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Failure of the bucket wheel excavator buckets

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ABSTRACT

Buckets are a vital substructure of all digging machines, and are intended for the realisation of the fundamental machine function - soil excavation. This paper presents the results of the experimental-numerical investigation of the cause of the bucket wheel excavator SRs 470 buckets failure. The chemical composition and mechanical properties, the impact toughness, hardness, tendency to cracks and the microstructure were determined using appropriate tests. Experimental examinations of working and residual stresses were performed using strain gauges. The superposition of the experimentally determined working and residual stresses and the calculation of the total principal stresses were conducted using the originally developed procedure presented in this paper. The bucket working stress state was calculated by applying the linear finite element method. Conclusions based on the investigation results show that the main reasons for the buckets failure were the 'design-in defects' - oversights made during the procedures of geometrical shaping and material selection. Furthermore, high values of residual stresses, as well as the cold cracking observed on the welded joint of the knife and the bucket body, suggest that the 'manufacturing-in defects' also played a significant role in the failure. The superposition of influences of the 'design-in defects' and the 'manufacturing-in defects' has conditioned the appearance and propagation of long-term fatigue cracks, leading to the total destruction of the buckets. The fact that buckets' failure appeared due to oversights made during geometrical shaping, material selection and manufacturing further points to the importance of the critical approach implementation during the design phase of the earthmoving machines working devices.

1. Introduction

The exploitation of bucket wheel excavators (BWE) in harsh working conditions, accompanied by loads of pronounced dynamic and stochastic character, leads to failures of their structural as well as mechanism parts [1–5].

This paper analyses the case of structural failures [6] of the BWE SRs 470 buckets, which occurred during coal excavation, Fig. 1. The coal block was relatively homogeneous, with rare and thin layers of hard sand/rock. According to the measurements conducted 'in situ', the obtained value of the cutting resistance per unit of cutting edge length was $k_{L,c} = 84$ kN/m for coal and $k_{L,hl} = 98$ kN/m for hard sand/rock layers, while the specific cutting force achievable by the excavating device had the value of 107 kN/m. The excavation was realised using the combined method with a dominant participation of the terrace cutting. The drop cutting method was used for the excavation of hard layers. It was obvious, Fig. 1, that the level of the buckets' degradation was so pronounced that

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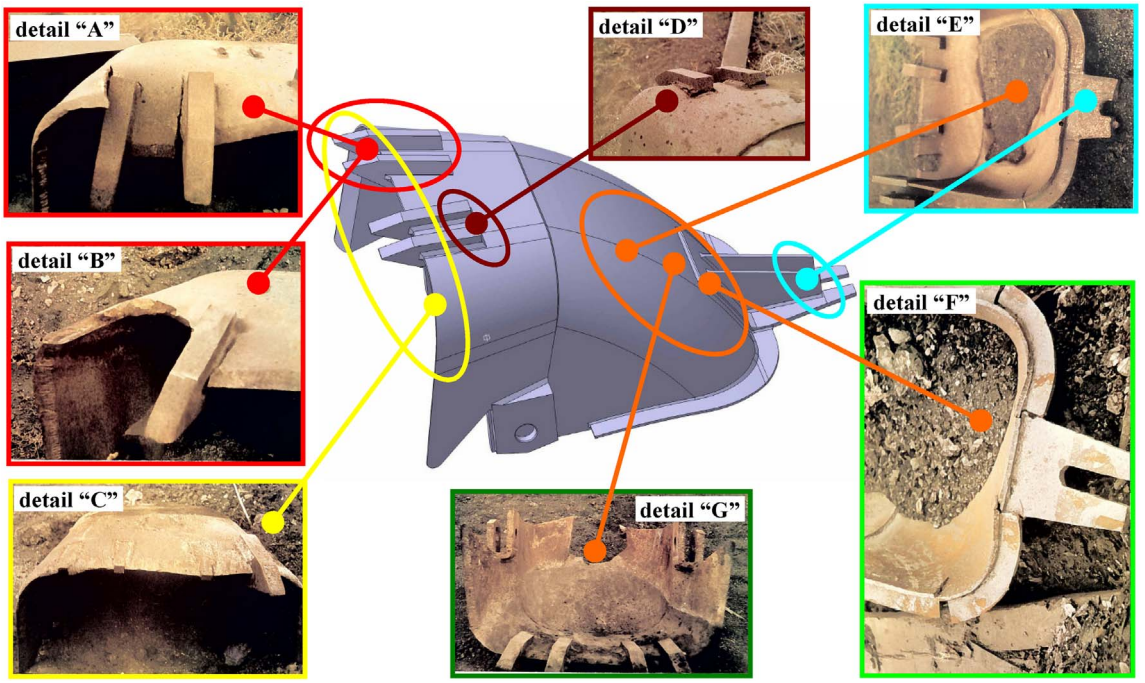

Fig. 1. Damage to the buckets' structure: details A, B, C, D – damage of the teeth and knife; details E, F, G – damage to the buckets' back and zones of rear wedge fastening.

they were practically unusable, leading to the conclusion that their repairing would be entirely unreasonable. In order to diagnose the cause of the bucket body damages, the following steps had to be performed:

- An experimental procedure which included: chemical composition and mechanical properties of base metal (BM); impact toughness and hardness; tendency to cracks; microstructure examinations; working and residual stress analyses using strain gauges, and
- The calculation of the bucket working stress state applying the linear finite element method (LFEM).

The presented investigation results are important for the following reasons:

- Buckets present the vital substructure of all digging machines, intended for the realisation of the fundamental machine function (soil excavation). Their structural failure leads to the appearance of direct and indirect losses caused by the complete system standstill [6];
- Specialized literature on the subject of BWE and working devices of earthmoving machines [7–13] does not deal with the problems of geometrical shaping and strength of buckets adequately, considering the importance of the mentioned substructures.

2. Experimental procedure

According to the design documentation, the bucket body was supposed to be made from steel quality grade S235J2G3 [14], while the bucket knife as well as the eye-plates of the front supports were supposed to be made from steel quality grade E335 [14].

2.1. Chemical composition, tensile properties, impact toughness, hardness and tendency to cracks

Chemical analyses of the bucket body (samples taken from two series of buckets) (Table 1) and the bucket knife material (Table 2)

Table 1
Chemical analysis (wt%) of the bucket body material and chemical composition of S235J2G3 [14].

Material	C	Si	P	S	Mn
Batch 1	0.080	0.215	0.012	0.033	0.390
Batch 2	0.155	0.230	0.028	0.025	0.460
S235J2G3	Max. 0.19	–	Max. 0.035	Max. 0.035	Max. 1.50