CLM CLAIMS & LITIGATION MANAGEMENT ALLIANCE™

ADVANCING ETHICS, COOPERATION AND EDUCATION

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Automotive Equipment Failure Analysis

I. Scene Investigation – A Subrogation Primer

Advanced proper notification to all interested parties is absolutely necessary before performing a scene investigation and vehicle inspection. Proper notice and opportunity to inspect the scene and subject vehicle is required to avoid defenses of spoliation of evidence. Scene investigation should include videotape and photo documentation of the area of origin of the fire in the most effective manner to show the origin is from the subject vehicle and the subject vehicle. Fire scene investigation techniques are governed by NFPA 921.

The logistics for the collection and removal of the subject vehicle from the scene must be coordinated with all interested parties and performed in advance of the field inspection. Proper collection and removal of the subject vehicle is critical to maintaining the integrity of the vehicle's component parts in order to perform laboratory examination. Testing protocol of the subject vehicle should be prepared and agreed upon before the component testing of the vehicle.

Depending on the type of vehicle component part failure, a varied laboratory services should be considered: metallurgical, plastics and chemical analysis; and use of SEM/EDS, optical microscopy, digital x-ray, computed tomography. For future presentation of failure mode, 3D laser scan may be used. The next sections discusses the various failure modes in vehicles.

II. Accelerator Systems

Cable and throttle by wire systems

In many vehicles, the car accelerator works off a cable which is connected to the accelerator pedal at one end, runs through the vehicle under the dash, and connects to a throttle body or carburetor mounted on the engine. There it operates a plate to control the amount of air entering the engine. Pressing on the accelerator pedal opens the throttle plate and thereby increases the flow of air into the engine (and subsequently power).

In older vehicles (pre 1990), the carburetor was used to mix the correct amount of gasoline with air prior to entering the engine. These were mechanical systems. The

increase in air flow increased the amount of fuel being drawn into the air flow. If too little fuel was mixed with the air, the engine would operate lean. If too much fuel was mixed with the air, the engine would run rich. From the carburetor, the fuel and air mixture is sucked into the engine's combustion cylinders where it is compressed and then ignited. When the air and fuel mixture is ignited, it expands abruptly and forces the pistons outwards. This is repeated thousands of times per minute, and results in the turning of the engine.

To meet stricter emissions requirements, the carburetor was replaced with the multi-port fuel injection system. These systems have a fuel injector located at each combustion cylinder which provides more accurate fuel metering and a quicker response. However, just like in a carburetor, (when you step on the gas pedal the throttle valve opens up more, letting in more air), the fuel injectors increase the amount of fuel sprayed into the combustion chamber, thus also increasing power. Sensors monitor the mass of air entering the engine, as well as the amount of oxygen in the exhaust. The engine control unit (ECU) uses this information to fine-tune the fuel delivery so that the air-to-fuel ratio is just right.

In a "wire" system, the cable from the accelerator pedal to the engine has been replaced with sensors. The Electronic Throttle Control (ETC) systems, uses information from the throttle position sensor (TPS), accelerator pedal position sensor (APP sensor), wheel speed sensors, vehicle speed sensor, and a variety of other sensors to determine how to adjust the throttle / fuel injector position.

Failure modes and common causes of failures

A common accelerator system malfunction is the entrapment of the accelerator pedal in the vehicle's floor mat. In these cases, the driver may have pressed the accelerator pedal to the floor, and when the pedal was released, the accelerator pedal became stuck in the depressed position resulting in uncontrolled acceleration of the vehicle. There are several possible reasons, including improperly installed floor mats, the wrong size floor mat or improperly designed floor mats.

Another cause of accelerator malfunction is a failure in the pedal, cable or linkages. Any one of these may become bound (stuck) due to corrosion, debris or wear. This also includes debris in the air flow that may become stuck in the throttle plate.

Older vehicles equipped with carburetors may have accelerator system issues due to weak, disconnected, or mis-connected throttle return springs, worn shot-pump barrels, chafed cable housings, and cables which jump their tracks in the throttle-body.

Pedal misapplication or pedal confusion is also a possible cause of uncontrolled acceleration. In these cases, the unintended acceleration resulted from driver error wherein the driver presses the accelerator when braking is intended.

