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Determination of parameters for automatic decompression of heat and power facility cylinders

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Abstract. This paper analyzes various types of startup systems used for the heat and power facility start-up. Factors impacting startup characteristics of the heat and power facility were considered. Methods for the modernization of the startup system and possible revamping of auxiliary starting aid devices of locomotive diesel engines without significant design changes by means of cylinder test valve opening were identified. Kinematic diagrams of device gearing for automatic decompression of the heat and power facility cylinders were developed and analyzed. The device requirements were determined, namely, response time, cylinder test valve open and closing torque overriding T_{min}=11 Nm. Based on the necessity of torque backup at least 30 % the gear ratio required for the selected engine and its dimensions was calculated.

1. Introduction

In order to start-up the heat and power facility (Internal Combustion Engine) the electric energy (the electric startup) and the pneumatic power (the pneumatic startup) are mainly used. In rare cases the explosive energy (the pyrotechnical startup), the rotational energy (the inertial startup) or the spring strain energy, etc. All listed startup systems face the high torque developed at the diesel engine start-up for overriding the crankshaft rotation antitorque moment resulting in the increased wear of shaft drive friction couples [1].

Locomotives use the electric startup system of diesel engines being the most important component of the system providing the diesel engine start-up. Articles concerned with the heat and power facility start-up repeatedly stated that the startup period is a transient process in the heat and power facility operation and the necessity of deeper studying of factors impacting the carburation and the startup itself, determining of technical solutions for improvement of the system startup characteristics [2].

Technical solutions for improvement of the system startup characteristics impacting the ignition and combustion of fuel mixture at the startup can be divided into controllable in the course of operation solutions and structural solutions that are impossible to control. For instance, the quality of fuel system operation depends on the fuel type, its cetane number and temperature. During the operation such parameters can be controlled by adding highly inflammable liquids [3], selection of fuel with corresponding cetane number [4], its heating before feeding to the engine, including the use of microwave radiation [5]. In addition, there is the common improvement of startup system using the boosted air preparation: heating by heating plugs; particularly promising are systems of boosted air heating upstream the vortex tubes' startup device [6]. In our opinion, a quire promising is the startup process improvement due to the cylinder decompression without significant design changes of the diesel engine design by means of the cylinder test valve opening.

2. The basic part

The one of possible design startup improvement solutions is the modernization of the heat and power facility startup system.

In the course of development of the heat and power facility startup system modernization the decomposition diagram (Figure1) was developed that allowed to separate hierarchical elements with certain number of decomposition elements for further studies. On the first study stage it was discovered that for resource saving at the locomotive diesel engine startup in order to eliminate negative impact of startup peak currents and accumulator battery life extension is possible to use the starting aid device. The proposed device design consists of step-geared engine that is interlocked with the cylinder test valve. The gear drive allows reducing the rotation speed and increasing the engine torque [7]. Moreover, the startup device design shall include the manual cylinder test valve drive in order to increase the reliability and possibility to conduct process operations during rheostatic testing and inspection [1].

