шей деформации, имеет равномерно распределенную по радиусу гомогенную структуру. Распределение размера зерна также равномерно по всему радиусу и составляет 8,5 (ASTM). Ультразвуковое исследование откованных осей показало отсутствие пор размерами более 3 мм. Так как полученные результаты являются многообещающими, в последующих экспериментах будет оптимизировано время ковки, а откованные оси будут подвергнуты заключительной обработке для окончательного анализа в соответствии с железнодорожными стандартами.

MICROSTRUCTURE ANALYSIS OF RAILWAY AXLES FORGED ON A HYDRAULIC RADIAL FORGING MACHINE TYPE SMX

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Introduction and motivation

Due to the high level of investment needed in countries such as e.g. Europe and Asia, there is an increasing demand for machines for the manufacture of rails, railway wheels and railway axles. At the moment railway axles are in most cases forged in a series of different forming processes. In an initial rolling process for example possible defects in the starting material are closed in order to get a homogenous microstructure. In a subsequent forging process, due to the low depth penetration capacity of the plants used, only the contouring of the axle is carried out.

This publication shows that using the SMX hydraulic radial forging machine from SMS Meer it is possible to produce railway axles in a single forming process. This means that pore-free railway axles with an excellent microstructure can be produced from conventional continuous cast material without any upstream rolling process being required. The high forming potential of the hydraulic radial forging machine makes this possible.

Plant and material

The railway axles were forged on the hydraulic radial forging machine, type SMX. Characteristic of the hydraulic plant concept is the application of the maximum forging force over the entire stroke, which results in excellent forging right through to the core zone of the workpiece.

Continuous cast grade C45 carbon steel with an initial diameter of 410 mm as per Table 1 was used as starting material.

Prior to forging, an ultrasonic analysis of the starting material was carried out in order to detect defects such as pores. In all of the ingots, axially distributed pores with a diameter of between 3 and 4.5 mm were discovered in the centre of the ingot.

