MULTISTAGE GEAR PROJECT OF THE ELECTRICAL CAR SGR2016 FOR THE SILESIAN GREENPOWER ORGANIZATION.

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***Abstract**: The subject of the paper, titled* '*Multistage Gear Project Of The Electrical Car SGR2016 for the Silesian Greenpower organization', is an analysis of a chain vibrations in drive gear of SGR 2016 bolide. The exact moment of gear switch presents the greatest threat of a stability loss. Tests have been conducted in 2 stages. The first stage was the determining of derailleur setting. The adjusted component was a mechanism responsible for increasing the drag movement of derailleur cage. Adjustment of this element caused change in vibration characteristics in different system parts. That element was adjusted so oscillations were minimized. The second stage of studies was pinpointing the correct rotational speed, at which gears should be changed, using previously defined derailleur adjustment. Speed, at which the gear switch takes place, was chosen so the vibrations are lowest possible. Oscillation amplitude was recorded using high speed camera, and the data was analyzed using a dedicated High Speed AVI software. Speed measurement had been done using magnetic field sensor. All studies have been conducted on inertial system, simulating real life race conditions. Comparing all results, optimal driving parameters in terms of drive gear work stability, have been defined.*

Keywords: DRIVE GEAR, VIBRATION, VEHICLE, DERAILLEUR

1. Introduction

For a long time, constructor had a problem with an engine torque transmission. It was solved in numerous ways, each one had its advantages and disadvantages. Reliability is the most important condition, which all systems must fulfill. In case of a breakdown it is necessary to stop entire system. That causes extensive work breaks. Gears should be constructed in a manner that prevents such occurrences.

In this paper a drive gear in Silesian Greenpower electrical vehicle SGR 2016 was investigated. Silesian Greenpower is an interdisciplinary student organization that constructs and develop electric vehicles. Bolides constructed by this organization participate in Greenpower education Trust races.

Up to this point, the team used belt transmission. Race rules allowed outside help during takeoff, this gave merit to this solution. Change in these rules forced the team to seek new solutions to this problem. Many different ways of solving this problem were taken into consideration, among them, chain gear showed great promise. This kind of transmission has great starting properties, thanks to the ability to change gears during the race. This option was unavailable using the previous transmission.

During test phase of implemented chain gear, several issues arose. The greatest flaw of this solution was frequent stability loss. This could result in drivers safety being compromised. In every real system, there are vibrations present. In considered case, both the vehicle chassis and the transmission vibrate. There are certain speeds at which vibrations can interfere with each other causing effect similar to resonance. This phenomenon is most visible in transmission strand. Subsequently, this phenomenon will be referred to as resonance. Shifting gears during resonance speeds may result in stability loss.

Deliberations were started with literature overlook. Most publications regarding chain gears show only single geared transmissions. Because of that most obtained information come from experts. The aim of our research is a modernization of chain gear, resulting in smoother and failure-free operation. [2]

Transmission ratio can be calculated from formula 1.1:

$$i = \frac{z_1}{z_2} \tag{1.1}$$

Where:

i – ratio [1];

$z_{1,2}$ *- number of teeth on smaller and larger wheel [1];* [1]

Mounted gear has the ability to change transmission ratios. The chain is being moved from one gear to the other on the powered wheel. Powering wheel has a constant teeth number of 11. Passive wheel cassette has two gears mounted on it. The lower gear has 27 teeth and higher 23 teeth. Avaible rations are:

$$i_1 = \frac{11}{27} \approx 0{,}41$$
$$i_2 = \frac{11}{23} \approx 0{,}48$$

2. Studies methodology description

Tests were conducted on a specifically designed test bench, which simulated conditions on the track. Vibrations were registered with a highspeed camera and analyzed using High Speed AVI software. Chain deviation from its nominal position was recorded in two planes, plane containing strand and perpendicular to it. Both are represented in picture 1.

