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The planned use of ADAMS/Engine in the development of valve-trains at AUDI

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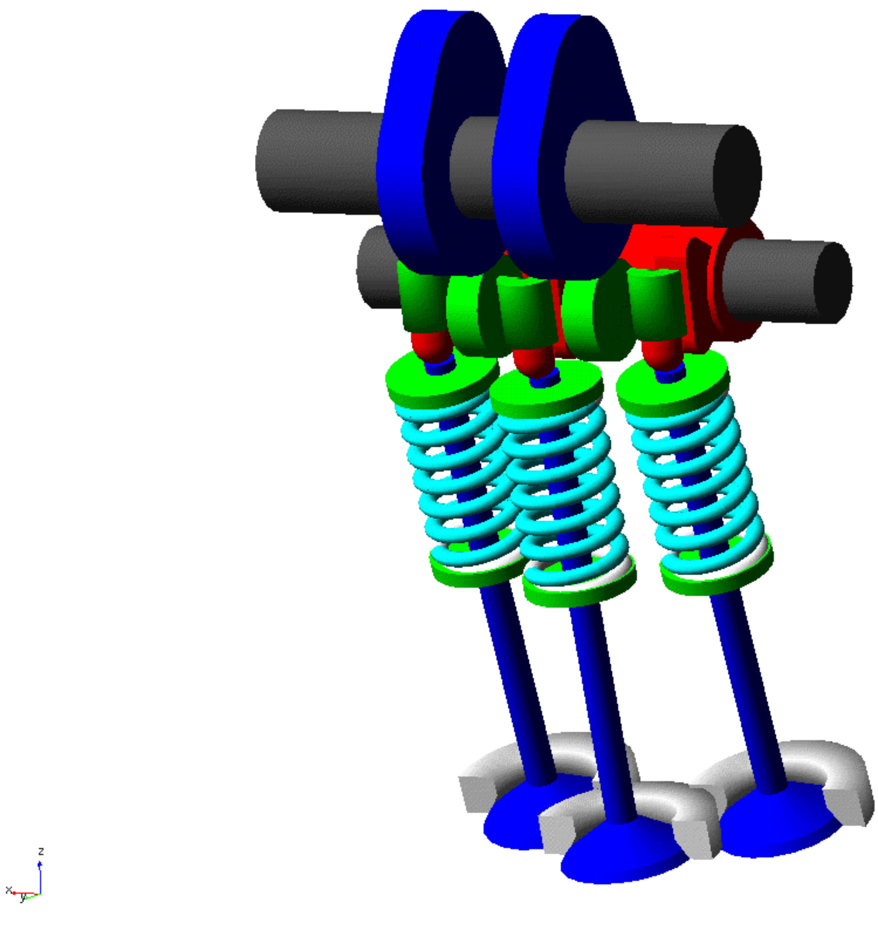

Abstract

ADAMS/Engine is a software package which has been developed for dynamic valve-train calculations. The development of ADAMS/Engine is supported by a consortium of vehicle manufacturers and parts suppliers. AUDI is a member of this consortium.

This report is about the planed use of ADAMS/Engine in the development process of valve-trains at AUDI. The motivation for the development of ADAMS/Engine is described as well as a short overview about the product development process of valve-trains. Further on, the different steps of the dynamic analysis are explained - from the tuning of valve-spring to the complete timing mechanism.

Introduction

The calculation of increased power at constant cubic capacity requires powerful computational software to support the engine development. Especially the loads on the valve-train are growing with an increase of engine speed and the requirement of a maximum period of valve lift. ADAMS/Engine will be a tool to support the development of engines which cover those requirements.

The development of the first stage of ADAMS/Engine is finished. Because of AUDI membership of the development consortium, it has been possible to do first calculations to verify the software and to get an impression of its capabilities.
At AUDI a process for the development of valve-trains has been defined which is supported by ADAMS/Engine. This report shows the introduction of ADAMS/Engine in this development process.

Motivation

Before describing this process, it is necessary to describe the motivation led AUDI to take an active part in the development of a new application to calculate valve-train dynamics. The main motivation to do valve-train dynamic analysis is the reduction of costs and time during the development process. The generation of the calculation model takes a large part of the analysis time. For this reason, the way of the creation of the model should be the most important part of a new development.

