Rail Accident Investigation Branch

RAIB Bulletin 04/2011

Derailment on the Bure Valley Railway, Norfolk 30 May 2011

Description of the accident

1 The Bure Valley Railway (BVR) is a narrow gauge heritage railway that runs nine miles (14.5 km) from Aylsham to Wroxham in the county of Norfolk (figure 1). The track gauge is 15 inches (381 mm).

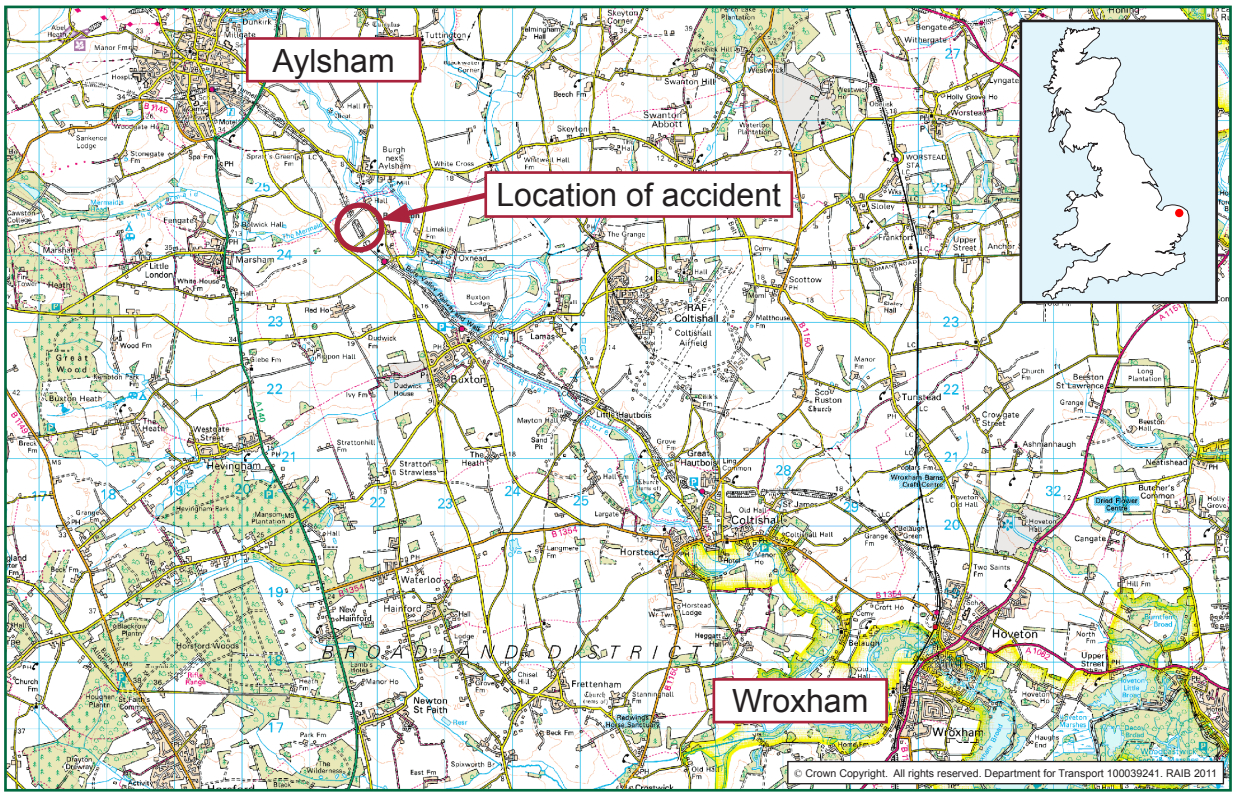

Figure 1: Location of the Bure Valley Railway

2 At approximately 15:25 hrs on 30 May 2011, the leading bogie of the second coach of the 14:40 hrs train from Wroxham derailed close to the village of Brampton, about two miles (3.2 km) from Aylsham (figure 2). The train was formed of nine coaches and was hauled by a steam locomotive.

