Erie Canal Technology: Stump Pullers

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Many years ago I saw a picture of a huge set of wheels that was used to remove tree stumps during the construction of the Erie Canal (1817-1825) and was intrigued by its use of leverage, mechanical advantage, and torque. Figure 1 is a scale model of the device based on my memory of the (lost) picture and published accounts.¹

The canal workers devised a machine with a pair of rolling wheels, 16 ft in diameter, connected by an axle 30 ft long and diameter of 20 in. In the middle of the axle was firmly fixed a third wheel 14 ft in diameter. To pull the stump, the axle was positioned over the stump, and a chain wound around the axle was fixed to the stump. After the outer wheels were chocked, a rope passing around the middle wheel several times was led to a team of oxen or horses. As the animals strained forward, the upward force of the chain on the stump removed it from the ground. In Fig. 1 the figure of the man is taken to be 6 ft and the device is scaled to this figure. Note that the rope leading to the imaginary horse on the right comes off the bottom of the middle wheel, thus allowing the horse to pull almost directly on the rope instead of on an angle.

Physics people put numbers into situations. A horse can typically exert a horizontal tractive force equal to about half of its weight, provided that it is working on a high-friction surface; this effort decreases when the horse starts to move forward at anything more than a slow walking pace. A typical horse, weighing 1000 pounds in English units, has a mass of about 450 kg and a metric weight of about 4500 N. To be conservative, let’s assume a tractive force of 2000 N. The total tractive force of a team of horses is likely to be somewhat less than the sum of their individual tractive forces, but let us assume that a team of four horses can exert a net force of 8000 N on the rope wound around the central wheel.

During the stump-pulling operation, the set of wheels is almost in equilibrium, so the torque exerted by the chain on the axle is equal to the torque exerted by the rope. The ratio of the radii of the central wheel and the axle is 192 in/20 in, which is close to 10. The tractive force of the horses is thus multiplied by a factor of 10, giving an upward force exerted by the chain on the stump of 80,000 N. According to contemporary accounts, this was enough to remove even the largest stump, and a good team of men and horses could pull 40 stumps a day.

References