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Research article

WOODEN SLIDING BEARINGS

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ABSTRACT

Wood, acting as a construction material, has been utilized by humans since the beginning of times. The early human-made machines were made entirely from wood. With time, technical progress gradually displaced wood from machine design and construction. However, despite the passage of time, due to the low cost and availability of wood, the elements in the quickly worn out machine parts still were made from wood. Sliding bearing shells or replaceable gear teeth need to be replaced here. These elements can still be found in pre-war mills. This article contains examples overview of wood application in such areas as bearings, and discusses their advantages and disadvantages. It also indicates the desirability of undertaking further research on the use of wood in tribological pairs.

KEYWORDS: sliding bearings, wooden bushings, wear

1. Introduction

Wood has been utilized by humans as a construction material for centuries. Initially, it was used to build simple, basic tools. Following the development of technology, many different, sometimes unconventional applications were subsequently found and developed [1]. Wood owes its common application in mechanical engineering to its easy accessibility, relatively simple harvesting and relatively easy machining. Today, wood as a construction material is no longer used equally often. It has been effectively replaced by other, more durable building materials (mainly metal materials and composites) [2]. In some branches of the economy, wood is successfully used to this day. That can specifically be observed in fields such as: aviation, boatbuilding, sports, agriculture and specific industrial applications [2-3]. Wood, like any construction material, has its advantages and disadvantages.

The advantages of wood as a building material are related to a number of facts [4-5]: its easy machinability, favourable ratio of weight to mechanical strength, invariance of dimensions in the conditions of a varying temperature, beneficial thermal conductivity coefficient, ability to suppress vibrations and noise. In addition, engineering sciences offer the possibility to modify wood characteristics to obtain material with desired properties, for instance to gain its resistance to chemical factors causing failure. It is also commonly known that wood produces a characteristic sound or noise increase is emitted prior to its failure and it forms a renewable resource.

Among the drawacks of wood, we can mention the following [4-5]: its anisotropy, relatively low hardness and abrasion resistance, variability of dimensions and shape under the effects of humidity resulting from swelling and shrinking, its low durability, its low compressive and tensile strength in tangential and radial directions relative to the fibers, as well as its flammability.

In the early stages of this study, we can state that the main problems associated with the use of wood in construction are related to its anisotropy and variability of properties resulting from the effects of the ambient environment and time. Although wood characterization is sufficiently described in the literature, it is relatively difficult to find adequate numerical data derived from such analysis. Their values should be sought in literature in this area [2, 6-9]. This statement is largely due to the history of human development. In the old days, there was no technical literature or manuals. The selection of construction material was guided by the intuition of the craftsmen, their experience and folk wisdom gained and passed down from generation to another. In the modern times, however, wood was considered an obsolete material. Hence the lack of professional literature sources. This paper aims to reconsider the solutions already applied and proven in practice and to refer to the pro-ecological importance of wood as a construction material. In the article, special attention is paid to “wooden” bearing bushings, as they are still successfully applied today. In addition, in some modern solutions, the use of wood in bushings is a deliberate and justified action. In the opinion of these authors, the use of wood for plain bearings is a somewhat forgotten practice, however, many benefits are hidden in this solution.

2. Wood as material in friction bearing assemblies

On the basis of the analysis of the technology development throughout history, we can note that wood played a very important role in the development of plain bearings. It was the material from which the first plain bearings were made. The most common lubricant at that time was birch pitch. Tar and animal fat were used to a lesser extent [10]. In order for the bearing to work properly, it must have appropriate properties that are strictly dependent on the operating conditions. Therefore, only certain types of wood were used in their construction. According to Sydor [10], wooden bearings were made of such tree species as:

- roughbark lignum-vitae(Carpinus betulus),
- common pear (Pyrus communis),
- boxwood (Phyllostylon brasiliensis),
- genus callophylum (Calophyllum tomentosum),
- teak (Tectona grandis),
- pedunculate oak (Quercus robur),
- red ironwood (Lophira alata),
- tallowwood (Eucalyptus microcorys),
- blackbutt (Eucalyptus pilularis),
- lemonwood (Calycophyllum candidissimum),
- camphorwood (Dryobalanops aromatic).

However, common experience shows that the service lives of machines built of wood and their bearings is often longer than the lifetime of the builder. For this reason, and mainly because of sufficient availability in domestic applications, native wood species were used.

3. Wood as material in friction bearing assemblies

Years ago, almost all machines and devices used in households were built of wood. One of the first applications of wooden bearings were wheel bearings in carts, wheelbarrows and horse-drawn

carts of the time, or bearings in equipment today classified as household appliances. Selected examples of wood-metal bearings are presented in Figs. 1 and 2.

