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A New Form of Toothed Gearing

The Necessity of a Form of Gearing Which Would Possess Sufficient Flexibility to Adapt Itself to Distortion Such as Occurs in Marine Work, Has Brought Forward the Ideas Here Set Forth

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THE PROBLEMS of power transmission have occupied the minds of many succeeding generations of engineers since Archimedes discovered the properties of the lever, gave unlimited extent to the notation of numbers, and founded the method of indivisibles or exhaustions which led up to the finest discoveries in geometry, and some of the greatest modern inventions. Following Archimedes, Apollonius of Perga, who was the first to derive the conic sections from a single cone, Pappus, Diocles and Nicomedes, who invented some of the higher curves, even Diophantus, who gave us the characters used in algebra, all helped towards the determination of that little curved line which encloses the form of a modern gear wheel tooth.

The higher geometrical science was originally applied to astronomical research, and enabled Aristarchus to expand immensely the conception of the solar system. By it Hipparchus sought to explain the apparent inequalities in the motion of the celestial bodies by the hypothesis of eccentrics and epicycles. Then mechanics naturally followed

From the same geometrical sources there came later square and triangular gears, and other less familiar variable speed devices.

It is commonly supposed that the greatest mechanical discoveries are the result of chance that the most celebrated mechanicians had no theoretical knowledge and that even famous mathematicians have failed when they attempted to put their ideas into practice. It is no doubt true that chance sometimes unfolds important inventions, and that useful results do not always follow the laborious investigations of the theorist; but it is necessary for this that the productive causes be of the very simplest kind. The chance mixture of some substances gave birth to important chemical combinations; two convex lenses, placed parallel to each other at a certain distance and directed to a distant point, indicated the principle of the telescope.

The First Gear

History tells us that the first gear wheel was composed of flat pieces of wood, arranged in the form of a cross, Fig. 1, which were made slightly longer in one wheel of a pair. This was not for the purpose of modifying speed or power, but to ensure engagement. Subsequent developments of this idea extending over centuries are illustrated in Figs. 2, 3, and 4. In the latter the extremities of the arms are stiffened by binding, and indicate the first approach to the modern toothed wheel. Previous to 1674 teeth were of no particular scientific form, but were merely more or less regular excrescences on the rims of the wheel and pinion. About that time Roemer, a Danish mechanician, first applied the epicycloidal curve with the object of securing uniformity of pressure and velocity.

Within the last 50 years makers of clocks, watches, chronometers and mathematical instruments shaped their wheel teeth to please the eye drawing them to an enlarged scale for better discernment then reducing them to the required size. Lancashire makers of watch wheels used the bay leaf as a pattern. It was not until the works of Camus were translated from the French that wheel teeth began to take a definite

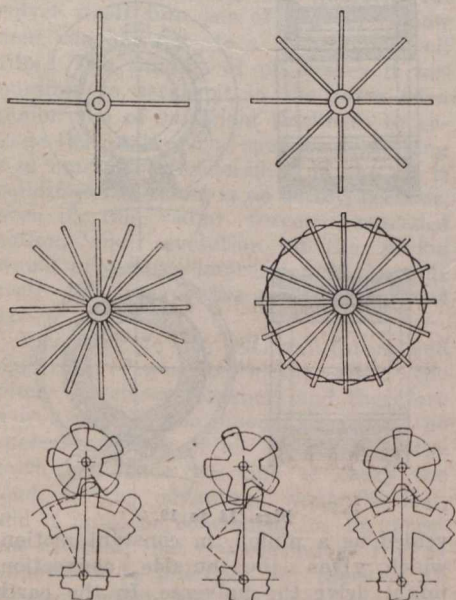
shape, and engineers and others realized that tooth designing was a science rather than an art and that only by following certain basic principles could they get uniform velocity, durability, and efficiency in their machines. Camus pointed out some of the limitations in toothed gears, for example, that pinions of a certain number of teeth were unsuitable for working with particular spur wheels, on account of the line of pressure being either outside or inside the pitch circle, Figs. 5, 6, and 7. In this connection it has long been considered unwise to have less than 14 teeth in any pinion, and in present-day work, whenever high ratios are required, involving pinions of small diameter, the teeth are made to a fine pitch with a corresponding widening of the face.

Tooth Pressure

This brings us down to modern times and the question of tooth pressures, which still awaits the final answer. It should be easy to determine, even in the laboratory, what pressures can be economically withstood by the various metals available for wheel teeth; but the great difficulty of maintaining, under certain conditions, the contact of wheel and pinion teeth along the whole face must be recognized, and also the possibility of intermittent point contact provided for in the design and material.

In the case of reduction gears of marine turbines, several devices have been tried, or proposed, for imparting flexibility and compensating inaccuracies of alignment and contact, but these have shown, naturally, better results in the testing department than in actual service. In so elastic a structure as a ship, no land trials can adequately indicate the behaviour of her machinery in heavy weather at sea. Even the most careful loading and trimming of cargo will leave the machinery in a different condition from that which prevails when running light. In a heavy sea there is a constant change of conditions, of torque, of alignment, of gear contacts, and of tooth pressures and it is not to be wondered at if heavily loaded gears wear more rapidly in heavy weather.

It is not proposed to make detailed mention of the best-known devices for



Figs. 1 to 7.

the discoveries of the great men of the Alexandrian school, and devised eccentric, elliptical, and planetary gears.