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A Review On Selection Of PGTs For Automatic Power Transmission

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Abstract—In this paper a review about planetary gear trains (PGTs) used in automatic power transmission is presented. The PGTs is highly compact and light weight in structure which allows high speed reductions with multiple transmission ratios. PGTs is widely used in automobiles like passenger cars, heavy vehicles. The design of the PGTs is very complicated and different method mathematical and software are there for finding the proper assembly and the number of teeth required for the gear to get high transmission ratio as well as the efficiency. For a PGTs a better speed ratio can be obtained by analyzing the conceptual designs, doing the kinematic analysis, power flow and efficiency analysis configuration design and choosing the right clutch coding. The efficiency of the system can also be improved using torque converters and choosing a right clutch coding. This paper discus on the different types of PGTs and three ways of selecting the suitable design for an automatic transmission.

Index Terms —PGTs; Lever analogy; Stick Diagram, Clutch Coding.

I. INTRODUCTION

PGTs assures the possibility of achieving a given speed ratio with a smaller weight and size then would be required with an ordinary gear train. The performance of a PGTs can be optimised by doing the kinematic and configuration analysis and selecting a suitable clutch coding. Many authors have contributed in the area of proper clutch coding for PGTs [1-3]. But the methodology presented was suitable for combination of two simple PGTs or for PGTs consisting of two sun gear, two ring gear, and one to three meshed planet gears mounted on a common arm. Three and four clutching sequence for Simpson, Ravigneaux and Type-6206 gear trains are given by Hsich &Tsai [4].

Mac Millan [5,6], Glover [7] and Radzimovsky [8] gives insight into the efficiency analysis of single degree of freedom PGTs. Glover [7] and Muller [9] analyses 6-link PGTs. Computation methods are proposed by Hedmean [10], Mathis and Remond[11],Tian and Li-quia[12] and Castillo[13]. For a given transmission ratio, the design can select from all matching PGTs those have the right combination of efficiency and simplicity of construction, this has been discussed in [14-16].

A methodology for an automated design search of single and double-planet planetary gear sets with the input of a number of system-level constraints associated with the spacing and phasing of the planets, and acceptable ranges of basic geometric design parameters is proposed by H. S. Kwon1, A. Kahraman, H. K. Lee and H. S. Suh [17]. An experimental method for power loses of gear sets having three-six planets under loaded and unloaded conditions is given by David C. Talbot, Ahmet Kahraman and Avinash Singh[18]. Iit gives an idea that spin power loss decreases with both reduction of number of planets and increase in oil temperature and the mechanical power loss decreases with a decrease in oil temperature and reduction in gear surface roughnesses. Taking the teeth number of each gear, the number of multiple planets and gear module, of an AT is analyzed by the distribution algorithm in [19]. A methodology for analytical expression of efficiency for a two degree of freedom system is presented in [20]. It applies the concept of virtual power since the efficiency of the systems are related to the internal power flows. A systematic methodology for the efficiency analysis of one and two degree-of-freedom (DOF) EGTs is described, and 14 ready-to-use efficiency formulas are derived for 2DOF gear pair entities (GPEs). This paper includes also a discussion on the redundancy of the efficiency formulas used for 1DOF GPEs. An incomplete in the efficiency formulas in previous literature, which make them susceptible to wrong application, is brought to light [21]. Using virtual power analysis an analytical expression for the total efficiency of the Simpson gear train is derived in [22]. It shows that the total efficiency of the Simpson gear transmission is more sensitive to the individual gear efficiencies when the speed reduction is higher.