3 When the derailment occurred, the train was running at about 16 mph (26 km/h). The driver became aware of jerking and stopped the train. No-one was injured as a result of the derailment. Most of the 61 passengers on the train completed their journeys by walking to Aylsham; a few were transported by road.

Figure 2: Derailed second coach (courtesy of the Bure Valley Railway)

4 The BVR quickly established that the derailment was caused by the failure of an axle fitted to the derailed coach; one of the journal ends[1] had fractured from the remainder of the axle adjacent to one of the wheels (figures 3 and 4).

Findings of the RAIB

The cause of the axle failure

5 The RAIB commissioned a metallurgical examination of the failed axle and the two wheels fitted to it (collectively referred to as a wheelset) to determine the cause of failure.

6 Neither the wheels nor the axle carried any identification markings apart from what were probably cast numbers on the outer facing web of each cast wheel. Residual weld metal on the fracture surface of the failed axle provided evidence that the journal end had been previously welded to build it up (figure 5).

7 Both wheels had also been welded to the axle at the rear of their bosses[2] by three short lengths of weld. Although cracks were found in these welds, they did not extend into the axle material and were not a factor in the subsequent failure of the axle.

[1] The two journal ends are the portions of the axle to which the roller bearings are fitted and which extend beyond each wheel. The roller bearings are fitted to the vehicle's bogies and support the vehicle on its axles.

[2] The boss is the central area of each wheel through which the axle is located. Between the boss and the rim of the wheel is the wheel web.

