the sun's heat, particles are detached from the nucleus, and the comet fritters down, so to speak. When the particles are detached, their very lightness exposes them to the repulsion of the sun's light, and they recede into space and are lost. The tail would soon disappear entirely if it were not continually regenerated anew.

Under these circumstances it is readily intelligible that an encounter with such a tail need cause us no anxiety. In the first place, the mass of comets is not very considerable. It has now been observed that it does not exercise the slightest perturbing influences upon the planetary orbits. A comet on a certain occasion passed between Jupiter and its satellites. Its trajectory was strongly modified, but neither Jupiter nor its satellites seemed to be in the slightest degree affected. La Place went so far as to say that the mass of a comet is only a few kilogrammes. In this he evidently exaggerated. An encounter of a comet's nucleus with the earth would no doubt cause some damage, but such an event is extremely improbable, for the nuclei are relatively very small, and we really stand very little chance of hitting such a small target. The same is not true as regards the tails, which spread over an immense space in the sky, but then

their density is negligible, as can be readily shown. The contrary might be supposed, in view of the light which they emit. Even if we admit the whole of this light is reflected sunlight, and that no cathode phenomena such as may occur in highly rarefied space, enters into the case, there really is no cause for anxiety.

If we consider a given mass lighted up by the sun, the amount of light which it reflects will be the greater, the more highly divided its substance. If this mass is formed of a large number of small spheres, the reflected light will be the more intense, the smaller the spheres. It is easy to realize this; let us imagine larger spheres of two centimeters radius, and smaller spheres of one centimeter radius; the volume or mass of the larger spheres will be eight times that of the smaller spheres, but the surface of the larger spheres will be only four times that of the smaller. Eight small spheres, therefore, will be equivalent to one of the larger ones in point of mass, but they will have twice the surface area and will therefore reflect twice as much light. The moon has a radius of some-

*The eminent French mathematician has here taken considerable liberties in rounding off his figures. As our readers know, the Moon's radius is 1081 miles.—Ed.

thing over 1,000 kilometers,* and the particles which we are considering measure one-thousandth of a millimeter in diameter. If, therefore, we were to fill the volume of the moon with particles of this magnitude in such manner that the total density were one million million times less than that of the moon, the light which would be reflected would still have the same brilliancy as that which we receive from the moon. If we viewed this collection of particles at the distance of the moon, they would present just the same appearance as the moon. If we were farther away we would see them smaller, but with the same brightness. As a matter of fact, the brightness of the comet's tail cannot be compared with that of the moon. It is, may be, one hundred times less, perhaps one thousand times—I am not aware that any measurements have been made. We must, therefore, conclude that the density of the particles is 10^{15} times less than that of water; we might as well say that we have, in the comet's tail, nothing but empty space, since it represents a density over one thousand million times smaller than the most extremely rarefied gas which we are able to produce in a vacuum apparatus with the most perfect means which modern technique places at our disposal.

Wheels, Ancient and Modern—II.*

From Log Roller to Wire-spoke Motor Car Wheel

By Henry L. Heathcote, B.Sc.

Continued from Supplement No. 1877, page 415

MODERN WHEELS.

The Suspension Wheel.—We will now pass on to the next stage in wheel development, which dates from the use of bicycles. During this gap of about 2,500 years the only changes of any importance were the dishing of wheels to resist lateral stresses due to ruts and rounding corners, and arranging the spokes on two cones instead of one. This last was done as early as 1828, and is still practised at Woolwich Arsenal in building ambulance wagon wheels. Strange though it may appear, wheels were not used generally for facilitating transit in Britain till comparatively recent times. The very first carriage was made for Queen Elizabeth in 1568; the first that plied for hire in London were in 1625, and the first stage coaches were in 1659. Broadly speaking, all the early wheels were compression wheels with radial spokes. The introduction of the suspension wheel for bicycles marked a great advance in the shock-absorbing powers of wheels. The first bicycle wheels were compression wheels, and had wooden spokes and rim with an iron tyre. The wheels were just ordinary light carriage wheels. The curved member connecting the back axle to the top of the front wheel is not altogether unlike that used in the chariots of the ancients. Later bicycle wheels had radial-wire spokes which, being in tension, kept the rim in position. In the older wheels the rim was normally in tension, and the spokes and hub in compression. In a suspension wheel the spokes and hub are in extension, while the rim is in compression. It is a common, though not unnatural error to suppose that the spokes of a modern bicycle wheel are sometimes in compression. As a matter of fact, they are always in tension, even those between the hub and the ground, when a heavy rider is in the saddle.

Fig. 1 represents one element of a wire wheel. If tension be applied to the spokes, the rim and hub would move toward each other were it not for the effect of the other segments; the resistance to the compression forces in the rim, and to the bursting stress in the hub shell prevents this movement. When compression is applied between the bottom of the rim and the hub-center of such a wheel, the tension of each spoke will, if the rim is inflexible, decrease proportionately to the

Fig. 1—The Torque Applied at the Hub Must be Transmitted Along the Wire Spokes to Overcome the Resistance at the Circumference.

cosine of the angle between the spoke, or, rather, the projection of the spoke in the plane of the wheel, and the direction of compression. When the cosine becomes negative, as when the spoke is above its horizontal

position, the decrease becomes, of course, an increase, having its maximum for spokes on the upper part of the wheel pointing in the direction of the compression. Obviously the spoke tension should never fall to zero nor rise above the elastic limit, and these limits help to regulate the choice of the initial spoke tension.

