# THE HAZARDS OF DEFECTS AND POOR QUALITY OF ALUMINIUM MATERIALS

Josef FORMÁNEK, Ludmila KUČEROVÁ, Mykhailo TOCHYLIN

*University of West Bohemia in Pilsen, Univerzitni 22, 306 14 Pilsen, Czech Republic, EU, skal@kmm.zcu.cz*

**Abstract**

Various materials can be used nowadays for vehicle construction, ranging from aluminium alloys and composite materials to high strength steels. For successful utilization of Al alloys, it is advantageous to carry out calculations using FEM and computer simulation tests to verify engineering construction design. This can help to map and take advantage of the potential of the material. On the other hand, the proper observance of the manufacturing process, the chemical composition and microstructure of the selected structural material can also provide us with important information. Material purity, homogeneous chemical composition, the correct production process, technological processing etc., are decisive for the further use of the material for the construction elements of a technical device in the form of fully-functioning components with the required lifetime.

**Keywords:** Defects, poor quality, Al alloys, fracture analysis, downhill scooter

## 1. INTRODUCTION

Various materials can be used nowadays for vehicle construction, ranging from aluminium alloys and composite materials to high strength steels [1,2]. The quality of the cast, the correct production process, technological processing, etc., are crucial for the further use of the material for the construction elements of a technical device. Poor quality materials used in technical equipment can cause not only severe material damage, but they also present high safety risks for humans involved, as they can cause injury or death.

A downhill sports scooter was used to test suitability of the materials. The most stressed parts of the scooter are the front fork and the frame. Steel and aluminium alloy forks were chosen for testing. To evaluate the properties of the forks, identical parameters for load, driving routes and mileages were selected.

Al-Si alloy were used to produce the front forks for a downhill sports scooter (see Fig. 1).

**Fig. 1** The front fork of a downhill sports scooter

## 2. PREREQUISITE FOR CONSTRUCTION

Steel fork

The loaded front wheel fork withstood test modes with only slight damage – enlargement of wheel mounts (see FIG. 2). The basic software simulation verified that the supporting profile was sufficiently structurally designed, and that is why no additional material analysis was carried out.

