Contact model for toroidal type continuously variable transmissions

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Abstract
Toroidal type Continuously Variable Transmissions (T-CVT) are mechanical transmission systems where torque is transferred by means of traction forces. This transmission type holds, slip and high contact pressures that affects its performance. Therefore, it is important to analyse the contact behaviour of this transmission to maximize the transferable power and life of the component, with the lowest power loss as possible. In this paper, a contact model to compute T-CVT efficiency is presented.

1. Introduction

Toroidal type Continuously Variable Transmissions (T-CVTs) are mechanical systems that continuously change the transmission ratio between two limits. This characteristic enables operating in the most efficient condition of any mechanism, which is a very important environmental concern nowadays. The power transference is carried out by means of traction forces between two coaxial discs pressed against several rollers (see Fig. 1a), which differentiates this transmission type from conventional geared devices [1].

2. Model description

The efficiency calculation model is summarized in the block diagram shown in Fig. 1b. The input variables refer to the geometric data, clamping force and torque to be transmitted.

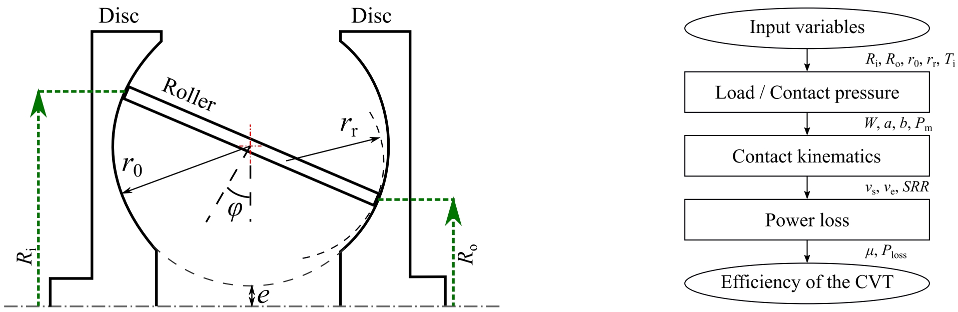

Fig. 1: a) Schematic representation of a T-CVT; b) Block diagram of the model

The geometry data and the clamping force used in this work are shown in Table 1, where the conformity ratio (*CR*) refers to the ratio between the toroidal cavity radius (r_0) and the roller curvature (r_r): $CR = r_r/r_0$. Three rollers where considered in the mechanism, therefore, the clamping force is divided into three points.

Table 1: model inputs

r_0	e	CR	φ	i	Fp
110 mm	-20 mm	0.5 – 0.8	± 25º	0.33 - 3	5, 10, 15 kN

The first block of the model, represented in Fig. 1b, computes the normal load acting on the contact point between disc and rollers considering the geometry and transmission ratio. The contact area and contact pressures generated by the normal load are also calculated in the first block. In the second step, the sliding motion as a function of Slide-Roll Ratio (SRR) is calculated to be used in the third block to calculate the power loss, typical values of SRR are around 2 % [2]. The traction coefficient used in the power loss calculation was measured in a ball on disc tribometer for different SRR, contact pressure and temperature values. Finally, the power loss of the transmission is calculated, which is the result of the product between sliding speed and traction force acting in the contact area. The calculation has been carried out by numerical integration of discrete values of contact pressure and sliding speed on the contact surface (see equation 1). The equation represents the power loss for a single contact point and should be used in the input and output.

$$\overline{P_{loss}} = \bar{\mu}(p_H, SRR) \cdot \sum_{i=1}^{n} \sum_{j=1}^{m} v_{s_{ij}} \cdot p_{ij} \cdot \Delta x \cdot \Delta y \qquad [1]$$

3. Results and discussion

On the one hand, Fig. 2a shows the transferable power and efficiency of the transmission as a function of SRR. At low values of SRR the transferable power is low because of the low value of the traction coefficient. For higher values of SRR, the traction coefficient also increases, as a result the transferable power increases. However, efficiency decreases due to the augmentation of relative sliding. In the box of Fig. 2a the size of the contact area, contact pressure distribution and sliding speed distribution for SRR = 2 % is shown. The obtained sliding motion paths resemble the ones obtained by Meyer [3]. The clamping force used in the calculation shown in Fig. 2 was 15 kN and the *CR* value was 0.7.

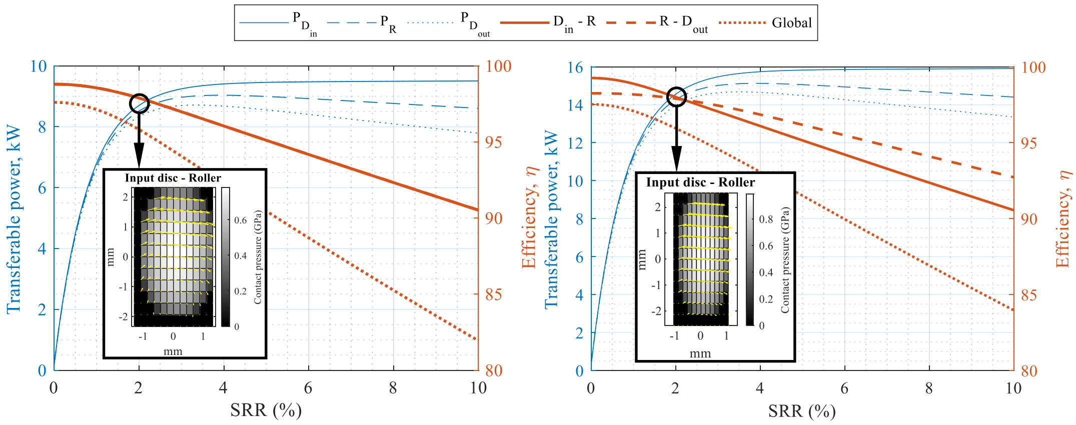

Fig. 2: Transferable power and efficiency / contact pressure and sliding speed distribution (SRR = 2 %). a) i = 1:1; b) i = 1:3

On the other hand, Fig. 2b shows the transferable power for a transmission ratio of 1:3, where it is shown that the efficiencies in the input and output points are not equal, this is due to the differences in the contact geometry between input and output points. The analysis has shown also that the *CR* value influences the transmission performance; for low CR values, efficiency at low SRR increases due to the reduction on the contact area, however, the contact pressure increases. Meanwhile, the opposite happens for high CR values.

4. Conclusions

In this work a model to calculate the efficiency of T-CVTs has been developed. The main conclusion inferred from this research work is that geometry plays an important role in T-CVTs performance. Results show that the transmission ratio affects efficiency due to changes in the contact area caused by differences in the input and output contact geometry.

References

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