The problem of fixing the axisymmetric elements on the example of pulley mounting on the shaft

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Abstract. The paper present the problem of permanent fixing of the axisymmetric elements relative position on the example of pulley mounting on the shaft. A method of permanent and quick fixing of pulleys on shafts has been sought for years. A number of detachable and inseparable joint solutions are available. The authors are looking for an inseparable solution allowing for quick assembly in serial production conditions. The quality of this connection is important for the geometry of the transmission gear, as it has a significant impact on the quality of the transmission gear operation and the belt life.

1. Introduction

One of challenges for belt gear designers is the development of a method for quick fixing of pulleys on shafts. This would allow to reduce the transmission gear replacement time, and is also important for serial production of machines and systems using toothed belts as well as in belt conveyor, rollers, conveyor, robotics and manufacturing systems etc. [1, 2]. The pulley mounting must be durable and correct in terms of its position in plane, alignment, etc. (figure 1).

Figure 1. Drive in coffee machine.

This is part of a broader problem of connecting axisymmetric elements. It concerns the production of large-size systems as well as micromechanism. Connections of this type are burdened with errors of
different kind. This can negatively affect the operation of the entire transmission gear and the system. All kinds of inaccuracies prevent increasing the linear speed of the belt, positioning and displacement accuracy [3, 4].

2. Pulley mounting errors
One of the advantages of belt transmission gears is the ability to work in "twisted" position. This means that the belt can work in tandem with pulleys lying in different planes. However, these types of transmission gears require precise wheel mounting while mounting errors in these gears can result in transmission gear damage. The most common errors include: twisting of the pulleys, displacement of planes, misalignment on the shaft, etc. [2, 5].

Pulley mounting errors can cause pulley run-out or whirling, which can also cause quick bearing damage.

![Figure 2. Measurement of pulley from car engine regulation system.](image)

The accuracy of the wheel's performance has a significant influence on the quality of wheel mounting. As studies show, especially the wheels produced in large series are far from ideal [6, 7]. The drawing shows the wheel and treadmill geometry errors (figure 2).

3. Basic system for pulley mounting on the shaft
The basic methods of mounting pulleys on the shaft include a hole with a key (the pulley is secured with a screw on the shaft). However, adapter sleeves and self-locking sleeves are most commonly used. Dimensional standards of such sleeves have been established and one can easily select a right pulley (figure 3, with a code on pulley and taper). The distinction between adapter and self-locking sleeves is based on the method of introducing compression stress between the pulley and the shaft. Such stress can be introduced in series production by keying fit with or without thermal deformation of the pulley [8, 9].

The mounting method depends to a large extent on the material the pulley and they are made of different materials (figures 1, 3).
Plastic wheels require additional bush fitting, in which case the sleeve is mounted on the shaft with close fit, while its connection to the rest of the pulley is of form-fitting nature. Scratches are made on its surface – by knurling, threading or it in the form of a polygon. In any case, the aim is to achieve quick and secure mounting of the sleeve in the plastic [10].

Measurements of the shaft on which the wheel is to be mounted indicate significant inaccuracies in its geometry. In conjunction with the wheel bore, interference and visible places are visible. Such a connection will cause stresses in the connection but also cause the displacement of the center of
rotation of the wheel $O$ by the value $dL$, which will negatively affect the coupling in the gearbox (figure 4) [11, 12].

4. Modelling of fast axisymmetric connections

Experimental tests have confirmed that when mounting a pulley on a shaft made of elastic materials, it is often sufficient to introduce stress that does not exceed the yield point. Yet in the case of metal-plastic connections, that stress must be exceeded. The metal part is properly shaped so that permanent strain occurs in the material [13, 14]. The torque between the pulley and the shaft is transmitted by form-fitting coupling.

Regardless of the type of coupling present in the gearbox, the wheel after mounting should be at the point $O$. Hypothetical center of rotation that does not introduce errors in rotation. Any change in the position $dL$ introduces errors in the cooperation of the wheel and the belt and has an impact on the friction force $T$, pressure force $N$, and thus on the stress $S$ occurring in the belt, speed $v$, and on the state of coupling [1, 2] with the pulley (figure 5):

$$\frac{S_1}{S_2} = f(\sigma_k, \sigma_p, K_W, A_{kp}, Y, Z, dL)$$  \hspace{1cm} (1)

where: $K_W$ – belt pitch utilization factor, $\sigma_k$ – cord deformation (extension and twist), $\sigma_p$ – belt material deformation causing belt tooth height change $\sigma_{ph}$ and the width change $\sigma_{pw}$ as well as shape change $\sigma_{ps}$, $A_{kp}$ – adhesion factor for cord, belt material and additional materials, $Y$ – the toothed belt pitch to toothed pulley pitch ratio, $Z$ – belt and pulley wear of volumetric $Z_v$ and energetic $Z_e$ type and point $O$ fault of position, $dL \to 0$.

5. Conclusion

Research on quick mounting of pulleys on axles and shafts indicate the advantages of solutions where the surfaces are shaped so that permanent surface strain occurs during assembly. The connection made in this way is an inseparable connection. In series production, especially of micro transmission gears,
neither disassembly of the belt nor the pulleys is provided for. The transmission gears in motor vehicles, installed in the power steering, braking, seat, door and sunshine roof control systems etc. are examples of such applications. Research indicates how important is the quality of pulley mounting for the efficiency of a belt transmission, which is why in series production it should be done with the utmost care.

6. References

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