Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 13 (2017) 267–274

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Optimal design of planetary gearboxes for application in machine tools

D.R. Salgado[a,*], A.G. González[b], J. García Sanz-Calcedo[a], E.M. Beamud[c], E. García[d], P.J. Núñez[d]

[a]*Escuela de Ingenierías Industriales, Avda. Elvas s/n, Badajoz 06006, Spain*
[b]*Centro Universitario de Mérida, C/Sta. Teresa de Jornet 38, Mérida 06800, Spain*
[c]*Escuela de Ingeniería Minera e Industrial de Almadén, Plz. Manuel Meca s/n, Almadén, Ciudad Real 13400, Spain*
[d]*E.T.S. de Ingenieros Industriales, Avda. Camilo J. Cela s/n, Ciudad Real 13071, Spain*

Abstract

Many machine tools are equipped with a motor-gearbox based on Planetary Gear Trains (PGT) to extend the constant power range of the machine tool spindle drive motor at low speeds. Other application of PGT in machine tools is for High Speed Machining (HSM). The use of a PGT transmission to approximate a conventional machine tool to HSM, providing an outstanding and cost-effective opportunity for upgrading an existing lower speed machine tool, can save substantial investment in new capital equipment. One of the cheapest solutions is the use of mechanical spindle speeders, used with proven performance in a variety of machining processes, such as drilling, milling, tapping and even grinding. In this paper the design of these PGT transmissions to extend the constant power range and for HSM are given. Results can be of great interest for manufacturers and engineers involved with the design of spindle drive gearboxes for machine tools.

Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.

Keywords: Machine tools; planetary gear trains; mechanical spindle speeders; high speed machining

* Corresponding author. Tel.: +34-924-289-600.
E-mail address: drs@unex.es

2351-9789 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.
10.1016/j.promfg.2017.09.069

1. Introduction

All of the current trends in machining—from high-speed machining (HSM) to knowledge-based systems—are geared towards maximizing production capabilities. HSM is growing rapidly, and it is providing several advantages over conventional machining, such as reduced machining time, reduced mechanical stresses, reduced heating of the workpieces, high surface quality, the use of smaller tools, etc. This necessity of HSM in industry has increased substantially the amount of research in this field [1–4]. Moreover, HSM represents a good solution for machining light metals (aluminium and magnesium for automotive and aerospace applications), machining cast iron with ceramic inserts, machining composite materials and other materials, including kovar, titanium, inconel, etc. There are different solutions to approximate a conventional machine tool to HSM, providing an outstanding and cost-effective opportunity for upgrading an existing lower speed machine tool, and can save substantial investment in new capital equipment. One of the cheapest solutions is the use of mechanical spindle speeders. Spindle speeders have been developed with proven performance in a variety of machining processes, such as drilling, milling, tapping and even grinding. They are used particularly in finishing operations, and are ideal for applications such as those encountered in the mould and die industry. In summation, mechanical spindle speeders are a low-cost option that allows the increase of the speed of a conventional machine tool to the speed of HSM. In this paper, the first objective is to give a set of optimal designs of mechanical spindle speeders for different powers and speed ratios.

The spindle is one of the main mechanical components in machining centers, since its design directly affects the finished quality of workpieces and machining productivity. Consequently, spindle design has been studied in depth in several works [5–8]. Machine tools cannot provide high torques over their entire speed range unless the motor is oversized. Nevertheless, the requirements of such an oversized motor to provide consistent torque across the machine tool's speed range increase not only the cost of the motor but also the operating costs due to higher power consumption. Additionally, the motor's weight would exceed the weight of a motor-gearbox combination. For these reasons, spindle drive gearboxes are used. The use of machine tool spindle drive gearboxes allows one to extend the constant power range of the machine tool spindle drive motors. This range extension of power and torque is illustrated in Fig. 1.

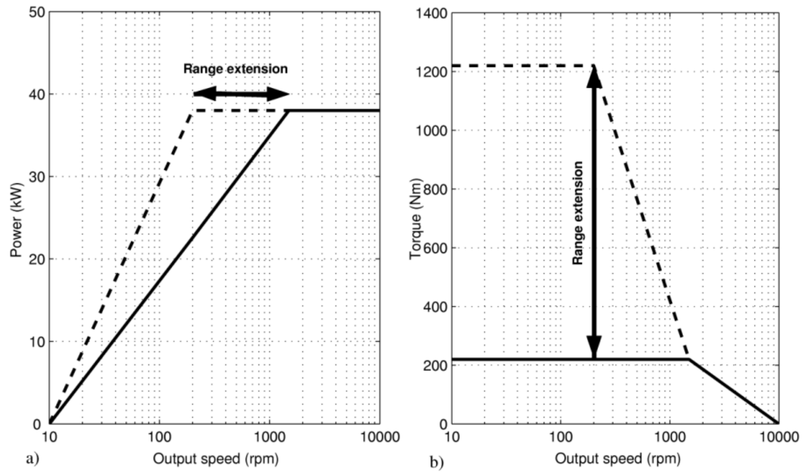

Fig. 1. Range extension of power and torque using a spindle gearbox

Traditionally, these gearboxes are used in conventional applications where the motor and gearbox are mounted outside the headstock, and the spindle is driven by belts, chains or gears. Nowadays, the gearboxes are integrated in-line between the water-cooled motor and the spindle inside the machine tool's ram. This integration enables the unit to fit into the bore of the machine tool ram and share in the coolant system. This compact, light-weight configuration maximizes efficiency while minimizing vibrations and noise. It is the design of this configuration that is studied in the present work.