In a wire system, there is no mechanical linkage between the accelerator pedal and the throttle valve. Instead, the position of the throttle valve or injectors is operated by an electric motor controlled by the ETC software. Software or electronic failures within the ETC have been suspected by some to be responsible for alleged incidents of unintended acceleration. Another reported possible ETC failure mode can originate from single-bit soft errors caused by ionizing radiation from a variety of sources, including cosmic ray neutrons. Sticking of the pedal at the floor board will result in the same unintended acceleration as with a cable system.

III. Hydraulic Brake Systems

Hydraulic brake system in vehicles

When you step on the brake pedal, the pedal moves down and through a series of linkages pushes against a plunger in the master cylinder. This forces brake fluid through a series of tubes and hoses to the braking unit at each wheel. Since the brake fluid cannot be compressed, the force applied at the pedal is transmitted directly to the braking unit. The brake fluid enters a cylinder in each brake unit that pushes a piston against a brake pad (disk brakes) or brake shoe (drum) toward the brake disc or brake drum. When the brake pad contacts the brake disc, friction between the two generates heat. The friction slows down the wheel, thereby slowing / stopping the car.

Failure modes and types of failures

There are many causes of brake failures. One of the most likely causes of no brakes is loss of fluid pressure in your brake system. The brakes operate using hydraulic pressure, so if there is a fluid leak in the fluid reservoir, brake lines, brake hoses, wheel cylinders or calipers, there may not be enough fluid pressure in the lines to apply the brakes.

If the brake pedal goes all the way to the floor when you apply the brakes, another cause might be severely worn brake linings, or, air in your brake lines, which would require bleeding the lines to get rid of the air. This is due to air being “compressible”. Contaminants such was water or the wrong fluid type of being added to the brake fluid reservoir can severely affect braking performance.

Another possibility would be a bad Master Brake Cylinder. If the piston seals inside the master cylinder are worn or damaged, and are not applying sufficient pressure when you push on the brake pedal (due to brake fluid by-passing the internal seals), less braking force is applied..

A faulty power brake booster that is not providing sufficient force, any power assisted braking will increase pedal effort, but it will not cause the brakes to fail. You just have to push on the pedal much harder than normal to stop your car.

Brake fade and/or brake fluid boil are other conditions that may occur as a result of the brakes getting too hot. As heat builds up in the brake linings, it takes more and more pressure to achieve the same friction and braking force when the brakes are applied. The pedal may remain firm but the brakes just do not seem to have much stopping power when you apply them. That is why water is not used in brake systems since it can "boil" and elevated temperatures, thus affecting braking.

Function and operation of ABS (anti-lock braking system)

ABS uses wheel speed sensors to determine if one or more wheels are trying to lock up during braking. The greatest amount of wheel stopping power is just before a wheel "locks up". If a wheel tries to lock up, a series of hydraulic valves limit or reduce the braking on that wheel. This prevents skidding and allows you to maintain steering control and decreases the vehicles stopping distance

Failure modes and types of failures

Brake failure might be due to a faulty ABS modulator that is leaking brake pressure internally and is not routing sufficient pressure to the brakes when you step on the pedal. Dirt or rust in the brake system can also enter the modulator and prevent the spring-loaded accumulator valve from closing, allowing the modular to leak internally, reducing the braking force.

IV. Steering Systems

How the steering system operates

The steering system converts the rotation of the steering wheel in the passenger compartment into a pivoting movement of the front wheels. This is accomplished through a series of linkages and gears located in the steering column and engine compartment. In addition to changing the direction of the front wheels, the force applied by the driver is also multiplied through a series of gears. The system allows a driver to use only light forces to steer a heavy car. Also, most late model cars have power steering which means the steering is assisted by power transmitted from a power steering pump.

Differences between rack and pinion steering systems and steering gear box systems.

There are a several different types of steering gears. The most common are rack-and-pinion and recirculating ball. A rack-and-pinion gear set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod, connects to each end of the rack. The pinion gear is attached to the steering shaft. When you turn the steering wheel, the gear spins, moving the rack. The tie rod at each end of the rack connects to the steering arm on the spindle.

Recirculating-ball steering is slightly different than on a rack-and-pinion system. The recirculating-ball steering gear contains a worm gear. A worm gear has two basic

parts. The first part is a block of metal with a threaded hole in it. This block has gear teeth cut into the outside of it, which engage a gear that moves the pitman arm. The steering wheel connects to a threaded rod that goes into the threaded hole in the block. When the steering wheel turns, it turns the threaded rod. Instead of twisting further into the block this threaded rod is held fixed so that when it spins, it moves the block, which moves the gear that turns the wheels.