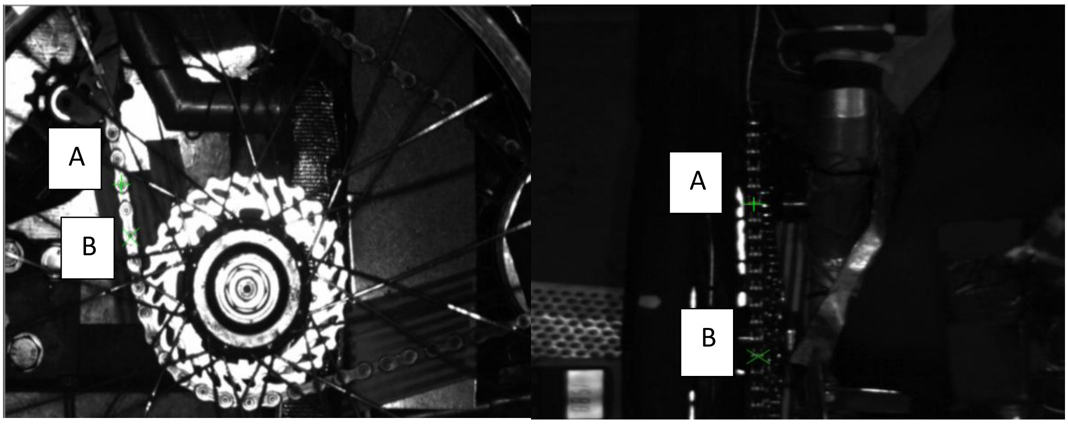


Fig. 1 *Method of determination vibration; where 1 and 2 – base links.*

Gear operation was divided into 3 stages. These stages were: start – from quiescence to gear switch, gear switch – brief moment before and after changing transmission ratios, maximal velocity - acceleration to speed limit. Subsequently, these stages will be referred to as such. Structure of regulation system is shown in picture 2.

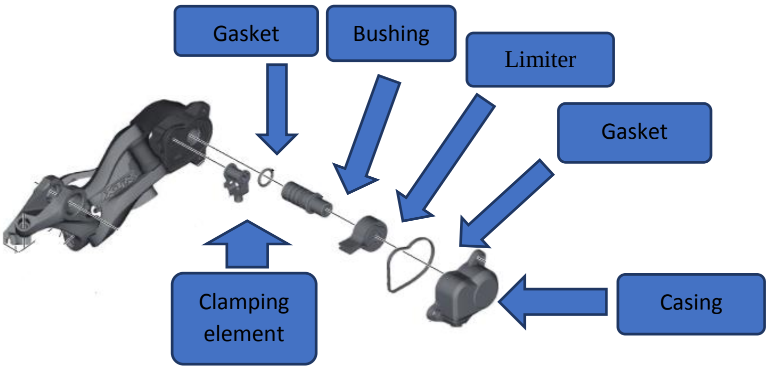


Fig. 2 *Scheme of mechanism* [3]

Main task of adjustment is to increase the movement drag of derailleur cage. In this paper this mechanism will be referred to as clutch. In studies assumed four configurations, 0;3;3,5 and 4. These numbers determine the number of rotations with which the adjustment screw was turned. Zero value means that the mechanism is switched off. Picture 3 shows a diagram of regulating device. This mechanism consists of screw, shaft and limiter. Limiter is used to increase wrap angle of bushing. Adjustment is done by pressing two plates in the left side of the image. The screw is being used to decrease the distance between plates in the limiter. Scheme of executive element is shown in picture 4.

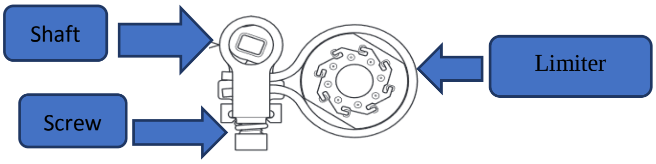


Fig. 3 *Scheme of regulation mechanism* [3]

Diagram in picture 4 shows the work principle of turning on mechanism in the clutch assembly. Engaging the clutch is done by pressing disks by rotating a lever.

