# Towards Studded Tires with Low Ultrafine Particle Emission Levels

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## 1. Introduction

During winter season, the use of studded tires is widespread in countries with winter season like the Nordic counties. However, studded tires provide better grip on ice and hard packed snow and hence reduce cost by decreasing accident rates, at the same time the studs itself increase the wear of the road surfaces. Some fraction of this wear is released in the form of airborne particulates, affecting the air quality in urban areas. In the Nordic countries Sweden, Norway and Finland, the non-exhaust PM10 (mass of particles less than 10 µm in aerodynamic diameter) vehicle emissions significantly exceed the exhaust ones due to the frequent use of studded winter tires. Further, the particle number concentrations are also of interest. Especially the size fraction below 100 nm that when inhaled enter deep into the human body are of focus. WHO has recently started to give recommendations of particle concentration levels in urban areas and has introduced recommended levels for the particle number concentrations. A stud for a studded tire consists of a core typically manufactured from aluminum, in which sits a carbide pin. The carbide pin (weight approx. 0.2–0.4 g) is made of tungsten carbide (WC-Co) containing up to 15% cobalt. Cobalt is a material that should be phased out from an environmental perspective both at the use phase as well as the manufacturing phase. Previous laboratory studies at KTH [1] show that the difference in hardness between the wear surface of the road surface and the stud material primarily affects road wear. The greater the difference in hardness, the more the road material wear. To the same degree, the number of airborne particles also increases with an increasing difference in hardness [1]. Today's cobalt-containing stud material is developed to remove rock material as well as possible during rock drilling. Alternative cobalt-free materials have been developed but so far have not reached the same rock removal capacity as those containing cobalt [2]. Cobalt was in [2] replaced with a Fe or Ni-based cemented carbide. A Ni-based cobalt free stud alternative has been evaluated in a pin on disc machine and a Izopod pendulum machine specially developed for studded tyre to road emissions [3]. Lower particle emission and wear levels was presented in [3] for the alternative stud material compared to the cobalt containing standard one. The purpose of the present study was to evaluate the ultrafine particle emission levels for the studded tire to road interface in a two-wheel test rig. This for a standard cobalt containing stud material compared to the alternative cobalt free stud material evaluated in [3].

## 2. Methodology

In this study, a test rig containing two wheels that rolls on a rotating disc was utilized [4], see Fig 1. The test machine was placed inside a clean chamber, using the same concept as in [1] to provide a clean chamber technique. At the outlet of the test chamber an HRELPI+ instrument from Decati was used to measure the particle number concentration between 6 nm and 10 µm size segregated in 500 bins. Before each test, the whole set-up was checked for zero particle concentration in the absence of friction.

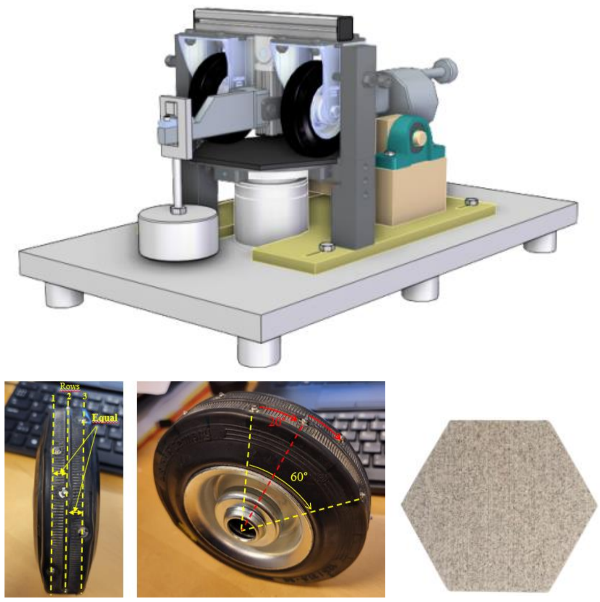


Fig 1. *Assembly of the two-wheel test rig without the sealing hood and photographs of a studded wheel and the granite road test sample.*

The road test samples (12 mm thick and 200 mm maximum testing diameter) were manufactured from granite (Bjärlövsgranit) and had one rough and one smooth surface. The sample representing a winter tyre stud was a circular stud with diameter 2.5 and length 6 mm. Two stud materials were evaluated in this study. The original stud material was based on a 12Co88W content. In the alternative stud materials, 85Ni15Fe is the substitute of Co with the same content of tungsten. Note that the studs are from the same material batches as previously tested in [3]. The wheels were studded by

Däckproffsen AB. And the used wheels had a diameter of 125 mm and a thread hardness of 65 Shore A, which is in the range of car tyre hardness. The test plan is summarized in Table 1 and contained a running in phase of the road test samples with unstudded tyres followed by testing with studded tyres tests. Each studded tyre wheel pair was tested on 4 road materials (2 rough and 2 smooth) as presented in Table1. The load was 60 N per wheel and the speed was set to 10 and 5 km/h. Both speeds were tested on both the rough and smooth road surfaces.