II. PGTs

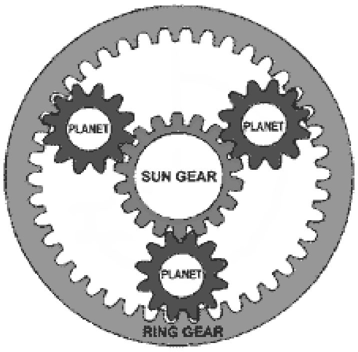

Figure 1: Planetary Gear System

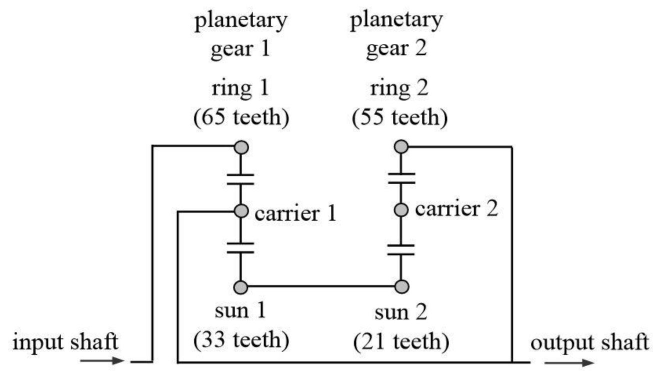

Figure 2(a): A stick diagram of two connected planetary gear sets

Automatic transmissions contain many gears in various combinations and the gears are never physically moved and are always engaged to the same gears. This is accomplished through the use of planetary gear sets Fig.1. The basic planetary gear set consists of a sun gear, a ring gear and two or more planet gears, all remaining in constant mesh. The planet gears are connected to each other through a common carrier which allows the gears to spin on shafts called "pinions" which are attached to the carrier.

Many more combinations are possible using two or more planetary sets connected in various ways to provide the different forward speeds and reverse that are found in modern automatic transmissions

A. Lever Analogy & Stick Diagram

Complexity of planetary gears can be made simple and easily understandable by using the liver analogy. In this the entire PGT is represented by a single vertical lever and the horizontal forces on the liver indicates the input, output and reaction torque on the gear. The Figure 2(a) is the representation of a two connected planetary gear sets using stick diagram and Figure 2(b) the lever representation of each gear set individually and the Figure 2(c) is the lever representation of the combination.

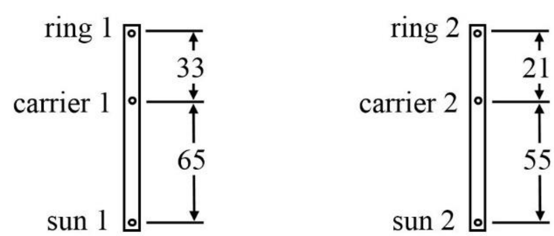

Figure 2(b):Lever representation of each gear set

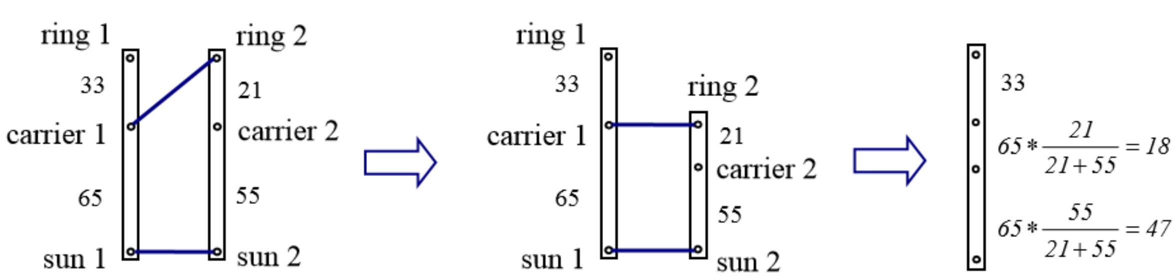

Figure 2(c): Two connected gear sets and lever representations

B. Stick diagram of common PGTs used for transmission

The 8 speed transmission used in BMW 7 series and GM is represented using the stick diagram in Figure3(a) and (b).