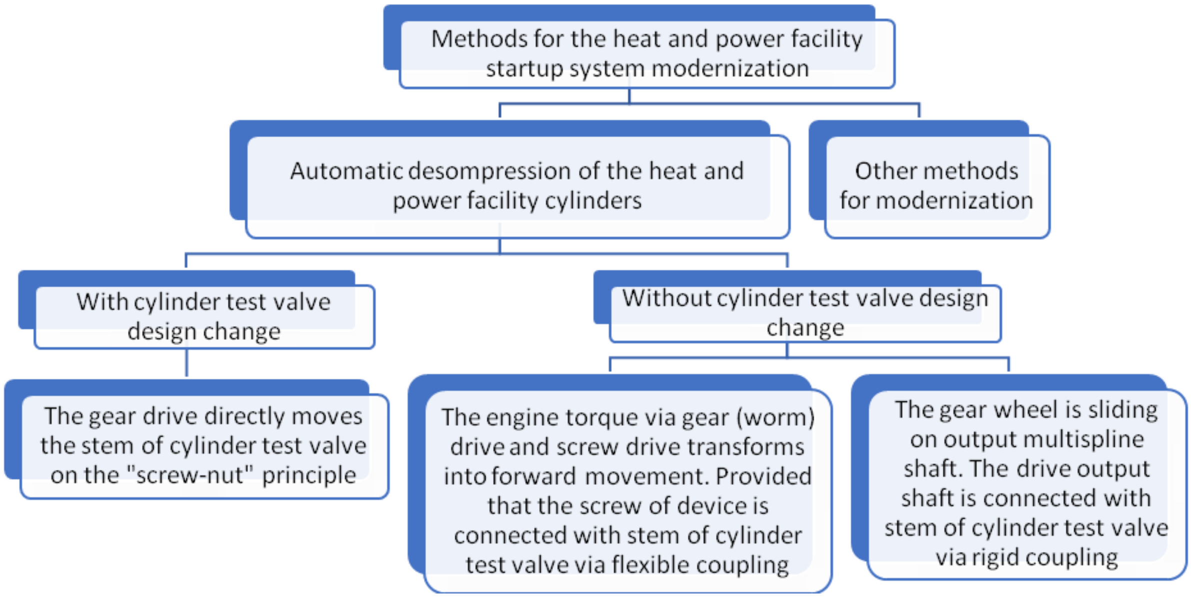

Figure 1. Methods for the heat and power facility startup system modernization.

It should be noted that the use of such devise is possible in two options:

- The first option foresees the necessity of stock cylinder test valve design change;
- The second option does not fore see the design change.

At the start of works on the drive arrangement the mentioned criteria were determined considering which such works will be performed. Among such criteria are:

- The cylinder test valve closing and opening speed, V;
- The torque required for cylinder test valve closing and opening, T;
- The drive dimensions, LxBxH.

The drive gear with cylinder test valve design change was selected, i.e. the gear directly moves the stem of cylinder test valve. Since the device should be fit in dimensions between the engine body and

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the locomotive hood doors, simplify the drive design, eliminate excess connections and improve operating conditions [8, 9].

On the next study stage, the step engine was selected considering its characteristics kinematic diagrams were further developed (Figure 2, 3, 4) [10, 11].

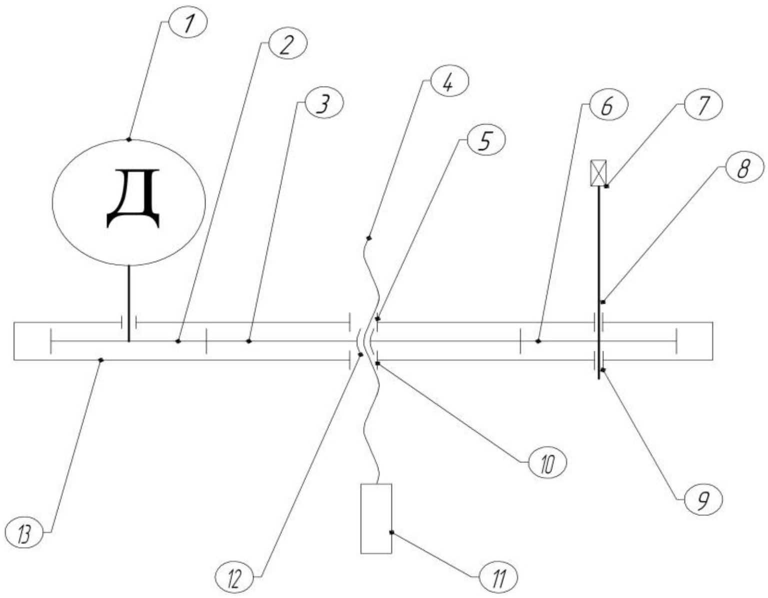

Figure 2. Kinematic diagram of spur gear drive:
1 – Electric motor; 2 – Spur gear wheel; 3 – Spur gear; 4 – Driving screw; 5, 8, 9, 10 – Bearings; 6 – Hand pinion; 7 – Shaft end for free handle; 11 – Cylinder test valve stem; 12 – Driving nut, 13 – Body.

