"Fastener Troubles, Causes & Solutions" Series

Tire Falling Accident of Large Vehicles- Overview of the Accident & Fastening of Dual-wheel Structure(Part 1)

by Toshimichi Fukuoka

1 · Introduction

Vehicles are categorized into passenger cars, mainly used for transporting people, small commercial vehicles, trucks and buses. Among them, trucks and buses are called large vehicles, in which large loads exert on their tires that support the heavy weight of luggage and a large number of people along with its own weight. In this case, cyclic loads exert on the wheels attached to tires as the wheels rotate. The wheels are installed with special threaded parts on the portion called hub located at the ends of the shafts. Due to the structure stated above, should the wheel bolts break apart, the tires will fall off and smash into the following cars, leading to critical accidents. Targeting tire falling accidents of large vehicles, this article will give an overview of the accidents and explain the fastening process of wheel bolts, the mechanism leading to rupture and its countermeasures.

2 · Overview of the Tire Falling Accident

In April, 2008, on Tomei Expressway, which is the most important expressway in Japan for mass transportation, the rear wheel of a large vehicle running on the opposite lane fell off and its tire flew into the front glass of an oncoming sightseeing bus, causing a serious accident. Multiple accidents of the falling-off of large vehicle tires have occurred before this one, but the media did not cover them as long as they did not involve human casualties. Since the tire falling accident of large vehicles is not predictable as to its occurring time and place, it becomes a big social issue threatening the safety of citizens. According to statistics, the tire falling accidents mostly starts at rear wheels, two thirds of which start from left rear wheels.

The main reason for tire falling-off is the fatigue failure of threaded parts that are used to install wheels on the hubs located at the ends of the shafts, as shown in Figure 1. As the root cause, it is recognized that JIS (Japanese Industrial Standards) type large vehicles have a dual-wheel structure on the rear wheels and a special type of threaded parts called wheel bolts is used to fasten the wheels in two steps— the inner wheel first and then the outer wheel. So far, when fastening wheel bolts, it was common to use impact wrenches having high operability because a large number of bolts are involved. However, as tire falling accidents became an issue, the use of torque wrench is strongly demanded in order to fasten with prescribed torque. On the other hand, as the rear wheel structure of large vehicles is complex, it is impossible to say that the expression between torque and axial force and an appropriate guideline for 2-step fastening are well-established. Further, because the problems involved in JIS type large vehicles are revealed, those manufactured after 2008 use 10 wheel bolts (2 bolts more than JIS type) and fasten inner and outer wheels simultaneously in conformity to ISO standard. It is expected that tire falling accidents disappear with the change in fastening methods. However, excluding Germany, American and European countries, which have been adopting ISO type, still face quite a large number of similar accidents. Additionally, since large vehicles are mostly used for a longer time compared to passenger cars, it is an important task to clarify the cause of tire falling accidents of JIS type large vehicles and establish its countermeasures.

Figure 1

3 · Structure of the Bolted Joint & Fastening Methods & Fatigue Failure of Threaded Parts

Figure 2 shows the rear wheel structure of a large vehicle, fastening procedure and the shape of threaded parts used there. The inner and outer wheels are fastened in 2 steps using threaded parts especially designed for large vehicles, which are composed of wheel bolts, inner nuts and outer nuts. Among them, the inner nuts are the threaded parts that characterize the fastening method of large vehicle wheels. M20 and M30 threads are machined, respectively, on the inner and outer side of the portion shaped like a temple bell. In the inner wheel fastening step, the inner nut acts like "female threads", and when fastening outer wheels, it acts like "male threads". The seat shapes of the inner and outer nuts are spherical with small area. Figure 3 shows the structure around the bolted joint at the time when the fastening process of outer and inner wheels is completed. Although the standard number of bolts used for JIS type is 8, wheels with shorter diameters are fastened with 6 bolts. Here, we will deal with wheels fastened with 8 bolts, which are mostly adopted in large vehicles. Shown below is the fastening procedure of rear wheels corresponding to Figure 2.

(1) Insert the wheel bolt sticking out of the hub into the bolt hole of the inner wheel.

(2) Install the inner nut to the wheel bolt, and apply torque on the upper square prism-shaped portion and fasten the inner wheel onto the hub.

(3) Insert the outer wheel, and install the outer nut to the male threads machined on the outer side of the inner nut, and apply torque to fasten.