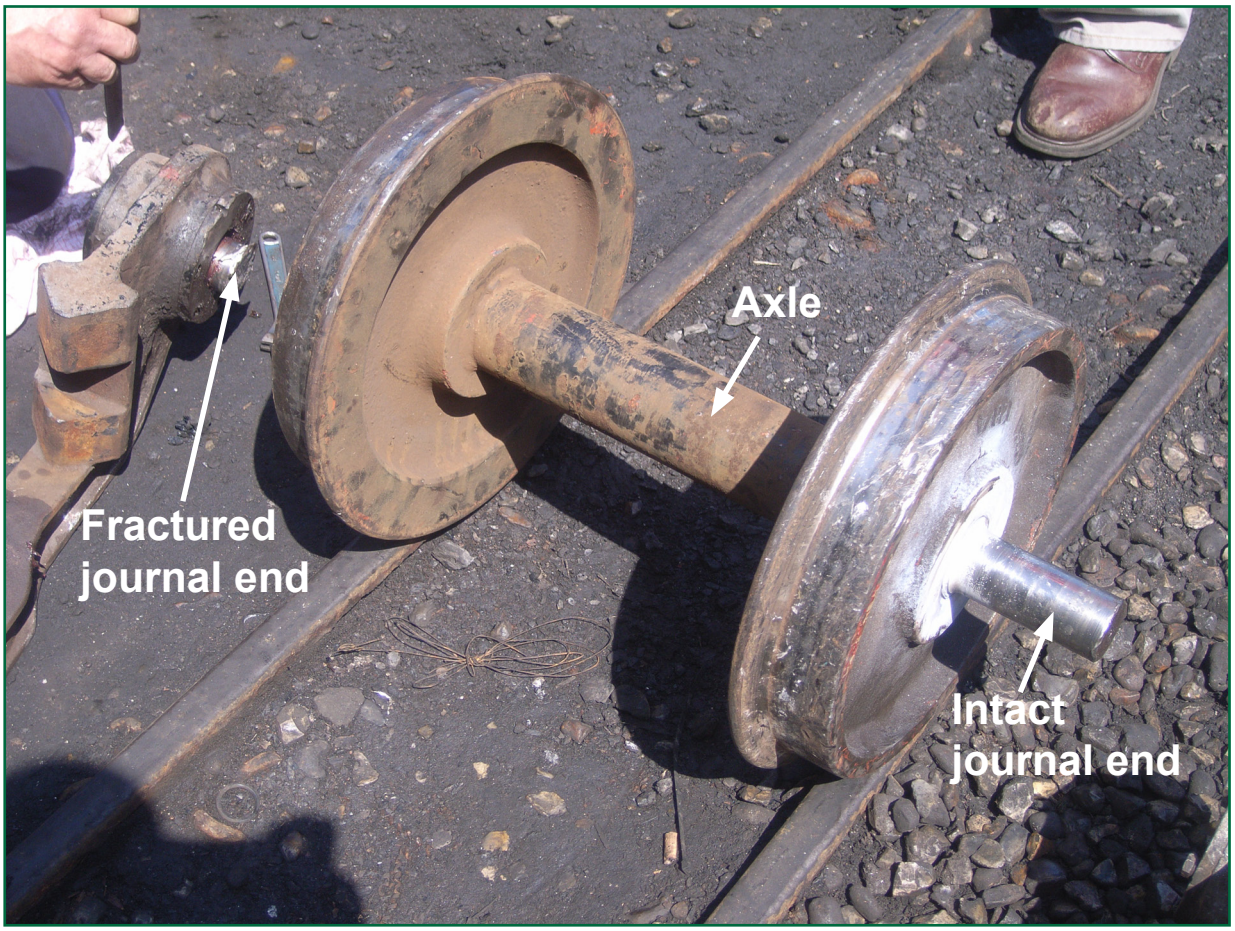

Figure 3: The failed wheelset (showing the unbroken journal end)

