Parking Brake Fires in Commercial Vehicles
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EXTENDED POSTER ABSTRACT

The NFPA 2010 "Fire Loss in the U.S." reports 215,500 vehicle fires occurred in the U.S. during 2010, causing 310 civilian fire deaths, 1,590 civilian fire injuries and $1.4 billion in property damage [1]. How many of the vehicle fires involve commercial vehicles is not well defined, but we do know that approximately 15.5 million trucks operate in the U.S. logging 432.9 billion miles in 2006 [2], out of a total of approximately 250 million vehicles registered in 2010 according to the U.S. DOT.

This analysis will address the appropriate methodologies used to help determine the correct origin and cause of parking brake fires in commercial vehicles. Fire origin and cause analysis on commercial vehicles can be very challenging due to the lack of familiarity and understanding by the fire investigation community about the specific pneumatic and mechanical systems associated with foundation air brakes and with the spring applied parking brakes systems that are commonly found on commercial vehicles. This analysis will focus on typically heavier trucks, tractor-trailers, and buses equipped with air drum brake systems (rather than hydraulic disc or drum brakes, or air disc brakes) and dual wheel/tire combinations at the wheel ends (rather than the newer and rapidly growing wide base single wheel/tire specification).

This analysis will provide the origin and cause investigator a review of how foundation air brake systems and their associated mechanical parking brake systems typically work on commercial vehicles. It will discuss common parking brake configurations and explain how their pneumatic circuits work. It will also review typical axle and wheel end configurations to help familiarize the investigator with other potential causes of wheel end fires, and will review all of the mechanical inspection procedures recommended to determine if the fire was caused by operating the vehicle with the parking brakes applied. This extended abstract will also provide a discussion of typical fire patterns caused by parking brake fires to assist an investigator in making a proper origin and cause determination. It will also review all other potential fire causes and fuel loads at a typical wheel end. The poster presentation for this abstract will provide photographic examples of the various wheel end components associated with the parking brake system as well as illustrate examples of typical fire patterns produced by a parking brake fire.

INTRODUCTION / REGULATIONS

Air brake standards in the United States applicable to new vehicles are promulgated by the National Highway Traffic Safety Administration by authority of Department of Transportation. Regulations are incorporated into the Title 49 of the Code of Federal regulations, Part 571 titled "Federal Motor Vehicle Safety Standards" (FMVSS). Regulations and standards specific to air brakes are Standard No. 121, and more commonly referred to as FMVSS 121. These standards are written as performance standards and do not dictate the design required to meet the performance requirements. The overall performance requirements are for the parking brakes to work in the forward and reverse direction, hold the full gross vehicle weight rating (GVWR) on a twenty percent grade, or for tractors with three or more axles, resist a drawbar force of 0.28 times the gross axle weight rating for all axles (except the front steer axle) or for all other vehicles, resist a drawbar force of 0.14 times the gross vehicle weight rating [3].

Since this extended abstract is intended to give an investigator a very broad based background and understanding of air brake regulations and performance requirements, it will explain the primary function of all of the major components involved in a modern airbrake system. It will discuss axle configurations and wheel end bearing systems found on these vehicles. It will provide a discussion of how foundation S-cam brakes work including brake chambers, automatic slack adjusters. It will also explain the driver controls involved in setting and releasing a parking brake, and discuss the warning(s) available to the driver. It will also look at the effects that anti-lock brakes systems and traction control systems can have on the foundation brakes.

WHEEL END AND BRAKE HARDWARE DISCUSSSION:

Typical hardware found at the wheel end of the rear axles of medium, heavy and severe service trucks and busses with air brakes consists of a hub and bearing combination that runs on a hollow spindle at the end of an axle assembly. The bearings are retained on the axle by various wheel end nut retention locking configurations allowing certain bearing endplay. The axle driving the hub is of a floating design in that it drives the hub by way of flange at one end of the axle shaft, and has no direct contact with the bearing, thus not carrying the load. This is in contrast to a semi-floating axle design in smaller vehicles where the axle shaft runs though the middle of the bearings and carries load. The hub is most commonly surrounded by a dual brake shoe and drum brake assembly referred to as the foundation brakes. The shoes expand to apply the friction material to the inside of the drum by rotation of an “S” shaped cam. The S cam is turned by way of a pneumatic diaphragm and push rod assembly. When the service brakes are applied, compressed air is allowed to enter a chamber with the diaphragm. The diaphragm pushes on a rod that turns the S cam and expands the brake shoes. Activation of the parking brake is accomplished by way of a spring replacing the pneumatic pressure in the brake chamber. During operation, the parking brake spring is held back with air pressure. The parking brake is applied by releasing the air pressure holding back the parking brake spring. This feature makes the brakes fail safe as the parking brakes apply automatically when there is insufficient air pressure present in the parking chamber to hold them off. The truck or tractor parking brakes are typically controlled by way of a yellow diamond pneumatic push-pull valve on the dash. Semi-trailer parking brakes are operated by a separate red octagon push-pull control valve that applies trailer parking brakes [5,6]. FMVSS standards require a visible red warning lamp in the instrument panel that advises the driver when parking brakes are applied. Some manufactures also offer an optional audible alarm that sounds if the vehicle is moved while the parking brakes are applied. Most 6x4 tractors in the U.S. (the most common tractor configuration) are equipped with parking brake chambers on both ends of one of the two rear axles and can be additionally configured with parking brake chambers on both rear axles if desired. Parking brakes are typically not used on front steer axles. Tractors and semi-trailers both are now required to be equipped with an Anti-lock Braking Systems (ABS). Traction Control System (TCS), Roll Stability Control (RSC), and Electronic Stability Control (ESC) options are also available from manufacturers. The effects these systems can have on the brake system are discussed in the “Determination of Cause” section below.

DETERMINATION OF FIRE ORIGIN:

The most commonly acceptable way of determining the root cause in any vehicle fire investigation is to follow the accepted procedures as described in NFPA 921. The process consists of first establishing the area of origin for the fire, and then determining the cause, which are the circumstances that bring together a fuel and an ignition source [4]. The area of origin is generally determined by an interpretation of the fire patterns left by the fire. It involves assessing the different amounts of damage to the various components involved; taking into consideration the progression of the fire which is determined by the various fuel loads and ventilation effects involved the physical properties of the various materials, and the dynamics of the fire itself.

In the case of a wheel end fire, it is best to analyze the fire and damage patterns on the basis of the individual wheel end components involved. Bearing failures are manifested by severe wear, scuffing, or even deformation of the wheel bearing(s), often with corresponding damage to the axle spindle. There are typically two bearing sets per wheel end, and the damage can be observed in either one or both. The outer wheel bearing is often the first to experience damage if lack of lubrication is involved due to the typical geometry of tapered wheel ends. This bearing damage should then also correspond to a radial heat pattern on visible on the exterior of the wheel hub around the bearings. The heat patterns from the hub should also then correlate to preferential heat damage to the outer wheel in applications with dual wheels. The outboard side of the outer wheel will also show more damage than the inner side because of its proximity to the bearings.

Brake fires generally will not significantly affect bearings and wheel hubs. In a brake fire, these components are usually unaffected, especially when the hubs are made of cast iron. Aluminum hubs may show some minor melting due to the external heat. The primary heat patterns observed in a brake fire are an overheating of the brake drum in the area where the brake shoes make contact with the drum. The friction material on the brake shoes may, depending on its composition, show areas of melting, scuffing, high wear, or even a small layer of ash around the edges of the friction material. It is also common to find the return springs have annealed and lost their tension. The overheating of the brake drum should also correspond with overheating of the inner wheel. The inside of the inner wheel will be the most severely damaged, followed by its outside surfaces, then the inside of the outer wheel and so forth. This damage to the wheels will also correspond to the damage to the tires. The inside tire will be more completely consumed by the fire than the outside tire. The inner tire is the first major fuel source in a brake fire as the brake shoes and drums are components are located within the inner wheel. The inner tire burning will then leave a classic “V” burn pattern on the frame of the vehicle, and for a tractor drive axle, possibly also on the trailer, depending on the location of the fifth wheel. The classic “V” burn pattern will also be quite noticeable on the sides of semi-trailers and buses.

