

*On the causes of the unexpected breakage of the Journals of Railway Axles; and on the mean of preventing such accidents by observing the Law of Continuity in their construction.* By WILLIAM JOHN MACQUORN RANKINE, Assoc. Inst. C. E.

The paper commences by stating that the unexpected fracture of originally good axles, after running for several years, without any appearance of unsoundness, must be caused by a gradual deterioration in the course of working; that with respect to the nature, and cause of this deterioration, nothing but hypotheses have hitherto been given; the most accepted reason being, that the fibrous texture of malleable iron assumes gradually a crystallized structure, which being weaker in a longitudinal direction, gives way under a shock, that the same iron, when in its fibrous state, would have sustained without injury.

The author contends that it is difficult to prove that an axle which, when broken, shall be found of a crystalized texture, may not have been so originally at the point of fracture, although at other parts the texture may have been fibrous.

He then proceeds to show that a gradual deterioration takes place in axles without their losing their fibrous texture, and that it does not arise from the cause to which it is usually attributed.

From among a large collection of faggoted axles which had broken after running between two and four years, five specimens were selected, of which drawings are given, representing the exact appearance of the metal at the point of fracture, which in each case occurred at the re-entering angle, where the journal joined the body. The fractures appear to have commenced with a smooth, regularly formed, minute fissure, extending all around the neck of the journal, and penetrating, on an average, to a depth of half an inch. They would appear to have gradually penetrated from the surface towards the centre, in such a manner that the broken end of the journal was convex, and necessarily the body of the axle was concave, until the thickness of sound iron in the centre became insufficient to support the shocks to which it was exposed.

In all the specimens, the iron remained fibrous; proving that no material change had taken place in its structure.

The author then proceeds to argue, that the breaking of these axles was owing to a tendency of the abrupt change in thickness, where the journal met the shoulder, to increase the effect of shocks at that point; that owing to the method of manufacture, the fibres did not follow the surface of the shoulder, but that they penetrated straight into the body of the axle; that the power of a fibre to resist a shock being in the compound ratio of its strength and extensibility, that portion of it which is within the mass of the body of the axle, will have less elasticity than that in the journal, and it is probable that the fibres give way at the shoulder, on account of their elastic play being suddenly arrested at that point. This, he contends, would account for the direction of the fissure being inward towards the body of the axle, so that the surface of the fracture was always convex in that direction.

It is, therefore, proposed in manufacturing axles, to form the journals with a large curve in the shoulder, before going to the lathe, so that the fibre shall be continuous throughout; the increased action at the shoulder, would thus be made efficient in adding strength to the fibres without impeding their elasticity. Several axles having one end manufactured in this manner, and the other by the ordinary method, were broken: the former resisted from five to eight blows of a hammer, while the latter were invariably broken by one blow.

The vibratory action to which axles are subjected is then considered, and it is contended, that at the place where there is an abrupt change in the extent of the oscillations of the molecules of the iron, these molecules must necessarily be more easily torn asunder; and that in the improved form of journals, as the power of resisting shocks is increased by the continuity of the superficial fibres, so is the destructive action of the vibratory movement prevented by the continuity of form.

The paper is illustrated by five drawings, showing the section of the journals of broken axles, and their appearance at the moment of fracture.

Mr. York agreed with Mr. Rankine in several points, and stated, that since the last meeting, he had made a series of experiments, which confirmed his opinion relative to the vibration in solid railway axles being arrested, when the wheels were keyed on tight. In all such cases, where the vibration was checked, fracture would, he contended, be more likely to ensue, but with hollow axles, there was very little difference of sound when struck, and no diminution of strength, after keying on the wheels; this he attributed to the regular distribution of the molecules in the metal of the hollow cylinder.

Mr. Parkes coincided with Mr. York's opinion, and he believed that hollow axles would eventually supersede solid ones, particularly if they had sufficient rigidity for resisting flexure. Their faculty of transmitting vibration more readily was in their favor; it was well understood, that in pieces of ordnance, and musket-barrels, great regularity of proportion in the metal was requisite, in order to insure the equal transmission of the vibration, caused by the sudden expansion of the metal at the moment of the explosion, and unless the vibration was regular, the barrel would burst, or the ball would not be correctly delivered.

Mr. Greener, of Newcastle, among other experiments, turned the outside of a musket-barrel to a correct taper, and fixed tight upon it at given intervals, several rings of lead, 2 inches in thickness; on firing a charge of 4 drachms of powder, he found that all the rings were loosened, and had all expanded regularly in their diameter.

It was a well known fact, that cannon seldom, or never, burst from continuous firing; such accidents, unless they arose from peculiar circumstances, generally occurred in consequence either of inequality in the nature of the metal, or irregularity in its distribution; to the latter cause must be attributed the bursting of the "Mortier monstre," before Antwerp, and of a large gun which was proved at Deal, some time since; this latter gun burst at the third discharge, after delivering the ball better than on either of the previous discharges; it was

evident that the fracture did not occur under the explosion of the powder, but on the re-entering of the air into the mouth of the gun after the discharge, and also because the thickness of metal was not well proportioned, whereby the vibration was unduly checked, the cohesion of the molecules of the metal was destroyed, and the gun fell into several pieces, without any of them being projected, as they would have been by the usual effect of an explosive force.

The most practical millwrights were well aware of the superiority of hollow shafts, and they were frequently used, as they were more easily kept cool than solid ones, especially at high velocities, when shafts were peculiarly liable to injury from percussive force, or from a series of recurring vibrations.

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### *Greenwich Pier.*

We abstained last month from giving any account of the failure of this pier, which took place on 16th of May last, as we had not then an opportunity of personally inspecting it, or of ascertaining its construction; we have since been favored by our valuable correspondent, O. T., with the following observations, and sketch of the pier. He observes, "the failure of Greenwich pier is not a matter of surprise to parties who understand the practical construction of such works. The immediate cause of the failure was dredging in front of the piles, after the contractor had left the works, and the arrangement of the piles being faulty, as regards construction; the upper part is composed of brick-work in cement B, 18 feet high, and 14 inches thick at top, capped with granite 1 foot thick, backed with concrete, C, and standing upon a foundation of Yorkshire stone landings, L, laid on a small quantity of concrete, with a substratum of foul gravel, G. The landing, in front, rests on a row of cast iron piles, I, P, 25 feet long, and 5 feet apart, grooved to admit between them three cast iron plates, each 6 feet in height, these iron piles were fastened by four, or two, pair of wrought iron land ties, T, 2 inches square, to wooden piles, W, P, 18 feet long, and 12 inches square, driven in land at a distance of  $25\frac{1}{2}$  ft. from the front, and 5 ft. apart." The high water mark is about 4 feet from the top, and low water mark 22 feet below, or about 7 feet below the stone landing. From inquiry, we rather suspect the lower ties, as shown in the sketch, were not fixed, nor do we see how they could

