

# Wheel Separations from Commercial Vehicles: Experiences in Ontario

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## Abstract

Wheel separations from commercial vehicles continue to be tracked in Ontario since the spotlight was first put on this issue in 1995 when several fatalities occurred due to separated wheels. It was recognized that wheel separations were a significant problem that needed to be addressed. This paper presents the statistics regarding the year to year trends, variation in occurrences between different vehicle types, wheel equipment, and modes of separation. As well there is an overview of the research that has occurred on this subject over the years, various remedies being pursued, and the government and industry response in Ontario to this on-going problem.

## Résumé

On continue de faire le suivi, en Ontario, des détachements de roue sur des véhicules commerciaux depuis qu'on a mis l'accent sur ce problème en 1995, année où sont survenus plusieurs accidents fatals causés par des roues qui se détachaient. On a reconnu que cet important problème devait absolument être réglé. Ce document présente les statistiques sur les tendances d'une année à l'autre, les variations dans les accidents entre les différents types de véhicules, le système de roues, et les modes de détachement. On y retrouve également un aperçu des recherches réalisées à ce chapitre au fil des années, des divers moyens de remédier à la situation, et des dispositions prises par le gouvernement et l'industrie en Ontario en réponse à ce problème récurrent.

## Introduction

Wheel separations from commercial motor vehicles (CMV) can have tragic results when these heavy wheel assemblies collide with other vehicles, people, or roadside objects. On January 31, 1995 such a collision resulted in the fatality of an occupant in a vehicle traveling on Highway 401 in Whitby, just east of Toronto. Again on April 3, 1995 another such collision occurred on the Queen Elizabeth Way highway just west of Toronto. From that time onward the problem of wheel separations received the media's attention and the concern of the public.

The Ontario Ministry of Transportation, the trucking industry, and others stepped up their efforts to understand the scope and cause of this problem so that they could respond appropriately. A series of activities was put in motion starting with a coroner's inquest in October 1995.

This paper gives an overview of the various investigations and activities regarding wheel separations, a presentation and analysis of the Ontario statistics, and suggests possible solutions. The focus of the paper is a technical analysis of the problem and although some mention of legal proceedings are necessary it is not the intent to deal with these extensively.

## Government and Industry Response

Although during the time from 1995 to 97 there were a number of initiatives made by government and industry that were aimed at improving truck safety, a quick overview of the specific actions regarding wheel separations will be helpful to better understand the statistics that come later in this paper. The focus of this section will be the timing of these activities while later sections will deal with the details of the work.

After two fatalities due to wheel separations early in 1995 the government called for a coroner's inquest into these tragedies. The inquest, which became

known as the Worona Tyrrell Inquest, was held in October 1995. The inquest had broad involvement and included participation from government, manufacturers, and the trucking industry. Much media and public attention was focused on this issue at the time.

During 1996 a cooperative effort was made by government and industry to improve the quality of wheel installation in the province by certification of people who undertake this work. An amendment to the Ontario Trades and Qualifications Act made it a requirement, starting on November 1, 1996, for any person involved in wheel installations on medium/heavy commercial vehicles to hold a certificate.<sup>1</sup> The training is provided or coordinated by the Ontario Trucking Association with the Ministry of Training, Colleges and Universities (formerly Ministry of Training and Education) issuing the certificates.

Also late in 1996 changes were made in the inspection criteria used in Ontario to place a vehicle out-of-service (OOS) for wheel defects. Prior to the change the North American Commercial Vehicle Safety Alliance (CVSA)<sup>2</sup> OOS criteria were used. The criterion regarding fasteners puts a vehicle OOS if, on a 10 fastener wheel any three fasteners or two adjacent fasteners are loose, broken or missing, or on a wheel with eight fasteners or less any two wheel fasteners are loose, broken or missing. In Ontario this criterion was changed so that there is no tolerance for any of these defects. As well there is criteria regarding limits for cracks, elongated stud holes, and mismatched hardware that was made more stringent in the Ontario criteria.

Another wheel separation in December 1996 resulted in a double fatality and with continued public pressure to improve the situation, the government passed new legislation in July 1997. This legislation (Highway Traffic Act, section 84.1) introduced an absolute liability offence for wheel separations. Making this an *absolute liability* offense as opposed to a *strict liability* offence removed the ability to defend against this charge

using a due diligence defence. The prosecution only needed to prove that the offence occurred to gain a conviction.

With these changes implemented there was a dramatic decrease of 54% in the number of wheel separations from 1997 to 1998. This decrease has been sustained up to the present time and is likely attributable to improved practices within the trucking and vehicle repair industries in response to the initiatives that were introduced.

