5. Right control arm strain comparison for highway and gravel road results. The highway data was very stable and clearly shows braking events, an example of which is enclosed by dashed lines. Driving on the gravel road resulted in greater strain shifts from impacts with bumps and holes as well as noisier data than the highway. These bumpy sections are enclosed in the dashed lines.