Figure 1. The wheelbarrow from the collections of the Opole Open-Air Museum of Rural Architecture

Figure 2. The bearing assembly of the drive wheel of spinning wheel [11]

The milling industry constitutes an example of the industrial use of wooden drive wheels [12]. A skillful selection of materials applied in the spinning wheels, their deliberate oversize and careful lubrication ensured long-term operation of these elements. A watermill located in the Opole Museum of Rural Architecture forms an example of such a solution. It should be borne in mind that the technical equipment in this spinning wheel is almost entirely made from wood. Only the power transmission shafts and some of the gears are made of iron. Examples of mill mechanism bearing units with wooden half-shells are shown in Fig. 3.

Agriculture forms another field of application of wooden bearings that has not been mentioned so far. Since ancient times, wood has been utilized as the basic construction material to build machines and devices that could improve manual labour on a farm. Typically, a horse-drawn cart wheel bearing assembly comes to mind here, but this forms only a far-reaching simplification. After all, we all know that a number of machines were created and used on the farm, which are now used by staff in specialist industries. Examples of such machines include weaving looms, butter churns, woodworking machines, the first machines for mowing or harvesting agricultural produce, etc. It is impossible to list all the applications of wooden bearing units in such a short study. What's more, the creative invention of the creators of that time was equally unlimited to today's. They only had other means of production and applied other building materials.

Figure 3. The examples of bearing assemblies with wooden acetabula

In the current era of development, it may occur to people that such a bearing of coupling elements should long be fallen into oblivion. Nothing further from the truth however. To this day, machines are produced in which wood-metal bearing assemblies cannot be built in any way. Examples of such solutions include disc harrows, cultivation rollers, grain harvesters or water turbines [3, 14-15]. In disc harrows, as in various types of cultivation rollers, the shaft axis is mounted in wooden bushings (half-shells). A general view of an exemplary cultivation roller and a close-up of the bearing assembly are shown in Fig. 4. In this application, wooden bearings are characterized by a particularly high mechanical strength.

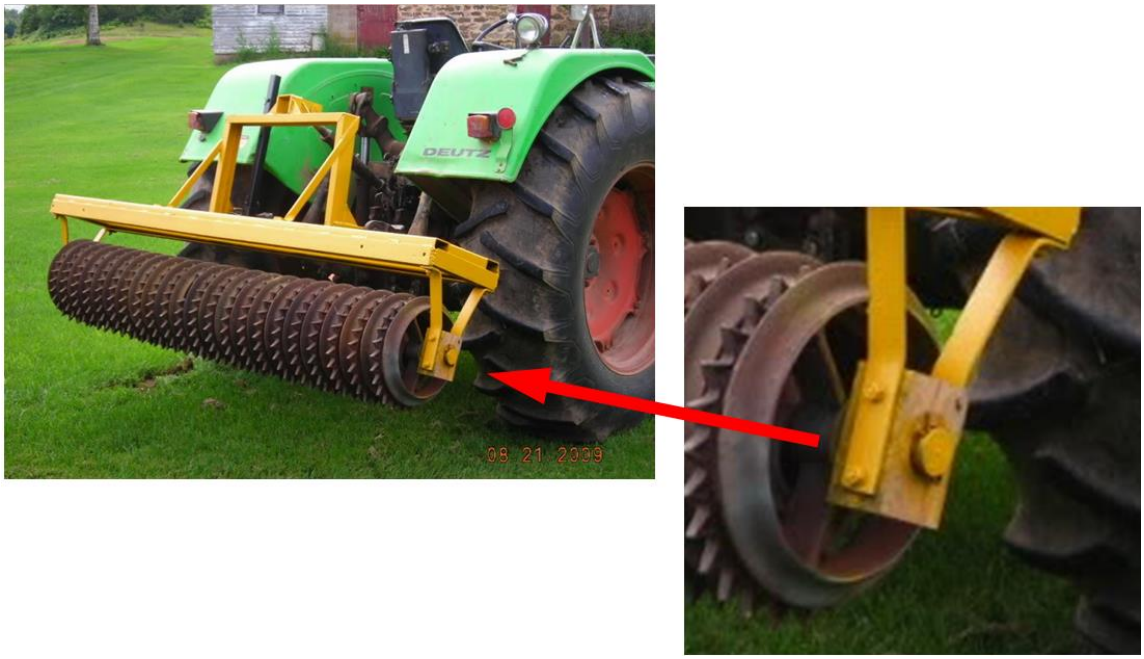

Figure 4. An example of the bearing assembly of the wooden half shells in cultipacker [16]

Figure 5. An example of a bearing assembly in a shaker of a Claas harvester combine