## Previous Investigations

Various investigations have been carried out over the last number of years concerning the problem of wheel separations from commercial vehicles. This section will give a brief overview of several significant projects that were undertaken and the main results or conclusions.

### US National Transportation Safety Board (NTSB):

In the fall of 1991 a series of wheel separation collisions in the US resulted in seven fatalities. As a result the National Transportation Safety Board initiated a special investigation to determine the magnitude of the wheel separation problem, the types and causes of failures, and the adequacy of current truck wheel inspection and maintenance guidance and procedures. In September 1992 the board issued its report.<sup>3</sup>

The report concluded that,

“...the leading causes of wheel separations from medium/heavy trucks are improper tightening of wheel fasteners and bearing failure; both are the result of inadequate maintenance.” (Conclusion 2)

Regarding repair practices the report concluded that,

“Under-tightening of wheel fasteners usually results from the failure to follow recommended wheel maintenance practices, such as always using a torque wrench, following proper tightening procedures, using only compatible

components, and avoiding paint build-up, debris, oil, or rust between wheel fasteners, threads, and mating surfaces.” (Conclusion 3)

“The trucking industry lacks uniform model guidelines for maintenance and inspection of all types of medium/heavy truck wheels.” (Conclusion 5)

The lack of adequate guidelines would likely have had a negative effect on maintenance practices.

Several recommendations were made in the report, primarily directed to manufacturing associations, the American Trucking Association (ATA), and the Society of Automotive Engineers. The focus of the recommendations were to develop and disseminate model guidelines for the inspection and maintenance of all types of wheels, and improved training and education regarding these guidelines.

In the next few years following that report there was action taken by these associations to address the concerns raised by this report. An example of one such action was the publishing of Technical Bulletin No. 114 by the Truck Trailer Manufacturers Association (TTMA) in July 1994 that highlights the issue of wheel separations and makes recommendations to follow manufacturers recommended procedures.<sup>4</sup> In an April 1996 letter from Jim Hall, Chairman of NTSB, to Richard Bowling, President of the TTMA regarding the recommendations of the 1992 NTSB report it was acknowledged that, “..the TTMA has taken the lead in developing truck wheel inspection and maintenance procedures. Furthermore, TTMA Technical Bulletin No. 114 advises operators of the potential dangers of axle hub and/or trailer wheel separations if improper maintenance procedures are used.” The letter goes on to state that it considers the recommendations to the TTMA as, “closed – acceptable action”, or “closed – acceptable alternate action”.

#### Ontario Worona and Tyrrell Inquest – October 1995.<sup>5</sup>

In order to better understand the cause of wheel separations that had occurred earlier that year and to determine how these events could be prevented, a coroner’s inquest was convened in October 1995.

The inquest was conducted over 17 days and had representation from the various parties directly involved in these wheel separation incidents as well as the Ontario Ministry of Transportation, component manufacturers, trucking industry and repair industry representatives, and others.

The inquest determined that in both wheel separation incidents, the separated wheel had recently been removed as part of a repair procedure. In both cases fasteners were defective or improperly installed.<sup>6</sup>

In all, the jury put forward 31 recommendations concerning wheel maintenance and inspection, monitoring and controlling work done, and how the justice system should respond.

The Executive Summary by the coroner, Kevin Flynn M.D., concluded the following in part.

“The standard of training and awareness of proper inspection, preparation, and installation of medium and heavy truck wheels in the trucking industry appears less than adequate. Manufacturers’ specifications for inspection and installation appear to be widely ignored. Tire services operated without training or certification. Wheel fasteners are torqued using uncalibrated air wrenches which can seriously under-tighten or over-tighten wheel nuts. Wheels are not removed for inspection annually.....Pre-trip inspections are not diligent or complete.”

“The jury has pointed out that priorities for change must begin with training, not only for mechanics but also for heavy truck drivers. In order to reduce unsafe practices a more effective system of inspection must also be instituted

followed by more severe penalties by a justice system better informed.”

#### Heavy Truck Wheel Separations: An In-Depth Study of Real-World Incidents<sup>7</sup>

Due to the high rate of wheel separations occurring in Ontario in the early part of 1997 and a desire to obtain a better understanding of this issue Transport Canada, in the fall of 1997, initiated an in-depth, on-scene research study of wheel separations in eastern Ontario.

The investigation included documenting information about the incident scenes, the vehicles involved, as well as the usage patterns and maintenance history of the vehicles involved. Wheel components were recovered and sent to a laboratory for metallurgical analysis.

