

An Analytical Method for the Calculation of the Efficiency of Planetary Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

ABSTRACT

This paper presents a synthesis of an analytical method for the calculation of the efficiency of simple or compound planetary gear trains. It is based on fundamentals formulae. It is intended to improve the accuracy of the rating of the efficiency of planetary gears to be included in a calculation of the thermal capacity.

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AN ANALYTICAL METHOD FOR THE CALCULATION OF THE EFFICIENCY OF PLANETARY GEARS

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1 INTRODUCTION

In the industrial field, planetary (or epicyclic) gears are generally designed for high speed applications such as turbo gear drives. They are also used when very high torque must be transmitted at medium and low speed (vertical cement mill ...). Sometimes planetary gears are appropriated when dimensions of a gear unit with an equivalent gear ratio or transmitted torque is excessive (manufacturing, transportation...), for example marine gear for high torque Diesel engine.

Planetary gears are very often applied in automotive industry, such as trucks gear boxes, automatic automotive gear boxes and axle drives.

In the industrial field the arrangements of epicyclic gears is generally quite the same. In special applications, specific arrangements are designed.

But in automotive industry, arrangements are more complex and very different. These arrangements are intended to realise many ratio, to make compatible the dynamic of the engine (torque vs speed) with respect to the dynamic of vehicle.

That is the reason why the efficiency of planetary gears has been studied by gear designers of automotive industry. [1], [2]. The efficiency of industrial planetary gears is rarely one of the main problems. This is quite different in automotive industry and for special applications such as spatial application where a very high ratio is required in conjunction with a low number of meshes and a minimum amount of space.)

The above mentioned studies proposes graphical methods, which sometimes may be difficult to use, even for an experienced gear designer.

More recently to improve the knowledge, automotive gear designers have developed more accurate and more user friendly methods [3].

This paper presents a synthesis of an analytical method, which may be included in the design stage of a planetary gear, because it is based on very well known fundamental formulae of planetary gears.

2 FUNDAMENTAL FORMULAE OF THE MOTION OF A PLANETARY GEAR TRAIN

2.1 KINEMATICS FORMULAE

In order to simplify the following explanations, let us consider a simple planetary gear like those drawn on figure 1. It is made of two kinds of gears: One external gear (1)-(4') and one internal gear (4)-(2)

It is obvious that the results may be applied to other planetary gear trains including more than two types of gears.

Let us consider two coordinate systems

- $R_0(O, \vec{x}_0, \vec{y}_0, \vec{z}_0)$ related to the frame (Reference coordinate system).

- $R_3(O, \vec{x}_3, \vec{y}_3, \vec{z}_3)$ related to the planet carrier. (relative coordinate system)

The motion of R_3 with respect to R_0 may be written as follows:

$$\vec{V}(R_3 / R_0) = \{ \vec{x}_0 \quad \vec{y}_0 \quad \vec{z}_0 \} \begin{Bmatrix} 0 & 0 \\ 0 & 0 \\ \omega_{30} & 0 \end{Bmatrix}$$