When the Wheel is Faster than the Vehicle

by Jozef Dominik www.ferodom.com

The statement *in the title could sound absurdly to the reader. How is it possible that the wheel can move faster than the automobile to which it belongs? But still, these cases really occur and they are not so unusual. Nearly 70% of the asked drivers at the age of thirty to seventy during their driving experience had some experiences with loosened fasteners, respectively with the wheel nuts of cars or lorries. 48% respondents stated that one or more nuts were missing after finishing the drive. Recorded were also worse cases, unfortunately, with tragic consequences. The rolling wheel cannot only destroy but also kill.*

Introduction

The National Transportation Safety Board states that in the USA the truck crashes happen to approximately 1000 trucks just because of loosened wheel nuts which are ca. 3 crashes per a day. According to the United Kingdom Department of Transport from 2006 in the UK there were about 400 crashes per a year, from these cases on average 7 ended tragically.

Is it many or few? In any case, it is enough for that to pay increased attention to this issue. Especially during winter operation, immediately after the tyre change because there is a latent risk of loosening nuts and wheels consecutively. Therefore, it is necessary to ask: "Do I have correctly mounted and sufficiently secured wheels against self-loosening on my vehicle? Are there reliable ways of bolted joints securing that could exclude similar cases?" The answer is not simple. This contribution is determined to help you understand the context of the issue.

Theoretical Analysis of the Issue

Even on pages of the various professional magazines it has been highlighted that the frequent cause of bolted joints fail is their spontaneous self-loosing during the operation. The cause is on the side of vibrations and cyclical loading of responsible structural nodes. If transversal force FT fulfils the condition:

FT > FV.μ,

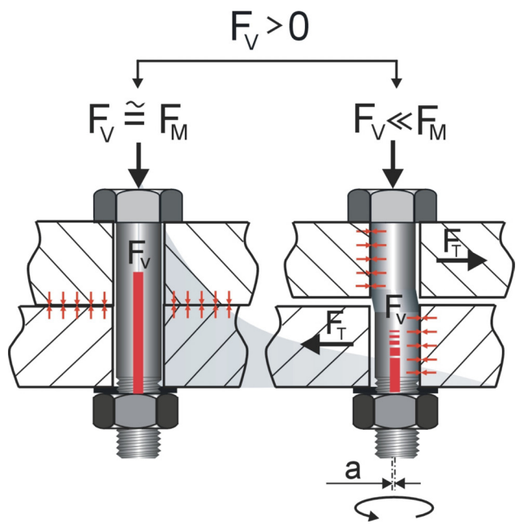


Fig. 1 Loosening of bolted joints (F_M – montage force, F_V – clamp force, F_T – transversal force, a – amplitude)

when μ is a friction coefficient, then it comes to the relative movement in partition lines, to the loss of the joint self-locking and progressively towards its total decay or fatigue fracture occurs. The decrease of bolted joint clamp force to zero is the side effect (Fig. 1) which is, e.g. for automobiles accompanied by depletion of holes for fasteners on wheels disks. This is very dangerous because there is a danger of progressive self-loosening of all the nuts/screws and the wheel could fall off during the operation and besides such disks are no more usable, even though there are some "trumps" who can cope with that - they bore new holes in the interpositions (Fig. 2) and let's drive again. No comment!

Fig. 2 The worn out original holes on the wheel disks and new holes bored amateurishly

The process of self-loosening has 3 known phases – the decrease of pre-stress caused by seating on the contact surfaces, self-loosened spinning and the decay. Generally, it is dependent on:

- **1.** The microplastic deformation of the material on the contact surfaces under the screw head and nut, between fastened parts and in the thread.
- **2.** The size, direction, sense, frequency and the time of the interaction of the variable operating forces and vibrations.
- **3.** The friction coefficient on the boundary of the contact surfaces.
- **4.** The surface stress, determined by the strength of the fastened parts, the size of assembly clamp force and seating surface.
- **5.** The number of partition lines and temperature influences.
- **6.** The screw grip length.

In the case of the automobile wheels the following specific factors have the influence on self-loosening of bolted joints:

- **1.** vehicle overload,
- **2.** damaged threads and damaged and contaminated contact surfaces,
- **3.** wheel bearings overheating,
- **4.** poor road conditions,
- **5.** different heat expansion of the joint components,
- **6.** intensive wheel vibrations,
- **7.** low hardness of bolts and nuts,
- **8.** nuts or bolt threads out of specification,
- **9.** too much interfaces,
- **10.** incorrect installation/assembly.