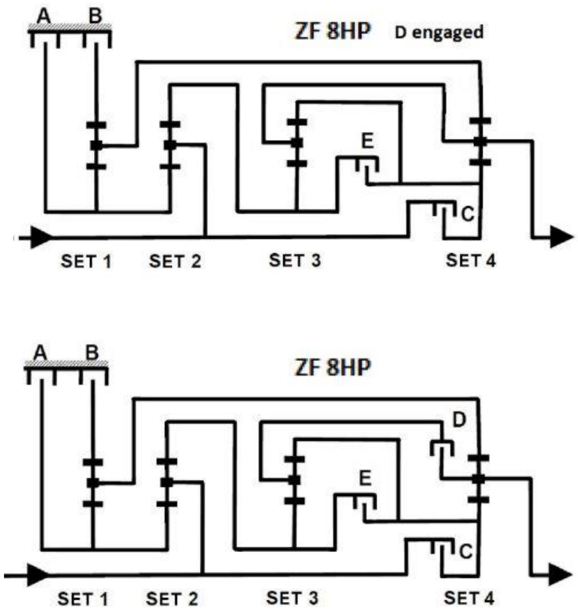

Figure 3(a): Stick Diagram for 8 speed transmissions

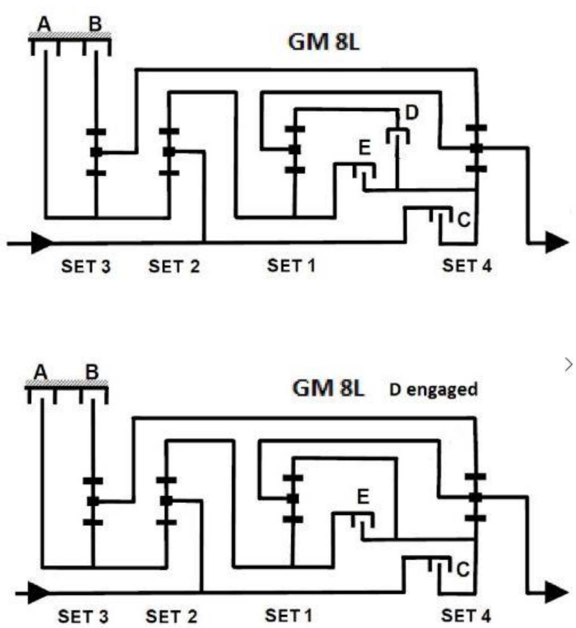

Figure 3(b): Stick Diagram for 8 speed transmissions

III.CLUTCH CODING FOR PGTS

A precise procedure to construct usable clutch layouts for ATs composed of two degree of freedom PGTs has been presented Hwang & Huang [23]. It introduces two rules, the first rule presents a non-interference condition for arranging band clutch and the second one knock out the invalid clutch sequence. For a four co-axial link PGT arrangement the coded clutch layout is presented. For a modified gear a two degree of freedom system is taken and after analyzing it, a PGTs with four co-axial links is developed with clutch coding without interference. Another four-speed clutching sequence is derived from the PGTs for which two separate clutch coding with interference was developed. The modified configuration of the Simpson Gear train for the analysis is represented using the stick diagram in Figure 4.

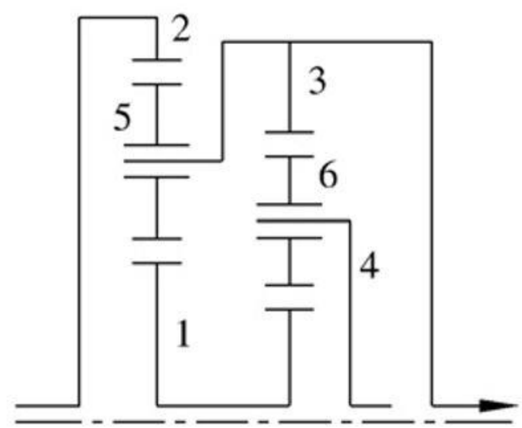

Figure 4: Alternative configuration for Simpson Gear train

Based on the analysis the non-interference condition for connecting the rotating and band clutch with a PGT is formulated and presented as rule one. For obtaining a non-interference condition PGTs engaged with rotating clutches, for a clutch sequence derived from n-coaxial link with e(e≤n-1) coaxial links with xy codes is

$$\left.\begin{array}{l} i \leq Min(a,b....e) \\ j \leq Min(\alpha,\beta....\varepsilon) \end{array}\right\} \quad [23]$$

Rule two finds the sandwich set and the feasibility of the clutch layout. Based on the two rules a feasible clutching sequence and code sketch is derived for a Simpsons gear train and an alternate configuration of Simpson gear train. The coded sketches are finally converted to stick diagrams Figure 5 for easy understanding. The methodology can be applied to PGTs with two-degree of freedom.