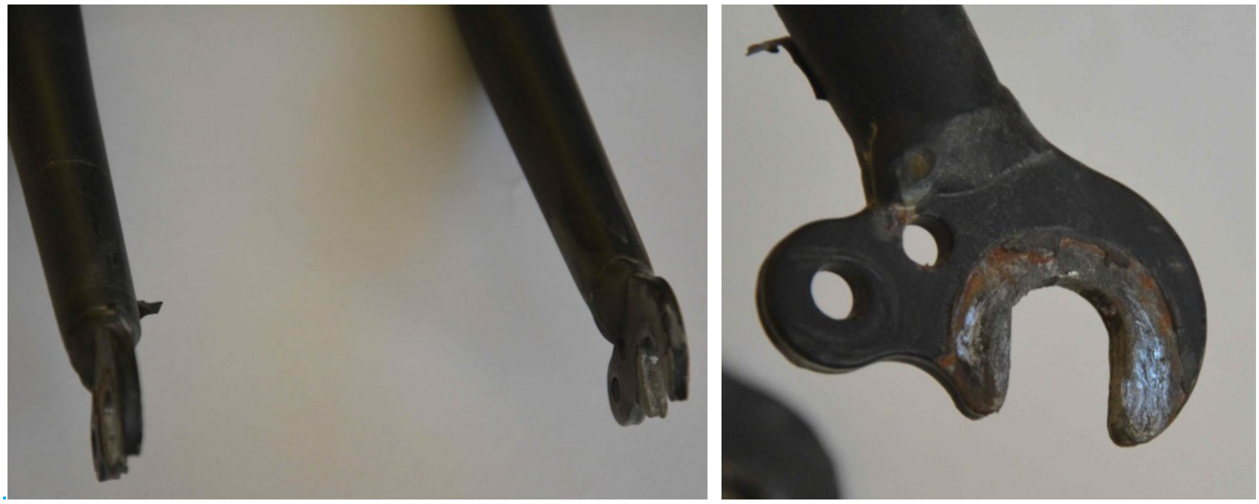


**Fig. 2** The steel front wheel mounts and detail of magnification opening handle

Al fork

Al alloys of various compositions have long been used for components of technical equipment. In this case Al-Si alloy was used to produce part of the front fork for a downhill sports scooter (see **Fig. 1**)", where any technical defects not only damage certain parts, but can also be dangerous for the safety of the rider, who can be seriously injured or even killed. The front suspension is very exposed, and it requires high-quality material composition, processed in to the final form. Technical requirements with design calculations can be taken into consideration using the finite element method (FEM) and software simulations in a PC. These methods enable us to identify and fully utilize the potential of the material. However, despite the help of advanced simulation and computational software, the quality of the final product can be achieved only when the declared material is really the material specified by the manufacturer.

The front forks have a lifetime warranty, and subsequent control simulation using FEM verified that the front forks have a real long-term durability of several tens of years. The reality was however different, this part broke after about 700 km, the damage being at the front wheel mounts. Small initialization cracks were found upon closer examination (see **Fig. 3**). According to the basic simulation in the SW, it was verified that the carrier profile was sufficiently structurally designed to bear the load and therefore we proceeded to carry out material and fracture analysis. Metallographic sections were created and examined in detail with surprising results.

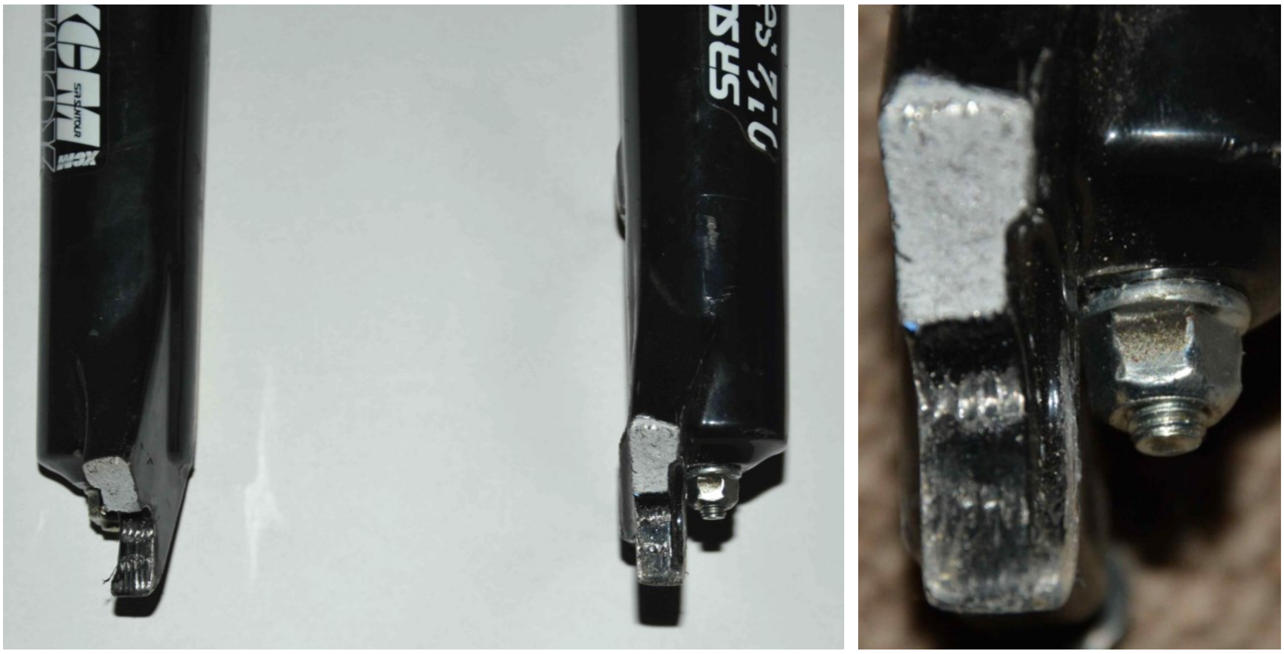


**Fig. 3** The damage to the front wheel mounts and detail of damage

## 3. MATERIAL ANALYSIS

Metallographic and fractographic analysis of the fractured part was carried out using a scanning electron microscope and a light microscope with Lucia image analysis software. The material of the fork was Al-Si alloy with about 10% silicon, further alloyed by small amounts of copper, manganese and iron. Small additions of iron (around 0.2%) are beneficial for the improvement of impact resistance and endurance limit of Al-Si alloys, as was already tested with EASA alloy [3].

