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Heavy Truck Wheel Separation: Failure Modes and Classifications

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I. ABSTRACT

The purpose of this paper is to illustrate the various wheel attachment systems and to define their components. Special failure modes and safety measures are discussed.

II. INTRODUCTION

An 18-wheeler is driving down the road at approximately 60 m.p.h.. A wheel from the right side of the "duals equipped" trailer detaches and gracefully rolls off the axle laterally, becoming a 190 lb., 60 m.p.h. stealth missile. It runs over a surveying crew working on the side of the road and continues to roll up an embankment flattening a fence and several small trees. Because the wheel comes off the right side of the trailer and the other wheels keep the trailer level, the truck driver continues driving with no knowledge of the destruction left in his wake.

According to the National Transportation Safety Board, variations on this heavy truck wheel separation accident scenario occur 1000 times a year. Wheel loss may lead to truck rollover, loss of steering ability and/or collision in addition to the devastation caused by the runaway tire striking vehicles, pedestrians and property.

Most wheels used on heavy trucks are disc wheels or demountable rims, (Fig. 1). Both types are attached to a rotating hub — disc wheels are mounted over studs and held in place by five to ten single or dual cap nuts; demountable rims are mounted over cast

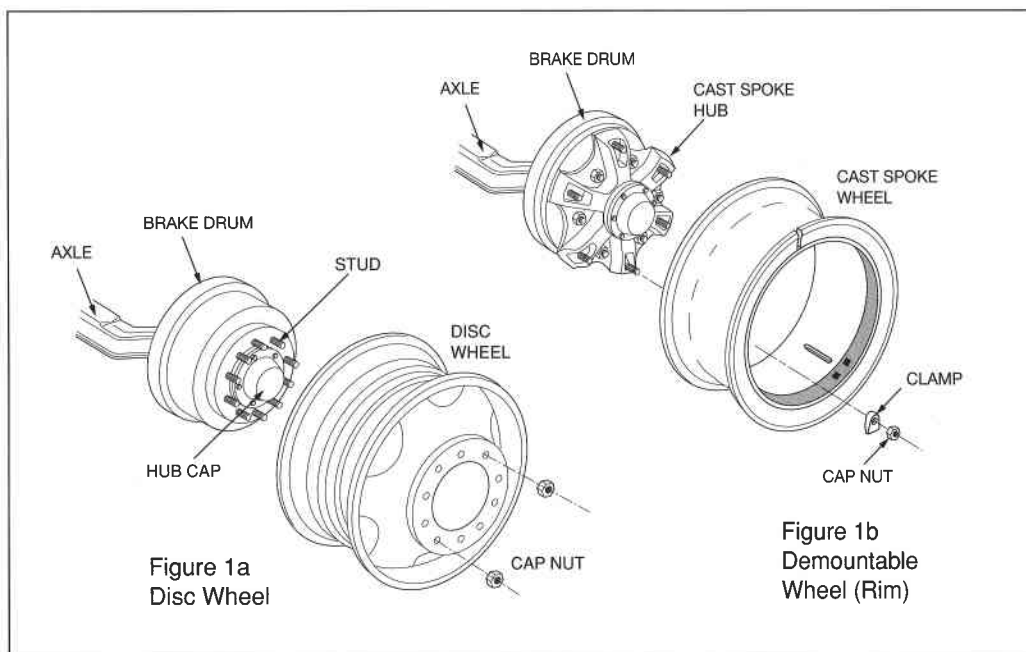


Fig. 1 Disc Wheel and Demountable Wheel (Rim)

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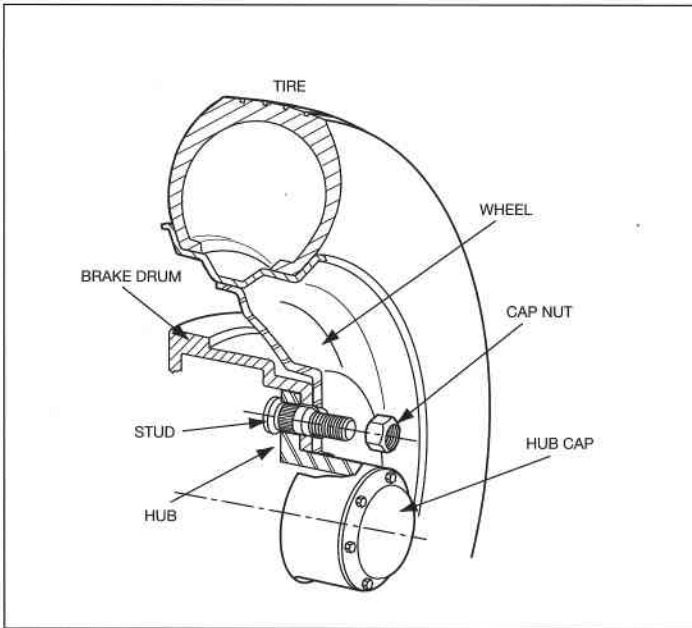