The number of cases described in the paper, 16 in total, was too small to allow for statistical analysis regarding the predominance of failures of a certain wheel type, the mode of failure, or other similar analysis. However, the detail of the investigations offers great insight into how failures occur and how factors such as improper or inadequate maintenance contribute to wheel separation failures.

The paper identified maintenance as an underlying factor in many wheel separations.

“Many separations resulted from the lack of proper maintenance (improper fastener torque, low oil in hubs), the use of unserviceable components (wheels with worn fastener seats), or improper repair practices (damaged spindle) that compromised existing wheel components. No defects were identified with any failed component.”<sup>8</sup>

The statement above regarding “no defects” is making reference to manufacturing defects. Therefore no manufacturing defects leading to wheel separation were identified during the investigations. Therefore in order to reduce wheel

separations improved maintenance practices should remain the focus of attention.

The paper also included a statement regarding other possible contributing factors to wheel separations.

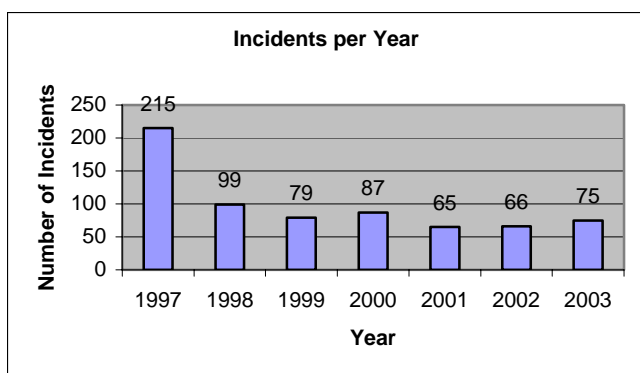
“While maintenance is clearly an underlying factor in many wheel separations, the extent to which axle loads, axle spreads, road quality, and temperature affect wheel fastener systems, and the subsequent demands on maintenance practice, remains to be investigated.”

#### **Ontario Statistics and Analysis**

Late in 1996 a wheel separation incident occurred which resulted in a double fatality. Although some reporting of wheel separation incidents was occurring prior to this incident, from this point onward reporting of these incidents became regular practice. Each wheel separation incident, whether investigated directly by the Ministry of Transportation Ontario (MTO) or by other police agencies, was reported to the Carrier Safety and Enforcement Branch of the MTO on a form specially developed for this purpose. The form includes general information about the incident (date, location, operator, etc.), the vehicle involved, vehicle type (truck, trailer, bus, or other), the mode of failure (fastener, bearing, axle, or wheel), and the type of wheel equipment (spoke, stud-piloted, or hub-piloted). In 1999 an additional question was added to the form regarding recent repairs. This was done after comments regarding recent repairs were being regularly reported in the general comments section of the report form.

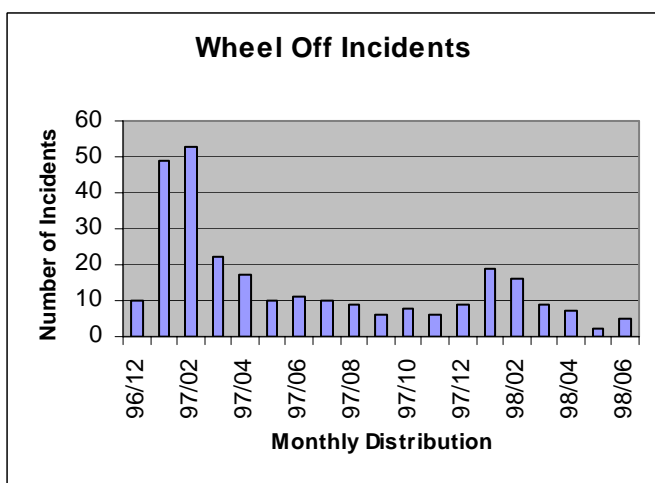
Up to the end of 2003 a total of 745 incident reports had been received. Seven fatalities resulted from these incidents.

The following charts and tables are a summary of the data that Ontario collected together with a brief statement of interpretation.