Fig. 3 The bent wheel fasteners of overloaded vehicle

Vehicle overload (carrying extra weight)
This is a very dangerous factor. Besides, it could cause the destruction of carrying construction automobile components, it disrupts drastically the geometry of bolted joints (Fig. 3), relatively quickly wears off the holes for fasteners (Fig. 2) and it sequentially causes the wheel fall off. Preventive measures are simple, they consist in respecting prescribed loading capacity. It is not only connected to lorries/trucks but also to cars for which zero tolerance should be valid this way.

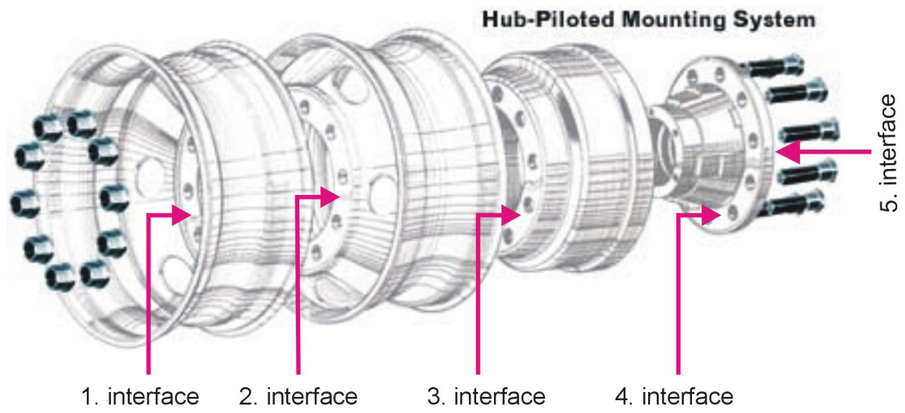
The damaged threads and damaged and contaminated contact surfaces
The threads are most often damaged by repeated wheel assembly, by careless handling with assembly tools or by other inappropriate mechanical actions. As well as damaged also contaminated contact surfaces are the source of the pre-stress loss. The relevant preventive measures consist in replacing damaged screws with new ones and in proper treating of the contact surfaces.

Wheel bearings overheating
There are several possible causes of wheel bearings overheating. The vehicle overload could be one of them. At that time the half-shaft perpendicularity of front and rear axle towards bearing could be damaged. The formation of pitting on bearing's swing, mechanical contamination, lack of lubricant and others could have the same effects such as overheating and the heat diffusion on other construction components including screws. Similarly, incorrectly adjusted brakes could have a negative influence. Therefore, regular bearings and brakes check should be natural, of course, not only because of above mentioned reason.

Poor road conditions
The potholes on the roads, the cracks, the furrows and other surface roughness of the roads cause, especially at high speed drive, inappropriate vibrations which could, together with unbalanced wheels, inauspiciously affect the stability of bolted joints and could equally cause the wheels loosening. The preventive measures include the control of wheels balance after every single change of tyres and the avoiding frequent drives on "racing circuits" which is usual after finishing winter period. If necessary, drive slowly.

Low hardness of bolts and nuts
There predominates a principle that the nut should be identically strong or rather one degree stronger than the screw to which it is mounted. The reason is very pragmatic. The internal thread is produced by turning resulting to the interruption of steel fibre by which the strength is reduced. The strength class has to be marked on each nut and screw with a visible mark. For instance, the screw with the strength 8.8 (tensile strength 800N/mm2 and yield strength 640N/mm2) should be paired with the nut of strength class 8 (strength 800N/mm2) or class 10 (strength 1000N/mm2), never with the nut with a lower strength class than the screw has. Otherwise, the extraction of the nut thread could occur.