Fig. 2 Typical Single Wheel Configuration (Stud Piloted)

spokes held in place by five or six clamps and cap nuts. The rotating hub, in turn, is held onto the vehicle by its own retention system. Wheel detachment occurs when the wheel separates from the hub or when the hub separates from the spindle. This paper covers methods of attaching wheels to hubs and failures leading to wheels separating from hubs. It does not cover hub attachment methods or hub separation. The information in this paper is found piecemeal in existing literature. An attempt is made here to create a graphic primer on the subject.

III. WHEEL ATTACHMENT SYSTEMS

A. STUD PILOTED SINGLE WHEEL

1. System Description

The studs of stud-piloted single wheels bear all of the load. A set of single wheel cap nuts is used to secure the wheel to the hub as shown in Fig. 2. The cap nuts go over the studs which are mounted to the hub.

2. Failure Modes

Wheel loss occurs due to loss of the cap nuts, failure of the studs, failure of the wheel disc or a combination of these. Insufficient torque and failure to follow proper torquing sequence (See Fig. 3) can lead to loss of cap nuts. Undertorquing may cause the cap nuts to loosen. A proper torquing sequence produces near uniformity in the positioning and preload delivered by the cap nuts. Overtorquing places excessive preload on the cap nuts and may strip the studs' threads.

Since the studs carry the full wheel load, excessive payload places them in jeopardy. In addition, overtorquing places excessive preload on the studs.

There are three common modes of wheel disc related failure. First, repeated overtorquing can enlarge the holes, causing the tapered cap nuts to be positioned deeper into the holes

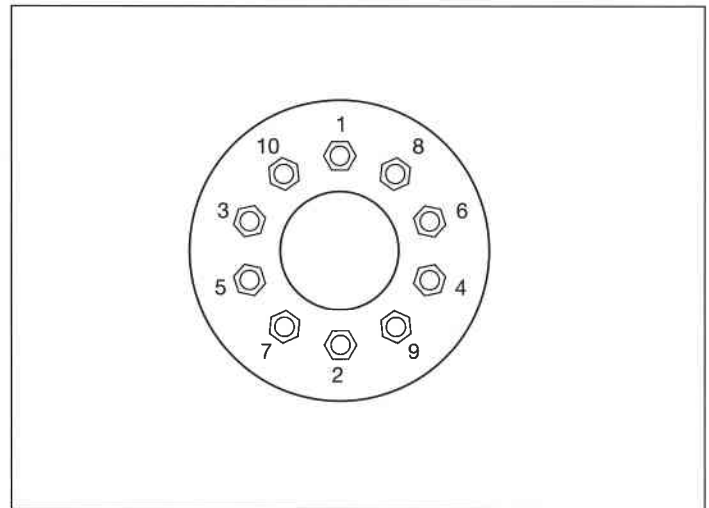


Fig. 3 Torquing Sequence (Stud and Hub Piloted Systems)

until they bottom against the hub surfaces. If this occurs, clamping force is lost. Further wheel damage can occur leading to failure and wheel separation. Second, undertorquing can lead to the elongation of the mounting holes as shown in Fig. 4 by allowing the wheel to rotate back and forth beating the sides of the mounting holes. Third, fatigue failure caused by overextended usage and/or excessive payload can cause cracking as shown in Fig. 5.

