Chapter 8
Fundamentals of Hybrid Power Trains Equipped with Planetary Transmission

ABSTRACT
Chapter 8 describes the most advanced hybrid power trains, which were generally depicted in Chapter 1. The presented figures consist of the two degrees of freedom planetary gears. It seems to be the best system of energy, split between the Internal Combustion Engine (ICE), the battery, and the electric motor, but unfortunately, it is also the most costly solution for its manufacture. This type of hybrid power train should be preferred as the best drive architecture composition from the technical point of view. For this reason, this chapter, in a detailed way, describes the features and the modeling approach to the planetary hybrid power train. Certainly, most attention is paid to the planetary two degrees of freedom gears, yet not only to them. Cooperating with the planetary gears, additional and necessary devices are considered. The role and modeling auxiliary drive components, such as the automatic clutch-brake device and mechanical reducers are discussed in this chapter. The design of electromechanical drives related to the planetary gear of two degrees of freedom controlled by the electric motor can be transformed to the purely electromagnetic solution. An example of the mentioned gear is given in the chapter. It is a complicated construction with the rotating stator of a complex, electrical machine requiring multiple electronic controllers. The increasing output torque of the electromechanical converter and its connection with the mechanical two degrees of freedom planetary gears are depicted as well.

DOI: 10.4018/978-1-4666-4042-9.ch008
INTRODUCTION

One of the most attractive power trains is based on planetary transmission as summing or differing the ICE and battery (via electric motor) energy flows. Certainly, this planetary gear is specially designed as two degrees of freedom, and additionally, equipped with a system of clutch/brake units. This chapter and the following one are dedicated to planetary power trains, because its energy economy can be most effective among all-known hybrid drive architectures, certainly, if it is properly designed.

1. PLANETARY GEAR POWER MODELING

The scheme of the planetary gear is shown in Figure 1. As it is exemplary, the sun wheel can be connected with an Internal Combustion Engine (ICE), through auxiliary transmission, whilst the ring is connected with the motor shaft and carrier through the drive reducer, which is connected with the axles of road wheels. Angular velocities of gear shafts, according to the assumed descriptions, fulfill the constraint equation:

\[ \omega_1 + k_p \omega_2 - (1 + k_p) \omega_3 = 0 \]  

where:

- \( k_p = \frac{z_2}{z_1} \): The base gear ratio,

**Figure 1. The kinematic scheme of planetary gear**

1. sun wheel    2. ring (crown) wheel    3. cage (carrier, yoke)    4. planet wheel
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