The Tangent-Spoke Wheel.—The tangent-spoke wheel in which the spokes are tangent to a circle having its center at the axle and are not normal to the rim, probably owes its origin to the curved arms used in driving pulleys and fly-wheels for transmitting considerable torque. Both ancient and modern radial spoke wheels are capable of transmitting a certain amount of torque, but the amount is limited, and depends not only on the bending strength of the spoke, but on the rigidity of its attachment to both rim and hub. Since no material has an infinite elasticity, it follows that however thick the spokes may be there must be a certain amount of twist of the hub (in the plane of the wheel) relatively to the rim, or no drive can be transmitted. When the torque is considerable—as in a motor car wheel—the actual twist sooner or later rises above that corresponding to the elastic limit at some or all of the spoke attachments, and this leads to gradual loss of rigidity and to creaking, and, in some cases, even to charring, owing to rubbing. In a radial-spoke bicycle wheel subjected to a torque in its plane, the hub must rotate relatively to the rim until the spokes are tangent to a small circle.

If the average tension on the N spokes is t , when transmitting the torque T the tangent circle will have a radius—

$$r = \frac{T}{Nt} \text{ approx.}$$

Applying this to a bicycle wheel with fifty spokes, and assuming the pull in the chain to be 300 pounds (which is about that due to a vigorous jerk), the chain ring to be 3 inches diameter and the hub flange $1\frac{3}{4}$ inches diameter, if the average final spoke tension be 80 pounds, it is easy to show that the hub will twist 7.35 degrees relatively to the rim.

In a tangent-spoke wheel the hub must also turn relatively to the rim, but the angular movement is far less. In this case torque has the effect of increasing the tension on half the spokes and decreasing it on the other half. Reverting to Fig. 1, if the initial tension on A B and C D be t and the added and subtracted tension be p , the torque due to—

A B will be $(t + p) r$, and to

C D will be $(t - p) r$.

The difference of these is the resultant torque due to this element—

$$\therefore \text{Total torque} = \frac{N}{2} \times (tr + pr - tr + pr) \\ \therefore T = N p r.$$

Fig. 2.

Fixed Wood Wheel. A Very Common Type.	Fixed Symmet- rical Wire Wheel. Double Spoked.	Rudge - Whitworth Patent Detachable Wire Wheel, Pat- ent Dished Con- struction, Double- Spoked.	Rudge - Whitworth Patent Detachable Wire Wheel, Pat- ent Triple-Spoked Construction.

* Paper read before the Royal Society of Arts and published in its Journal.

bined, is not nearly so great as those diagrams indicate.
EXPERIMENTS WITH WIRE WHEELS.

Fig. 4 shows a polar diagram of the tension on the spokes of a Rudge-Whitworth detachable wheel fitted with a tyre sustaining a load of one ton. About one-quarter of the spokes have their tension relieved, but the others experience nothing like the same increase, and it is distributed fairly evenly all round.

To test the effect of combined load and torque, the pull was applied to a dummy tyre made of iron, so that its line of action did not pass through the center of the wheel. By varying the distance between the wheel center and the line of pull the ratio ——— could be varied

at will. In this way tests imitating all sorts of conditions of road surface, car load, and horse-power engine have been carried out.

Fig. 5 shows a polar diagram for a wheel having the same number of outside and inside spokes, the outside spokes of which transmit their pull to the hub and not to a revoluble ring. The outer dotted line indicates the initial tension on the inside spokes, the inner that on the outside ones. The dots show the effect on the tension of the combined load and torque. In this test the inner hub, hub-shell nipples, and rim are all tested, and the results demonstrate beyond controversy the enormous strength of these wheels for forces and couples in the plane of the wheel. The point to which I would particularly call attention is the great advantage of a flexible rim which, as these results show, quite obviates the high tensions or compressions which would otherwise obtain, and which would prove so destructive every time the wheel was jerked off the ground.

In addition to determining the effect of load and torque, separately and combined, we have subjected both wood and wire wheels to a side-pull applied at the rim or to a dummy tyre. Fig. 6 shows a Denison testing-machine, adapted to imitate the stresses set up in rounding a sharp corner at very high speed or in a bad side-slip. The results of some of these tests will be seen in Fig. 7. In nearly every instance the deflection of the wood wheel for the same pull is greater, and in every case the wood wheel sustained permanent damage at a lower pull than in the wire wheel. The same applies to the sheet-steel wheels. The arrangement of the spokes in the Rudge-Whitworth wire wheel has been the subject of careful design and experiment. Fig. 8 shows the results of some of these experiments, and makes it clear that the strength attained, even with precisely similar rims, hubs and spoke material, depends greatly on the design selected. These tests have given valuable data as to the best designs and materials for the rims, spokes, and hub shells. It does not follow, however, that designs and materials proved suitable for withstanding a steady force are also suitable for impulsive forces, so the various types of wheel have been investigated under impact.

