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Numerical and experimental study of automotive riveted clutch discs with contact pressure analysis for the prediction of facing wear

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A B S T R A C T

In this work, we investigate the behavior of the riveted clutch disc assembly which allows a soft gradual re-engagement of torque transmission. This progressive re-engagement is obtained by the clutch disc characteristics in the axial direction. The nonlinear axial elastic stiffness of the riveted clutch disc is described by the cushion curve which is an important technological constraint prescribed by car manufacturers. Therefore, we propose to perform a finite element riveted clutch disc model in order to predict the cushion curve. This model will allow to design new clutch discs while assuming car manufacturers specifications. One of the more important problems of the riveted clutch disc is the degradation of the cushion curve during the lifetime of this component. This degradation is due to an embedding phenomenon (facing wear). In this work, we propose to verify that the determination of the contact pressure distribution on the facings at the beginning of the clutch disc lifetime enables the embedding phenomenon to be estimated.

1. Introduction

In a vehicle, rotary motion is transmitted between the engine and transmission by a clutch system. The function of the clutch is to produce a soft gradual coupling between these two systems until the complete transmission of the engine motion to the wheels [1]. Conventional clutches, include electromagnetic clutches [2,3], gear clutches [4,5], friction clutches [1], over-running clutches [6,7] and centrifugal clutches [8]. Car manufacturers requirements for greater power transmission, lightweight, low cost design, smaller design space, high comfort and high effectiveness lead to develop new clutch mechanisms such as ultrasonic clutches [9] or piezoelectric clutches [10]. Nevertheless, today's passenger cars and light trucks are now almost exclusively equipped with conventional friction clutches (i.e. diaphragm spring clutches). In this work, we only consider dry friction clutches. It is composed of the clutch disc, the flywheel and the mechanism, which is itself composed of a cover, a diaphragm spring and a pressure plate (Fig. 1). When the engine rotates freely (no gear engaged) no torque is transmitted because the clutch disc is not in contact with the mechanism and rotates freely (Fig. 1). When a gear is engaged, the clutch disc is compressed by the diaphragm spring between the pressure plate of the mechanism and the flywheel transmitting the rotary motion and the torque to the mechanism and thus to the wheels.

The necessity of coupling or decoupling the engine and transmission during gearshift induces the development of optimized clutch components that aim to soften the contact occurring during the re-engagement of the rotational motion and to transmit the torque between the pressure plate and the flywheel. In this work, we investigate the behavior of the riveted clutch disc assembly (cushion disc, rivets and riveted facings) (Fig. 2). It is the clutch's central connection element. In combination with the clutch pressure plate, it both separates and links engine and powertrain. It allows a soft gradual re-engagement of torque transmission. This progressive re-engagement obtained by the clutch disc characteristics in the axial direction preserves the driver's comfort and avoids mechanical shocks increasing the lifespan of the engine.

1.1. The cushion curve

The axial elastic stiffness of the riveted clutch disc is obtained by a cushion disc (Fig. 3(a) and (b)) which is a thin-waved sheet, located between the two facings and fixed by rivets. It acts like a spring allowing a soft gradual re-engagement. This nonlinear axial stiffness is obtained by cutting the cushion disc into paddles and forming them to get a wavy shape (Fig. 4). The nonlinear axial elastic stiffness of the riveted clutch disc is described by the cushion curve (Fig. 5). This load–deflection curve gives the axial

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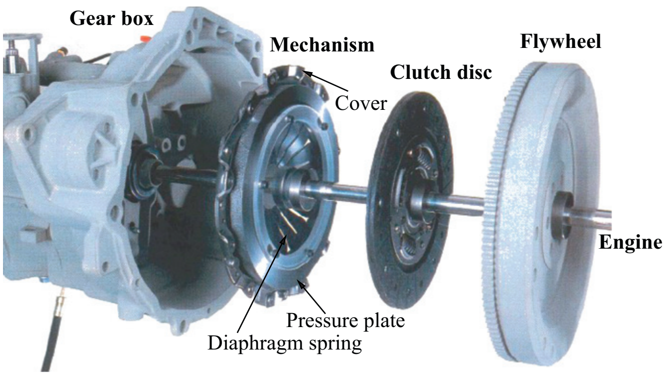

Fig. 1. View of the clutch.

load versus axial displacement obtained by compressing a clutch disc between two flat pressure plates. This experimental test validates a clutch disc. The wavy shape of the cushion disc is the key element for obtaining this progressive cushion curve [11]. The cushion curve is an important technological constraint prescribed by car manufacturers which must be located between an upper bound and a lower bound (Fig. 5). The cushion disc participates to the driver's comfort during the clutch pedal operation. The correlations between biomechanical parameters and understanding of discomfort have been studied and practical recommendations of clutch pedal design have been discussed and suggested [12].