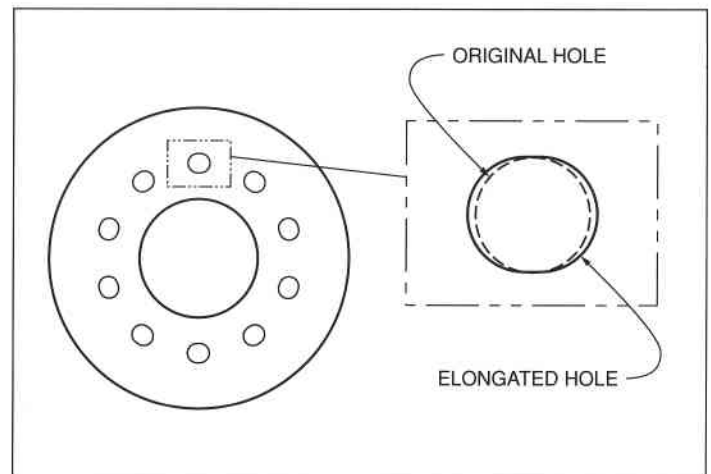


Fig. 4 Elongated Holes in Stud or Hub Piloted Wheels

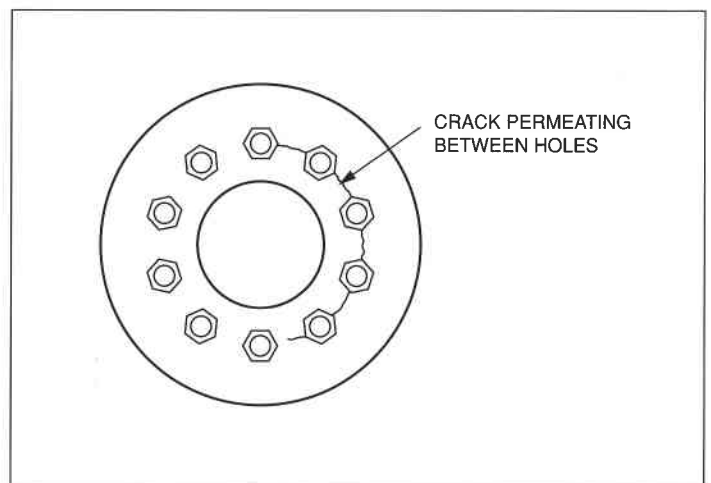


Fig. 5 Crack Permeation in Stud or Hub Piloted Wheels

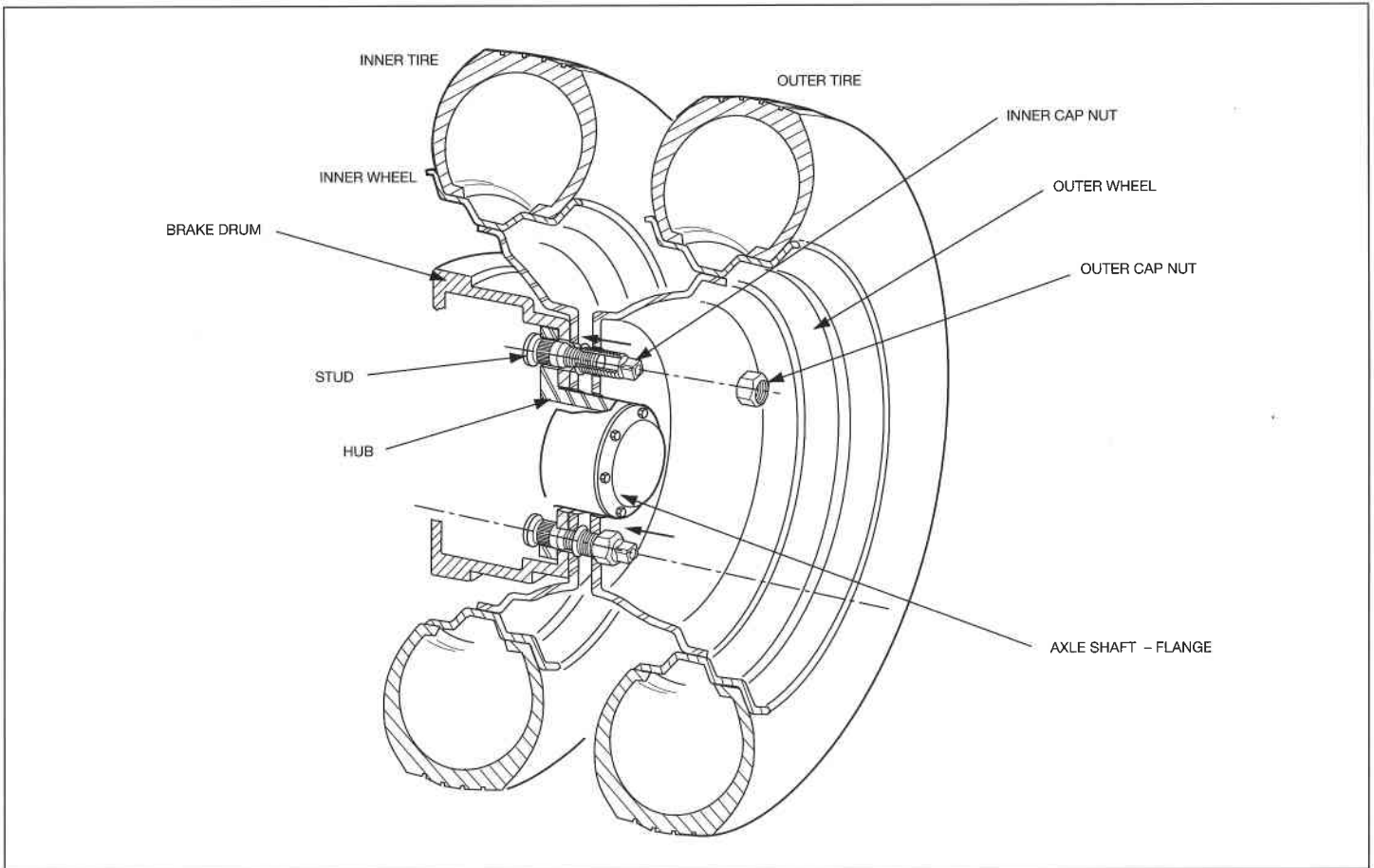


Fig. 6 Typical Dual Wheel Configuration (Stud Piloted)

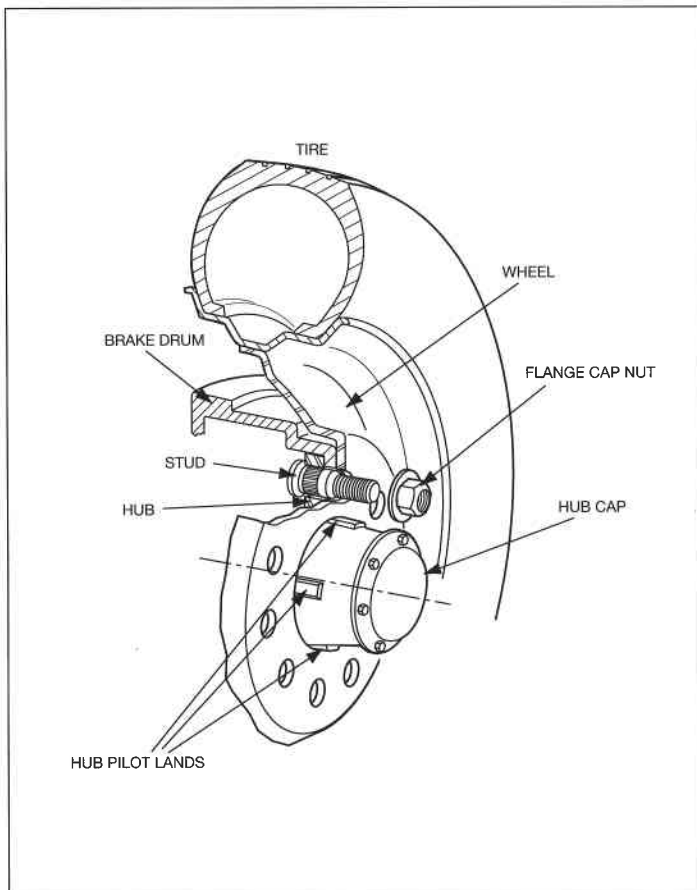


Fig. 7 Typical Single Wheel Configuration (Hub Piloted)

B. STUD PILOTED DUAL WHEEL

1. System Description

Stud piloted dual wheel systems carry all of the load on the studs. A set of inner cap nuts secures the inner wheel onto the hub as shown in Fig. 6. The outer wheel is installed over the inner cap nuts which are threaded on their outer surfaces for the purpose of attaching the outer cap nuts. The outer cap nuts screw onto the inner cap nuts securing the outer wheel onto the inner wheel.

2. Failure Modes

Wheel detachment may occur because of: loss of the outer cap nuts which leads to the loss of the outer wheel; failure of the inner cap nuts which leads to the loss of the outer wheel (if the failure involves the separation of the inner cap nut and the stud, both wheels can be lost.); or failure of the stud which leads to the loss of both wheels. Wheel detachment may also occur due to failure of a wheel disc. Obviously, all nuts must be properly torqued and sequenced; tightening the outer cap nuts will not ensure properly torqued inner cap nuts.