Table 1. *Test plan with running in phase and studded tyres test phase.*

| | Running In (RI) | | Tests | | | |
|---|---|---|---|---|---|---|
| Time | 30 min | | 30 min | | | |
| Tyre | Plain | | Studded tyre 85Ni15Fe | | Studded tyre 12Co88W | |
| Purpose | Material deposit/RI plate | | Particle emission | | Particle emission | |
| PN instrumentation | - | | ELPI+ | | ELPI+ | |
| Nb of plate | 4 | | 2 | | 2 | |
| Surface type | Rough | Smooth | Rough | Smooth | Rough | Smooth |

## 3. Results

The results for the particle number concentration measurements are presented in Table 2 and in Fig 2 are photographs of the studs presented before and after test. From Table 2 one can identify that the alternative stud material (85Ni15Fe) always presented the lowest particle concentration levels independently of test conditions. This agrees with previous findings in [3]. However, in [3] was an optical particle counter used that had the size range of 0.3 – 10 µm which do not include the ultrafine particle fraction that is below 0.1 µm as the HRELPI+ instrument used in this study. Noted could also be the tendencies of a running in phenomena of the studded tyres particle number concentration levels. The particle number concentration levels are lower for both Test 3 compared to Test 1 as well as for Test 2 compared to Test 4. One can also see that the ratio of the particle number concentration levels for 85Ni15Fe/12Co88W was 0.95 for test 1 and 0.65 for test 3. If one, compare Test 2 and Test 4 this rate changed from 0.89 to 0.65. This demonstrates a tendency that the 85Ni15Fe stud materials running in performance reduces the particle concentration levels. Here further studies are necessary. If one look at the studs before and after tests as presented in Fig 2 it is hard to identify any major damage mechanism on them like wear of fracture by visual inspection. Here also further studies are necessary.

Table 2. *Total particle number concentration level (no/cm$^3$) measured during 30 minutes of test with a HRELPI+ instrument.*

| Particle concentration | 85Ni15Fe | 12Co88W |
|---|---|---|
| Test 1 (rough road 1) | 5150000 | 5390000 |
| Test 2 (smooth road 1) | 370000 | 415000 |
| Test 3 (rough road 2) | 748000 | 1160000 |
| Test 4 (smooth road 2) | 217000 | 330000 |

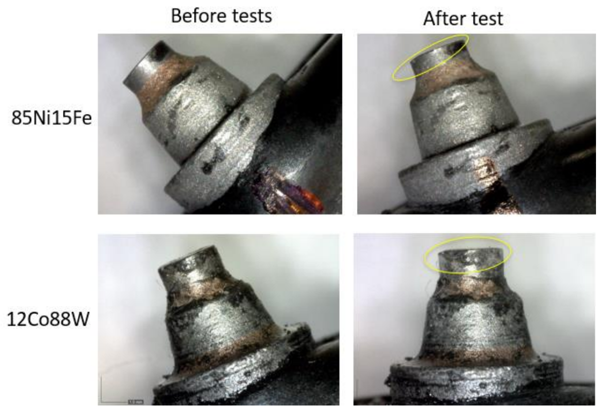


Figure 2 *Photographs of tested studs before and after test.*

## 4. Conclusions

The airborne number concentrations in the size range of 6 nm to 10 µm was significantly reduced, when using wheels with studs manufactured from the alternative 85Ni15Fe material.

## 5. Acknowledgment

Thanks to Mats Carlsson and Tomas Carlsson Däckproffsen AB for valuable discussions and assistance with the studded tires. The financial support from Trafikverket (Requirements for studs to reduce wear and particle emissions with contract no:TRV 2023/33639) is acknowledged. This research was supported by the European Commission's Horizon 2020 research and innovation programme: nPETS (grant agreement No 954377).

## 6. References

[1] Olofsson U., Tu M., Nosko O., Lyu Y., "A pin-on-disc study of airborne wear particle emissions from studded tyre on concrete road contacts", Wear Vol. 410–411, 15 September 2018, Pages 165-172

[2] Jacobson, F., "Wear and degradation of Co, Fe and Ni-based cemented carbides against sandstone and granite, M.Sc. thesis Uppsala University 2018, UPTEC Q18 013.

[3] Olofsson U., Lyu Y., Homström E., " Towards Low Particle Emission Cobalt Free Studded Tires" submitted for publication 2024.

[4] Szumin M., Redesign of a tribological pin on disc machine, Maskinkonstruktion KTH, M.Sc Thesis, TRITA-ITM-EX 2022:472