Restrictions in the design of gear wheel components and drives for micro technology

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Abstract

According to enhanced interest for use of micro mechanical gear drives increased requirements occur for the transmittable power output with at the same time proceeding miniaturization. To meet these future necessities research trends lead to micro technical parts from metal and ceramic materials. Using these materials the design of the parts has to meet restrictions of several disciplines, predominantly manufacturing and molding technologies.

1. Introduction

Micro mechanical components and systems are more and more of central interest. Up to now it is common to use assured manufacturing technologies nearly limited to the application of polymer materials. A special group of Karlsruhe research institutes within the DFG funded collaborative research center (Sonderforschungsbereich) “Development, production and quality assurance of primary shaped micro components from metallic and ceramic materials” tries to increase the focus on a broader range of steps in the product development process with its central task of micro primary shaping of metallic and ceramic parts.

As far as the design is concerned there exists a lack of systematically collected and edited know-how acquired during the concept and draft development of micro mechanical parts and systems which could be generalized so it can be used as a template for future product developments.

1.1 Manufacturing techniques

Since the parts will be primary shaped the form tools have to be cut of high strength steel to ensure a high tool life for economic middle and large series production. Besides the molding techniques micro molding and micro powder injection molding the micro milling represents momentarily the predominant restrictive technology.

1.2 Restrictive criteria using micro milling

The smallest for reproducible cutting results utilized tool is a 100 µm measuring end mill. This sets the basis for minimum structure measurements. Due to a direct relation the realizable cutting depth can only be between two and three times the diameter. Moreover, the resulting rounding at the part contours have to be taken in account for the design of micro technical parts.

2. Micro planetary gear

To represent and examine the methodologically driven development of micro mechanical parts a three stage micro planetary gear was designed.

Each stage of this demonstrator consists of three planet wheels arranged with an offset angle of 120° around the central sun wheel and the ring gear.

Implementing a first design draft standardized design criteria of the macro gear design theory have to be taken in account as far as transferable on the micro scaled components. Furthermore, they have to follow the detected restrictions on the part of the form tool manufacturing and the molding technologies.

2.1 Gear Tooth Layout

The gear tooth layout of the planet gear corresponding to micro specific design rules is shown in figure 1.

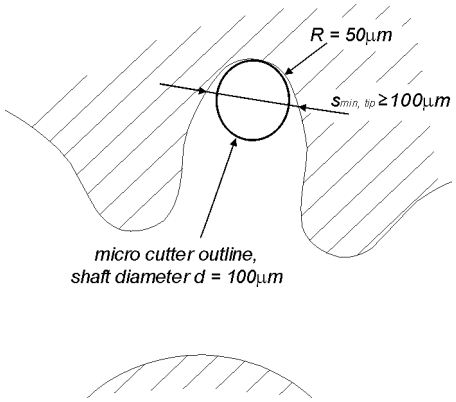

Figure 1: Gear tooth layout of the planet gear corresponding to micro specific design rules

As the sun gear has 12 teeth and the planet gear only 10, the gearing lies significantly below the permissible practical limit for the minimum number of teeth respectively to DIN 867. To avoid undercut a positive addendum modification is necessary to sustain an appropriate root-strength of teeth and to guarantee a minimum transverse contact ratio greater 1. It also improves the removal of the part from the mould.

Another characteristic of a positive addendum modification is a tip formation on the tip of the tooth. Since micro cutting is the utilized manufacturing technique for the form tool the designer has to keep in mind that the end mill will numerically controlled proceed along the tooth profile up to the tip of the tooth. Hence the tooth thickness in the tip sector should narrow at the most so the mill just tangents to the tip circle. Of the same tenor the resulting profile relief due to the rounding of the addendum flank must not fall below the minimum transverse contact ratio.

Following this restrictive criterion a pressure angle of $\alpha = 10°$ was constituted which leads to a more curved flank profile and noticeably thicker tip of the tooth.

3. Literature

[1] W. Krause: “Konstruktionselemente der Feinmechanik”, Carl Hanser Verlag, München/Wien 1993

[2] W. Krause: „Zahnradgetriebe für Kleinst- und Mikromotoren“, conference Mainz 09./10. may 1996, VDE-VDI-Gesellschaft Mikroelektronik; Mikro- und Feinwerktechnik, GMM.-Düsseldorf: VDI Verl. 1996

[3] G. Niemann, H. Winter: „Maschinenelemente“; volume II, 2nd Edition, Springer-Verlag, Berlin Heidelberg New York Tokyo 1983

[4] K. Roth: „Zahnradtechnik“, volume 1, volume 2, Springer-Verlag, Berlin Heidelberg 1989

[5] Ch. Thürigen: „Zahnradgetriebe für Mikromotoren“, Fortschr.-Ber. VDI, Reihe 1, Nr. 326, Düsseldorf: VDI Verlag 2000