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ANALYSE OF POWERTRAIN SYSTEM IN A PASSENGER VEHICLE WITH USING PLANETARY GEAR COMBINE WITH CONTINUOUSLY VARIABLE TRANSMISSION

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ABSTRACT
Engineers have achieved almost a full perfection of the internal combustion engine, but fuel consumption and quantity of smoke that comes from internal combustion engine are still higher. Reduction of fuel consumption and quantity of smoke from internal combustion engine can be achieved also by improving the power transmission system in vehicle.
In this paper will analyze powertrain system in a passenger vehicle which use planetary gear combine with continuously variable transmission which allows internal combustion engine to operate more time in optimum range with changing continuously variable transmission ratio.
Analysis of the powertrain system is made through mathematic model and own worked out programmed code in MATLAB are calculated characteristic parameters of the powertrain system versus continuous variable transmission ratio (i_{CVT}).
Keywords: passages vehicle, gearbox, planetary gear, continuous variable transmission, power, transmission ratio, etc.

1. INTRODUCTION
Powertrain for passenger vehicle, it can be realized through: mechanical gearbox, automatic gearbox, and lately through continuously variable transmission **- variator**.
Continuously variable transmission (CVT) which provides a continuously variable transmission ratio between internal combustion engine (ICE) and wheels drive and give in possibility that internal combustion engine to operate more time in optimum range and affects of reduction fuel consumption and quantity of smoke. Combine continuously variable transmission with planetary gear (PG) which uses power split creates the possibility that this transmission to use in vehicle with large displacement internal combustion engine and is well-known ***planetary gear combine with continuously variable transmission*** **(PGCWCVT).**
In order that transmission to use in passenger vehicle is necessary to integrate step – up gearbox with two sets gears (set gear high/low –L/H) which does not cause losses of energy.

2. MODEL FOR POWERTRAIN SYSTEM IN A PASSENGER VEHICLE WITH PLANETARY GEAR COMBINE WITH CONTINUOUSLY VARIABLE TRANSMISSION
This powertrain system (figure 1) consists from: continuously variable transmission, planetary gear, step – up gearbox and differential. ***Continuously variable transmission*** is consisting from: driving pulley (a), driven pulley (c) and variable belt drives (b). ***Planetary gear*** is type **1AI** and consists: sun gear (z_a), ring gear (z_b), planet gear (z_g) and planetary carrier (s). ***Step - up***

gear has two sets of gear: high set (H - z_1, z_2) and low set (L - z_3, z_4).
This system of powertrain in vehicle allow to work in some working options, depending on the demand of driver and electronic units, which realised with fixing gears: sun gear (z_a), ring gear (z_b), through brakes: (B_1) and (B_2) and clutches: A, B C, D, E (figure 1).

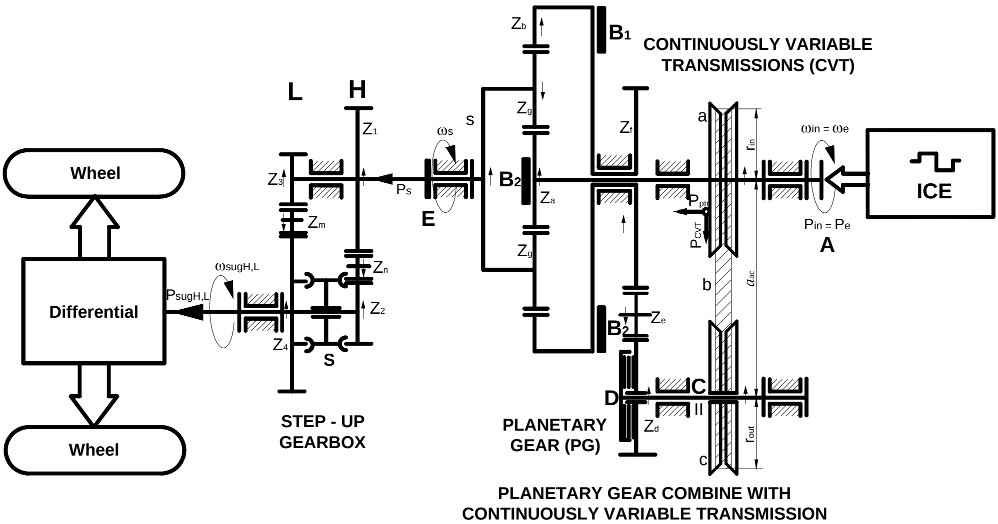

Figure 1. Model of powertrain system in a passenger vehicle with planetary gear combine with continuously variable transmission

In order to achieve better transmission ratio of this powertrain, this system should have the optimum number of teeth gears: (z_a), (z_b), (z_d) and (z_f) and radius of driving (a) and driven pulley (c) which determines the range of continuously variable transmission ratio.