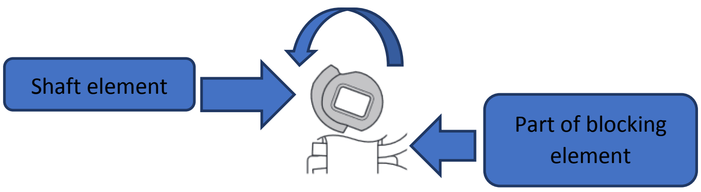
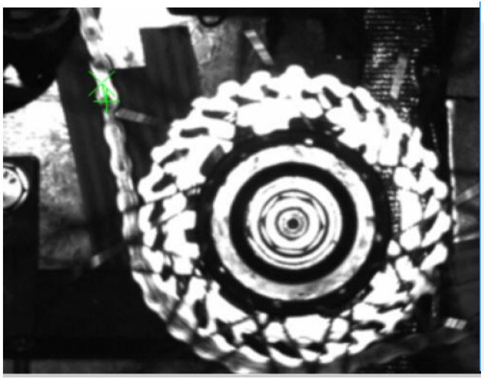
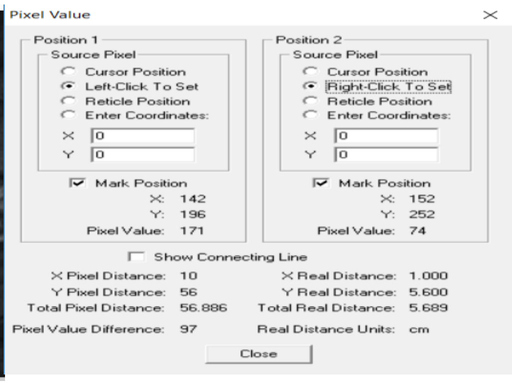


Fig. 4 *Scheme of turning on mechanism* [3]





Studies were conducted as follows:

- Determining of base link
- Determining the starting position of base link
- Selecting links in relation to which, translation was calculated
- Pointing link position during movement
- Calculating distance between, base and maximal positions.

Picture 5 shows starting position of the chain. Stripes in the background are the scale of reference to the vibration amplitude. One stipe has exactly 2 [mm] in width. Points, which are marked are the links were being analyzed during the test. Point coordinates were read off the pixel value module (Fig. 6).

Fig. 5 *Method of determining vibration*

Fig. 6 *Pixel Value module*

Next stage of vibration analysis was calculating the real distance translation of chain link.

$$p = x_1 - x_2 \quad (1.2)$$

Where:

p – distance between link positions [1],

x_1 *– position of deviated link [1],*

x_2 *– position of base link [1].*

$$p = 146 - 142$$

$$p = 4$$

$$x_r = \frac{2}{6}p \quad (1.3)$$

Where:

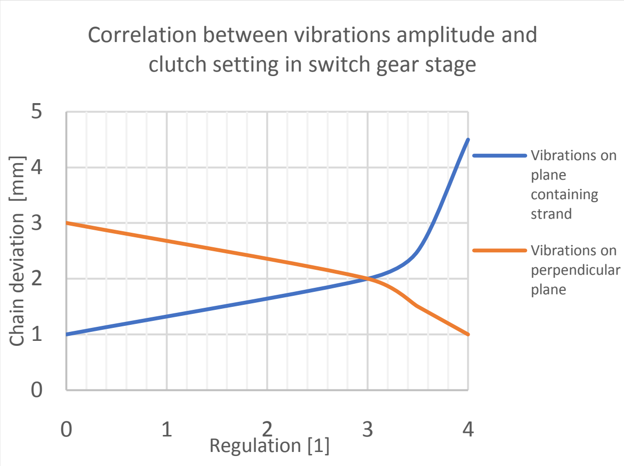
x_r *– calculated translation[mm]*

$$x_r = 1{,}33$$

3. Studies

Diagram 7 describes the correlation between vibrations amplitude and clutch setting in switch gear stage. It shows how clutch adjustment impacts vibrations in both planes. Higher clutch setting results in decreased vibrations in one plane and increased in the other.

From the diagram, it can be deducted that the best setting, in terms of work fluency, is setting number 3. However, this regulation has a negative impact on a fluency in the maximum velocity stage (Fig 8).