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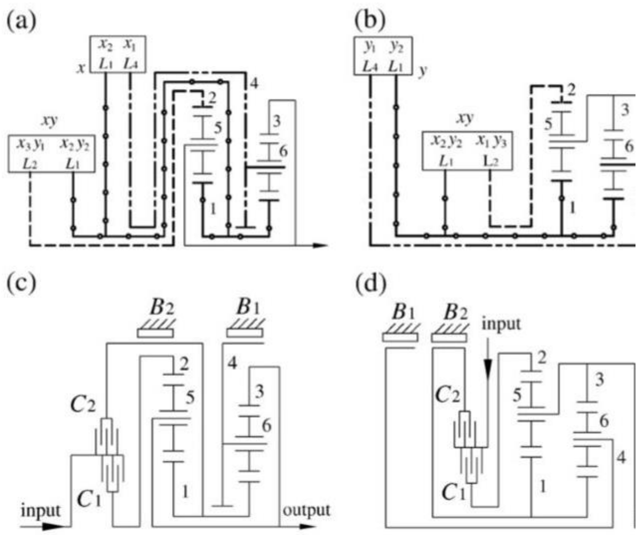
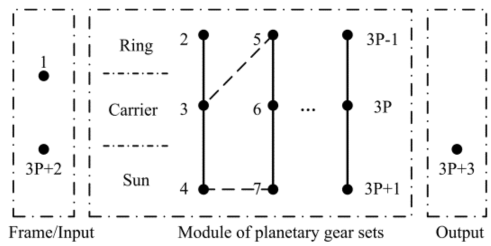


Figure 5: Coded layouts and stick diagram

IV. STRUCTURE OF PGTS

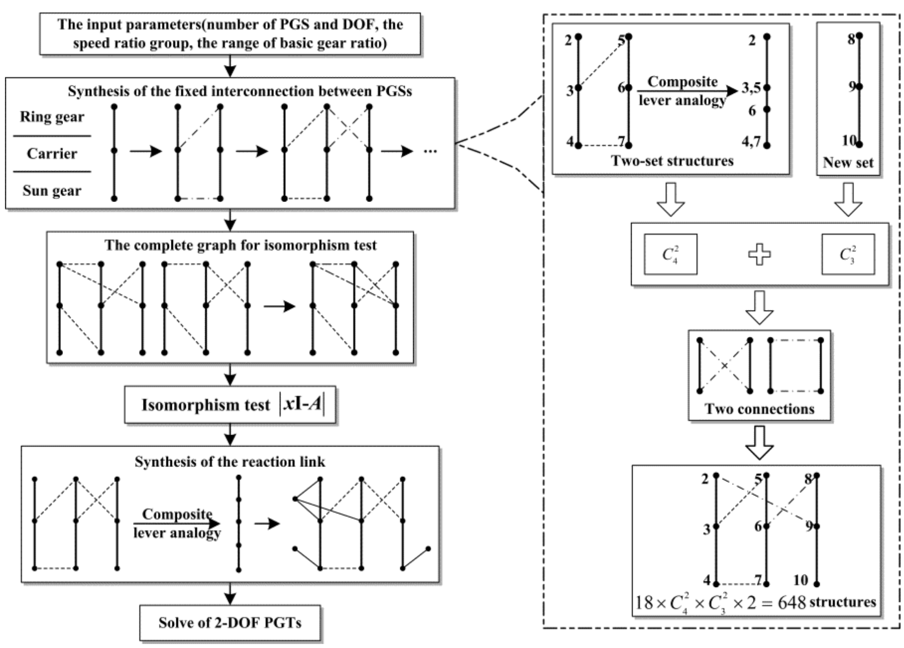
A. Design of Multiple degree of freedom PGTs

For a multiple degree-of -freedom PGTs various structures are formed by changing the fixed interconnection edge. The connection characteristics of fixed interconnection edges are developed from power flow analysis. To complete the synthesis a graph model and lever analogy is used. The variable structure synthesis is highlighted for a three-PGS PGTs in Figure 6.



Connection type	Weight
Fixed interconnection	1
Brake connection	3
Clutch connection	4
Ring-Carrier connection	*g*
Carrier-Sun connection	*h*
Input-link connection	5
Output-link connection	6

Figure 6: Lever analog



y

Figure7: Synthesis Algorithm for multi degree-of-freedom PGTs

(B). SYNTHESIS OF SEVEN SPEED PGTS

A number of cars have been equipped with seven or more speed PGTs with torque converter [24]. Many companies concentrate on the design of PGTs with high reduction speed ratio and multispeed [25,26,27]. One method of design is to expand the design based on the original scheme. A systematic synthesis method of seven speed PGTs with high reduction speed ratio based on six speed original PGTs is described in [24]. For synthesis a seven speed PGT, a six speed PGTs with 3 DOFs and 3PGs are synthesized using the deducing graph model and then 2 PGSs PGTs with the high reduction speed ratio is found out. To do all the synthesis the method of switched –input and variable fixed interconnection is used. The parameter considered for selecting the seventeen valid six PGTs are the ratio step, efficiency and mechanism planarity and single transmission shift. Figure 8 shows the synthesis algorithm. The synthesis gives the UDs, ODs and RDs and according to the importance of each speed ratio 3UDs are selected to solve 2-DOF PGTs which are the base of six-speed PGTs. Figure 9 is stick diagram of 2-PGS with appropriate high reduction speed ratio. According the requirements three principles for the series design are