Failure modes and types of failures

The most common cause of steering failure is a loss of power steering. This occurs when some portion of the power steering pump has failed or the engine has lost power. However, this is not a true steering failure. The ability to steer the vehicle remains, it just takes a greater force to turn the wheel.

Another pseudo steering failure may occur during brake lockup. Vehicle's that do not have ABS brake may lock up during heavy brake application. If the front wheels of a vehicle are skidding, turning the wheel will have no effect on the direction of the vehicle. Releasing the brakes will return steering function.

However, a failure in any of the linkage connections from the steering wheel all the way to the wheel could result in a steering system failure. The linkages may become bound due to corrosion, debris or wear.

V. Suspension Systems

How the suspension system operates

The job of a vehicles suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers. If a road were perfectly flat, suspensions would not be necessary. However, this is not the case. Irregularities, or bumps, in the road apply forces to the wheels. The size of the bump changes the magnitude of the force. The bump also causes the wheel to move up and down perpendicular to the road surface. This also occurs when a vehicle is maneuvering through a curve or turn.

Without an intervening structure, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels would lose contact with the road. Then, under the downward force of gravity, the wheels would slam back into the road surface. The vehicles suspension absorbs the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road.

There are several different types of suspension systems that include the MacPherson strut and the double-wishbone. Each system contain may different parts including coil springs, leaf springs, torsion bars, shock absorbers, struts and anti-sway bars.

Failure modes and types of failures

Suspension systems are often blamed as a cause of an accident. However, suspension issues rarely result in catastrophic failures. The typical issues may result in poor handling and noticeable vibrations. Typically, driver error or poor maintenance can explain many of the issues. Still, improper design or manufacturing defects should be examined as possible causes.

VI. Transmission Systems

How automatic and manual transmissions operates

The vehicle's transmission is the powertrain that converts the engine's force into a controlled source of power. It acts as a go-between between the engine and the wheels, and converts the high power the engine produces into torque (a rotational force), which is then transferred to the axles, which in turn rotates the wheels.

The power produced by an engine is too high and variable to create a useable speed for direct operation of the vehicle. The typical engine is operating at speeds of 2,000 to 5,000 revolutions per minute (rpm), while the wheels are operating at speeds of 0 to 1,800 rpm. The transmission is able to keep both your engine's RPM, and the RPM of the wheels, at optimal rates, and it sends power to the differentials which turns the wheels. It does this all through the use of gear ratios in the transmission.

The primary difference between an automatic and a manual transmission is the method the car uses to shift gears. In an automatic transmission, the car decides when to shift and automatically changes gears for you. In a manual transmission car, you are responsible for shifting gears using a clutch and the gas pedal.

How clutches operate

Most cars use a friction clutch operated either by hydraulic fluid or by a cable. When a car is moving under power, the clutch is engaged. A pressure plate bolted to the flywheel exerts constant force, by means of a diaphragm spring, on the driven plate. The driven (or friction) plate runs on a splined input shaft, through which the power is transmitted to the gearbox. The plate has friction linings, similar to brake linings, on both its faces. This allows the drive to be taken up smoothly when the clutch is engaged.

When the clutch is disengaged (pedal depressed), an arm pushes a release bearing against the center of the diaphragm spring, which releases the clamping pressure. The outer part of the pressure plate, which has a large friction surface, no longer clamps the driven plate to the flywheel, so the transmission of power is interrupted and gears can be changed.

Failure modes and types of failures

There are several ways to damage a transmission. Overheating the transmission due to overloading can reduce the life expectancy of a transmission. Improper fluid level can result in a lack of lubrication and increased temperature. A failure to change the fluid according to the manufacturer's schedule can result in dirty fluid with less lubrication. Adding the wrong type of transmission fluid can damage the transmission. Manual and automatic transmissions use different fluids, mixing the two can result in significant damage. Sudden, jerky or fast acceleration can produce a lot of heat. Not giving the transmission a chance to cool down will cause it to overheat quickly.

A forced downshift at high engine RPM can cause excessive wear on transmission friction components. Placing the shift lever into drive or reverse when engine is at high RPM is also improper. This can cause abrupt transmission engagement, leading to early failure of clutches, bands, gear sets, driveline components, and engine or transmission mountings. Starting to drive the vehicle before the fluid reaches operating temperature can result in premature wear. Towing the vehicle with the drive wheels on the ground, and/or tow over the factory recommended limit, can also cause damage.