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Research Article

Nomographs and Feasibility Graphs for Enumeration of Ravigneaux-Type Automatic Transmissions

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Although there are many epicyclic-type automatic transmissions in production, the related configuration design methods are still tedious and borne to human error. A simple methodology for the systematic design of the Ravigneaux-type epicyclic gear transmissions needs to be developed. First, fundamentals and gear-shifting of four-speed and six-speed epicyclic-type automatic transmissions are illustrated to establish the design requirements. Second, based on the kinematic nomographs of the corresponding basic gear ratios, a simple clutching-sequence method is proposed and illustrated. Next, a planar-graph representation is presented to arrange the desired clutches for each possible clutching sequence into the epicyclic gear mechanism. Then, with the above methods, the systematic designs of the epicyclic gear mechanisms are given for demonstrating the feasibility of the proposed methodology. The result of this work shows that the seven-, eight-, and nine-link two-DOF Ravigneaux-type epicyclic gear mechanisms could reach four-, six-, and eight-forward speeds at most, respectively. New five-, six-, seven-, and eight-velocity automatic transmissions are enumerated from the two-ring eight- and nine-link Ravigneaux gear mechanisms. It is a major breakthrough to design completely satisfactory eight-speed automatic transmissions from the nine-link Ravigneaux gear mechanism.

1. Introduction

For a long-time automatic transmissions with planetary gear trains are used in the automotive industry. Ravigneaux in 1940 proposed seven- and eight-link two-degree-of-freedom (DOF) epicyclic gear mechanisms [1, 2]. These epicyclic gear mechanisms are called the Ravigneaux gear mechanisms. Figure 1 shows an automatic transmission which provides three forward speeds and one reverse speed [3]. It consists of a seven-link two-DOF Ravigneaux gear mechanism, two rotating clutches C_1 and C_2, and two band clutches B_1 and B_3. In the associated clutching sequence Table, X_i indicates that the corresponding clutch is activated on the ith link for that gear. The ranges of output velocities are classified into two kinds: under drive (UD) and reverse drive (RD) according to whether the velocity is between zero and the input velocity, or less than zero. A "direct drive" (DD) is equal to the input velocity.

The seven-link two-DOF-Ravigneaux gear train has been developed by nearly all automotive manufacturers as three- or four-velocity automatic transmission [3]. It can be found in Ford C_3, Ford C_5, Mercedes Benz, Toyota A40, and Nissan, to name, a few three-velocity automatic transmissions. It can also be found in KM 175 and 176, Ford AOD, ZF 4 HP 14, and Borg-Warner [4], to name, a few four-velocity automatic transmissions [5]. Figure 2 shows the ZF 4 HP 14 automatic transmission [6], which can provide four forward speeds and one reverse speed.

Sometimes, the seven-link two-DOF Ravigneaux gear train is integrated with a simple epicyclic gear train to form ten-link three-DOF epicyclic gear mechanisms to enhance the number of speeds [6, 7], providing six forward speeds. Figure 3 shows Lepelletier automatic transmission and its clutching sequence table [8]. A widespread gear set concept is that of Lepelletier. This design is based on a single planetary gear set with rear-mounted Ravigneaux gear set. In 2003, ZF [9] used this gear set design to bring the first 6-speed passenger car transmission 6 HP 26 on the market (Figure 3).

Two-DOF eight-link Ravigneaux gear mechanism, shown in Figure 4(b), consists of a long pinion and two