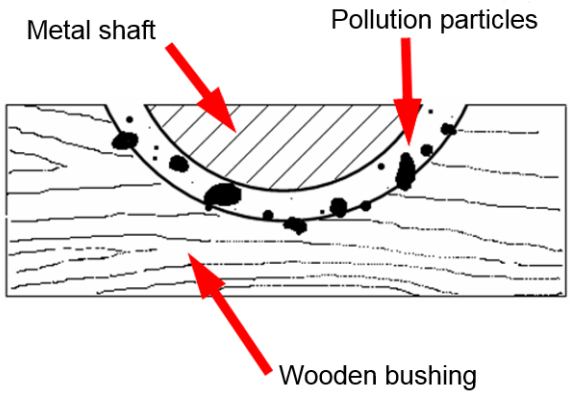

Figure 6. The mechanism of wear of mating surfaces

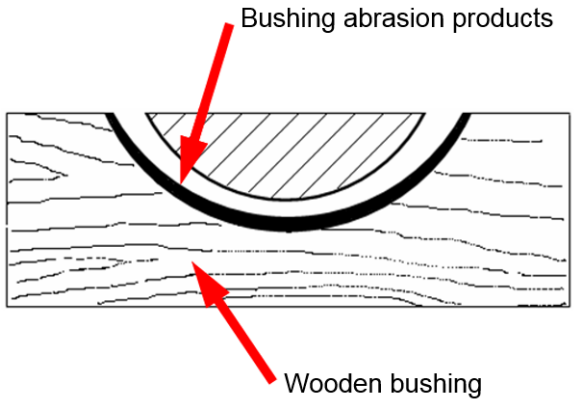

Figure 7. The mechanism of formation of a char layer

Such a solution does not require any sealants or lubrication systems. A similar solution is still used today in combine harvesters. Bearings with wooden semi-pans are used there in scrapers and shakers [3]. This way of bearing performs more effectively in this case than metal plain bearings or rolling bearings. The advantages of such an application may be evidenced by the fact that bearings with wooden bushings applied in walkers and scrapers are included in designs by the leading manufacturers of these machines, such as Claas or John Deere [3].

In agricultural machinery, bearings with wooden pans need to perform well in difficult conditions. This is due to their exposition to constant contamination and lack of lubrication. In most cases, the bushings are a component designed for controlled wear. Therefore, the machines provide an easy way to install them and provide sufficient space to ensure trouble-free replacement. Two such different materials of the friction pair as wood and metal obviously determine the behaviour of the entire bearing arrangement. In the conditions that exist throughout agricultural work, it is inevitable that dirt particles penetrate between the bearing elements. Typically, these particles, under the influence of pressure, are driven into the soft surface of the pans (fig. 6). Hard inclusions embedded in the shell surface and preserved between mating surfaces naturally lead to wear occurring in the bearing. However, the wear rate of the wooden bushing is much faster than that of the shaft. This is mainly due to the large difference in hardness of both materials of the friction pair.

Such bearings are maintenance-free in a majority of cases. As a result, they often run with minimal lubrication or perform in a “dry condition”. It is obvious that in the case of dry friction or

with insufficient lubrication, the temperature of the friction pair increases. In the case of lubricant-impregnated bushings, an increase in temperature results leading to a minimal amount of lubricant. As a consequence, the friction decreases and the bearing temperature stabilizes at a level that does not pose a threat to the service life of the bearing. However, if the bushings are not soaked, a char top layer of occurs in the bearing. This phenomenon is schematically shown in Fig. 7. The minimum layer of separated carbon reduces the coefficient of friction between the shaft and the bearing shell. However, in this case, the temperature of the friction node does not drop enough to significantly slow down the process of wear of the mating surfaces. Due to high surface pressures, such a process is intensive and should be defined as catastrophic bearing wear.

Apart from the agricultural sector, metal/wood bearings are successfully applied in the power industry. In small hydro schemes, wooden bearings with special designs are often applied to act as bearings of water turbines. Such bearings usually are submerged in water. Water is therefore a cooling and lubricating agent here. In this solution, the risk of contamination of the watercourse with lubricants coming out of the bearing slots is practically minimized to zero. Due to the nature of the loads carried by the contacting surfaces, turbine bearings are of considerable size. Therefore, in order to ensure appropriate working conditions, the shells of such bearings have appropriate cuts (water channels) or are made of appropriately shaped segments. An example of a half acetabulum of water turbine, built of segments, is shown in Fig. 8.

Figure 8. An example of the half acetabulum of water turbine [15]

4. Conclusions

On the basis of the literature review and long years of practical experience, we can conclude that the benefits of progress in technology include many areas of everyday life. However, despite the modernity that surrounds us, it is valuable to pay attention to solutions that have demonstrated their practical performance for years. The wooden bearings discussed in this article will be successfully used in niche solutions for many years to come. In addition, it seems that due to the lack of better materials for such specific applications, the conditions will not change in the near future. In addition, the increasingly strong pressure to use pro-ecological solutions strengthens our conviction, that we should consciously increase the share of wood in friction pairs used in machine construction.

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