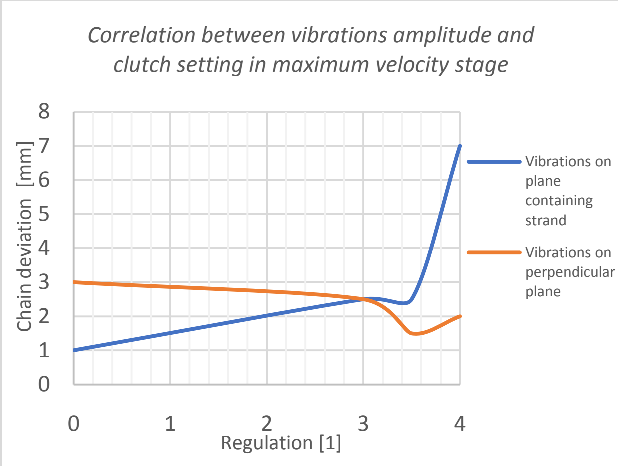
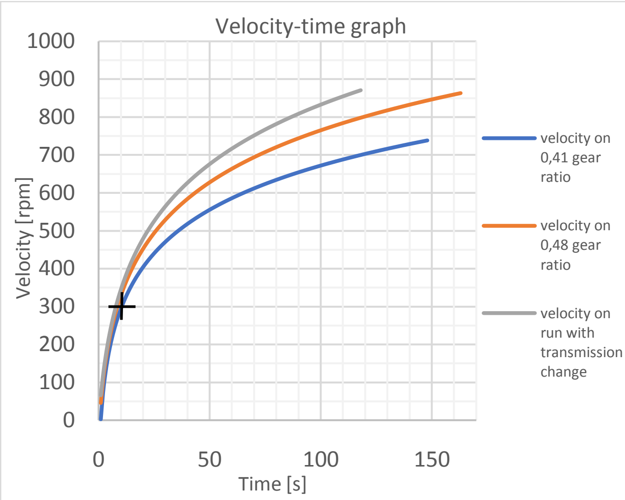


Fig. 7 *Correlation between vibrations amplitude and clutch setting in switch gear stage*

Fig. 8 *Correlation between vibrations amplitude and clutch setting in maximum velocity stage*

For this reason, it has been decided to further study setting 3,0 and 3,5. These studies had a purpose of determining the exact moment of vibration occurrence in switch gear stage, from this point vibrations increase in magnitude.

Another argument advocating for setting 3,5 is the fact that system oscillations were much higher before changing transmissions, which could be caused by resonance. This anomaly has adverse influence on SGR vehicle, due to an increased possibility of stability loss. This phenomenon was observed at a spot marked on diagram 9.



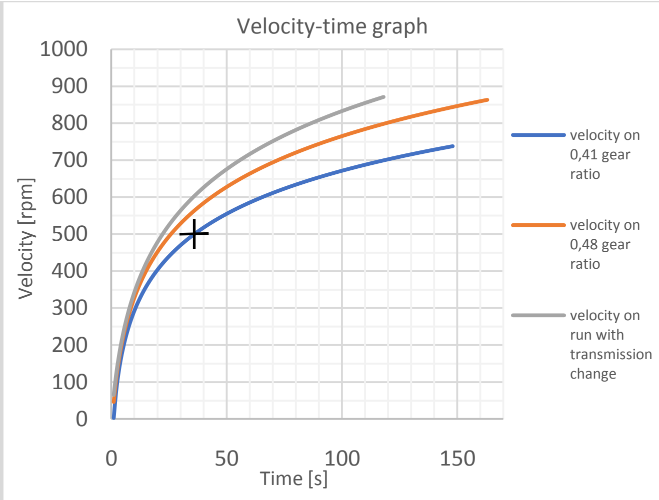


Fig. 9 *Velocity-time graph using regulation 3,0*

Fig. 10 *Velocity-time graph using regulation 3,5*

In order to unify the findings only 0,41 transmission ratio was taken into account. Times of resonance occurrences were confronted for settings 3,0 and 3,5.

Analysis revealed that for regulation 3,0 resonance occurred much sooner than for 3,5. Using setting 3,5 resonance was avoided by switching gears before it occurs (Fig 10).

Conclusions.

A correlation between vibrations amplitude and clutch setting in switch gear stage can be noticed. During work of the drive transmission system, the moment of changing gears represents the greatest threat of losing stability. Because of that, it is essential to adjust the system parameters to decrease the chance of stability loss. Conducted research showed, that increasing derailleur cage movement drag, causes vibration amplitude of the chain to increase in one plane and decrease in the other. Regulation 0 and 4,0 can not be chosen because of difference between vibration amplitudes in planes investigated. Clutch settings 1,0 and 2,0 show better work parameters of chain, however regulation 3,0 and 3,5 indicate a better strand stability.

From among four different regulations, setting 3,5 shows greatest properties in all work stages.

It minimizes chain vibrations and decreases the chance of stability loss overall.

Literature.

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[3] Internet page containing technical data regarding Shimano products (access 20.12.2017) http://productinfo.shimano.com/#/com/3.0