Hub dynamometric stand test features of the ATV engine and continuously variable transmission unit

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Abstract. This article discusses the ATV V-belt variator test features using hub dynamometric test stand. The problems encountered related to obtaining the necessary data for testing and ways to solve them are described, the test methodology, as well as examples of test results with their analysis are presented. The results of the study of the ATV transmission ratio are presented.

1. Introduction
For Russia, quadricycles or ATVs (all-terrain vehicles) are a rather specific and not widespread type of vehicle. They have a fairly narrow specialization — off-road movement, which also explains the specifics of their legal registration. In addition, such vehicles have a high price, especially foreign samples. This may explain their rather limited use in Russia. However, such vehicles are very common abroad. Their concept is of interest for use in the oil and gas fields, for communications service, and in active recreation areas related to off-road movement. Also, ATVs may be of interest for the military forces as a means of increasing the mobility of personnel.

The design of such vehicles (for example, ATV Can-Am Outlander 570) has a number of characteristic features, one of which today is the widespread use of continuously variable transmissions. V-belt variators with mechanical transmission ratio control are used as a gearbox in such transmissions. Such transmissions have a number of significant benefits providing high performance and ease of ATV driving [1].

Figure 1 shows an example of the design of V-belt variator with a centrifugal drive pulley control mechanism.
2. Test objects
Characterization of the engine-transmission unit, which is a combination of an internal combustion engine and a V-belt variator, is of interest.

The main tasks are to evaluate the modes and features of this type equipment stand testing and to study the nature of changes in the transmission ratio with regard to the operation of a stepless variator, the characteristics of which depend on its design and are not disclosed by the manufacturers.

Stand description.
For the tests there was used a Dynapack Daqplus 43 hub dynamometric stand installed in the Volgograd State Technical University Department of Transport Machines and Engines laboratory.

This stand helps to study the power and load characteristics of the power units of complete vehicles with the possibility to connect additional sensors and results recording [2, 4].

The test vehicle has off-road tires with a deep tread, which can complicate testing with a chassis dynamometer. When testing on the hub stand, where the wheel hubs are attached through adapters to loading devices, there is no such problem (Figure 2, Figure 3).
2.1 Test description

During the trial tests, the reactions of the ATV engine-transmission unit to the wheel loads preset by the stand were evaluated. In addition, the operation of the testing sensors (engine speed and throttle position) was checked. The trial tests revealed the following:

- ATV engine speed reliable signal registering and signal input to the stand was complicated without common communication protocol and easy access to ATV sensors. The engine nozzle signal was used with its transforming to rectangular pulse signal suitable for the stand;
- the settling of the minimum engine speed was impossible due to the ATV big total transmission gear ratio and the characteristics of the loader operation with continuous gear ratio changes;
- the parallel communication to the ATV standard sensor was used for registration of the throttle position signal and its input to the Dynapack stand;
- ATV was tested both in all-wheel drive and in mono-drive mode.

Taking into account the identified features, the following method was used to study the engine-transmission unit operation: 1. With a constant position of the throttle (control according to the readings of the ATV standard throttle position sensor introduced to the stand) the ATV accelerated to the maximum speed (engine speed, taking into account the change of gear ratio with variator, engine speed was controlled by a signal output of the fuel injection nozzle and communicated via adapter to the stand input); 2. The stand loaded the wheels to achieve the minimum stable engine speed. The ATV was tested for various throttle opening (from 10 to 100%).

For this loading mode the stand memory recorded the wheel speeds, torque moments on wheels (axles), power on wheels (axles), engine speeds, throttle position. These parameters allowed us to determine the instantaneous transmission gear ratio (with known total transmission gear ratio of the transmission mechanical part it was possible to calculate the variator transmission gear ratio), as well as the nature of its change versus time or engine speed.

2.2 Test results

Figures 3 and 4 show the examples of test results according to the presented methodology for all-wheel drive transmission.

Legend for all figures:
- Tacho — engine speed acc. tachometer, rpm;
HubRpm — stand wheel revolutions, rpm
AxleTrq — wheel torque moment (total), Nm;
AxleTrqM — rear wheel torque moment (total for axe), Nm;
AxleTrqS — front wheel torque moment (total for axe), Nm;
AxlePow — power on wheels, hp;
Ratio — the value of the current total transmission gear ratio calculated by the formula Tacho/(HubRpm*Ntr), where Ntr = 12.03 — gear ratio of the gearbox part of the ATV transmission (transfer case and main gear) according to the technical documentation [3].
TPS — throttle opening percentage, %

![Graphs of test parameters vs time with 50 % throttle opening](image1)

**Figure 4.** Graphs of test parameters vs time with 50 % throttle opening

![Graphs of test parameters vs time with 100 % throttle opening](image2)

**Figure 5.** Graphs of test parameters vs time with 100 % throttle opening

The graphs show the following: engine speed graph peaking corresponds to the beginning of loading (stand feature). The low speed zone demonstrates a sharp change of the gear ratio (growth). A longer test time has little effect on the transmission gear ratio. The Figure 6 shows the separate graphs
of the transmission gear ratio for the considered test cases. In addition, the front and rear axles torque moments are equal (see the corresponding graphs on Figures 4 and 5), which corresponds to the transmission operation mode (all-wheel drive) during the tests. The limiting values of the gear ratio at the end of the tests may be somewhat overestimated, which is probably explained by the previously mentioned loader feature (minimum allowable speed).

![Figure 6. Transmission gear ratio vs engine speed](image)

On the graph you can see the specific nature of the reaction of the engine-transmission unit to the increased load: the change in the gear ratio in a substantial revolution range represents almost linear function for both the considered throttle opening percentages.

3. Conclusions
The tests helped to understand the operation of engine-transmission unit with a V-belt variator during stand tests, to obtain data on changes in the transmission ratio based on V-belt variator operation. The data obtained indicate the specific variator setting for its operation as a part of the particular vehicle transmission. More accurate specifications can be obtained after further testing.

References
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