**Figure 1**

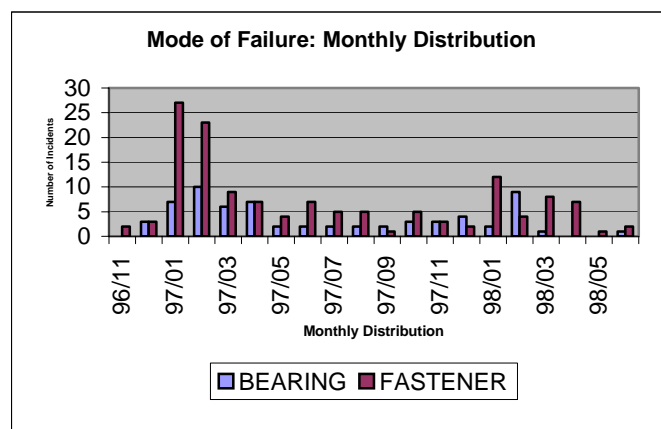
Figure 1 shows the total number of wheel separations per year. There is a dramatic 54% decrease in the number of wheel separation occurrences in 1998 compared to 1997. This decrease can be attributed to the actions that were being taken by both industry and government in 1996 and 1997 as described in the previous section, *Government and Industry Response*. The two main influences being the wheel installers certification program and the new wheel separation legislation.



**Figure 2**

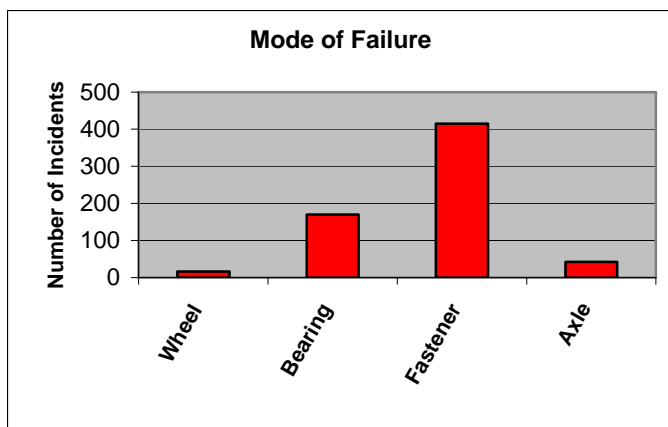
The month-to-month distribution of incidents as shown in Figure 2 indicates a dramatic increase of wheel separations in the winter months of January and February for 1997 and 1998. This trend is consistent throughout the range of data up to the present.

The rise of incidents in winter could be attributed to two possible factors. The effect of low temperatures on wheel components is one possible factor. Less effective daily pre-trip inspections by the driver and roadside repairs, both of which are made more difficult by inclement weather, may also contribute to the increased number of wheel separations during the winter. Although some concern has been expressed that the colder temperatures of Canadian winters may affect components and contribute to wheel separations there is no evidence to support this. Yet there is repeated evidence in the incident reports that improper repairs or lack of maintenance was a contributing factor and very likely the cause of separation.



**Figure 3**

This seasonal trend in separations is not restricted to one mode of failure alone. Figure 3 plots the two major modes of wheel separations, fasteners and bearings during the same time period as Figure 2. The plot indicates that both of these modes of failure follow the general trend of increased incidents in winter.



**Figure 4**

Figure 4 shows the distribution between the different types of failure modes in the 643 incidents where the mode of failure was reported. Failure of the wheel fasteners occurred in 65% of the incidents, while wheel bearings were the mode of failure in 26%. What is worthy to note is that these two modes of failure representing the vast majority of incidents involve the components that require the most amount of maintenance and therefore are most affected by poor maintenance and inspection practices. The other two modes of failure were only indicated in 9% of incidents.

The following sections give an overview of the four different modes of failure and briefly discusses how lack of maintenance affects the wheel end and leads to wheel separation.

#### Mode of Failure – Wheel:

There is no regular maintenance required for spoke or disc wheels, however, they must be regularly inspected for rust, excessive wear, cracks and other damage. If any problem becomes evident the wheel must be serviced or replaced if necessary.

A wheel separation that involves the failure of a wheel directly usually comes about from the development of cracks in the wheel. The cracks grow progressively until the wheel fails totally. Of the 16 wheel separations that involved a failure of the wheel the statistics indicate two failures with spoke wheels and 14 with disc wheels.

#### Mode of Failure – Axle:

In cases where the axle spindle or other portion of the axle fractured and separated from the vehicle the incidents were classified as a wheel separation. In situations where the whole axle assembly became detached from a vehicle they were not included as a wheel separation incident.

Most axle failures occurred when a crack developed at the bottom of the axle spindle in the location of the in-board bearing. This area can only be inspected when the hub and bearings are totally removed from the spindle.

Besides inspections there is no recommended maintenance for the axle spindle.

