Park Lock Dynamic Analysis using VALDYN

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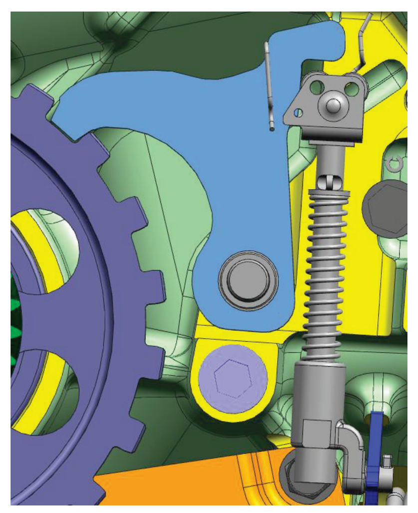
Introduction

A park lock mechanism is a device fitted to a motor vehicle's automatic transmission in order for it to lock up the transmission. It is engaged when the transmission shift lever selector is placed in the "Park" position.

Park lock designs differ between vehicles. In general, the park lock system consists of a park gear which is on the transmission's output shaft, a park pawl that can engage and disengage from the park gear, and an actuation mechanism that moves the pawl in and out of Park. An example park lock design is shown in the picture below.



In recent years, Ricardo consulting engineers have successfully conducted dynamic analyses of the park lock system using Ricardo Software's VALDYN. A typical park lock project is presented to show how Ricardo employed VALDYN's general-purpose dynamic analysis capabilities to arrive at design solutions for complex engineering problems.

Park lock design requirements

It may seem like a simple thing to lock the transmission and keep it from spinning; but there are actually some complex requirements for this mechanism:

- When the vehicle is traveling at a high speed and park is engaged, the park lock system must ratchet or slip, thereby not engaging until the vehicle has slowed to a targeted "engagement speed". This is generally called the engagement speed test. It is a government requirement that the vehicle cannot engage park above a certain speed. Engaging at a higher speed also causes higher stresses in park lock and other transmission components and can cause wear, fatigue, and eventual failure.
- When the vehicle is on a hill and the driver has engaged park and lets his foot off the brake, the vehicle must not rollback beyond the targeted "rollback distance". This "rollback test" is also a government requirement. The maximum speed that the vehicle generates when parking on the hill should be lower than the park lock's engagement speed. Otherwise, the vehicle will be rolling down the hill and can't be stopped.
- The driver has to be able to disengage from park after the vehicle has been parked on a hill, especially after an extended period of time
- Once engaged, the park lock needs to stay engaged. The design has to prevent the pawl from popping up and disengaging.

The analysis approach

The first step of a park lock analysis is to gather design requirements and product specifications from the customer. Usually, this includes targeted engagement speed, rollback distance, maximum hill grade, etc.

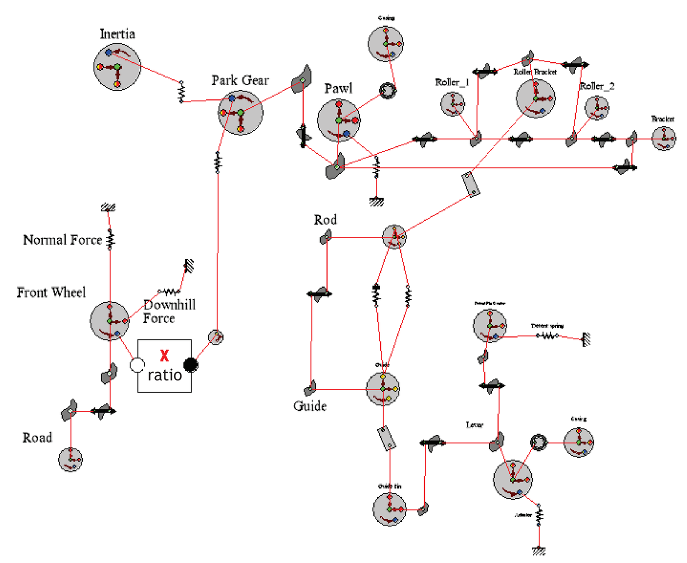
Typical parameters required to model the system are:

- Vehicle mass and weight transfer
- Final drive ratio
- Pawl and park gear geometry
- Actuation and engagement component geometry
- Park lock components and driveline inertias and stiffnesses

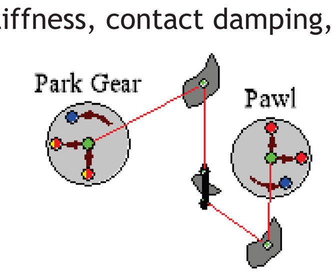
Analysis provides the following outputs:

- Predicted engagement on both level ground and hill
- Predicted disengagement on a hill
- Driveshaft and park gear torques
- Contact loads between park gear and pawl
- Other reaction forces
- Specify/design a system which will meet all the requirements

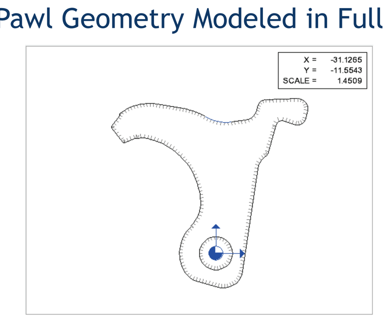
VALDYN's modelling library includes many general-purpose dynamic analysis elements, as well as elements for accurately representing more detailed geometry, making it an ideal tool for modelling this system. The VALDYN model shown below includes vehicle mass and inertia, driveline stiffness and rolling ratio, and detailed geometries for park lock components.

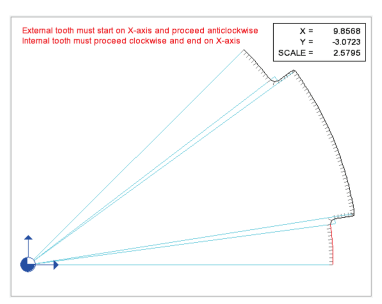


Park lock geometries are defined using VALDYN's LAMINA and LAMINAGEOM elements. The contact prosperities between each contact element are defined in the LAMINALINK element where contact stiffness, contact damping, and contact friction inputs are required.



Pawl Geometry Modeled in Full





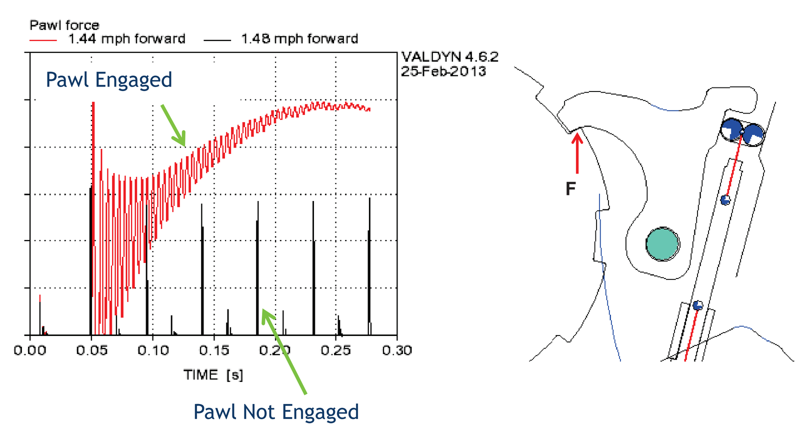
Park Gear Geometry Defined in LAMINAGEOM. Only one tooth shape is required.

It may take many iterations to come up with a park lock design that meets all design requirements. Typically, the park gear's tooth width and tooth gap are adjusted to meet the engagement speed requirement. Spring forces can be adjusted as well. In this project, a design of experiment (DOE) approach is used to finalize the park gear geometry.

The variables for the DOE were:

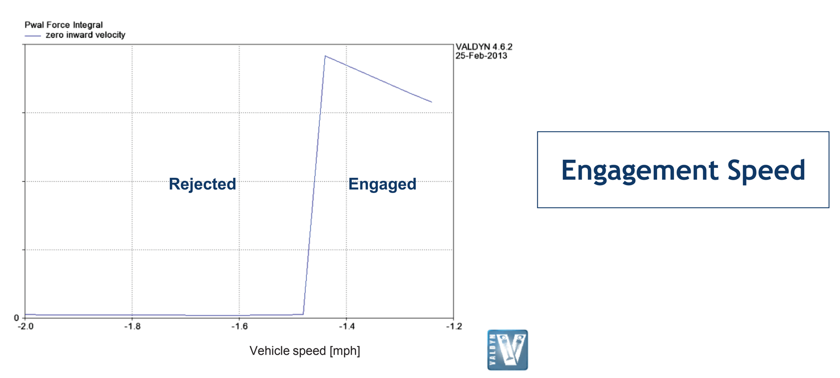
- Number of teeth
- Tooth gap
- Vehicle speed

The force integral between the pawl and park gear was used as the response. When the pawl engages, the force is continuous; when the pawl is kicked out, there are only spikes. Therefore, the integral of the force over the entire time (average force) was chosen as the response. A higher force integral indicates engagement and low force integral indicates rejection (see details in results section).