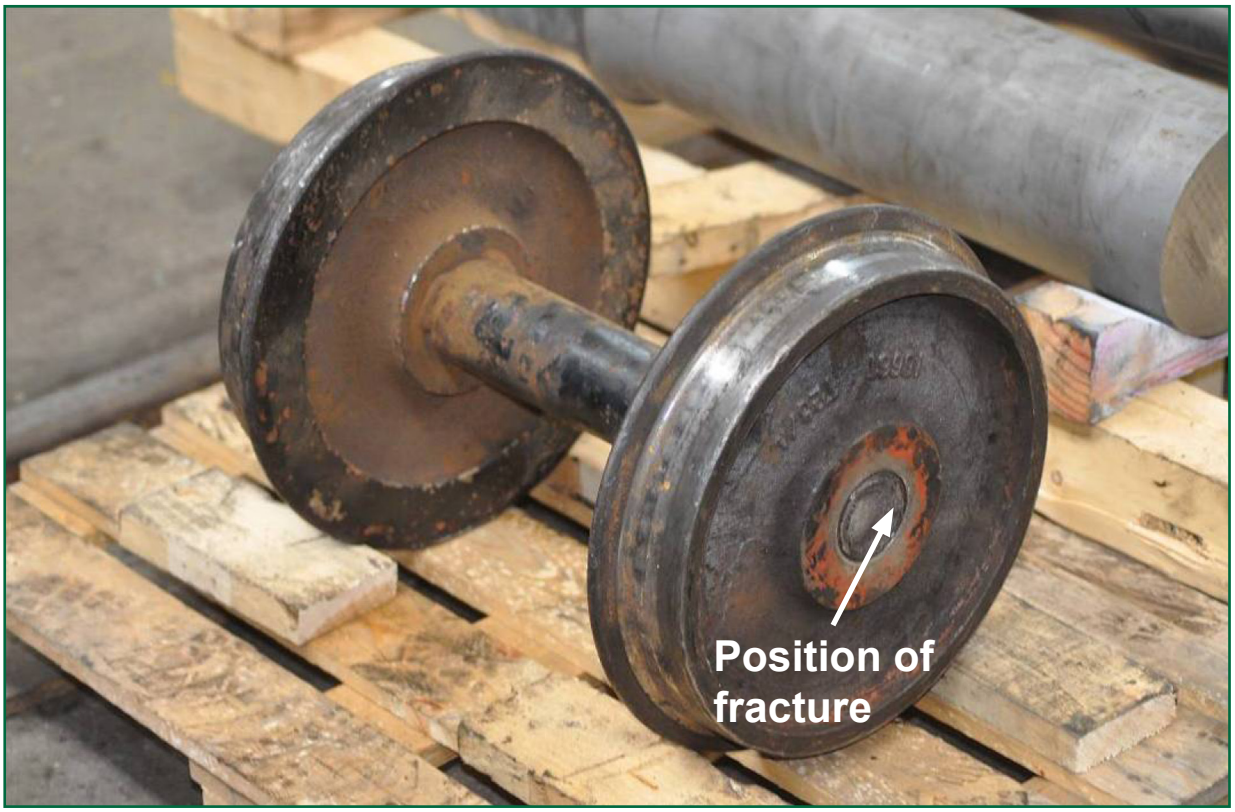

Figure 4: Wheelset showing the position of the fracture (courtesy of Serco Technical Consulting Services)