C. HUB-PILOTED SINGLE WHEEL

1. System Description

The hub-piloted single wheel system illustrated in Fig. 7, bears all of the wheel load onto the hub. Specifically, the hub pilot lands act as the load bearing elements. Single flanged cap nuts are used to secure the wheel to the hub.

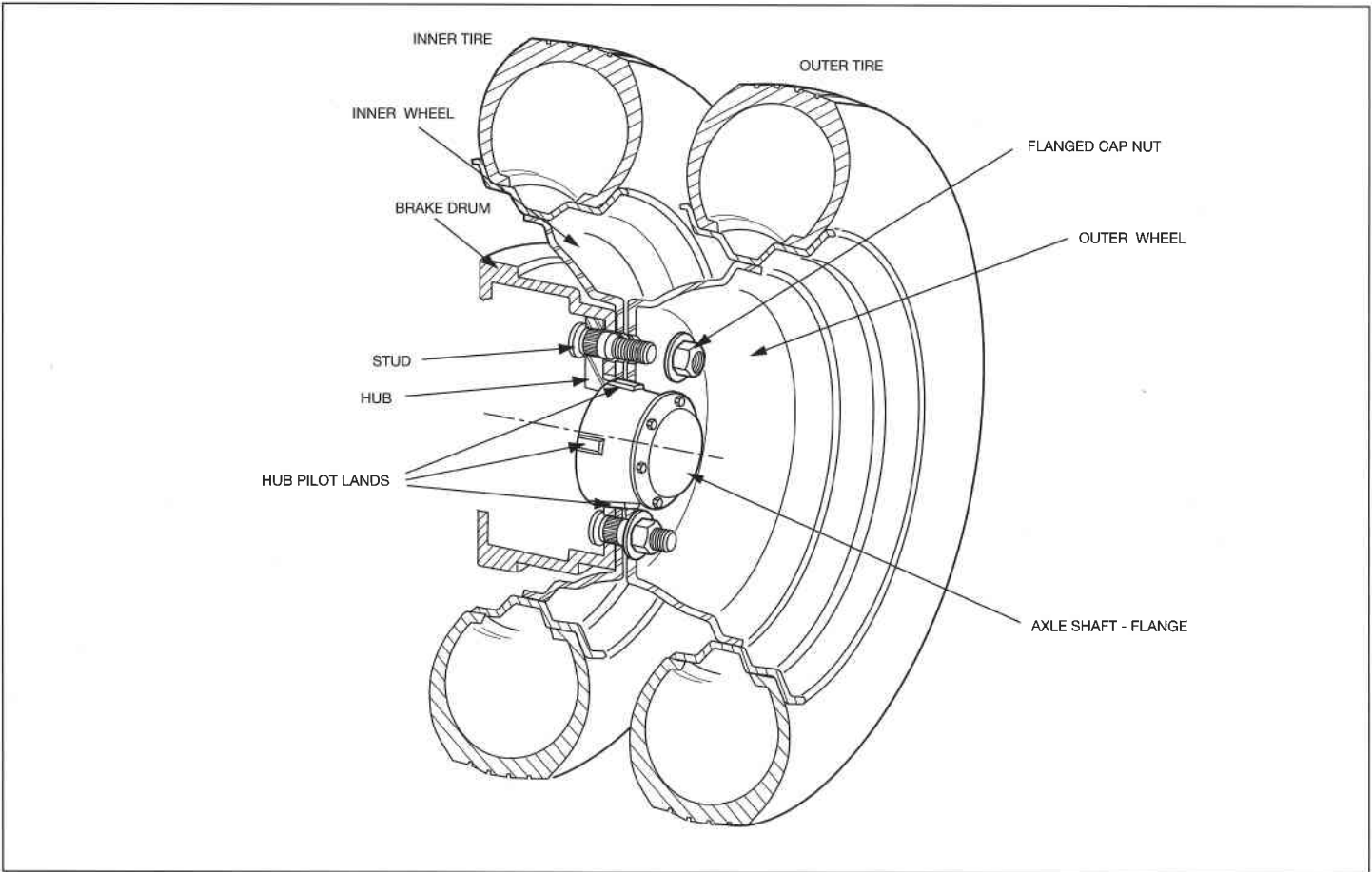


Fig. 8 Typical Dual Wheel Configuration (Hub Piloted)

2. Failure Modes

The dominant causes of single wheel detachments are loss of flange nuts and stud failure. Insufficient torque, overtorquing, improper torquing sequence and improper seating of the wheels on the hubs, all produce the detachment modes.

