Abstract

The synchronizer mechanism represents the essential component in manual, automatic manual and dual clutch transmissions. In order to carry out the experimental tests, three different synchronizers (single cone, double cone, and triple cone synchronizers) were used on the test rig machine. For the purpose of synchronizing time estimation, an analytical formulation is proposed. This model consider applied force as function of time. The time dependency of this method can be considered as the novelty of this method. The calculated error of this method in worse case was less than 11% in compare with experimental results. Another mathematical model for every phase of synchronization was stablished and the results of this model were compared with experimental data. There is a good agreement between extracted results. This model gives a rough estimation about dynamic behavior of synchronizer regarding fast calculation time. Because of rigid body assumption the reliability of this model in different loading conditions and changing the geometrical dimensions can be reduced. A FE model was generated to evaluate the natural frequency and modal dynamic behavior of the system. The modal responses of different synchronizers under various loading and boundary conditions were examined. The results highlighted the resonance frequency for each synchronizer based on transient modal dynamic. The developed FE model was modified in order to multi body dynamic analysis of three synchronizers. Two different MBD methods (rigid and flexible) were created and the results of those method were compare with experimental data. These three dimensional multi body dynamic models are developed to predict dynamic response of synchronizer especially for calculation of synchronization time. There is a good agreement between both model and experimental results. However the accuracy of flexible model is much closer to the real test condition. A sensitivity analysis was performed on the rigid MBD model and effect of changing the angle of friction cones was investigated. A new expression as a force ratio error was proposed as the outcome of this study. The flexible MBD model was simplified to a sub-model in order

to use for DOE optimization method. Furthermore the results of this validated model were used for DOE- RSM method in order to obtain the best operational condition for each kind of synchronizers. After performing different statistical verification tests some empirical model with more than 96% accuracy were proposed in order to predict the synchronization time, maximum contact pressure, and friction dissipated energy. The calculated synchronization time from DOE method was compared with experimental data and show less than 2% error for different synchronizer mechanism. Based on DOE method a sensitivity analysis was performed to study the effect of different factors when the friction cones have different tolerance dimensions. After applying verification test on the statistical models the final empirical models for each condition were presented. In general, different models which expressed in this thesis can be applicable for different applications. The proposed methodology provides dynamic behavior of synchronizers regarding computational cost and detail information of synchronization during shifting process.