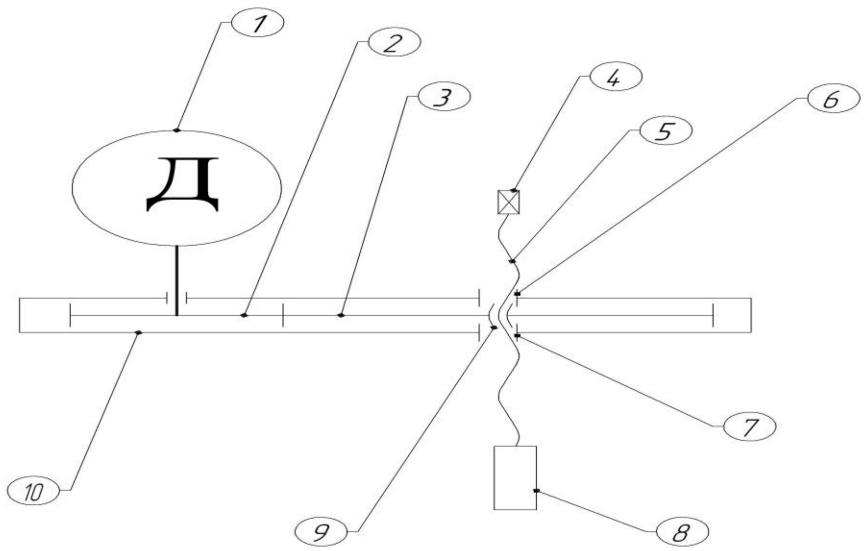

Figure 3. Kinematic diagram of spur gear drive without hand pinion:
1 – Electric motor; 2 – Spur gear wheel; 3– Spur gear; 4 – Driving screw end for free handle; 5 – Driving screw; 6, 7 – Bearings; 8 – Cylinder test valve stem; 9 – Driving nut, 10 - Body.

The kinematic diagram of spur gear drive (Figure 2) is characterized by large dimensions due to additional hand pinion.

In order to decrease the device dimensions, it was decided to pivot from hand pinion (Figure. 3) and move hand drive free handle to gear shaft. However, the application of such arrangement of spur gear still has not allowed to fit in dimensions.

The further study of different gear drives has shown the necessity to use the worm gear and made it possible to provide the transmission with high gear ratio resulting in the gear small size.

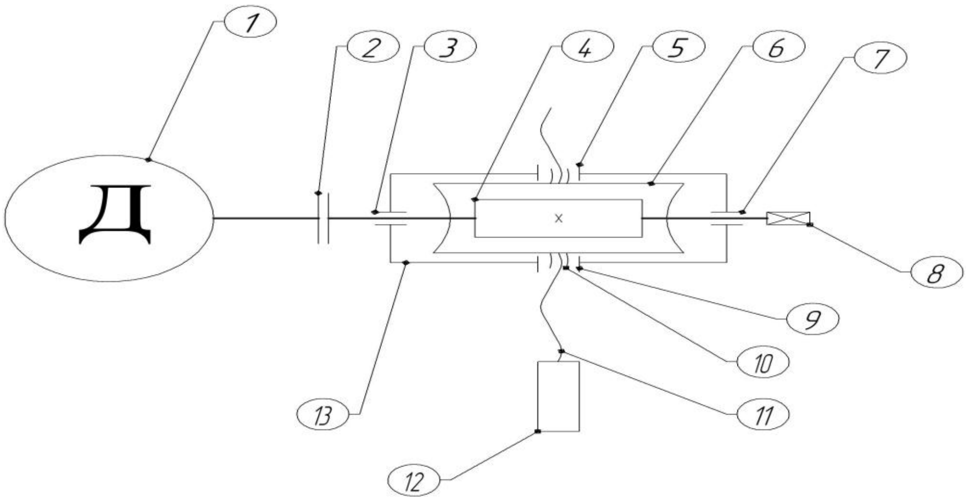

Figure 4. Kinematic diagram of worm gear drive:
1 – Electric motor; 2 – Coupling; 3, 5, 7, 9 – Bearings; 4 – Worm gear; 6 – Worm gear wheel; 8 – Shaft end for free handle; 10 – Driving nut; 11 – Driving screw; 12 – Cylinder test valve stem, 13 – Body.