#### Mode of Failure - Wheel Bearings:

Wheel bearings must be installed according to a precise procedure that ensures proper adjustment. They must be properly lubricated, and the wheel ends regularly inspected for lubricant leaks to ensure that the proper lubricant level is maintained. Evidence of improper installation, damaged seals, or insufficient lubrication was indicated in many wheel separation reports. During a wheel bearing failure many of the components are damaged and it is difficult to determine the pre-failure condition of the bearings and associated components. Therefore it is difficult to determine the likely cause of the separation. Figure 5 shows a picture of an axle spindle with the outboard bearing and the adjusting and locking mechanism after a wheel separation incident. It may be possible to determine if an adjuster or locking device was incorrectly installed, an incorrect seal was used, or some other similar fault was present. However, because of the extensive damage from this type of failure it is not possible to determine for certain whether the bearing was improperly adjusted, or insufficiently lubricated. In some cases during an investigation, it is possible to ascertain the probable cause of a wheel separation by looking at the other wheels on the vehicle. There may be evidence of insufficient or contaminated lubricant, improper repair methods or the use of incorrect components. This type of



evidence would point to a problem of poor maintenance practices in general. It would not be conclusive evidence of the reason for the wheel separation however it could prove to be very useful to a maintenance manager trying to prevent its reoccurrence.



**Figure 5**

#### Mode of Failure – Fasteners:

Wheel fasteners are a critical component when it comes to preventing wheel separations since they are represented in 65% of the incidents where the mode of failure is known. Defective components, overloading, over-torquing, under-torquing, or the failure to recheck torque after wheel installation all can lead to loose wheels and eventually wheel separation.

Failure to properly install fasteners can lead to a wheel separation. For any wheel type it is important that the fasteners are the proper size (i.e. sufficient thread engagement between stud and nut) and are in good condition. The worse the condition of the threads on a fastener the more the applied torque on the nut will be used to overcome friction (nut to stud) rather than to increase clamping load. With fasteners of very poor condition a wheel could remain relatively loose even though the proper torque was applied to the nuts.

In the case of disc wheels it is important to have wheel surfaces that are clean, without excessive rust or thickness of paint that can prevent the wheel and brake drum surfaces from properly seating against each other. As the vehicle is operated on the highway there is an interaction between the surfaces which causes the surfaces to seat against each other. This causes the thickness of the clamped component to be reduced and thereby the clamping force is also reduced. The reduction in clamping force if significant enough will eventually allow the wheel end components to move relative to each other, resulting in wear and a further reduction in clamping force. It becomes a vicious cycle of more wear and more movement. Eventually the movement of the outer wheel will cause the nuts to rotate in the loosening direction. Once the nuts start to loosen the movement of the wheel increases, which again increases the rate at which the nut loosens, and a wheel separation is imminent.

The initial reduction in clamping force due to the seating of the components after installation is normal. Depending on the condition of the wheels and other possible factors this reduction in clamp force after installation can differ from wheel to wheel. In most cases the degree of loss in clamp force will not be sufficient to lead to a wheel separation. In some cases, however, if the wheel nuts are not retorqued and the loss in clamp force is significant a wheel separation may occur in as little as a few hundred kilometers. This process of losing clamping force can also take a significant amount of operation and may not lead to a significant problem for quite some time. It is hard to know how long this process will take but it is important that the corrective action of retorquing the wheel should occur after the wheels are sufficiently seated in position and before the first possible chance of a wheel separation could occur. The Ontario statistics indicate that a wheel separation due to the failure of the fasteners is common shortly after a wheel was reinstalled. Of the 80 reports from 2000 to 2003 that indicated recent repairs 66, or 83%, involved failure of the fasteners while the rest involved bearing failure. The manufacturers of heavy truck

wheels recommend that wheels be checked for correct torque between 80 and 160 kilometres after wheel installation.<sup>9</sup>

In the case of spoke wheels proper studs, clamps and spacers that are in good condition are important to ensure retention of the demountable rim on the spoke wheel. From Figure 6 it can be seen that although spoke wheels are over represented regarding bearing failures they are under represented regarding fastener failures.