2.1. Determine of the efficiency powertrain system
Efficiency of planetary gear combine with continuously variable transmission will determined with expression [3]:

$$\eta_{PGCWCVT} = n_1 \cdot i_{CVT}^2 + s_1 \cdot i_{CVT} + u_1 \text{, for } i_{CVT} <= 1$$
$$\eta_{PGCWCVT} = n_2 \cdot i_{CVT}^2 + s_2 \cdot i_{CVT} + u_2 \text{, for } i_{CVT} >= 1 \qquad \text{... (1)}$$

Efficiency of step up gearbox high/low, determined with equation:

$$\eta_{sugH} = \eta_{1n} \cdot \eta_{n2} \quad \text{and} \quad \eta_{sugL} = \eta_{3m} \cdot \eta_{m4} \qquad \text{... (2)}$$

Efficiency for powertrain system with step up gearbox high/low determined with equation:

$$\eta_{totsugH} = \eta_{PGCWCVT} \cdot \eta_{sugH} \cdot \eta_{dif} \quad \text{and} \quad \eta_{totsugL} = \eta_{PGCWCVT} \cdot \eta_{sugL} \cdot \eta_{dif} \qquad \text{... (3)}$$

2.2. Determine of the power in main part of powertrain system
Power in sun gear (P_a), ring gear (P_b) and planetary carrier (P_s), determined according equations:

$$P_a = P_{PG} = P_e \cdot \frac{i_{ab}^s \cdot i_{CVT}}{i_{ab}^s \cdot i_{CVT} + i_{fd}} \qquad \text{... (4)}$$

$$P_b = P_f = P_{CVT} \cdot \eta_{df} = P_e \cdot \frac{i_{fd}}{i_{ab}^s \cdot i_{CVT} + i_{fd}} \cdot \eta_{CVT} \cdot \eta_{df} \quad \text{... (5)}$$

$$P_s = P_{PGCWCVT} = (P_a + P_b) \cdot \eta_{PGCWCVT} = T_s \cdot \omega_s \quad \text{... (6)}$$

Power in step up gearbox high - P_{sugH}/low - P_{sugL}, determined according equations:

$$P_{sugH} = P_s \cdot \eta_{sugH} \quad \text{and} \quad P_{sugL} = P_s \cdot \eta_{sugL} \quad \text{... (7)}$$

Power in driven wheels with step up gearbox high/low, determined according equations:

$$P_{wsugH} = P_{sugH} \cdot \eta_{dif} \quad \text{and} \quad P_{sugL} = P_{sugL} \cdot \eta_{dif} \quad \text{... (8)}$$

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3. ANALYZE OF CHARACTERISTIC PARAMETERS IN POWERTRAIN SYSTEM OF PASSENGER CAR

To realize the goal in this research was using the program code in MATLAB [1], to calculate characteristic parameters for the powertrain system. Input data in this program are: characteristic of internal combustion engine, characteristic of powertrain system and drive wheel.

3.1. Powertrain efficiency as functions of continuously variable transmission ratio (i_{CVT})

In figure 2 is shown efficiency of planetary gear combine with continuously variable transmission ($\eta_{PGCWCVT}$ – curve with full line) and total efficiency with step up gearbox high/low ($\eta_{totsugH}= \eta_{totsugL}$ – curve with interception line) as functions of continuously variable transmission ratio (i_{CVT}).

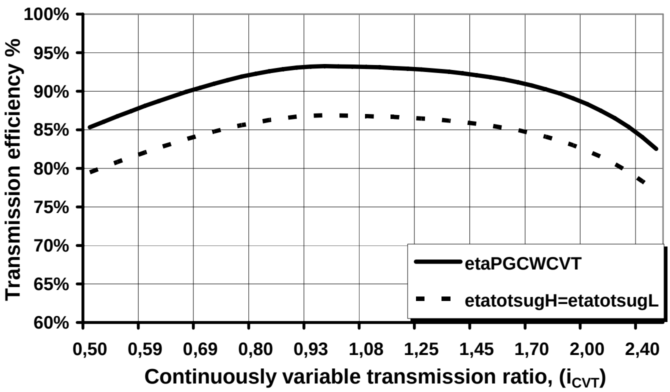

Figure 2. Powertrain efficiency $\eta_{PGCWCVT}$ and $\eta_{totsugH}= \eta_{totsuL}$ as function of continuosly variable transmission ratio (i_{CVT})