Fig. 4 Example of double wheel mounting system (www.bridgestonetrucktires.com)



Number of interfaces
The higher number of contact surfaces the higher risks of the assembly force decrease of the bolted joints. Every interface absorbs humidity from the atmosphere which causes the corrosion and besides that the higher number of interfaces the total seating of material rises followed by the pre-stress decrease (see Table below). The example of double truck/lorry wheel fastening is shown within Figure 4. As it is clear from the figure, presented hub-piloted mounting system has together 5 interfaces and if we figure the interfaces between external and internal thread in, we have 6 of them. Then it is much more important to check the condition of bolted joints regularly, especially after reassembly of wheels, e.g after changing tyres for winter period. Removing mechanical contamination, corrosion, oil, etc. from contact surfaces is necessary to take for granted.

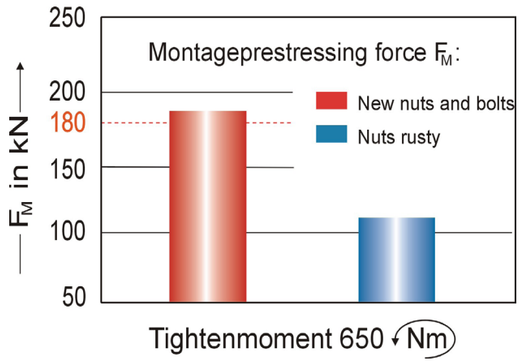


Fig. 5 The differences of tightening new and corroded screws

Incorrect installation
Correctly dimensioned, exactly tighten bolted joints are the general condition of a safe drive. Insufficient pre-stress could cause relatively quick loosening of bolted joints and on the other hand when they are tighten with too high torque moment, there is a danger of the destruction by fracture or thread extraction. Both are very dangerous because it could end with falling off the wheel during the drive. The preventive measures consist in controlled tightening with the help of torque wrench with correctly adjusted torque moment. Mainly in the case of amateurish assembly, e.g. after a tyre puncture on the road it is recommended to check wheels in an authorized garage as soon as possible. In connection with the wheels assembly it is important to highlight the importance of friction among threads and under nut and under head of the screw. As it is generally known, dominant part of the torque moment is consumed to overcome friction and only a small share is used for the screw pre-stress. It is documented in Figure 6 from which it is clear different resulting prestressing force FM when applying new or corroded screws or nuts. At constant tightening moment 650 Nm, the new screws are tightened to more than 180 kN while the corroded are tightened to only 100 Nm.

Interface	Stress: tensile – pressure Surface roughness R_Z [mm]		
	£ 10	10 - 40	³ 40
Under head	2,5	3	4
Under nut	1,5	2	3
Between parts	2,5	3	4
In threads	3	3	3

Table: The size of seating [mm] on different partition lines

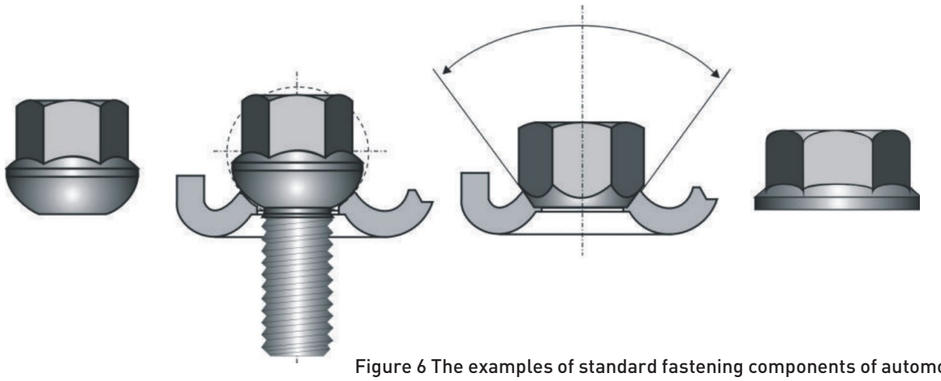
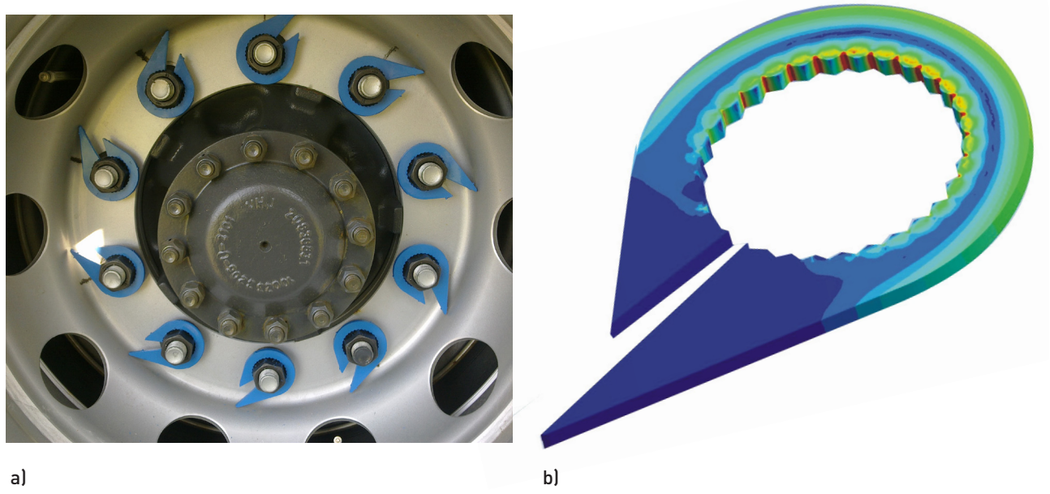