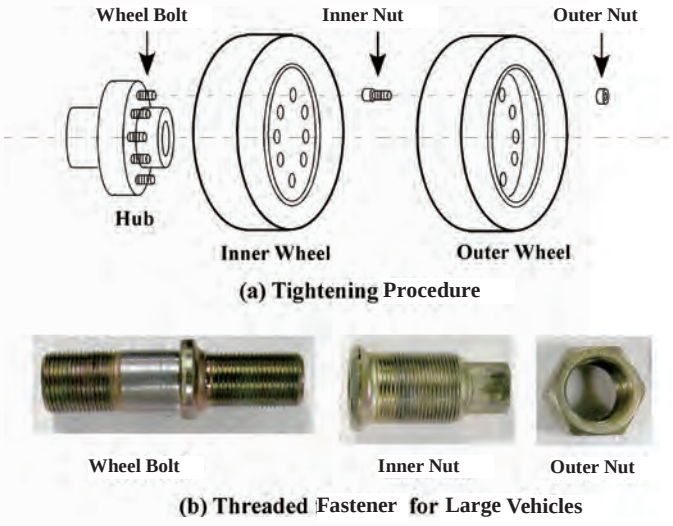

Figure 2

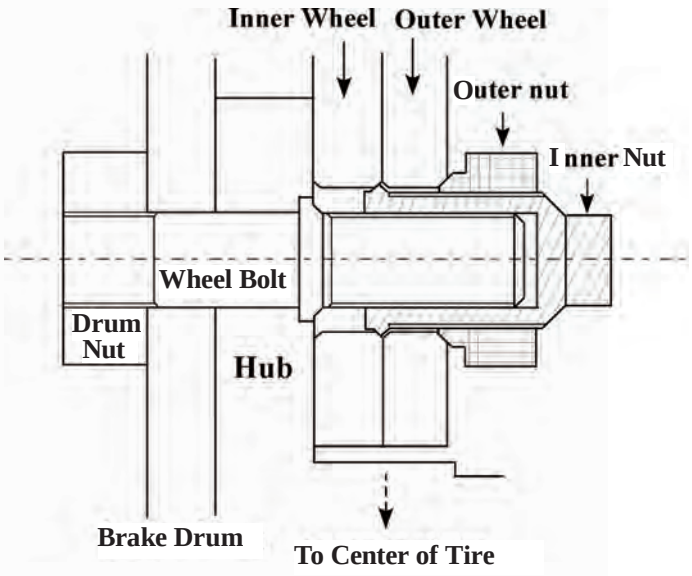

Figure 3

As shown in Figure 2, the rear wheels of a large vehicle are fastened in two steps, one for the inner wheel and the other for the outer one. In each case, the fastening torque is specified as about 600Nm. Next, let's look at the number of times of bolt fastening. In the case of front wheels with a single-wheel structure, the fastening times are equal to the number of bolts; on the rear wheels with a dual-wheel structure, the fastening times become twice the number of bolts. Hence, in the case of the minimal composition of one shaft in the front wheel (single-wheel structure) and two shafts in the rear wheel (dual-wheel structure), a total of 80 times of fastening is required. The case of 3 shafts in the rear wheels needs 112 times of fastening. Thus, the fact that large vehicles significantly require larger number of fastening operations, comparing to passenger cars, is also one of the reasons for tire falling accidents.

Tire falling accidents mostly occur on the rear wheels, two thirds of which being on the left rear wheel. The reason is partly because Japan adopts left-side traffic. Figure 4 shows the examples of the rupture of wheel bolts and inner nuts. Referring to the bolted joint structure shown in Figure 3, in either case, the rupture occurs around the "first thread root" nearest to the nut's seating surface, as well as ordinary bolts and nuts.

4 · Recommended Fastening Torque Value & Fastening Method

Formerly, the recommended fastening torque value for wheel bolt is about 400Nm, and then tire falling accidents became a social issue and the value was revised to 600Nm, 1.5 times the former value. The axial force should be as high as possible to increase the fatigue strength of bolts, as long as there is no problem in static strength. More detail is explained in my previous 9th article in Fastener World Magazine. However, 600Nm is a considerably large torque value. A recommended standard torque wrench has an arm length of 1.2m and weighs 72N. Dividing 600Nm by 1.2m, the force that the operator applies to the torque wrench is found to be 500N, which might be generated only by a sturdy grown man. To cope with this problem, some company develops a torque wrench that reduces the fastening torque to 200Nm by utilizing simple principles of mechanics. However, since the required amount of work remains the same, it needs 3 times the rotation angle of a standard torque wrench. In any case, it is substantially impossible to fasten, say, a total of 80 bolts by hand. That may be the reason why an impact wrench is used considering the operability. Meanwhile, large vehicles running on cold areas in winter need to conduct tire replacement between standard tires and winter ones. Therefore, they require tire exchange twice a year. Such exchange may cause the deviation in axial force of the wheel bolt from the appropriate value, which also possibly increases the probability of accidents.

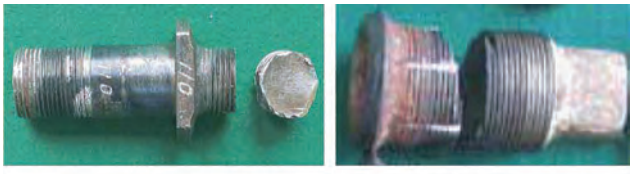

Figure 4

5 · Conclusion

With proper and correct fastening of wheel bolts, the probability of tire falling accidents of large vehicles will be extremely low. However, large vehicles usually run a long distance while bearing huge loads, and the total distance they run a year is very long, so such a heavy use of large vehicles may increase the probability of troubles occurring around the bolted joints. In my next article, I will explain the fastening characteristics inherent in wheel bolts and the mechanism that leads to fatigue failure. ■

Reference

1 · Toshimichi Fukuoka, "Threaded Fasteners for Engineers and Design – Solid Mechanics and Numerical Analysis –", pp.264-280, Corona Publishing Co., Ltd. (2015)