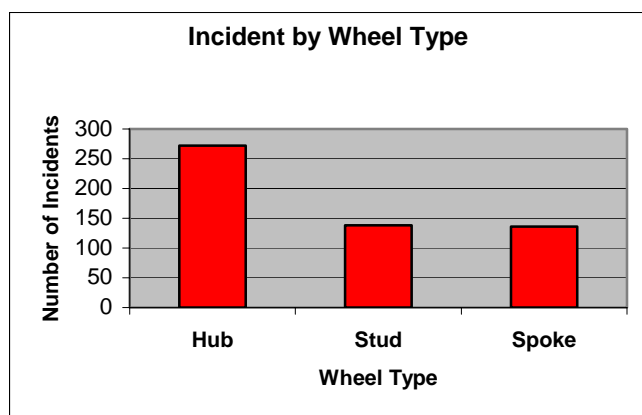
	<b>Hub -Pilot</b>	<b>Stud- Pilot</b>	<b>Spoke</b>
Fastener	207	108	45
Bearing	54	24	63

**Figure 6**

This may be due to the aspect of spoke wheels that offers the driver of the vehicle an advance warning of an impending problem. If the fasteners become loose the braking and acceleration of the wheel will cause the rim to spin on the wheel. This will often cause the tire inflation valve stem to be sheared off causing the tire to go flat. This is a warning that there is a fastener problem on the wheel, a warning that the driver is not likely to miss or ignore.

#### Wheel Type:

Figure 7 shows the distribution of wheel types involved in the wheel separation incidents where this information was known.



**Figure 7**

The chart shows that all wheel types are involved in wheel separation incidents. However there is a clear predominance of separations involving hub-piloted wheels. Although hub-piloted wheels were involved in 50% of the wheel separation incidents it cannot be assumed that these wheels are more problematic than the other wheel types.

Information from Accuride<sup>10</sup>, a major manufacturer of disc wheels, shows an industry trend towards hub-piloted wheels starting in 1987. In 1987 sales of wheels to truck manufacturers were approximately 2.5% hub-piloted wheels, 47.5% stud-piloted wheels, and 50% spoke wheels. The percentage of disc wheels sold compared to spoke wheels steadily climbed to 98% in 2002. At the same time the makeup of the disc wheels steadily changed so that in 2002 97% of disc wheels were hub-piloted. Therefore of the three wheel types hub-piloted wheels went from a market share of 2.5% in 1987 to a 95% market share in 2002.

Although this information cannot be correlated directly to on-highway exposure of these different wheel types it is a very good indicator that hub-piloted wheels significantly out number stud-piloted and spoke wheels in the last few years.

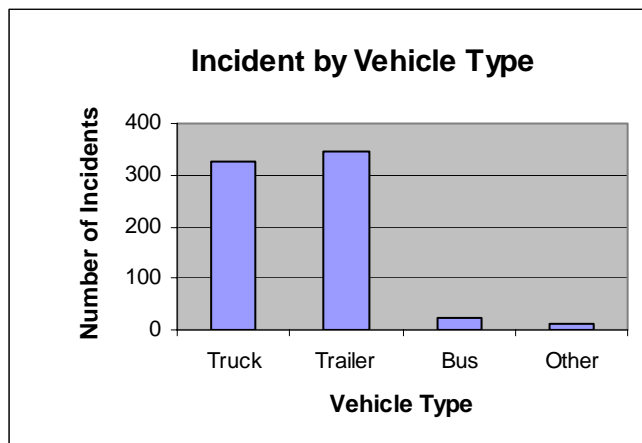
Given the above information about the predominance of hub-piloted wheels in the market we would expect, as is the case, to see a predominance of this wheel type in the wheel separation data. However, without precise information about the percentage of the different wheel types actually in use on vehicles operating on the highway it is not possible to make any conclusive assessments about the relative risk of wheel separation from the various wheel types.

#### Vehicle Type:

Figure 8 shows the distribution of vehicle types involved in the reported wheel separations. There is only a slightly higher number of incidents from trailers as compared to trucks. With regard to buses and “other”<sup>11</sup> vehicle types the numbers are relatively very small. These numbers of course



need to be looked at in light of the exposure that each of these vehicle types has on the highways in Ontario.



**Figure 8**

The MTO every few years does a detailed survey of commercial vehicles operating on Ontario highways. From the survey information of 2001<sup>12</sup> the daily distance in Ontario by trucks was 18.6 million kilometers, and 17.1 million kilometers for trailers. The survey did not include information regarding bus travel.

From the information regarding kilometers travelled compared with the information of Figure 8 we can see that trailers operate about 8% less kilometers per day than trucks yet are represented in about 6% more wheel separations than trucks. Although we can determine from this that wheel separations are more predominant with trailers than they are from trucks the difference is not large.

### **Solutions: Can Wheel Separation Be Prevented?**

Much of the concern raised by the NTSB report cited earlier regarding inadequate guidelines has been dealt with by the industry. Therefore the problem comes down to ensuring that industry personnel have access to the guidelines, are adequately trained, and have the time, equipment and incentive to carry out the task properly.

