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Shaping of Non-classical Cogbelt Pulleys using Selected Methods of Erosion Blasting

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Abstract. This paper presents the possibility of shaping the envelope of non-classical cogbelt pulleys used in non-parallel cogbelt transmissions. A characteristic feature of these transmissions is the periodic change of kinematic features due to the use of eccentrically mounted ellipsoidal, oval or round pulleys. The use of envelope or shape machining methods for such cogbelt pulleys creates the need to develop complex machine tool control programs. The author suggests using selected methods of erosion blasting for this purpose.

Introduction

Incorrect execution and assembly of machinery and equipment [1-2], unbalance of rotating components, wear of components [3], change of the transmission belt temperature and low resistance to grease and dirt may cause improper operation of belt transmissions. In the case of non-parallel belt transmissions, an additional source of malfunction may be a significantly different shape-friction coupling process between the cogbelt and the cogbelt pulleys. The difference in the coupling process results directly from the geometrical features of cogbelt pulleys (which can be e.g. elliptical or oval) and the kinematic features of a cogbelt transmission. The main problem in the coupling characteristics in such a cogbelt transmission is the need to design variable pitches on a non-circular cogbelt pulley to obtain their proper engagement with a standardized cogbelt. This requires adjusting the "fixed" cogbelt pitch to the momentary engagement conditions in the cogbelt transmission. The issue of the cogbelt pitch variation should be taken into account in the design of the geometry of non-circular pulleys in the CAD system. In order to eliminate the possibility of errors already at the design stage, it is necessary to develop numerical [4-5], material [6-7] and structural models [8].

The development of a program controlling the operation of a CNC milling machine requires the determination of the x and y coordinates of the pulley notch and the orientation angle of a workpiece in relation to the assumed zero axis of the coordinate system. Other machining parameters are to be selected according to generally known technological recommendations. When machining an elliptical cogbelt pulley, the method's inevitable disadvantage is the possibility of non-machining the tooth point profile on a small arc radius, while a damage to the tooth point profile can occur on a large arc radius. This issue is illustrated in Fig. 1.

The use of finishing machining with end mills or the use of a set of profile cutters allows for eliminating this disadvantage; however, it significantly increases the cost of cogbelt pulley manufacturing. The error value decreases as the "non-circularity" of the cogbelt pulley decreases. Figure 2 shows a fragment of a cogbelt pulley with a non-circular generating line. The figure illustrates the change in the pitch value. The subsequent designations R_1 to R_{12} indicate the cogbelt pulley envelope parts, on which the variable pitch p_z is designed, r_z denotes the outer cogbelt pulley radius, and t_o is the distance between the outer cogbelt pulley radius and the pitch radius r_p.

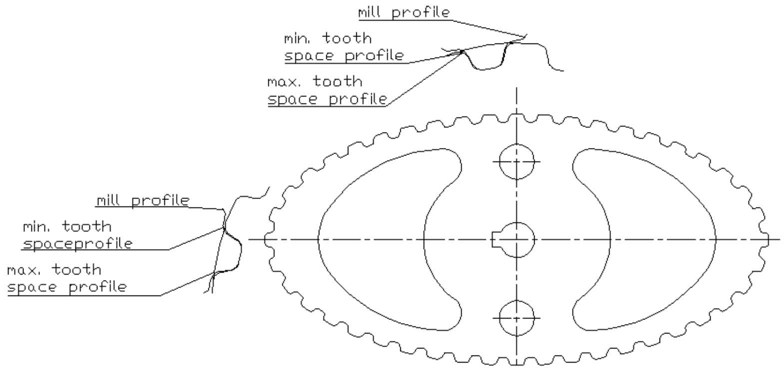
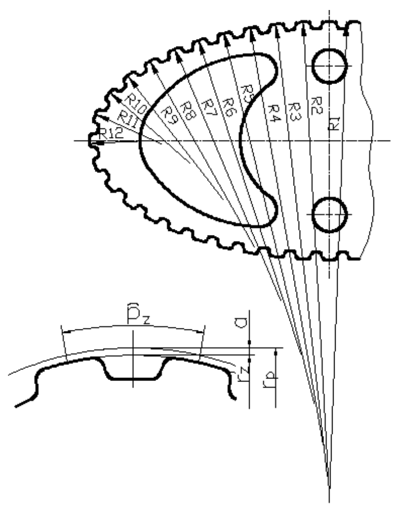


