



**Article citation information:**

Petroci, J., Mantic, M., Kulka, J., Boslai, R. Design of a compact dual-purpose starting clutch in the drive of a prototype vehicle. *Scientific Journal of Silesian University of Technology. Series Transport*. 2016, **91**, 107-112. ISSN: 0209-3324. DOI: 10.20858/sjsutst.2016.91.11.

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**DESIGN OF A COMPACT DUAL-PURPOSE STARTING CLUTCH IN THE DRIVE OF A PROTOTYPE VEHICLE**

**Summary.** Initially, the development of a dual-purpose clutch was based on racing experiences and application requirements, as well as the results from testing the new power unit in the existing prototype vehicle. In order to achieve the highest possible driving range of the prototype vehicle, it has been necessary to eliminate the maximum possible losses and drive in unnecessary components. The design aimed to achieve simple access, reliability and low weight.

**Keywords:** centrifugal clutch, prototype, engine

**1. INTRODUCTION**

The internal combustion four-stroke engine Honda GX 25, which is designed for small agricultural and garden use, involves a manual starting system. Output power is transmitted through a simple centrifugal clutch mounted on the flywheel. A crank shaft on the starter

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mechanism side is designed with a relatively low metric 6mm thread and a surface with a diameter of 11mm, meaning that it is not sufficiently sized to transmit the torque of the electric motor used for starting the prototype drive unit. Applicable electric motors for radio-controlled cars generate high stress on the crankshaft as well as on the gear mechanisms, which in turn breaks the threaded part. Automotive-type starter motors, which are used in small motorcycles with a sliding pinion gear, are also unsuitable given the small dimensions of the thread shaft. In other words, when the slide pinion bumps into the starter flywheel, a bending force impacts on the crankshaft, resulting in bending and breakage. Basic theoretical principles, which are necessary when addressing these matters, are described in [1], [2].

## 2. CONSTRUCTION

The crankshaft is shaped on the outlet cone and features a key for the precise assembly of the flywheel, which is used for cooling and driving the centrifugal clutch, and a magnetic pulse that controls the ignition system by magnets moulded into the flywheel.

The dimensions of the engine compartment in the existing prototype require a compact design of the power unit and a crankshaft speed sensor to initiate the run-up mechanism. The design of the components must be focused on simplicity, reliability, low weight and compact dimensions.

The appropriate solution for transferring the torque of the engine and the starting mechanism involves a pair of automatic centrifugal clutch. Questions concerning engine dynamics and related problems are analysed in [3], [4].

To meet the competition rules, both automatic clutches must be constructed to engage different speeds in order to prevent the transmission of torque from the electric starter motor to the driven wheel via the clutch and shaft. To comply with this rule, centrifugal clutch springs for the wheel drive stiffen the coupling elements with a lower weight or a bigger radius.

The difference in clutch engagement speed is shown in Fig. 1.

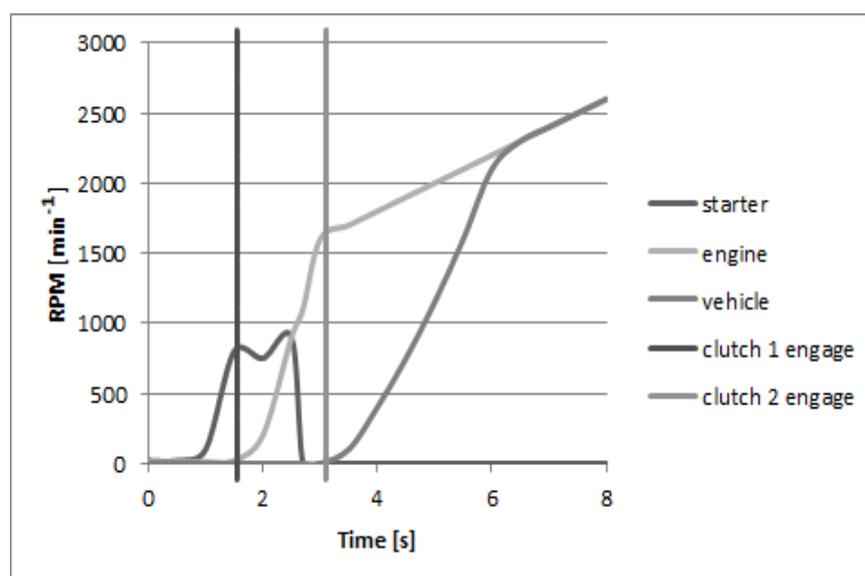


Fig. 1. Clutch engagement diagram

The following calculates the centrifugal force acting on the operating coupling elements:

$$F_c = m \frac{v^2}{R} \tag{1}$$

The mass of the clutch element in relation to the centrifugal force must be calculated according to the part that is particularly affected. The weight of the mounting part of the element, which moves around the guide pin, must not be included in any calculation.