### 3.1 Microstructure analysis

A metallographic sample was prepared from an area about 1cm below the fracture surface. Many pores and shrinkages of various sizes were observed at the polished surface of the sample, proving the poor quality of the material. These defects were so large that they were also visible by the naked eye, some of them reaching sizes in the range of mm (**Fig.3**).

The sample was further etched using Keller reagent to reveal the microstructure. The microstructure was dendritic and rather complex, consisting of solid solution matrix with Al-Si eutectic among them (**Fig.4- Fig. 6**). A relatively large fraction of the microstructure, about 50%, consisted of primary aluminium α-Al dendrites distributed relatively evenly in a eutectic matrix.

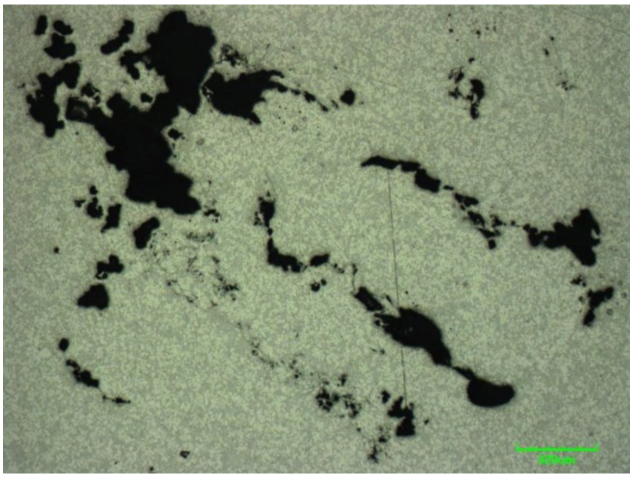


**Fig. 3** Large shrinkage in material.

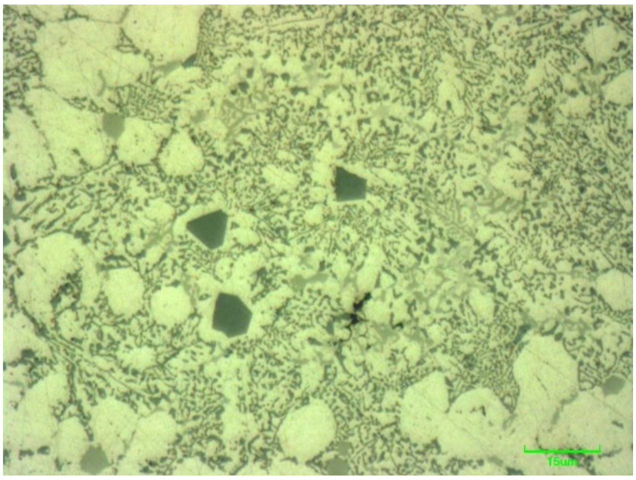


**Fig. 4** Dendritic microstructure with eutectic network and several kinds of particles.

Local chemical composition of individual structural components was established by point and linear EDX analysis. Due to the small size of some of the particles, the effect of Al-Si matrix composition influenced the obtained values and it is therefore impossible to establish the exact chemical composition of the particles.

There was a network of fine particles with higher Cu and lower Fe content along dendrite boundaries, and two kinds of larger individual particles were found inside the α-Al dendrites. Several dark sharp edged particles of primary Si were observed inside the dendritic areas and occasionally sharp edged light grey particles rich in Fe and Mn, with Fe:Mn ratio around 2:1 (**Fig.5-Fig.6**).