From previous investigations and the on-going investigations of the MTO, as have been discussed up to this point, we can conclude that maintenance is the underlying factor in many wheel separation incidents. Therefore it seems logical to conclude that the solutions we must pursue require a focus on maintenance. Although other factors such as increasing wheel loads, wide spread axles, the use of lift axles, and poor road conditions make wheels more susceptible to separations, these factors do not cause wheel separations directly. Rather, they make wheels more susceptible to wheel separations. Maintenance practices that take these factors into account are necessary. The focus remains on maintenance. Notwithstanding the focus on maintenance, the manufacturing industry should develop wheel system designs that require less maintenance and that are less sensitive to maintenance deficiencies.

There are several maintenance deficiencies regarding wheel servicing that can cause wheel systems to fail and result in a wheel separation. Each of these deficiencies will be reviewed and solutions suggested.

One deficiency in maintenance is the use of incompatible fastener components and parts that are incorrect for the application. This may occur for example when switching steel wheels to aluminum wheels, which require longer studs because of the thicker aluminum wheels. The solution starts with adequate training, ensuring that parts are inspected as part of repair procedures, and that new replacement parts are stocked and readily available and properly selected for the correct application. A note about the different wheel types would be appropriate here. Both stud-piloted wheels and spoke wheels have a much wider assortment of wheel fastener components than those required for hub-piloted wheels. As well, proper thread engagement between the stud and the inner cap nut on a dual wheel is not readily evident as is thread engagement on a standard stud and nut on the hub-piloted wheel system. As was discussed earlier the use of hub-piloted wheels has increased

substantially in the last 10 years and its use is still increasing. This increasing use of hub-piloted wheels will simplify maintenance due to the factors mentioned above.

Deficiencies such as worn or damaged threads can increase the friction between the stud and the nut and cause the applied torque to be consumed more in overcoming friction than increasing clamping force. This would result in an insufficiently clamped wheel that would more readily allow movement between components of the wheel that could lead to a wheel separation. It is important that fastener components are carefully inspected as part of the repair process and any worn or damaged parts be replaced. Training should emphasize the consequences of deficient fasteners and how to properly inspect and identify them.

There are several situations that cause wheels and brake drums not to seat properly together. Wheels that have rusty or damaged surfaces or wheels that have excessive paint on them do not seat properly together and cause excessive seating of the components after installation. This leads to less clamping force which may allow wheels to move against each other and begin the process of loosening the wheel nuts which in turn may result in a wheel separation. The solution in this case is to ensure that the mounting surfaces of the wheel and drum are clean, smooth, and have a maximum paint thickness of no more than 0.003 inch (3mils)<sup>13</sup>. Another important aspect is to follow the recommendations of the manufacturers which consistently state that wheel fasteners must be retorqued between 80 and 160 km after a wheel has been installed. This is a key recommendation that in many cases seems to be ignored by the industry. Failure to comply seems to be the difficulty in performing this work at the recommended distances. Companies claim that it is difficult to plan a vehicle's route, that will bring it to a location where this work can be done to meet the specified distance. The retorquing of wheels may compensate for many installation problems, readily identify them before the wheel fasteners fail and yet is not regularly practiced.

Proper retorquing of wheels is a necessary practice that must be followed. The trucking industry needs to explore means by which this procedure can be put into practice on a regular and consistent basis. Some trucking firms have implemented a compromise with practices such as operating the vehicle over short severe routes (such as figure eights in a parking lot) to rapidly seat the wheel components and then to retorque the wheels. There is information from the British Standards Institute's Code of Practice<sup>14</sup> that may merit investigation for application in North America. The code requires that the torque on wheel fasteners be checked on commercial vehicles 30 minutes after initial torquing of the wheel or between 40 to 80 km of operation after initially torquing the wheel. This code of practice introduces the idea that seating of components has a time element to it. This practice is not being recommended as a solution but does warrant investigation.

Another problem that has come to light is the situation where disc wheels are installed and torqued with the parking brake applied. This is done to prevent the wheel from rotating during the torquing procedure. The problem is that with the parking brake applied the brake drum, and therefore the wheels as well, is prevented from being pulled into the hub properly during the torquing procedure because of the force of the brake shoes against the drum. Once the parking brake is released the wheel assembly is immediately loosened to some degree. Training is again a solution to issues such as this.

Some would suggest that if 500 lbft torque is good to ensure proper clamping of the wheel assembly then surely 600 lbft must be better. Over torquing of wheel fasteners by such practices can cause studs to plastically yield and thereby be less capable of maintaining the required tensile force. Training has to emphasize the adherence to manufacturers recommendations and help service people better understand the consequences when these recommendations are not adhered to.