Single-transition shaft is required between the new speed ratio and original first speed ratio, the new structure caused by the additional set and shift elements is feasible and out of interference with the original scheme, the basic gear ratio and gear number of original scheme should be invariant to inherit the manufacture line.

Following the matching design method six suitable seven-speed PGTs are obtained as given in Fig.10. Out of this one is of Allison HD4070 which shows that the method prosed is effective.

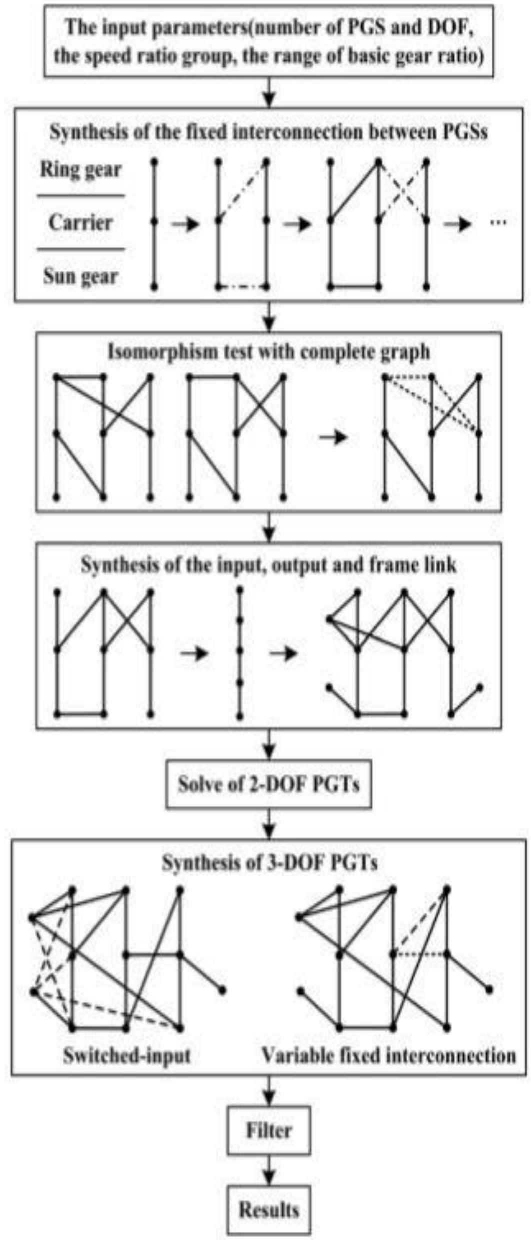


Figure 8: Synthesis Algorithm for seven speed PGTs

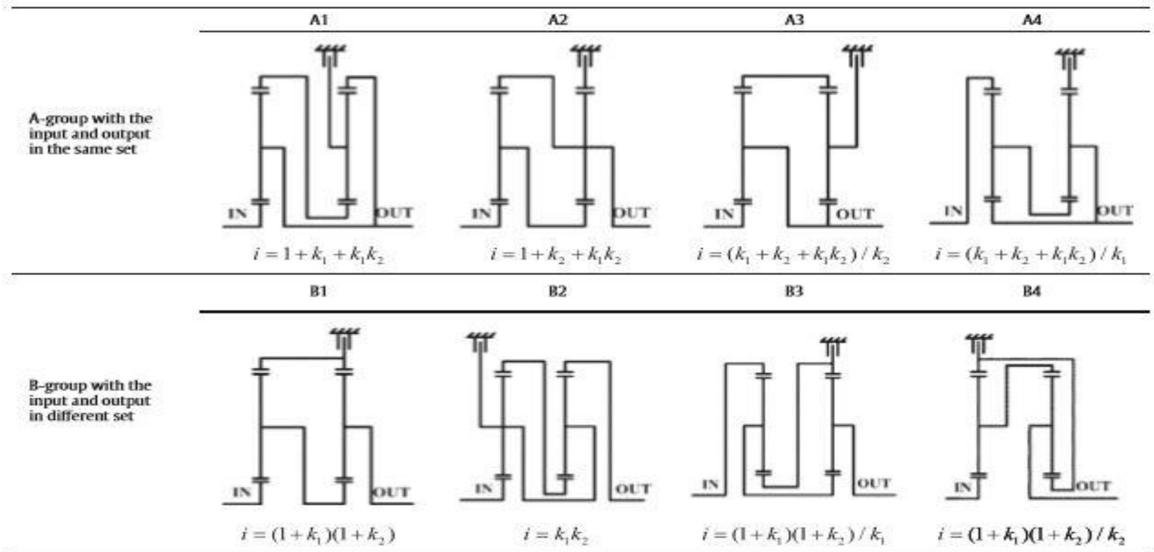


Figure 9: Stick diagram of 2-PGs PGTs with high reduction speed ratio.

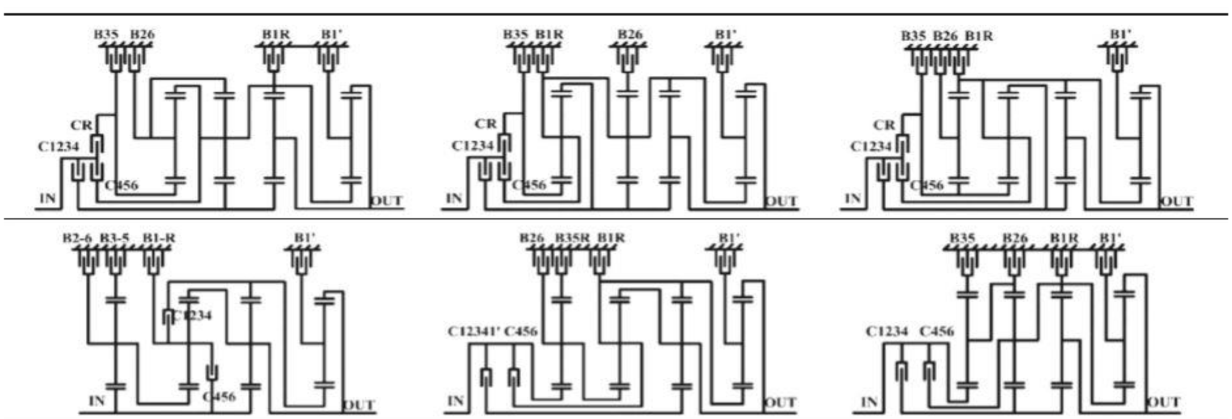


Figure 10: Stick diagram of seven speed PGTs.

V. Efficiency of PGTs

The lower weight and size enables PGTs with advantages over ordinary gear trains, especially for high transmission ratios. However, the power losses may be considerably greater than in an ordinary gear train. For this one of the and torque equation and the concepts of virtual gear teeth ratio, based on relationship between the power and the speed ratio.

The expression for efficiency

$\eta = \omega out/\omega^* out$ ----------[29]

