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# Power Analysis and Efficiency Calculation of the Complex and Closed Planetary Gears Transmission

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**Abstract**

2K-H planetary gears transmission power diagram is drawn by analyzing the kinematic, torque and power balance of the basic gear transmission, the corresponding relationship between typical 2K-H planetary gears transmission diagram and power diagram and power balance. Combining one specific example, the power distributions of the complex and closed planetary gears transmission are analyzed and its overall transmission efficiencies is calculated under considering power losses or not. The results show that the graphical representation is a simple, intuitive and practical method for power analysis and efficiency calculation, it can provide theoretical references for design work of the complex and closed planetary gears transmission.



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*Keywords:* basic circuit; closed planetary gear transmission; power analysis; transmission efficiency;

## 1. Introduction

Closed planetary gear has the advantages of compact structure, high transmission ratio and small size and so on, it is widely used in modern mechanical transmission [1], but the power analysis and efficiency calculation of the closed planetary gear become difficult to carry out as its complex structure. Pennestrì and Valentini [2] analyzed the planetary gears transmission efficiency of two degrees of freedom, then with Mariti and Del Pio [3, 4] applied graph method to analyze the motion, power flow and transmission efficiency of spur and bevel gear planetary gears transmission. Del Castillo [5] proposed the transmission efficiency analytical expressions for any spur planetary gears transmission by the concepts of speed, torque, virtual gear ratio and the relationship between the power and the

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speed ratio of the gears, then with Salgado [6,7] analyzed the power flow and transmission efficiency of planetary gears transmission with multi-members based on graphical representation method. Laus and Simas, et al, [8] analyzed the transmission efficiency of duplex planetary gears transmission by graph and screw theory. Chen Xiaoan and Chen Hong [9] proposed an analysis geometric method applied to the kinematic and efficiency calculation of compound planetary gear, and then Li Yunsong [10] introduced that method to analyze the complex and closed planetary gears transmission with them. C. Chen [11] analyzed the split-power and transmission efficiency based on the theory of virtual split-power and applied the new concept of the split-power ratio and virtual split-power. Wang Huiwu, et al, [12] analyzed the characteristics of the power flow, transmission efficiency and self-lock conditions, and proposed a new analysis method of critical power design parameters which is the ratio of the main branch power to the input total power. Dong Wanfu, et al, [13] analyzed the power flow based on the relationship diagram between the structure and power flow of closed planetary gear train. Li Qingkai, et al, [14] applied bond graph theory to analyze the power flow of the closed planetary gear train.

The methods reported were cumbersome to analyze power flow of the complex and closed planetary gears transmission and calculate its efficiency. They were also difficult for practical application, therefore much of difficulties for design work of the complex and closed planetary gears transmission were caused and the development and applications were restricted seriously. The power distributions of the complex and closed planetary gears transmissions of the aircraft engine power split planetary gear reducer is analyzed and its transmission efficiency is calculated based on two rules, which are all types of complex or compound gear can be decomposed into basic gear transmission with a single degree of freedom or two degrees of freedom and the basic gear transmission meets with the torque and power balance. The results show that the graphical representation is a simple, intuitive and practical method for power analysis and efficiency calculation, it can provide theoretical references for design work of the complex and closed planetary gears transmission.

## 2. Basic gear transmission (BGT) analysis[3,15]

### *2.1. Structure Kinematic and power analysis of BGT*

All types of complex or compound gear can be decomposed into basic gear transmission with a single degree of freedom or two degrees of freedom. The kinematic relation of BGT is shown in Fig. 1, where *i*, *j* represent the gear, *k* represents the gear frame, *G* represents the gear meshing pair, *R* (a) and *R* (b) represent the rotating pairs of the gear *i*, *j* with the gear frame *k*.

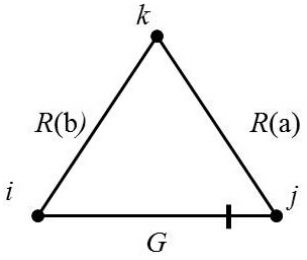


Fig. 1. Kinematic relations of the gear *i*, gear *j* and gear frame *k*

The number of teeth ratio of the gear *i* and the gear *j* is shown as formula (1).

$$R_m = \pm \frac{z_{jm}}{z_{im}} \tag{1}$$

where $R_m$ is the gear ratio of the gear *i* and the gear *j* in the $m^{th}$ circuit, $z_{im}$ and $z_{jm}$ are number of teeth of the gear *i* and the gear *j*,where the ± sign represents internal and external gear pairs, respectively.