FE oriented Virtual Test of Closure Systems

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1 Introduction

Closure systems are an important element of the automotive passenger safety concept. They include common standard functionalities such as ensuring closure, opening and locking functions. Furthermore, they are enhanced by customer specified comfort functionalities, for example central lock, double lock, open-by-wire (OBW), electrical child safety and soft close automatic (SCA). The integration and realization of all functions leads to a complex mechatronic component in the door system of a vehicle. It contains strongly coupled mechanic and mechatronic operation chains.

The continuously rising requirements regarding costs, weight and development times can't be satisfied by only analytical approaches anymore. Therefore in the field of virtual strength and structure testing at Brose, methods have been established that enable the simultaneous FE analysis of the single part strength and the overall system performance, including the main effecting boundary conditions, e.g. loads caused by springs or electrical drives. These simulations are part of a specific virtual test program that covers the various product requirements. The aim is the evaluation of a new product design in a very early design phase and therefore the reduction of expensive hardware testing loops.

2 General Build Up of Closure Systems

The key features of a latch are the closure parts consisting of rotor, pawl, pins and back plate, see Figure 1. They are dimensioned to withstand high static and dynamic forces (e.g. crash) but have to guarantee at the same time an easy access (in a way with low handle forces) to the door.

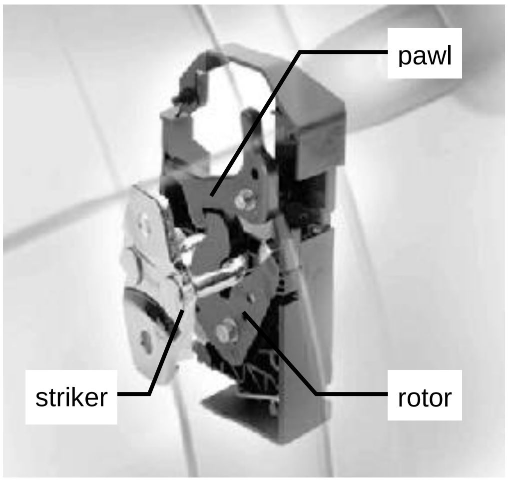

Fig.1: side door latch with striker

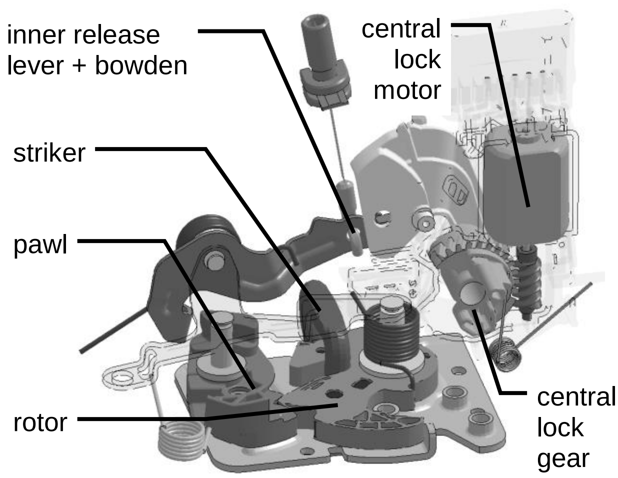

Fig.2: closure parts with mechatronic chain

Opening and locking is realized by mechanical lever chains acting onto the closure parts, e.g. outer or inner release chains, which are connected to the corresponding door handles via Bowden cables. Most of the levers are loaded by leg springs in order to rotate back and to keep its starting position, even when effected by crash accelerations. Comfort functionalities are typically implemented with motor driven gears. In Figure 2 is shown a latch with one mechatronic chain, the central locking chain.

3 Dynamic Overload Strength Test

The FE-based virtual test setup is divided in three main fields: (1) the quasistatic tensile test of the closure parts in all relevant directions according to FMVSS 206, (2) the quantitative and dynamic overload calculations of all existing operation chains in the latch and (3) the mechanical stop simulations of all existing mechatronic chains. The focus of this paper is the dynamic overload test of mechanic lever chains because this load case covers most of the modeling issues.

Excluding the meshing, the main aspects regarding the model build up close to the real test set up will be discussed. Due to the high complexity, an efficient contact generation is needed. Getting the realistic nonlinear load also in the mechatronic chains a suitable model of a DC motor is created. The boundary conditions are oriented by the real test equipment.

3.1 Standardized automatic generation of latch specific contacts

The basis of an efficient contact definition is the unique identification of all possibly occurring components in a latch. A part library with function oriented standardized short names and related identification numbers is created. More than 600 different parts are available in this library.

The theoretically possible number of 100’000 contact pairs had to be reduced significantly for efficient handling in simulation and post processing. An analysis of practically occurring part interactions resulted in 4’600 relevant contacts collected in a master contact template. A specific latch consists of a subset of all parts in the part library and the contacts for this subset are detected by a python script. The script derives additional contacts, where a detailed analysis requires a further subdivision of contacts. Depending on the complexity of a latch, this results in 100 to 250 actually occurring contacts.

3.2 Integration of electro-mechanic DC motor operation

Due to the short operation times of locking functions a strongly nonlinear behavior of the DC motor has to be taken into account. A defined operation point cannot be detected in the characteristic curves of the motor.

The electrodynamic behavior of the DC motor can be approximated by an equivalent network. This network should be able to calculate the current in normal operation mode as well as in a short circuit constellation. The small finite elements in the latch model lead to very small integration steps. This enables the combination of the electrodynamic differential equation with a simple Euler based integration step. Thus it is possible to include the motor model together with the integrator by the usage of common LS-Dyna-Keywords.

3.3 Boundary conditions

Nowadays a latch is connected to its mechanical interfaces by Bowden cables. In the corresponding test setup, the chain is activated at a constant high Bowden cable velocity that is three times the normal velocity. This reproduces the fast pulling of the door handle by the user. These cable velocities are applied by developed standard templates. Furthermore, a constant door seal load is applied onto the striker as a second force based boundary condition. Additional to the opening movement of the inner release lever chain and pawl, the status of the central lock chain including gear and motor has to be reset. It is changed from “locked” to “unlocked”, the so called “override” function. The motor inertia and – when intended – the counteracting short circuit torque are passive loads.

3.4 Evaluable Results

The results of this load case are the measurement of force and displacement at the Bowden cable that are necessary to open the latch. Furthermore the stresses and deformations are derived for each single part, those in the operating chain as well as for the housings. Potential for improvements regarding strength or weight is identified and verified in another simulation loop.

4 Summary

This paper presents the combination of mechanic and mechatronic components into a single simulation model with the objective of reproducing the complex boundary conditions of the real test setup. This is essential in highly function oriented part designs, e.g. closure systems in order to detect the highest single part load within a wide operating range and the effect of coupled velocity dependencies. Simultaneously the total dynamic performance regarding Bowden force and travel is calculated. This virtual test allows the first verification of a concept design as well as the detailed strength evaluation.