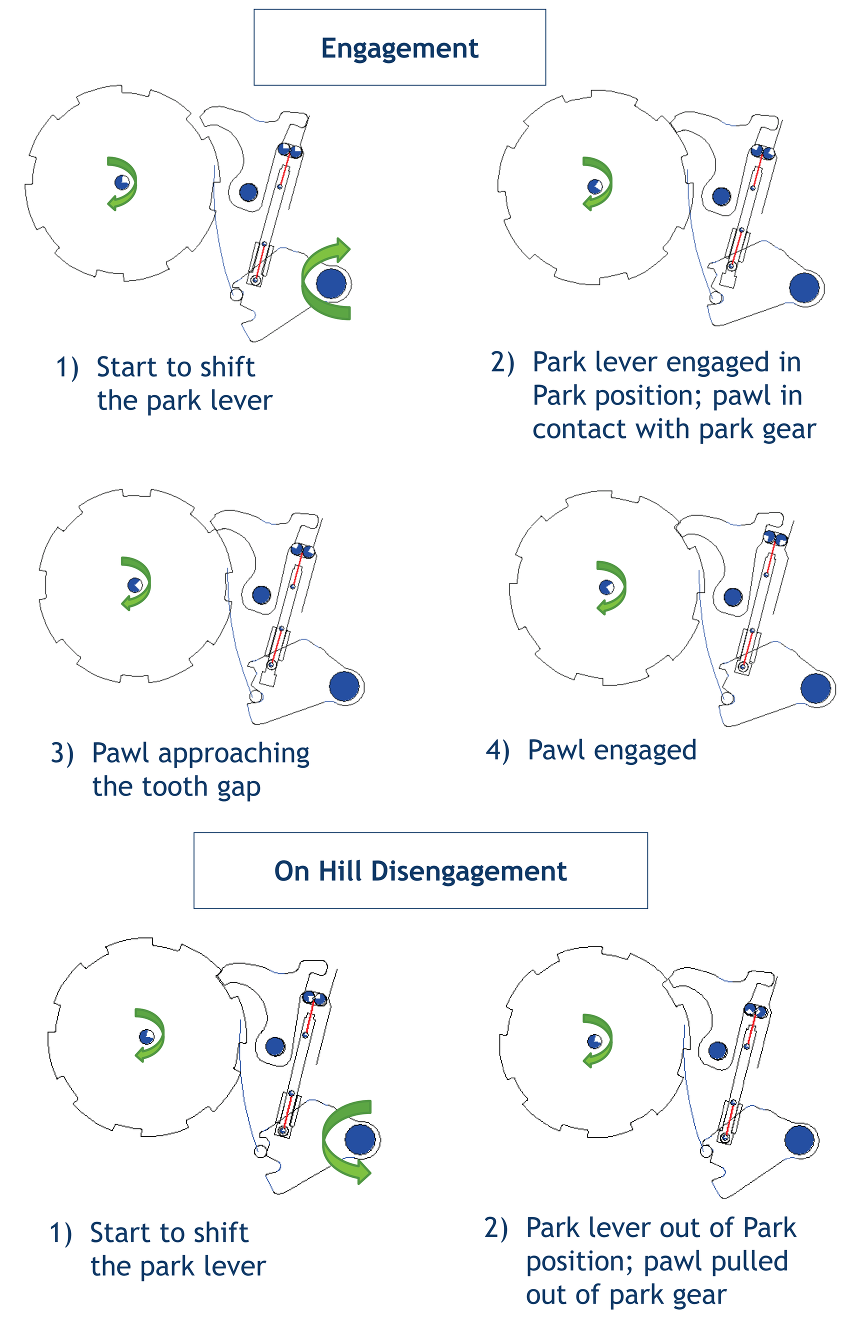
Dynamic analysis results

The DOE results showed an 8 tooth park gear design would satisfy the engagement speed requirement. Plots shown below suggested that at vehicle speed of 1.44 mph and below, the pawl is engaged; at vehicle speed of 1.48 mph and above, the pawl is rejected.



Following the DOE, additional analyses were performed to take a closer looks at the system dynamics and also evaluate the system's on hill engagement and disengagement performance. The maximum vehicle speed when parking on a hill was predicted to be 0.75 mph for both forward and reverse directions, which is less than the 1.44 mph engagement speed. Therefore, the vehicle will not roll away.

In addition to the plots generated by VALDYN, the animator is a very useful tool to examine the system's dynamic behavior and see how each component moves and interacts with each other.



Conclusions

The park lock system was successfully modeled and its dynamic behavior was predicted in VALDYN. VALDYN's flexibility as a general-purpose mechanical dynamics modeling tool was well applied and a park gear design was specified that meets all design criteria.

Acknowledgment and contacts

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