Figure 6 The examples of standard fastening components of automobile wheels

Current state and above-standard solutions

The automobiles producers try to solve the problems with loosening screws with the increase of the friction coefficient on the contact surfaces by the choice of ball or cone seating, or rather by nuts with integrated flange (Fig. 6). Such solutions are usually satisfying and the drivers do not have to be worried, that the wheel will fall off. However, it is worse after several tyre changes in the garage or amateurishly or provisionally on the road. The experience indicates that critical phase is after driving first ca. 50 to 100 km. The professional garages this fact also mention within the bill/invoice. By that the responsibility is determined but the problem itself is not solved at all. Especially, when we know that most drivers are negligent and ignore this fact and therefore it would be required to take extra preventive measures which would principally solve the safety of the drive.

The term above-standard locking, for these purposes, means such preventive measures which are beyond the original construction of the given automobile producer. The current market offers several of these solutions. For example in Canada, there are the time-proven position indicators



a) b)

Fig. 7 Safety locks TaTrim on the wheel (a) of Renault vehicle and the stress distribution (b)

of the nuts "wheel check" used for trucks and buses, which are not locking anything but they provide the visual information on a partial turn of the nut, respectively the screw. Similar systems are known also in a version with integrated plastic cover. Here, it is necessary to remind the treacherousness of any nuts covers because they do not only fulfil the safety function against corrosion but also through the leaks, especially at cracked covers, they absorb humidity and dust and help the corrosive processes, which are not checked, because they are invisible. The nuts with the flexible flange with implemented pair of wedge washers and many others are also well-known. They are mainly based on using higher friction on the contact surfaces. Recently, the new plastic safety locks of wheels TaTrim have appeared (Fig. 7), their advantages are simple assembly and the ability to lock effectively bolted joints independently of the friction and size of torque moment. It is sufficient to mount them manually on tightened commercial nut or the head of the nut and to prop to the nearest support by a longer arm, e.g. to rim offset. A clamp effect of the safety lock prevents reliably from its falling off during the drive.

There are many other non-standard ways of locking automobiles wheels. Paradoxically, corroded bolted joints (Fig. 8) present one of the most effective locking methods. As seen, nature can help itself without any intervention of a man. The American Navy has supposedly patented method of the artificial corrosion process acceleration in order to lock screws against loosening just before dropping the ship on the sea but there is no word about possible problems with disassembly while servicing. Equally the drivers have to keep in mind possible problems with corroded screws when changing tyres because not always a popular "extension arm" helps.

Fig. 8 Corroded bolted joints

Conclusion

The bolted joints of automobiles present significant safety risk. The incorrect assembly and disrespecting the principles of their behaviour during the operation could be dangerous not only for the crew of the incriminated vehicle but also for the unsuspecting surroundings. It is inadvisable to be overtaken by the wheel from your own car. As it was shown, there is no need to be afraid. It is important to observe the recommended rules of the wheels assembly and do not regret the time for their continuous check. It will surely pay.

The author and the editorial staff wish all the readers a safe journey and in conclusion one appeal: Share your own experience with loosened automobile screws with Fastener World. Contribute this way to the increased safety on the roads because it will be the source of the instruction for the others.

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