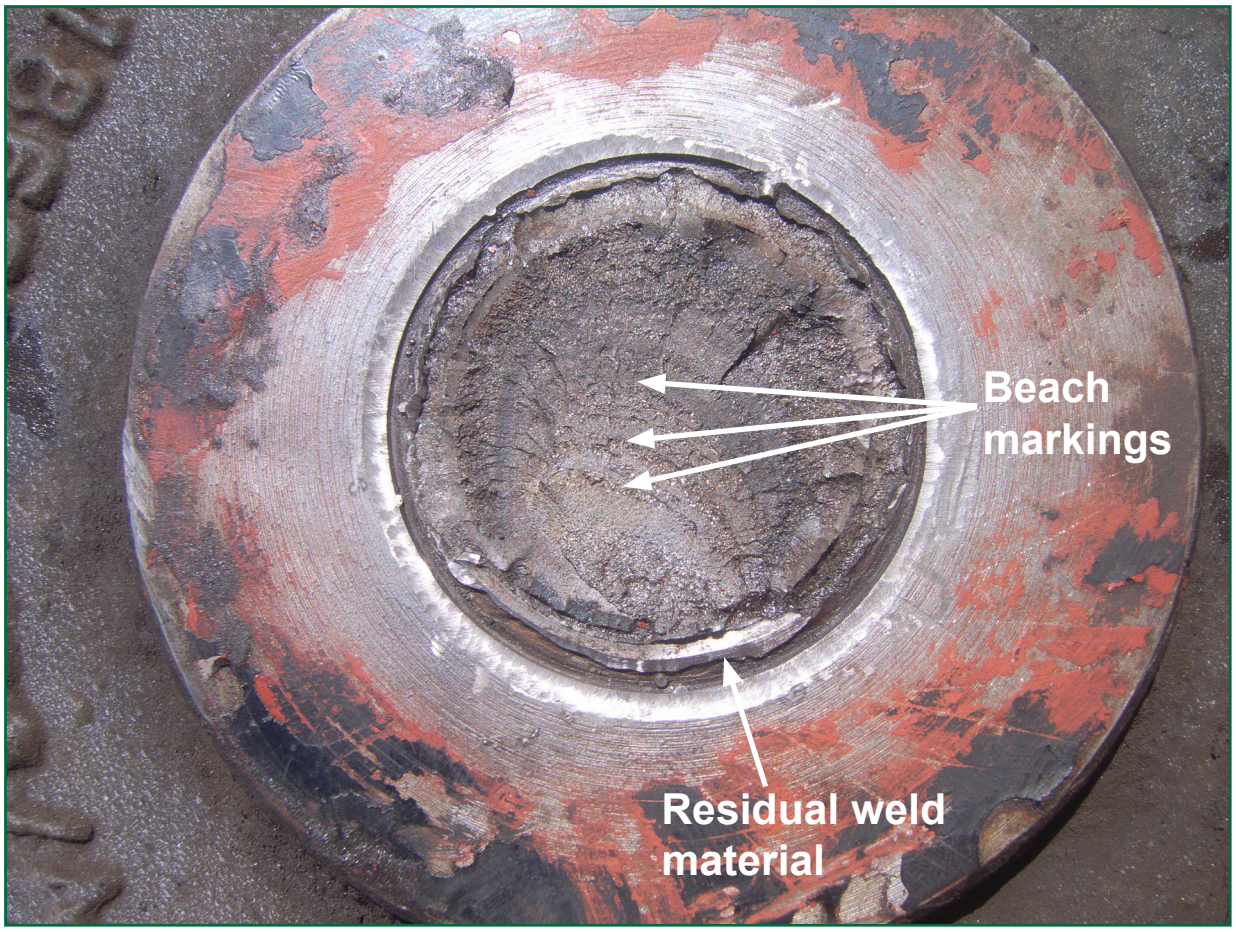

Figure 5: Fracture face of the axle

8 The metallurgical examination concluded that the fatigue forces in the axle caused the growth of cracks, which were produced when the axle journal end was built up with weld metal. This ultimately led to the axle's failure.

9 The beach markings, which are characteristic of fatigue failures, (figure 5) were very coarse and appeared to have some narrow bands of brittle failure between them. This indicated that the crack propagation was fairly rapid.

10 The measured hardness values of the material suggest that the welding was carried out without pre-heating[3] of the journal end causing hard brittle areas (known as martensite) to form in the material.

11 The tendency for cracks to form in the martensite is greatly increased if hydrogen is present in the weld metal. Hydrogen content can be minimised by ensuring that the weld electrodes are dry before use; the wide crack opening that was observed during the metallurgical examination suggests that high hydrogen content was present and so may have been caused by the use of damp electrodes.

12 Because the cracks formed in the hard brittle areas of the axle were underneath the weld metal deposited on top, they would not have been visible to the eye.

13 Whereas axles fitted to trains on the national railway network are subject to a regime of non-destructive testing, this is not generally the case on heritage railways, such as the BVR, where trains run at much lower speeds.

[3] Pre-heating slows the cooling rate of the weld metal and parent material so that martensite is less likely to form.

14 The welding of wheelsets fitted to railway vehicles that run on the main line railway network is prohibited, unless it is set out in a validated procedure (ref. Railway Group Standard Code of Practice GM/RC2496 'Recommendations for Railway Wheelset Maintenance'[4]). Furthermore, any action which would cause weld spatter to fall on a wheelset should also be prohibited.

The history of the failed wheelset

15 According to the railway's records, the wheelset with the failed journal end was one of four that were manufactured in 1990, and which were originally fitted to two four-wheeled guards vans. In all four wheelsets, the wheels were welded to their axles at the rear of each boss. This welding played no part in the later failure that occurred.

16 In 2001 or 2002 (the records are not sufficiently clear on this point) the journals of the wheelset that was later to fail were built up with weld metal and skimmed to a diameter of 50 mm. It is likely that this was done because the journals had worn and become loose in their bearings.

17 Subsequently, in 2008, the maintenance records show that this wheelset and a second wheelset were removed from each of the two guards vans and the journal ends turned down to a diameter of 45 mm. This left only a thin layer of weld metal on the journals of the failed wheelset (there are no records of the second wheelset having its journal ends welded). The evidence from the BVR is that both wheelsets were then subsequently fitted to the bogie of the coach which derailed.

BVR procedures concerning wheelsets

18 The journal ends of the wheelset that failed were built up with weld metal when the railway was under a different ownership. The evidence from the BVR is that when they were subsequently turned down to a diameter of 45 mm in 2008, under the present management, the welding was not apparent and was not noticed from the previous records that state that the journal ends had been built up with weld metal.

19 Prior to the derailment, BVR procedures did not explicitly forbid welding axles, but it was generally understood by those responsible for maintenance that welding of axles must not be carried out as it can result in axle failure.