From figure 2 shown the curves which determine efficiency of planetary gear combine with continuously variable transmission ($\eta_{PGCWCVT}$) and total efficiency with step up gearbox high/low ($\eta_{totsugH}= \eta_{totsugL}$) are similar. Maximum value is for i_{CVT} = 1.0 and is $\eta_{PGCWCVT}$ = 93.26 %, respectively $\eta_{totsugH}= \eta_{totsugL}$ = 86.84 %.

3.2. Power in main part of powertrain system as functions of continuously variable transmission ratio (i_{CVT})

In figure 3 and figure 4 are shown curves of: power internal combustion engine, type AEB 1.8 i, which is used in passenger car Audi A4 ($P_{in} = P_e$ – curve with full line), power in planetary carrier (P_s - curve with long interception line) and power in drive wheels with step - up gearbox high/low ($P_{sugH} = P_{sugL}$ - curve with short interception line) as function of continuously variable transmission ratios (i_{CVT}) for minimal engine speeds of internal combustion engine n_{emin} = 800 RPM, P_{emin} = 14.37 kW and when internal combustion engine work with maximal torque at engine speeds n_{Temax} = 4000 RPM, P_{emin} = 77.87 kW.

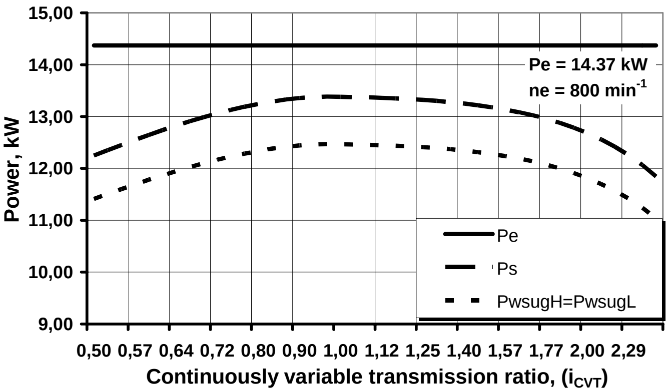

Figure 3. Power in main part of powertrain system as functions of continuously variable transmission ratio (i_{CVT}) for n_{emin} = 800 min^{-1}

From figure 3 shown powers in main part of powertrain system as functions of continuously variable transmission ratio (i_{CVT}) are similar with curves which determine efficiency of powertrain system. Maximal value is for i_{CVT} = 1.0, P_s = 13,39 kW (0,98 kW input power lose), respectively P_{wsugH} = P_{wsugL} = 12,47 kW (1,90 kW input power lose).

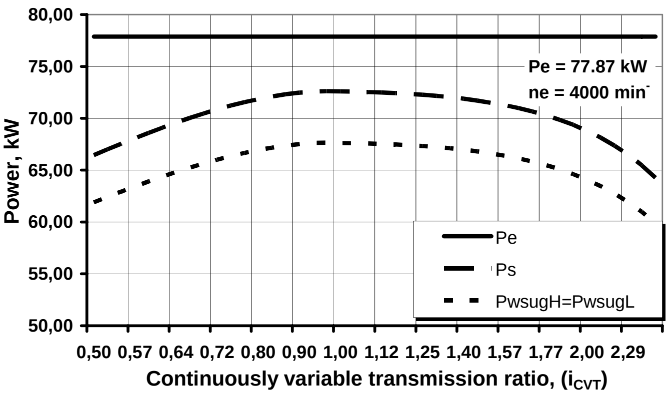

Figure 4. Power in main part of powertrain system as functions of continuously variable transmission ratio (i_{CVT}) for n_{Temax} = 4000 min^{-1}

In figure 4 showed that maximum value of power in planetary carrier (P_s) and wheels drive (P_{wsugH} = P_{wsugL}) achieved in case when continuously variable transmission ratio is i_{CVT} = 1.0.

4. CONCLUSION

Based on the results achieved through application program MATLAB for planetary gear combine with continuously variable transmission in a passenger car, can be concluded that:

- Efficiencies of powertrain system have maximal value for value of continuously variable transmission ratio i_{CVT} = 1;
- Power in drive wheels, due to high efficiency also is maximal for continuously variable transmission ratio i_{CVT} = 1.

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