Fig.1. Errors of noncircular-elliptic pulley machining with a profile cutter

For toothed wheels used in mechanical gears, the pitch radius is below the outer radius, while in cogbelt pulleys this radius is above the outer profile. Pitch values have been determined for the changing values of external and pitch radii. If the cogbelt pulley had a round contour, then the pitch would be fixed and equal to 9.525 (for the L type cogbelt). The table (Fig. 2) gives the determined values of variable (p_z) and averaged (p_s) pitch.



radius	r_z	a	r_p	p	p_z	p_s
R1	172.91	0.381	173.29	9.525	9.5041	
R2	170.55	0.381	170.93	9.525	9.5038	
R3	163.54	0.381	163.92	9.525	9.5029	
R4	152.18	0.381	152.56	9.525	9.5012	
R5	136.96	0.381	137.34	9.525	9.4986	
R6	118.60	0.381	118.98	9.525	9.4945	9.4467
R7	98.08	0.381	98.46	9.525	9.4881	
R8	76.68	0.381	77.06	9.525	9.4779	
R9	56.06	0.381	56.44	9.525	9.4607	
R10	38.31	0.381	38.69	9.525	9.4312	
R11	25.92	0.381	26.30	9.525	9.3870	
R12	21.38	0.381	21.76	9.525	9.3582	

Fig. 2. Geometry of a non-circular (elliptical) cogbelt pulley: R1-R12 - parts of an envelope of the noncircular cogbelt pulley with a variable pitch p_z; r_z - outer radius of the noncircular cogbelt pulley, a - distance between outer radius r_z and pitch radius r_p

Cogbelt pulley profiles with variable pitch values on the outer contour (Fig. 2) were plotted in the AutoCAD program. Cogbelt pulley models were saved in the "dxf" format and, in this form, they were read into programs for erosion blasting machines.

Shaping the envelope of a toothed ring using electroerosive cutting

The first method of shaping the teeth of cogbelt pulleys with a non-circular envelope was electroerosive cutting (WEDM - *wire electrical discharge machining*) (Fig. 3). The tool for this machining was a thin brass wire with a diameter of 0.02-0.5 mm. Wires made of copper, tungsten and molybdenum or coated wires, e.g. galvanized brass wires, are also commonly used.

The technology of cutting on CNC EDM machines is quite expensive, e.g. in comparison with laser cutting or water cutting.

a) b)

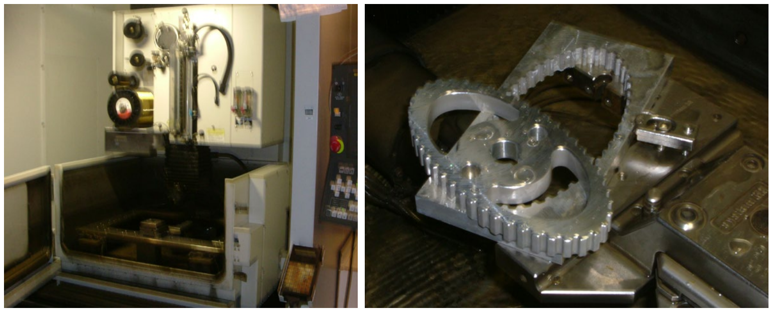


Fig. 3. Shaping a non-circular cogbelt pulley rim in the WEDM machining process: a) machining, b) elliptical cogbelt pulley made

Erosion cutting has the following advantages: the universality of the electrode, i.e. eliminating the need to make electrodes with complex shapes, eliminating the problem of wear of the working electrode when designing the machining process, the possibility of making parts with complex shapes and very small dimensions (machine tools with high production flexibility), high degree of automation due to the use of numerically controlled machines, the possibility of making parts with the equidistant line profile using one program for the NC system, high machining accuracy (from 0.02 to 0.001 mm). Due to erosive wear, the wire is rewound from a spool into a container or from a spool onto another spool at a speed of 0.5-20 m/min. In order to ensure high accuracy of positioning of the wire in relation to the workpiece, special wire eyelet guides and a constant wire tension of 5-20 N are used.