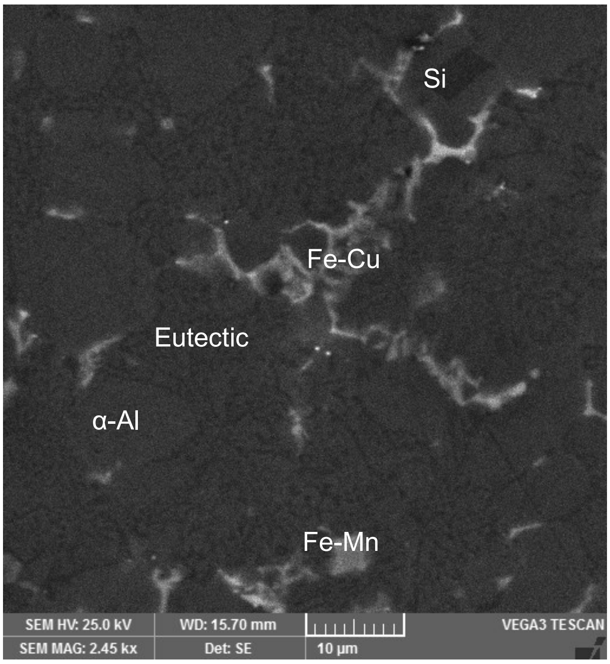



**Fig. 5** Dendritic microstructure of the fork with interdendritic eutectic network, particles at dendrite boundaries (Fe-Cu) and two kinds of larger particles inside dendritic areas (primary Si and Fe-Mn).

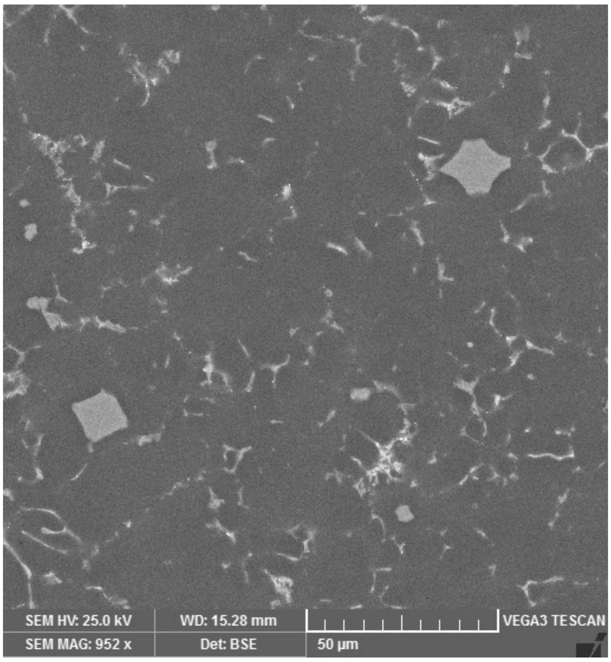
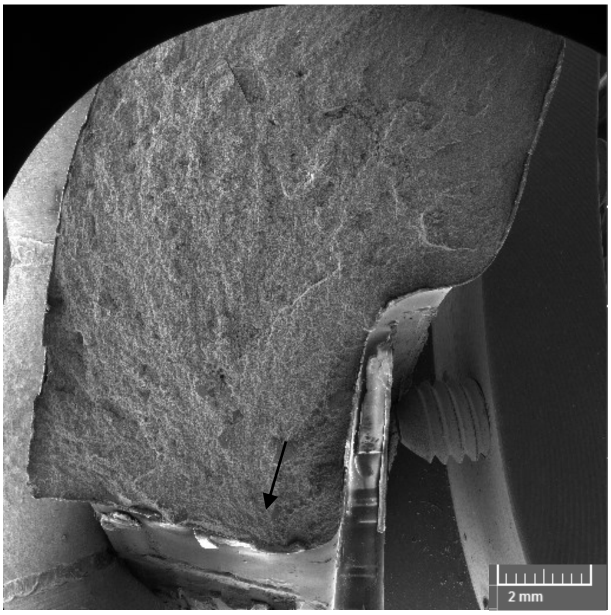



**Fig. 6** Detail of light iron-copper phase at dendrite boundaries and light iron-manganese sharp particles in BSE mode.