For this purpose use is made of an impact pendulum, which is released against the top of the rim of the tyre wheel. The length of the pendulum is about 12 feet and the bob weighs nearly a quarter of a ton. In some tests increasing blows were applied to the same part of the wheel, in others a moderate constant blow, e. g., 200 foot-pounds—was applied at successive points on the rim eleven-thirtieths of the whole circumference apart. Fig. 9 shows characteristic diagrams for wood, wire and sheet-steel wheels subjected to increasing blows at the same place; and Fig. 10 shows the results of testing wood and wire wheels with similar blows, the wheel being turned eleven-thirtieths of the way round after each blow.

The question will probably suggest itself as to whether a motor-car wheel is ever called upon to stand side-thrusts and blows as great as those represented by the upper part of Figs. 7 and 9. The magnitude of the stress depends in every case, not entirely, but primarily, on the force that the ground can exert on the wheel. For

Fig. 9—Behavior of Wheels Under Successive Blows Applied to the Same Point.

Fig. 8—Tests Showing the Influence of Design of Hub and Spokes when the Material is the Same.

instance, the forces that turn a car round a corner reside in the round. It is quite a mistake to suppose that the driver at the steering-wheel really steers the car; the path followed may be indicated by the steerer, but it is dictated by the ground. The most the driver can do is to turn the wheels into such a position that, if the ground permits, the forces developed under and near the wheels will alter the direction of the car to the desired extent.

Fig. 10—Behavior of Wheels Under Successive Blows Applied to Successive Points on the Circumference, in the Order Indicated on the Circle.

The stresses set up when rounding corners, without skidding have been very fully investigated by J. V. Pugh (*Autocar*, 1906, pages 910 and 948). When traveling at twenty miles per hour round a curve 30 feet radius, the side-thrust on an outside wheel, at the tyre, may be as much as $1\frac{1}{4}$ times the load on the wheel when traveling straight. When skidding, the side-thrust may be considerable, not only when stopped by a curb-stone, but also when the side-slipping wheels are arrested by a dry, sandy, or rough part of the road.

If the rear wheels of a car weighing one ton skid sideways at a corner, and are brought to rest by the outer wheel running on to a dry, rough, or sloping part of the road, and if two-thirds of the load is borne by the rear wheels, and they attain a sideways velocity of five miles per hour, and stop after sliding three inches beyond the slippery part, then, taking moments about the front wheels, the retarding force is

$$\frac{2}{3} W \cdot \frac{v^2}{2gs} = \frac{2}{3} \cdot \frac{2240 \times 53.8}{64 \times 0.25} = 5020 \text{ lbs. approx. on one wheel.}$$

On a smooth surface, even if dry, the ground would not exert so great a force on the tyre, but when rough and sloping, even greater forces can be exerted.

(To be Continued.)

Motor-Driven Circular Saw Bench

Our illustration, adapted from *The Engineer*, shows a portable motor-driven circular saw bench specially designed for use on battleships, large liners, and so forth. On such vessels there is always a considerable amount of carpentry work to be done, and it is considered that such a tool will also be found useful for yard work and in other cases where it is more convenient to take the machine to the timber than to convey the timber to the mill. The machine is, as a fact, particularly adapted for work in the open by reason of its strong design, and as the motor is inside the main framing and totally inclosed, no trouble is likely to arise either through dust or from the effects of the weather.

The main framing, which is of solid construction, is mounted on a trolley running on wheels for purposes of transport. Provision is also made for bolting the machine to a deck or foundation if desired. The top part of the machine is made to swivel on a turntable, so that it can be swung round and secured at any angle without changing the position of the base. The machine carries saws up to 26 inches in diameter, and will cut through a depth of 8 inches. It is fitted with an adjustable fence, arranged to cant to any angle for bevel cutting, and made to turn over the end of the bench to leave the table clear for cross-cutting. A cross-cut slide with a quadrant adjustable to any angle is also provided for miter cutting.

The saw spindle runs in hardened ball-bearing journals, and has a double ball thrust bearing for taking up end play. The armature of the motor is fitted direct to the saw spindle, and the electrical parts, brushes, etc., are accessible from the top by means of a removable brass cover fitted in the table immediately over the motor. The main standard in which the motor is fitted is made with a large radiating surface to keep the motor cool.

An automatic feed motion is provided. This consists of two horizontal rollers placed one in front and one behind the saw, and connected with each other

Portable Circular Saw Bench.

by a driving chain. The rollers are driven through totally inclosed worm gearing, by a friction disk, and can be instantly stopped or started. The feed can be varied from 5 feet to 45 feet per minute by traversing a friction wheel across the disk, this motion being controlled by a lever at the front of the machine. If preferred, however, the machine can be supplied without the feed gear. The motor is capable of giving out five brake horse-power. Its speed is 1,500 revolutions per minute. The table measures 4 feet 6 inches by 2 feet 9 inches, and the weight of the machines including the motor, is 25 hundredweight.