After the gear drive selection, the works were focused on the determination of drive device parameters itself, among which is the gear ratio u, that shows how the rotating speed decreases and the torque on the cylinder test valve stem increases in comparison with the engine. Provided that the following shall be considered:

$$u \rightarrow 1 \Rightarrow V \rightarrow max,\ T \rightarrow min,\ LxBxH \rightarrow min;$$

$$u \rightarrow max \Rightarrow V \rightarrow min,\ T \rightarrow max,\ LxBxH \rightarrow max;$$

The measuring of required torque has shown the following value T_{min}=11 Nm. Due to the necessity of torque backup at least 30 % and maximum increase the closing speed of the cylinder test valve, decrease the dimensions the gear ratio required for the selected engine was calculated (Figure 5).

As the graph shows, gear ratios u=2 and u=4 don’t correspond the set parameters and the possible reliable operation starts at u=5; for this reason the gear ratio u=8 was chosen for the device implementation because it completely complies with the backup criterion, its response time and fits in the required dimensions.

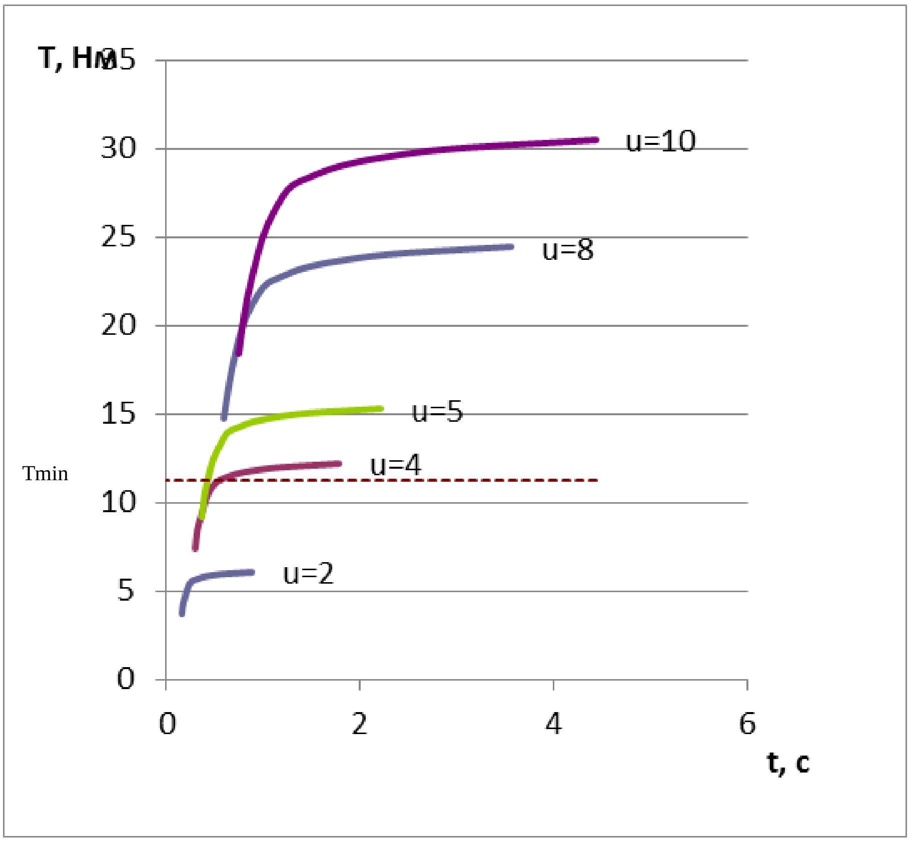

Figure 5. Cylinder test valve closing time depending on gear ratio.

3. Conclusions

The examined locomotive diesel engine startup systems have numerous disadvantages that adversely effect the whole heat and power facility technical conditions. Among such adverse factors are:

- The direct connection to accumulator battery at the traction generator startup;
- The sharp increase of startup current of accumulator battery resulting in the lifetime decrease;
- The additional wear of diesel engine due to increased starting torque.

In order to mitigate adverse effects, it was suggested to improve the startup process using the automatic decompressor; determined technical requirements to the device and its optimal response time; calculated the gear ratio of the cylinder test valve opening mechanism required for the chosen engine and its dimensions.

On the basis of these data it can insisted on the necessity to continue the work on the heat and power facility startup system optimization. I.e. it is required to change the startup system control parameters and further modernization of hardware design solutions for the heat and power facility startup easement.

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