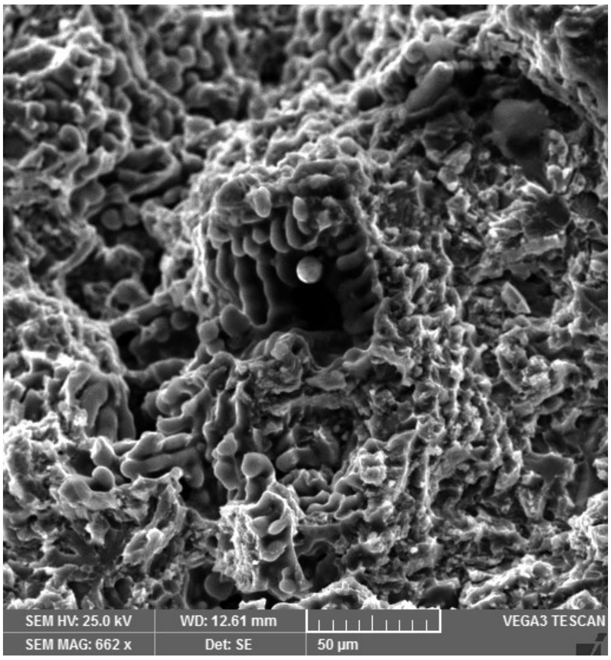




**Fig. 7** Fracture initiation area at the surface of the fork, larger shrinkages visible.

**Fig. 8** Dendrites on the fracture surface

### 3.2 Fractography

Both fracture surfaces were observed using a scanning electron microscope. The initiation of the fracture was just under the surface of the thinner part of the fork (**Fig.7**). The characteristic appearance of shrinkage casting dendrites is clearly evident and it is in agreement with the microstructure features (**Fig.8**). Brittle fracture areas, sometimes with oxidised surfaces, were observed in the shrinkages. The fracture surface between the shrinkage porosity exhibited a dimple rupture character. No evidence of progressive fatigue failure was observed anywhere on the fracture surface.

It can therefore be concluded that the dimple rupture fracture surface was the result of sudden impact, overload failure. Even though Al-Si alloy was a suitable type of material for this application and the addition of iron further improved its impact resistance and endurance limit, the presence of shrinkage and porosity resulted in significant decrease of the real cross section of the part, thus contributing to the overload of the remaining volume of material.

## 4. SUMMARY

A suitable Al-Si alloy was used for the front fork of a downhill sports scooter. Although the material was well chosen for this application and the part was properly designed, high shrinkage and porosity of the used material resulted in the premature overload failure of the fork. There has been a significant failure in the quality control of the output and input material in the manufacturing chain leading from the material producer to the semi-product supplier and finally to the fork producer.

It is very important for the successful industrial application of Al-Si alloys not only to ensure correct engineering construction design with the use of FEM calculations and computer simulation tests, but also to guarantee proper observance of the manufacturing process and the chemical composition of the chosen structural material. Only high quality materials produced by controlled procedures and technologies can satisfy the requirement of fully-functioning components with the required lifetime, without posing a threat to human health and life and material damage.

## ACKNOWLEDGEMENTS

***This paper includes results created within the project MSM-SGS-2013-050. The project is subsidised by the University of West Bohemia in Pilsen.***

## REFERENCES

[1] KUČEROVÁ, L., JIRKOVÁ, H., MAŠEK, B. The Effect of alloying on mechanical properties of advanced high strength steels, *Archives of Metallurgy and Materials*, 2014, Vol. 59, Is. 3, p.1189-1192.

[2] MAŠEK, B., et al. Improvement of Mechanical Properties of Automotive Components Using Hot Stamping With Integrated Q-P Process, *Journal of Iron and Steel Research International,* 2011, Vol. 18, p. 730-734.

[3] WANG, R., LU, W., Quality Wheels of Direct- Electrolytic Al-Si Alloy (DEASA), SAE Technical Paper 2001-01-0820, 2001, doi:10.4271/2001-01-0820.

[4] FORMÁNEK, J., CHVAL, Z. Comparing experimental measurement at machine and of his model with simulation in CAD. In *Experimental Stress Analysis 2008.* Ostrava: VŠB - Technical University, 2008. p. 63-66. ISBN: 978-80-248-1774-3