D. HUB-PILOTED DUAL WHEEL

1. System Description

With a hub-piloted dual wheel system, the load is transferred to the wheel through the hub pilot lands. Single flange nuts are used for wheel securement; both the inner and outer wheels are placed over the rear studs mounted to the hub as shown in Fig. 8. This system uses fewer parts for wheel

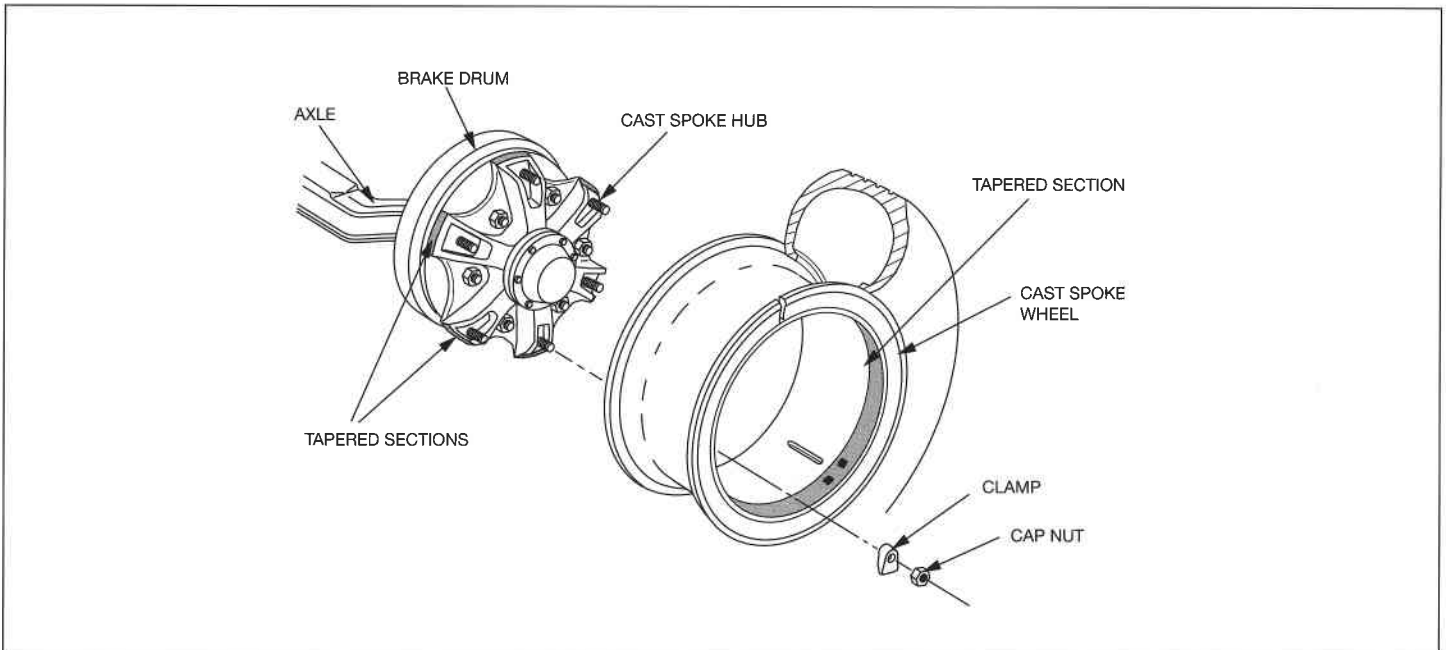


Fig. 9 Demountable (Cast Spoke) Single Wheel

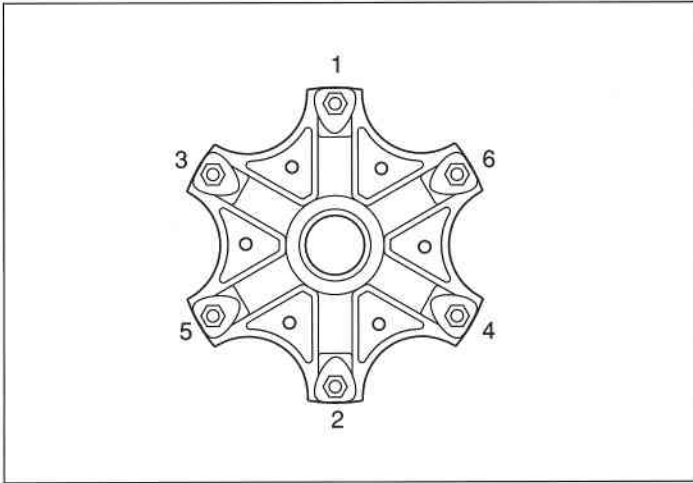


Fig. 10 Torque Sequence (Cast Spoke System)

securement than a stud piloted system. This translates into reduced system complexity and slightly less truck weight.