Table 1. **Chemical composition of the C45 starting material**

0,47	0,68	0,27	0,015	0,02	0,14	0,03	1,4 ppm	0,0031	0,016

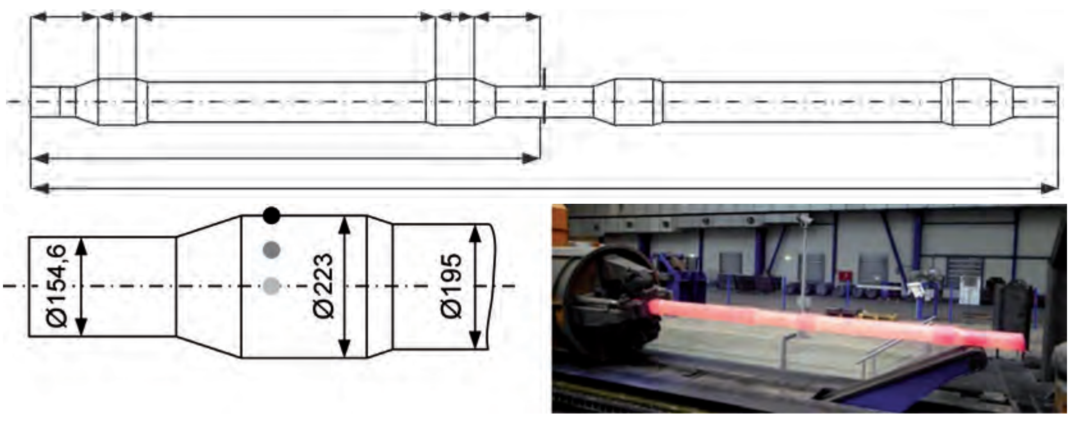

Fig. 1. Twin axle: Geometry with analysis positions and forged twin axle

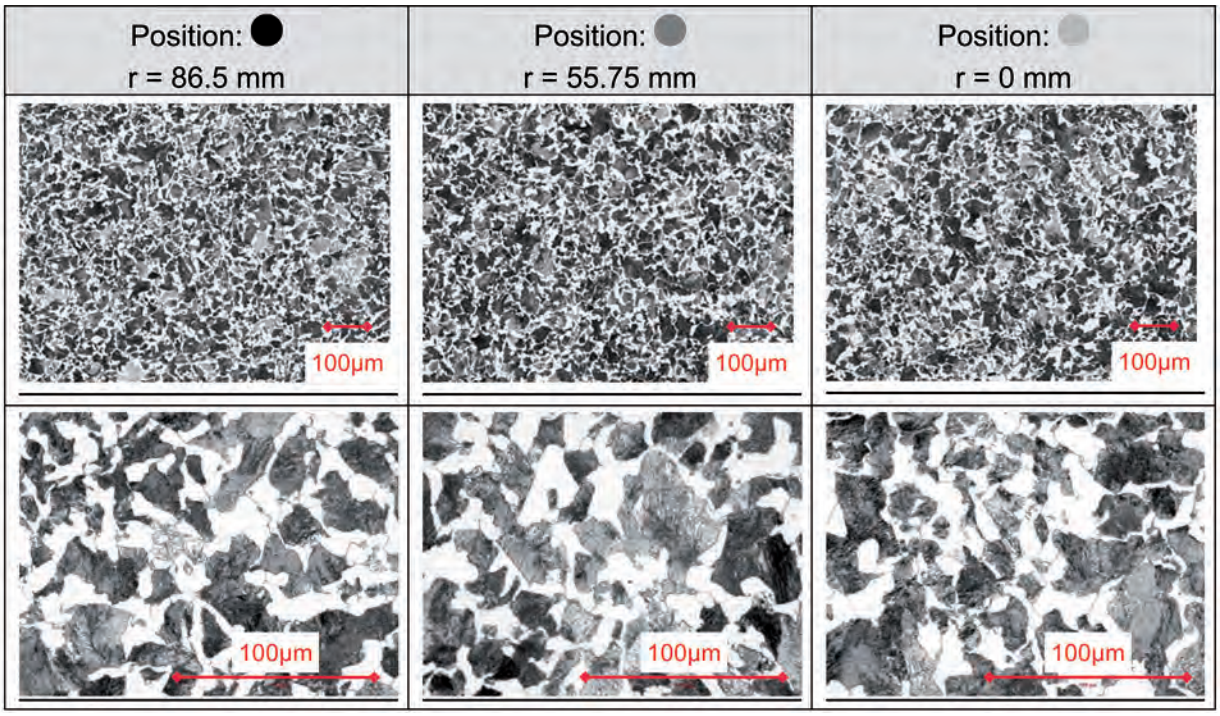

Fig. 2. Microstructure of the forged twin axle for different analysis positions across the radius

Table 2. **Grain size distribution across the radius**

Position: ● r = 86.5 mm	Position: ● r = 55.75 mm	Position: ● r = 0 mm
8.75	8.55	8.47

Twin axles and analysis results

Twin axles were forged on the hydraulic radial forging machine from the continuous cast starting material in just one heat. As shown in Fig. 1 two identical railway axles which are forged from one ingot of starting material are separated after forging. This procedure is time-saving as, for example, there are no double loading and unloading times.

Fig. 2 shows pictures of the microstructure in the outer shoulder zone with a diameter of 223 mm. The area subjected to the least forming has a homogenous and excellent microstructure across the radius.

An examination of the grain size as per ASTM E 112-96 shows a slight decrease in grain size across the radius, the average size however being an excellent 8.5 (tabl. 2).

To get an indication of possible defects within the entire axle, the axle was ultrasonically tested in accordance with EN 10228-3, Class 3, the standard applying to railway axles. As the twin axles were examined not in finish-machined condition but only in "sand-blasted" condition, the result can only give an overview of the quality of the forged axle. In the case of the above-mentioned ultrasonic analysis with a recording threshold of 3 mm for defects, it was not possible to detect any defects with a diameter of more than 3 mm.

Conclusion

Using the hydraulic radial forging machine, continuous cast carbon steel with defects running in an axial direction was forged into a railway twin axle in only one heat. The analyses carried out with regard to microstructure, grain size and pore detection produced very good results. In the zone with the least degree of forming, we have a homogeneous microstructure evenly distributed across the radius. The average grain size of 8.5 (ASTM) is likewise evenly distributed across the radius. An ultrasonic analysis of the forged axles showed that there are no pores larger than 3 mm. As these results are very promising, the forging time will be optimized in subsequent tests and the forged axles will be finish machined for a final analysis in accordance with the railway standard.