The dimensions of the centrifugal clutch elements for the torque transmission depend on the friction linings' coefficient, their number, the friction radius, the centrifugal force and the spring force, which keeps the coupling elements in the off position.

The following equations are for calculating the linear spring stiffness and friction torque:

$$F = k \cdot y \tag{2}$$

$$F_{pr} = F_0 + F \tag{3}$$

$$M_T = (F_c - F_{pr}) \cdot f \cdot n \cdot R_T \tag{4}$$

In order to save as much space as possible when mounting the engine, three narrow clutch elements were constructed. Torque and heat transfer of the three elements will be more reliable in racing when using the start-stop power unit system to save fuel.

The course of the load in relation to time when using the start-stop system, as commonly used in Shell Eco-marathon races, is shown in Fig. 2.

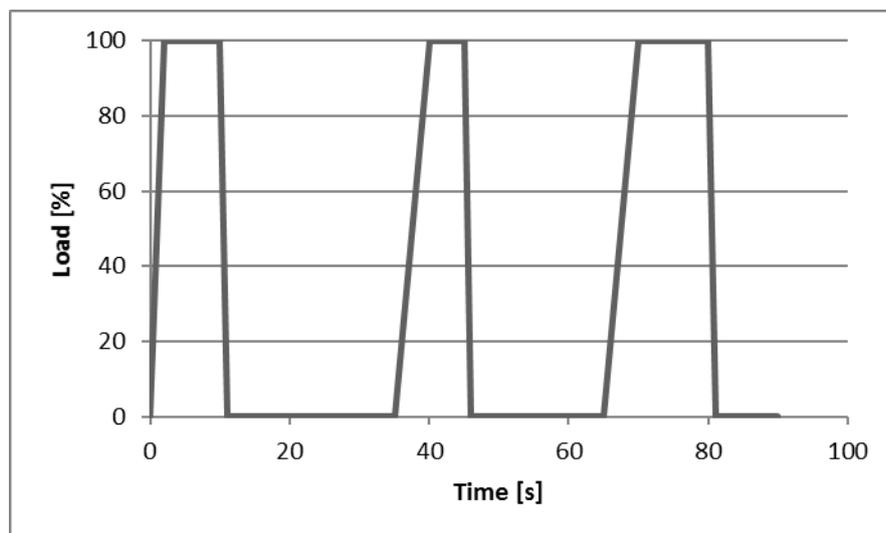


Fig. 2. Engine load during races

### 3. DESIGN

To avoid losses in the starting mechanism drive, the spur gear with mounted centrifugal clutch elements rotates around the engine crankshaft on ball bearings, which are secured on the outer bearing ring with screws. Mechanical losses involving the driving mechanism are serious problems, as discussed in [5], [6]. The mechanical losses, which are connected to mechanical vibrations, are usually considered as negative phenomena [7]. With regard to simplicity, interchangeability of parts and reliability, the same construction and number of friction elements for the drive clutch are used. The difference between the starter and drive clutch construction is stated in chapter 2.

The complete assembly cut-out of the dual-purpose drive clutch without tension springs and cooling holes in the friction wheels is shown in Fig. 3.