Teeth shaping using cutting with a jet of water with an abradant

While searching for cheap and reliable methods of shaping cogbelt pulleys, the author also considered the possibility of making them use laser processing. The literature on this method is broad and indicates its various applications [9-17]. Unfortunately, with a wheel thickness of 15 mm, the use of the gas laser cutting method is significantly limited due to the occurrence of heating and, consequently, deformation of the workpiece. The treatment with the use of a water jet (Fig. 4) does not have this disadvantage. The material being cut is not subjected to mechanical overloads or thermal influences. The surface obtained as a result of the treatment has a good quality and does not require further processing. The main advantage of this method is that the physical and chemical properties of the material after processing remain unchanged. Before cutting with a water jet, it is very important to choose correct machining parameters and geometrical features of the cutting head. The cost of this method is influenced by machine tool, water and abradant costs. An important issue during material processing is the abradant recycling, which consists in continuous collection of abrasive sand, particles of cut material and water from the water table. Segregation consists in the initial separation of waste with a granulation below 80 microns, followed by drying of the remaining mass and further segregation into clean abrasive sand with a grain size of 80-100 micrometers and remaining waste. Recycled water returns to the water table. Aluminum Pa6 was the material used to make the non-circular cogbelt pulleys using this method. Waterjet cutting technology has the following advantages: the ability to process almost all available materials, using electricity to drive the device, and water with natural sand to cut the material, which makes this technology environmentally friendly; no harmful substances are created when cutting (gases, etc.), the waste remaining after cutting is easy to segregate, it is possible to cut much thicker machine parts in comparison with laser cutting, the material being cut does not heat up, so there is no contraindication to the treatment of fragile materials with this method.

a) b)

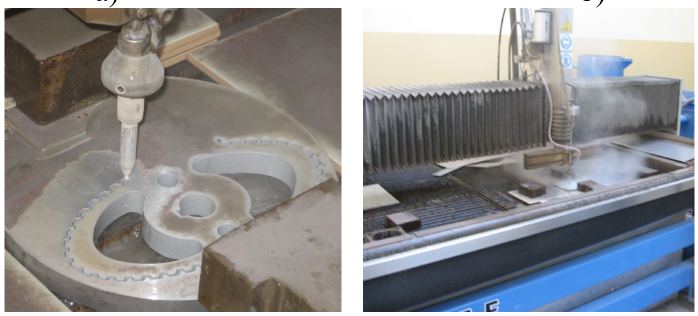


Fig. 4. Shaping of non-circular cogbelt pulleys: a) cutting a cogbelt pulley with a jet of water with an abradant, b) CNC machine used for machining

The edges of processed details, unlike laser machining, do not undergo discoloration or thermal hardening and do not undergo structural changes resulting from the thermal effect. The advantages of numerically controlled cutters also result from the possibility of fast and efficient development of the technological process.

The above-described application of methods for shaping non-circular cogbelt pulleys was subjected to verification, one of the main criteria of which was the analysis of the correctness of mapping of geometrical features and surface stereometry. To evaluate the mapping of geometrical features, a Zeiss coordinate measuring machine was used, and the surface quality condition after treatment was checked with a Taylor Hobson profilographometer. Selected cogbelt pulley parameters are given in Table 1. The obtained values meet the requirements for cogbelt pulleys.

Table 1. Comparison of geometrical features and surface stereometry of non-circular cogbelt pulleys obtained with various shaping methods

Geometrical features and surface stereometry	R_a [µm]	Tolerance of outer profile of cogbelt pulleys [mm]	Parallelism tolerance of teeth in relation to cogbelt pulley axis [mm]	Conicity tolerance of cogbelt pulley (for a width of 0.5”) [mm]	Pitch errors for cogbelt pulleys (for two adjacent teeth) [mm]	Pitch errors for cogbelt pulleys (for total pitch in an angle range of 90°) [mm]
WEDM	0.534	±0.01	±0.02	±0.02	0.03	0.06
Cutting with a water/abradant jet	2.676	±0.05	±0.03	±0.03	0.03	0.08

Summary

The assessment of the surface quality of the cogbelt pulleys indicates that the proposed methods of erosion blasting can be successfully applied. The advantage of the proposed solutions is the relatively low cost of machining and the possibility of making cogbelt pulley shapes of any geometry, the need to design a specialized tool has been eliminated, the program preparation time is relatively short. Accurate transmission of a cogbelt pulley design to the CAD system is very important in this process. This requires considerable skill and experience of designers.

The obtained results and accumulated experience may also be interesting for other areas of production and processing of machine parts, e.g. production of protective coatings by ESD method [18] and subsequent laser finishing [19, 20], hydraulics of heavy working machines [21], as well as creating realistic simulators of ship engine rooms [22]. The study of the surfaces obtained by erosion blasting may inspire further development of image analysis methods [23].

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