Therefore, in order to rapidly and efficiently design new clutches while assuming cushion curves specifications, the numerical simulation of clutch disc behavior is of prime importance. The shape of the cushion curve, the displacement at

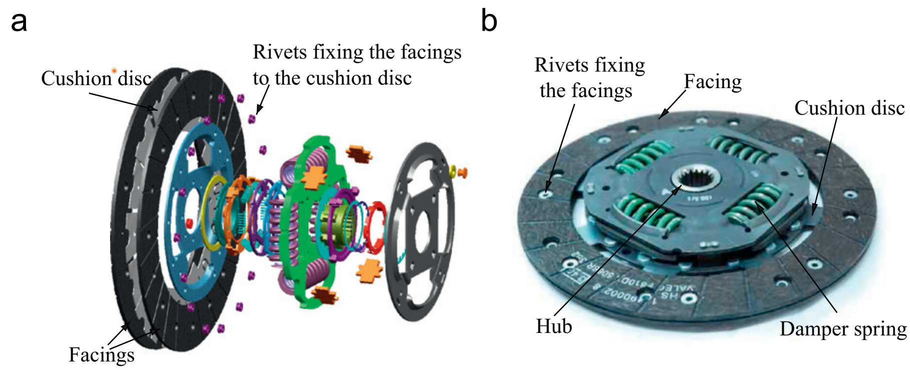

Fig. 2. Detailed design of the riveted clutch disc: (a) Exploded view and (b) Assembled view.

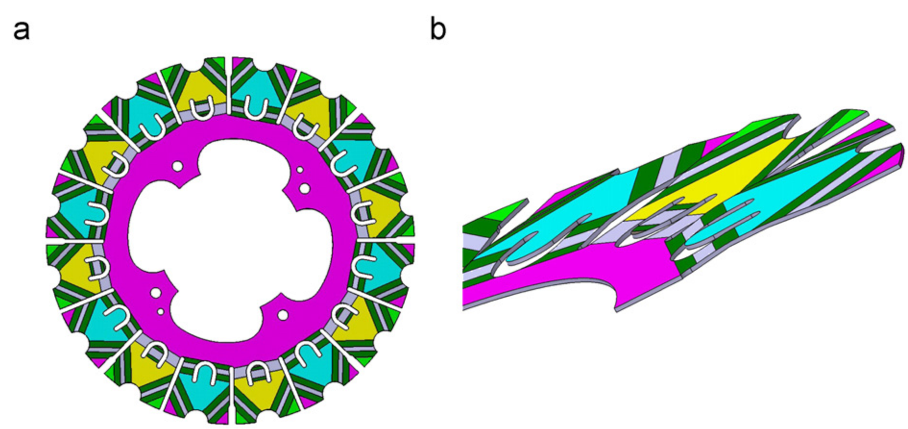

Fig. 3. Cushion disc (each color corresponds to different heights): (a) Front view of the studied cushion disc composed of 16 paddles and (b) Cut view of the cushion disc.

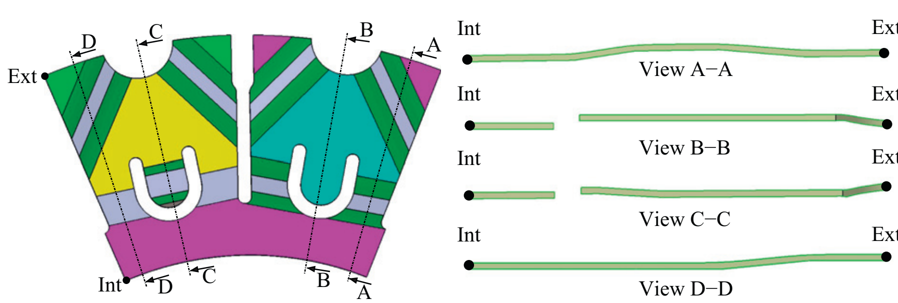

Fig. 4. Two paddles of the cushion disc with different sections.