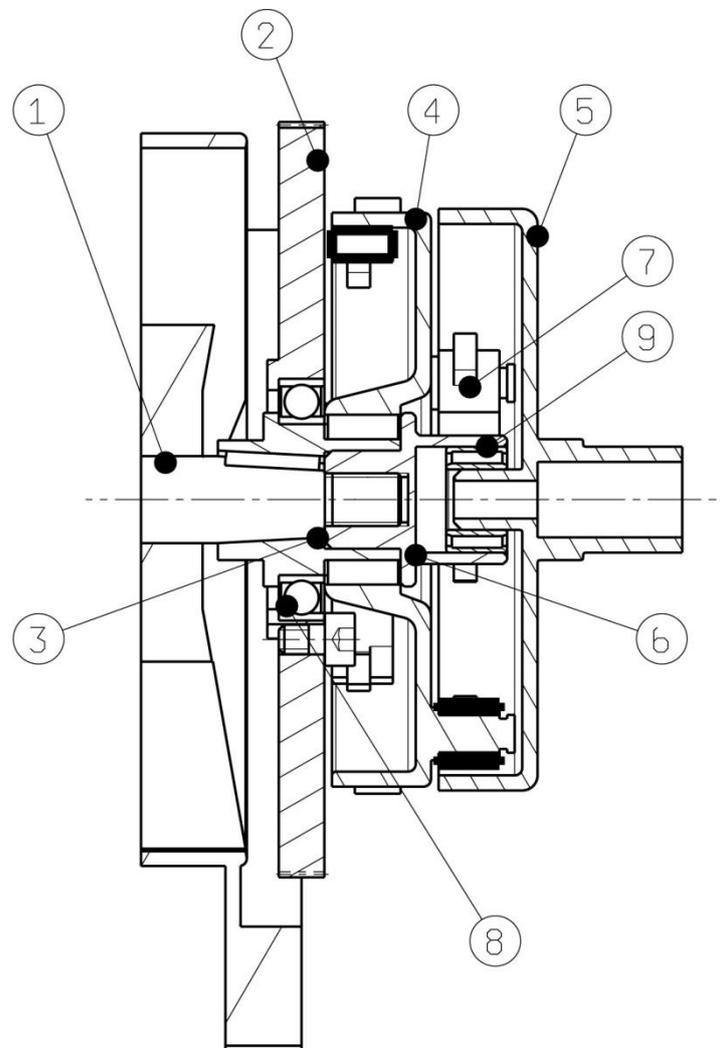


Fig. 3. Dual-purpose drive clutch cut-out: (1) crankshaft, (2) starter spur gear, (3) hub, (4) toothed flywheel, (5) centrifugal drive clutch friction wheel, (6) nut, (7) clutch element, (8) ball bearing and (9) needle bearing

Each rotating disc in the dual clutch must be precisely balanced and manufactured to avoid crankshaft and bearing failure, which result from the small dimensions and design of the original power unit.

The used hub, which is mounted on the output side of the crankshaft with a key, creates more space, as well as offers more options to use other parts, such as bearings, locking keys and surfaces. To achieve the minimum inertia and weight in each part, the spur gear, engine flywheel and output friction wheel are designed with holes on their faces. Heat transfer and the cooling of friction clutches are important in terms of making them reliable in the course of every race lap. The design of every race component also aims for simplicity regarding the speed of changing and repairing each part or the whole assembly. Simply put, easy access for screws, nuts and locking rings must take place.

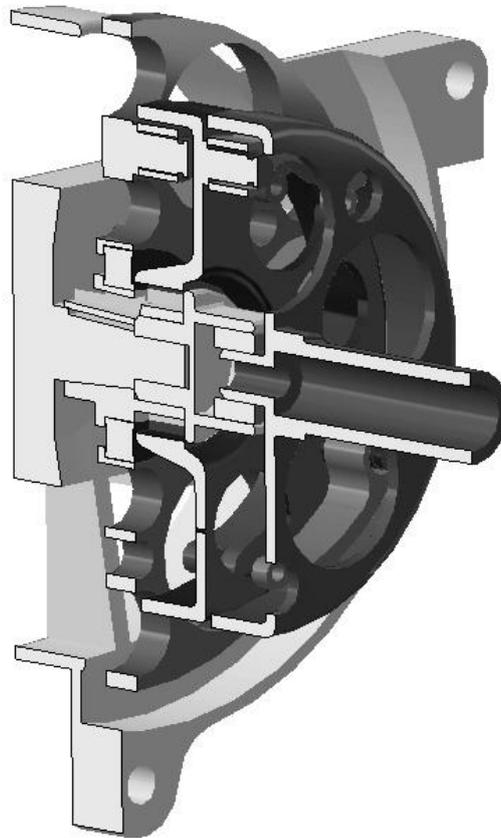


Fig. 4. 3D cut-out of a complete dual-purpose clutch assembly

#### 4. CONCLUSIONS

1. One of the possible complex designs of a starting and drive mechanism for small power units aimed to avoid the maximum possible losses.
2. This design was compromised by low part inertia, reliability, simplicity and tough race conditions.

This paper was elaborated within the framework of the following projects: VEGA1/0197/14 – research on new methods and innovative design solutions in order to increase efficiency and to reduce emissions of transport vehicle driving units, together with the evaluation of possible operational risks; VEGA 1/0198/15 – research on innovative methods for emission reduction of driving units used in transport vehicles and optimization of active logistic elements in material flows in order to increase their technical level and reliability; and KEGA 021TUKE–4/2015 – development of cognitive activities focused on innovations in educational programmes in the discipline of engineering, as well as building and modernizing specialized laboratories specified for logistics and intra-operational transport.

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Received 09.12.2015; accepted in revised form 19.03.2016



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