2. Failure Modes

Wheel detachment will occur when the flanged cap nuts come off. If they come loose, both wheels will begin to vibrate creating elongated mounting holes (Fig. 4) and crack permeation (Fig. 5) of the wheel disc.

E. DEMOUNTABLE RIMS (CAST SPOKE) SINGLE WHEEL

1. System Description

The cast spoke single wheel system illustrated in Fig. 9, bears all of the wheel load onto the spokes. Clamps are used to secure the wheel to the cast spoke hub along with typical cap nuts.

2. Failure Modes

Detachment will occur when the cap nuts loosen. The wheel will slip and vibrate and may cause failure of the studs or cracking of the cast spoke which will free a stud(s). Either of these will cause the wheel rim to detach from the hub. During installation, the proper torquing sequence must be followed (Fig. 10). A proper torque sequence assures that the wheel rim is flat against the hub and also develops uniform preload to each cap nut.

F. DEMOUNTABLE RIMS (CAST SPOKE) DUAL WHEEL

1. System Description

The cast spoke dual wheel is illustrated in Fig. 11. As with the single wheel, the wheel load is transferred to the cast spoke hub. The inner wheel is placed over the hub and is pushed on until it bottoms against a tapered hub boss. A spacer ring, is then placed in front of the inner wheel. Finally, the outer wheel is placed over the hub bottoming against the spacer ring. This entire group of components is secured with clamps and cap nuts.

2. Failure Modes

Detachments occur in ways similar to those described for the single wheel – loss of flange nuts and stud failure caused by overtorquing, undertorquing, improper torquing sequence and improper seating of the wheels on the hub. Additionally, if the spacer ring is collapsed or untrue, a loose condition may occur creating vibration and potential component failures.