20 Following the derailment, the Office of Rail Regulation[5] (ORR) conducted its own investigation (including liaising with the RAIB) to ascertain compliance with the Health and Safety at Work etc Act 1974 and the Railways and Other Guided Transport Systems (Safety) Regulations 2006. It found that the BVR did not have an adequate safety management system, which had gaps in procedures, standards and instructions. As a result, the ORR issued an Improvement Notice requiring the BVR to put in place an established, complete and recorded safety management system to include risk assessments, maintenance standards and record keeping. The notice was to be complied with by 31 October 2011.

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[4] GM/RC2496 has been published by the Rail Safety and Standards Board to give details of a recommended method which, if followed, would meet the requirements of Railway Group Standard GM/RT2466 'Railway Wheelsets' (see www.rgsonline.co.uk).

[5] The Office of Rail Regulation is the safety regulator for the railways in Great Britain.

The consequences of the accident

21 The potential consequences of the accident were increased because when the axle failed, and the derailment occurred, the other wheelset on the same bogie forced its way through the plywood floor of the coach into the passenger accommodation (figure 6). Fortunately, this did not injure any passengers.

Figure 6: Incursion of the derailed bogie into the passenger accomodation (courtesy of the Bure Valley Railway)

22 The BVR started a programme in 2005 to refurbish its coaching stock that was delivered in 1990, when the railway opened. The refurbishment includes replacing the plywood panels over the bogies with steel panels. The coach that derailed was waiting to be refurbished. Had the failed axle been fitted to a refurbished coach, it is unlikely that the passenger accommodation would have been penetrated.

Action taken by the BVR following the accident

23 Following the accident, the BVR has reported to the RAIB that it has taken action that includes:

- removing the other three wheelsets of the batch of four manufactured in 1990 from service with the intention that they be scrapped;
- checking the records of other wheelsets fitted to passenger vehicles and concluding that none of the axles had neen welded;
- removing all axles that have been welded (usually on the rear of wheels) from all operational freight vehicles;
- issuing written instructions to its engineering staff prohibiting the use of welding on the axles of wheelsets;
- starting to number all wheelsets as they are re-profiled; and
- introducing a database on a computer sytem to record all maintenance, together with the inter-relationship between components.

Conclusions

24 The immediate cause of the accident was the failure of the axle by fatigue cracking. This was probably caused by the welding of the worn journal end in order to restore its diameter so as to provide a secure fit in the bearings.

25 Although not a factor in the failure of the axle, the welding of the wheels to the axle to hold them in place should not be necessary if there is a sufficient interference fit between them. The cracks found in the welds show that this is not a competent practice.

26 There were no identification markings on the failed wheelset apart from what are probably cast numbers on the outer faces of the wheel webs. This could have made it difficult to trace the history of the wheelset from when it was manufactured. The guidance on minor railways published by the Office of Rail Regulation[6] states that the 'identification of wheels, tyres and axles should be conveniently visible'.

27 If there had been a single comprehensive record of all the work done on the failed wheelset, it is possible that the welding of the journal ends (paragraph 16) would have been identified when they were turned down later (paragraph 17).

28 In the light of the actions already taken by the BVR and the Improvement Notice served by the ORR, the RAIB does not believe that a further investigation would lead to the identification of any formal recommendations. However, the RAIB does believe that there are some learning points that other railway operators should note.

Learning points

29 The learning points from this accident are:

- Unless carried out as a part of a properly assessed and controlled procedure, axles should not be welded (and should never be placed at risk of weld spatter) because this can lead to the generation of cracks and failure by fatigue.
- There were no identification markings on the wheelset that failed (apart from cast markings) and this could have made it difficult, or impossible, to trace its history. Wheelsets should be uniquely identified and appropriate records kept relating to them.
- There should be specific procedures governing the maintenance of equipment and components, such as wheels and axles, whose failure could be critical to safety. These procedures should be implemented (including by briefing staff) and checked periodically that they are being complied with.

[6] Guidance on Minor Railways, Railway Safety Publication 5, www.rail-reg.gov.uk/upload/pdf/rsp005-minorrail.pdf

This bulletin is published by the Rail Accident Investigation Branch, Department for Transport.

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