major step in the design of PGT is to estimate its efficiency. An insight into efficiency analysis of single degree of freedom PGTs is presented in [5-9]. Computation methods are given by Castillo [29] presents analytical expression for efficiency of PGTs based on two concepts, the speed where ω^*out is the output speed calculated with the virtual gear ratios.

The relations hip between gearing power and sped ratio is

$E_k = Z_k/\omega_{out} \quad \delta\omega_{out}/\delta Z_k \quad = -T_{ikk}(\omega_{ik} - \omega_{rk})$ -------[29]

The efficiency equation for a four link PGTs is

$$\eta = \frac{R(Z_{ij})}{R(Z_{ij}^{*})} = \frac{Z_{14}}{Z_{14}-Z_{24}} \frac{Z_{14}/\eta_{14}-Z_{24}\eta_{24}}{Z_{14}/\eta_{14}} = \frac{Z_{14}-Z_{24}\eta_{14}\eta_{24}}{Z_{14}-Z_{24}} = R-(R-1)\eta_{14}\eta_{24}.$$ ------- [30]

VI. CONCLUSION

In this paper a study has been made on the automatic power transmission with PGTs. It gives an idea about the selection of a suitable PGTs for the required condition based up on the structure, clutch coding and efficiency. It also describes the lever analogy, stick diagram representation of PGTs and existing PGTs for the automobile in use.

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