PRACTICAL CONSIDERATIONS FOR BELT DRIVE SYSTEMS

by Dave McClary

Having "engineered" the installation of belt drive systems for operating four antique machine tools in the Zagray Farm Machine Shop museum, it is appropriate to document the knowledge gained and sources of information for the benefit of those who might embark on such endeavors in the future. Practical knowledge is found in turn of the century books on machinery operation such as Joshua Rose's Modern Machine Shop Practice published in 1887. Another book recently found in an antique store, McGraw-Hill's American Machinist's Handbook second edition of 1914, contains more detailed additional information with a focus on horse power requirements for machines of the time in consideration of the advent of electric motors. These types of sources are most useful when working with vintage machines, shafting, hangers and pulleys in a museum-like environment as well as for practical purposes. Other more current books such as Machinery's Handbook of 1978 contain similar even more detailed information that leads to similar results although different unstated safety factors may have been used.

Most important is to first gather information that is known and establish the objective to be accomplished. Starting with the machine to be driven, what cutting speeds will be used and what is the machine drive pulley rpm required. Next what is the pulley diameter and how wide is the pulley. That will define the horsepower needed for designed use which may not be known unless there was an original electric motor attached. Information in the above books focuses on leather belting but a variety of synthetic belt materials are available today. A belt supplier such as New England Belting in Berlin, CT, can be consulted and would first ask what the smallest pulley diameter is because of concern about belt flexibility as that may limit the number of belt plies or thickness permitted. With multiple machines driven off a line shaft, each machine must have the ability to be started and stopped independently with the line shaft turning. Two ways to achieve that are using a clutch on the counter shaft or a belt shifter that engages or disengages an idler/drive pulley combination. Both ways are in use at the Zagray Farm Machine Shop.

Selecting pulley sizes may be complicated by the limited availability of pulleys and counter shafts among the used items available from which selections can be made. This writer does not know if anyone is making flat belt pulleys or counter shaft assemblies today. The power source and line shaft rpm have to be taken into consideration during the process of arriving at a system design. Assuming a diesel or gas engine would be used, a governor is of course required, like on a tractor. It comes down to a matter of trial and error to put together the speeds and available pulley sizes, along with belt widths to arrive at a proposed scheme. With more power than is needed from an engine, the belts become limiting. All these variables make it an interesting challenge. Pulleys can be picked up at flea markets or auctions when something is seen that looks like it could be useful some day. Old factories can be a source for shafting, hangers, pulleys and countershaft assemblies. Factory line shafts were generally run at about 200 rpm, probably for vibration considerations. Shafting can be purchased today, but available hangers have fixed size journals. The shaft size depended on what material was used. It was learned that forged or wrought shafts were turned to 1/16 inch under a nominal size used for cold rolled shafts. A donated twenty foot long line shaft in the Zagray Farm Machine Shop museum has a diameter of 1 15/16 inches for example. Hangers are the next consideration. A caliper is needed when selecting individual items to ensure a match between shafts, hangers and pulleys. Counter shafts were usually supplied complete with machine tools because they had to match the machine and were then cheap to manufacture. Cone pulleys on clutches for example matched the cone on a lathe so that belts could be shifted readily. A counter shaft with hangers should be kept together and not separated other than to change pulleys. Pulleys may be cast in one piece or made split and bolted together from cast or stamped steel. One piece cast pulleys should only be used near or at the end of a shaft to simplify changing it. Split pulleys usually have cast inserts that can be changed to suit shaft size, or various size inserts can be made and split in half for this purpose. Even wood can be used so long as there is clearance enough to tighten the halves on the shaft. Machinery's Handbook provides limiting speed information for pulleys and states belt speeds greater than 6000 feet per minute are not recommended as centrifugal forces lead to belt slippage. Split cast pulleys may have less than 60 percent of the solid cast pulley maximum speed. It states that solid cast pulleys have a safe rim speed of 5000 feet per minute or about 3000 feet per minute for split cast pulleys. For split stamped steel pulleys the 6000 feet per minute limit applies. The split stamped steel pulleys are much lighter in weight. Dividing belt speed by the pulley circumference in feet gives the rpm for a specific pulley.

Most of the old hangers are self aligning, but if there are more than two on a shaft, they have to be carefully aligned so as not to introduce vibrations due to a flexing shaft. One method of checking horizontal alignment of shafts with more than two hangers is to string a taught small diameter flexible wire parallel to the shaft and measure offset along the length. The same method or a sensitive level can be used for vertical alignment. Hangers should be no more than about eight feet apart and belt load forces should be near the hangers. Mounting of hangers has to be fairly solid because of the forces that will be applied by the belts and the weight of the hangers, shafts and pulleys as well as providing mass for absorbing vibration. Most importantly, two shafts belted together must be parallel in a plane in order to keep the belts on the pulleys when running. This applies between line and counter shafts and also machine shafts.

The Machinery's Handbook mentioned above contains useful information about horse power considerations. A formula that relates horsepower, belt velocity and belt width is given for leather belts with tables of factors that need to be applied for pulley diameter and belt thickness. The tables include the use of double and triple thicknesses of leather belting. The formula is HP = V x W divided by F, the factor(s) that should be applied. V is the velocity of the moving belt in feet per minute and W is the width of the belt in inches. The factor(s) F are shown in tables and range from 1100 for a single belt on an 8 inch pulley, to a smaller factor for larger diameter pulleys, and smaller yet as belt layers are added such that a triple layer belt on a pulley less than 21 inches in diameter has a factor of 440. Some interpolation has to be used along with some judgement. But it can be seen that faster running belts transmit more horsepower as do wider belts. Going further, additional factors may apply depending on the difference in belt tension between the driving and slack sides of the belt and the number of degrees that the belt is in contact with the pulley. The information provided is based on good practice and belt longevity for economical factory usage. Another table provides horse power ratings for steel line shafts that is based on the formula HP = D(cubed) x rpm divided by a factor of 80 where D is the diameter of the shaft in inches. The factor varies with different usage and material. It appears to be based on the use of turned shafts as all sizes listed are in odd sixteenths of an inch. Machinery's Handbook has tables that indicate cold rolled steel is about 30 percent stronger than forged.

Planning a new installation should be undertaken with the intent of doing the research and calculations necessary for the usage intended. In the case of the Zagray Machine Shop as a museum, a slow turning line shaft (43 rpm) using a half horse power electric motor is sufficient to run an 1860 lathe, an 1893 shaper, a 1905 hand miller and an 1850 iron planer individually when cutting soft materials for demonstration purposes. The large reduction in rpm from 1750 for the motor provides a large increase in torque sufficient to run the machines. The formula HP = Torque x RPM divided by the constant 5255, shows that increased torque results from reduced rpm with a constant horse power. Safety considerations lead to the use of slow belt speeds and soft materials, wax and wood are used, and allows close observation of machine operation by visitors.