When evaluating heat patterns from a brake, it is of utmost importance to determine which wheel ends show signs of overheated brakes and if they correspond with the wheel ends equipped with parking brakes. Knowing if the vehicle is equipped with ABS, TCS, RSC, or ESC is also import, and its significance will be discussed in the cause section below.

Tire fires can happen when either a vehicle is operated with a flat tire [7], when road debris gets caught between two tires, or when the duals are both low on air and rub together. Tire fires rarely affect the wheel bearings, brake components, or cast iron hubs, but may show limited damage to aluminum hubs. Also, tire fires are most common on the inner tire as it is the most difficult for the driver to check during his pre and post trip inspections. During a wheel end fire inspection, if there are no signs of mechanical distress in the bearings and hubs, if the brake drums and brake components within the drums are unaffected by excessive heat, and if the wheels do not show heat patterns where they are bolted to the flange, then the probable fire origin is in the tire(s).

DETERMINATION OF CAUSE:

The discussion above should lead the investigator to realize that there are generally only three major competent sources of heat within a wheel end; brakes, bearings, and the tires, provided the vehicle was moving at the time of the fire initiation, and not subject to any incendiary or environmental causes. Since parking brake fires are the emphasis of this extended abstract, they will therefore be explained in more detail the other two alternatives.

When the fire patterns point to the wheel hub as the potential origin, the wheel bearings are the most common cause. They are either in good working order, or they are burn, melted, scuffed, and have affected the axle spindle. Leaking wheel bearing seals have not been found to be a fire cause. Bearing issues are not related to parking brake fires.

When the fire patterns point to a single tire as the origin, the fire was most probably run while flat, with debris, or under-inflated.

If the fire patterns point towards more than one wheel end as a potential fire origin, a parking brake fire cause should be considered, provided the suspect wheel ends are equipped with parking brake chambers. Since not all brakes are adjusted exactly the same, and since one side of the vehicle may be cooler depending on wind direction, it is very common for one wheel end's thermal damage or fire to progress further than the other(s). The investigator also needs to keep in mind that the parking brake system is independent of the service brakes, and that driving with the parking brakes applied is therefore not a malfunction of the service brakes. It is simply an oversight by the driver. The driver failed to release the parking brakes, and failed to notice the warning lamp on the dash.

ABS only releases the brakes, and therefore cannot be a cause of a fire, as a brake that is released does not create heat. TCS can apply the brakes, but only works on driven wheels and only on one side of the vehicle at a time. In a typical 6x4 tractor, only one side of the two rear axles are applied at the same time because of how these are configured with the sensors and modulating valves that apply the brakes. Modern and emerging electronic brake system enhancements such as electronically controlled RSC, ESC, and even newer automatic braking systems involving full stability control, adaptive cruise control, and collision mitigation do potentially apply certain selective brake sets. Thus there is a potential for failure modes in these applying and then not releasing selective service brakes (on wheel end equipped with or without spring parking brakes). No such failures are known or expected to have occurred and would also not be expected to correspond directly with the wheel ends with potential spring brake applications. This analysis additionally has not considered any unusual or rare failure modes in the brake system design that could be potentially envisioned to mimic a parking brake fire.

The parking brakes on typical tractors or straight trucks are applied by the driver by way of a push pull valve(s) located on the dash. Releasing the parking brakes prior to moving the vehicle is the driver's responsibility. Failure to release the parking brakes and operating the vehicle results in the parking brake equipped wheel ends to overheat the brakes which then typically catch the inner tire on fire first, with the fire then progressing depending on how long it burns prior to extinguishment or lack of fuel.

CONCLUSIONS

Many modern commercial vehicles are capable of "driving-though" their spring applied parking brakes even though they comply with and meet all their applicable FMVSS 121 standards. The controls available to the operator allow the vehicle to be operated with the parking brakes applied, and operating the vehicle in this manner can cause a fire in one or more wheel ends of a commercial vehicle. Once the function of the foundation airbrakes and spring applied parking brakes is understood by a fire investigator, though tires are usually burned, the fire patterns left by a parking brake fire can usually be easily recognized and used to arrive at a correct causal determination.

KEYWORDS: commercial vehicle, truck, tractor, trailer, air brake, parking brake, brake fire, parking brake fire, wheel end, bearing, tire.

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