IV. REMARKS

A. Some wheel detachments are associated with mismatched fasteners. For example, special cap nuts designed for use

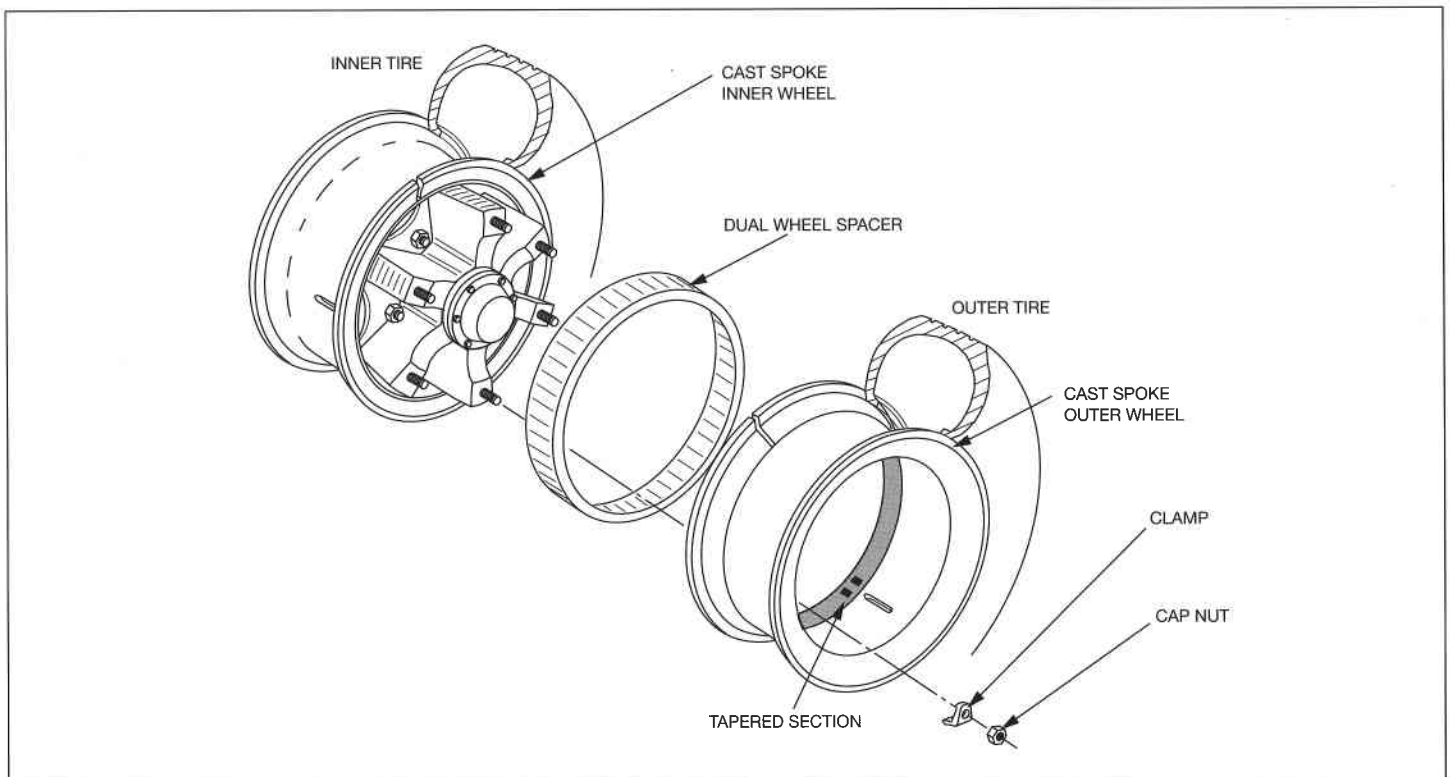


Fig. 11 Demountable (Cast Spoke) Dual Wheel

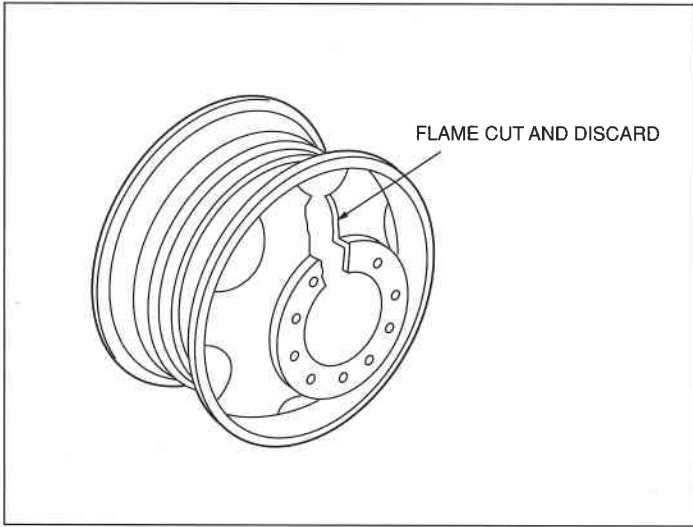


Fig. 12 Typical Stud or Hub Piloted Wheel - Flame Cut

with aluminum wheels cannot be replaced by tapered cap nuts used to secure steel wheels. Correct mounting hardware is specified in related manuals.

B. Torque settings on pneumatic wrenches which are appropriate for some wheel systems will over - or undertorque others. A hand operated torque wrench can be used to verify that proper cap nut torque is being applied.

C. Proper preparation of the wheel is vital. All metal burrs, rust, paint and scale should be removed from the wheel disc and the hub mating surface. These foreign materials may compress during the operation of the wheel and consequently, reduce the preload introduced during the original torquing process thus loosening the connection.

D. Damaged wheels must be removed from vehicles immediately and destroyed. Flame cutting wheels as shown in Fig. 12, ensures that wheels never again enter into service.

E. Some operators choose to use chrome cap nut covers for aesthetic reasons. Proper inspection may require removal of these decorative covers because they can hide the condition of the stud threads, the position of the cap nut against the wheel disc and any elongation of the wheel mounting holes.

F. Not all wheel detachment accidents occur on the road; some occur in the shop. A popular trick for removing an outside dual wheel on a stud piloted system involves driving the vehicle's inner wheel onto a block of wood. This elevates the outside wheel without the use of jacks or jack stands. If the same technique is used with hub piloted wheels, a dangerous condition is created. Here, once the flange nuts are removed, the entire wheel has an escape geometry which leads to detachment and collapse.

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