SUBJECT INDEX

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C

H

I

K

L

Q

R

S

T

U

V

W

X

Y

Z

Current Developments in EQUIPMENT AND DESIGN

The history of the pulley, basic form of power transmission, is traced from its first applications to modern use.

Discussed by Charles Owen Brown

When one inspects a modern chemical plant with dozens of separate units, from small agitated tanks to large heavy, grinding mills, it seems a matter of course to view a belt of some sort between the driving motor and the driven equipment. It is difficult to realize that this simple device which transmits power from a prime mover to the driven equipment has had such an intricate development.

Many of us will recall that the subjects of physics and mechanics are usually introduced by a treatment of four simple, so-called machines. They are listed in this order: the lever, the inclined plane, the wedge, and the wheel. All have to do with power transmission. This article deals with the last one, the wheel, or pulley, and particularly power transmission devices between two or more pulleys. It is interesting to note that the pulley received its earliest application as only part of a wheel known as the shadoof. The shadoof, which also might be called the first crane, was in use in Egypt as early as 3000 B.C. This simple device was used mainly for drawing water from a river. A brick pier, several feet high, was erected on the bank of a river. On the top of this pier a long, unbalanced pole was placed on a pin so that it could be turned around, or up and down. This pole resembles part of a wheel. Two opposite spokes of the wheel only were used, one heavily weighted arm hanging over the stone pillar on the land side and the longer, lighter arm projecting over the river. To the end of the river arm was attached a rope carrying a bucket to hold water. A second rope was also attached to the long arm just over a convenient position on the river bank where it could be reached by the operator. This rope lowered the bucket into the water and when it was full, the operator simply released the rope sufficiently for the heavier land end of the shadoof to raise the pail out of the river. Then the operator walked the shadoof around with the rope guiding the pail to the river bank. When the water was emptied the operation was repeated. Modifications of this simple device were many throughout the ancient world. The picotah was a similar device, although usually better constructed.

The bow drill was the first useful application of the combined wheel and pulley. This device consisted of the bow ordinarily used with arrows and a shaft or upright spindle which was revolved by the bowstring wrapped once around the spindle when the bow was drawn back and forth. The bow drill was developed to ambitious proportions. There are pictures dated about 1500 B.C. showing an enlarged bow drill which required an operator on each end. In a chair placed on top of the spindle, a third individual sat in order to impart constant pressure to the drill. Here, the power transmitting medium was the rope on the bow, and the first rope drive seems to have been the bow drill. These crude machines were in use until about 250 B.C. when a horizontal adaptation of the bow drill accurately resembling a lathe was used by artisans. Many of the great men in ancient history such as Herodotus, Xerxes, Archimedes, and Philo of Byzantium, contributed in the adaptation of wheels to the spindle formerly revolved by the bowstring.

The Romans, accustomed to doing things on a grand scale, took the wheel in hand and developed large installations of power in a forceful but undesirable manner. The wheels were built not only very large and wide but they were also enclosed to form cages in which were confined a sufficient number of slaves to revolve the wheel and furnish the equivalent amount of power. Wheels were also adapted to recover the power in falling water wherever possible. Antipater of Thessalonica, about 85 B.C., raised the living standards for millers of grain in the following recommendation, "Ye maids who labor at the mills cease your toil. Sleep to welcome the dawn. Ceres commands the water nymph to do your task. These throw themselves upon the wheel, forcing around the axle."

In devious ways the wheel became highly developed. Except for the bow drill, it was not possible for a long time to transmit much power from the driver to a second wheel by means of a flexible drive. The first transmission of larger amounts of power between wheels was obtained by the famous painter, Leonardo da Vinci, who created what would pass for a fairly good pinion and gear wheel using the cog. Furthermore the first record of a belt used to drive a driven wheel is credited to da Vinci. Among his artistic accomplishments was the creation of pottery. The record states that he used a round leather thong to transmit power from a foot treadwheel to the revolving pottery spindle. Although all over Europe and Sweden there was great activity in methods of transmitting power, the lack of any flat strong material like tanned leather and the absence of good glue confined such attempts to small amounts of power until the 15th century.

With the widely influential Industrial Revolution, new names appeared in the transmission of power. Watt, Rennie, and Aveling, in England, made important contributions. Flat belts for the transmission of power in relatively small amounts, played a prominent part in the phenomenal growth of American industry. Not long ago it was an extremely familiar sight to see in any dye plant numerous vats and reactors driven by a maze of belts, all transmitting power from an overhead line shaft. Considerable ingenuity was used in locating this line shaft in inaccessible places which could not otherwise be usefully employed. It was up to the oiler and the belt man to find out how to service the shafting and repair the belts. Throughout this era of increasing applications to heavier loads, the rope belt more than held its own. The successful competitor was the flat leather belt, especially on drives of medium length from the factory ceiling to the floor. A reference in *Dinglers Polytechnisches Journal* states that flat leather belts were introduced to Germany by America in 1838. When one rope was insufficient to transmit the required power, several ropes were used, and troubles developed. The multiple endless rope drive was not successful because of the character of the ropes themselves, and particularly because the ropes were used in V-shaped grooves while the rope was round in cross section. Rope is a twisted mixture of small fibers, larger groups of fibers, and then larger groups of this latter cordage. Separate cords within a rope do not wear well under heavy loads and short centers. Fairly successful drives were installed by Walter H. Dodge, in the 1880's; nevertheless his highly developed continuous warp system of rope drives was not well received because the rope drive has been replaced.

When small leather thongs, running in V-shaped grooves, were used to transmit power, early mechanics noticed that a worn belt was always V-shaped when it was removed. The first people to demonstrate that the V-belt had great possibilities were the automotive engineers who used such a belt around 1922 to drive radiator fans. This application which demonstrated reliability, smoothness, and unusual freedom from trouble, aroused the engineering world to the possibilities of V-belt drives. After the first V-belt had proved successful and economical, there were still many improvements to be made before multiple V-belts could be used on the same pulley. The trouble arose from simple findings. The belts were not sufficiently uniform in width or length. One belt took more of the power than another, became overloaded and failed. For example, six belts would not carry six times the load placed on a single belt.

The modern multiple V-shaped belt drive was designed and developed about 1924 by Walter Geist in Milwaukee. The success of his work came through an appreciation of research. He realized the number of technical problems in a seemingly simple belt drive. The first V-belt applications found success, not because it was properly designed, but because it was over-designed and was required to transmit (*Continued on page 86*)