Wheel bearing failures, that lead to wheel separation, are caused primarily from improper installation, lack of sufficient lubrication, contaminated lubricant, and damaged seals and hubcaps.

Improper installation, improper adjustment of bearings, both of which can lead to premature failure, can both be addressed with proper training. The procedures to adjust wheel bearings for example are well established<sup>15</sup> and are readily available.

The wheel seals can leak because of damage during installation, from excessive bearing end play, or from normal wear during operation. Avoiding seal damage during installation and ensuring correct bearing adjustment is a matter again of proper training while leaks from operating wear can be observed, and addressed, during regular inspections by mechanics and drivers.

There are three different means by which non-driven wheel ends are lubricated; number 2 grease, semi-fluid grease, and oil. The use of number 2 grease for wheel ends was long established when in 1951 STEMCO, a truck equipment manufacturer, introduced the concept of oil lubricated wheel ends for non-driven wheels.<sup>16</sup> Both oil lubricated and semi-fluid grease lubricated wheel ends have seals that require such a tight seal to prevent leaking that they require a vented hub cap. The use of oil in wheel ends did prove to simplify the maintenance of wheel ends however susceptibility to seal leakage and contamination by way of the hub vent did present a challenge. New and improved products were introduced to the industry to address these problems. It is worthy to note that in Europe the move to oil lubricated hubs never occurred as it did in North America. Grease lubricated wheel ends remain the primary system in Europe.

The hubcaps on oil lubricated hubs have a clear window of some kind so that the oil level can be observed. It is important that this window be kept clean and the oil level be inspected on a regular

basis. In one wheel separation incident in which insufficient oil level was suspected there was a hubometer attached to the outside of the hubcap. The hubometer blocked a clear view of the oil level window and therefore made a proper oil level check much more difficult. Situations like this should be avoided.

As a way to reduce leakage from oil lubricated wheel ends the use of semi-fluid grease was introduced to the industry during the 90's. The same seal and vented hubcap were used as in the oil lubricated wheel end. The proper fill level for the grease did become an issue and was claimed by some to be a factor in wheel separations. The industry explored this problem and eventually established a new standard in 1999 for an increased fill level than that which was previously recommended.<sup>17</sup>

Since grease is much easier to retain in the hub, grease seals are designed so that the hub can "breathe" out through the seal and therefore have hubcaps that are completely sealed. A hub and bearing assembly that uses number 2 grease is therefore less susceptible to contamination. The Timken Company, a major bearing manufacturing company, is promoting the increased use of wheel ends using number 2 grease as a way to reduce the susceptibility of leakage and contamination of lubricant.<sup>18</sup>

## Conclusions:

It's been said many times in the real estate business that the three most important factors that affect the value of a property are location, location, location. Well when it comes to preventing wheel separations from commercial vehicles the three most important factors are maintenance, maintenance, maintenance. Of all the factors that contribute to wheel separations lack of maintenance is either directly responsible or improved maintenance practices could compensate for other issues.

The main targets for improved practices should be:

- improved training in manufacturer's and industry's recommended practices,
- more attention paid to the condition and compatibility of wheel fastener components,
- the use of torque wrenches for the final tightening of wheel fasteners during wheel installation,
- compliance with the recommended practice of torque checks for fasteners between 80 and 160 km after wheel installation,
- adequate inspection of wheel ends by drivers on a regular basis (which may require better training to identify potential problems before they become critical), and
- avoidance of axle overloads.

The requirement for a torque check after wheel installation continues to be a difficulty for many operators and yet this is an important aspect in ensuring proper clamping force on wheels. The recommended practice of the British Standards Institute of doing a torque check 30 minutes after installation, as was discussed previously, would warrant investigation by the industry.

The pursuit of improved equipment and maintenance practices is an ongoing endeavor that must continue. Equipment manufacturers should explore how various operating conditions affect wheel-end systems and the level of maintenance they require. There may be some factors that result in a level of maintenance that is difficult to achieve or uneconomical to sustain. Road conditions, axle configurations, overloading, the use of lift axles, extreme temperatures and the like have an affect on the life of wheel-end components and their need for maintenance. New systems that can reduce the maintenance requirements brought on by these factors may benefit the industry if they can be achieved without increasing the overall life cycle cost of operating the vehicle. Although systems that are less susceptible to reduced maintenance should be strived for, the maintenance requirements of current systems cannot be ignored.

## Disclaimer

The conclusions reached and opinions expressed in this paper are solely the responsibility of the author. Unless otherwise stated, they do not necessarily represent the official policy of the Ministry of Transportation, Ontario.

## References and Notes

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