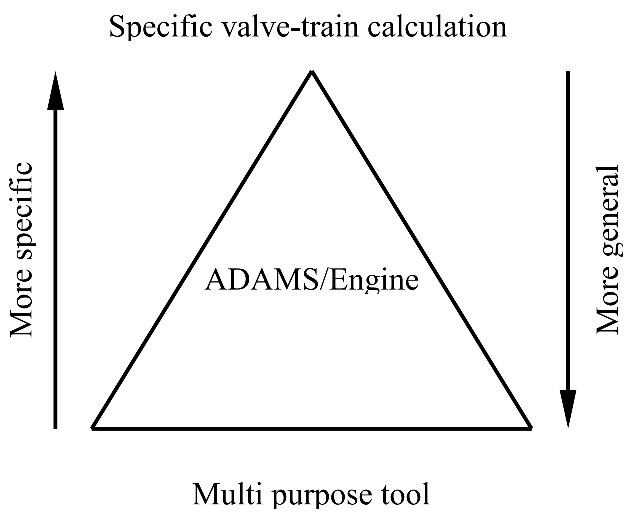

Fig.1: Different options to reach the aim

There are two kinds of software tools for dynamic valve-train analysis on the market. On the one hand there are multi-purpose-tools like ADAMS and on the other hand there are tools for specific valve-train dynamic calculations. At AUDI one of the specific tools is currently being used. This tool works well for the traditional valve-trains. However, it isn't able to cope with new kinds of valve-train topologies like the rocker of AUDIs V8 engine. That rocker is driven by two cams and acts on three valves. For the current program, a way was found to describe the physics of such a rocker. It doesn't however truly describe the characteristics because several rockers and finger followers were used to represent it.

There are two options to reach the above mentioned aim using parts of a toolbox for standard valve-trains and having the opportunity to generate complex valve-trains.
The first one is to make the specific tool more general and the second one is to make a multi-purpose tool more specific. The second option had been chosen so that a toolbox for standard elements is combined with the capabilities of a multi-purpose-tool.

Development Process

The development process of valve-trains is described, to demonstrate at which stage of the process ADAMS/Engine is used.
The first step of the development of a valve-train is the design of its geometric topology. The topology contains the position of the cam-shaft, the socket pivot and the theoretical valve seat, etc. In the next step, the motion of the valve is calculated in according to the thermodynamics of the combustion. After this, the cam-profile is calculated under the geometric boundary-conditions. At this time the cam-profile is written in the Neutral Data Format, which is readable by ADAMS/Engine. The next step is the dynamic analysis of the valve-train with ADAMS/Engine. It could be necessary to repeat some steps of the process in order to optimize the results.

Dynamic Analysis

The following section describes the different steps of the dynamic analysis. It starts with the generation of a template, followed by the tuning of the valve-spring. The next steps are the building of the subsystem of the single-valve-train and complete-valve-train. The final step would be the analysis of a complete timing mechanism including the chain or belt drive from the crankshaft to the camshaft.

1. Generation of Templates

The first step of the dynamic analysis is the generation of the template which contains the generic structure of a valve-train. The template can be designed with those parameters that are used for the kinetostatic calculation of the cam-profile. Because of that, the standard user doesn't have to recalculate the geometric parameters again. The creation of the templates has to be done only once for each kind of valve-train e.g. direct driven, rocker with radii, rocker with roller and radius or the above mentioned rocker. The advantage of designing templates is the opportunity for each company to design their own set of templates for their own requirements.

2. Tuning of Valve-Sping

The next step is the tuning of the valve-spring. At the beginning the comparison of the calculation results with test data is very important to gain experiences of the right choice of parameters to tune the spring. Generally, this tuning is done with the rise-rate, the density and the shear modulus. Only these parameters should be used for the tuning because it is recommended to take the geometry just from the data sheet of the spring. Otherwise the behaviour of the spring is described without any relation to the geometry of the spring.

The tuning can be done with a virtual testrig which is a part of the software package. The testrig avoids an influence from the remaining single-valve-train system on the spring. Because of that it is quite easy to tune the valve-spring. Data from a real testrig are used to be compared with the calculated data. Care should be taken with the test data with regards to the eigenvalues of the spring, because it is difficult to get reasonable test results. Anyway, test data of the valve-spring are available at an early stage of the valve-train development.

3. Generation of Single-Valve-Trains

After tuning the spring, the single-valve-train can be built by creating a subsystem from the template and adding the data of the components. The subsystem includes the geometric data of the valve-train whereas the structure is delivered by the template. The figures show three single-valve-trains with different kinds of rockers.

The first one contains just a rocker with two radii which is a part of the tool box of ADAMS/Engine.

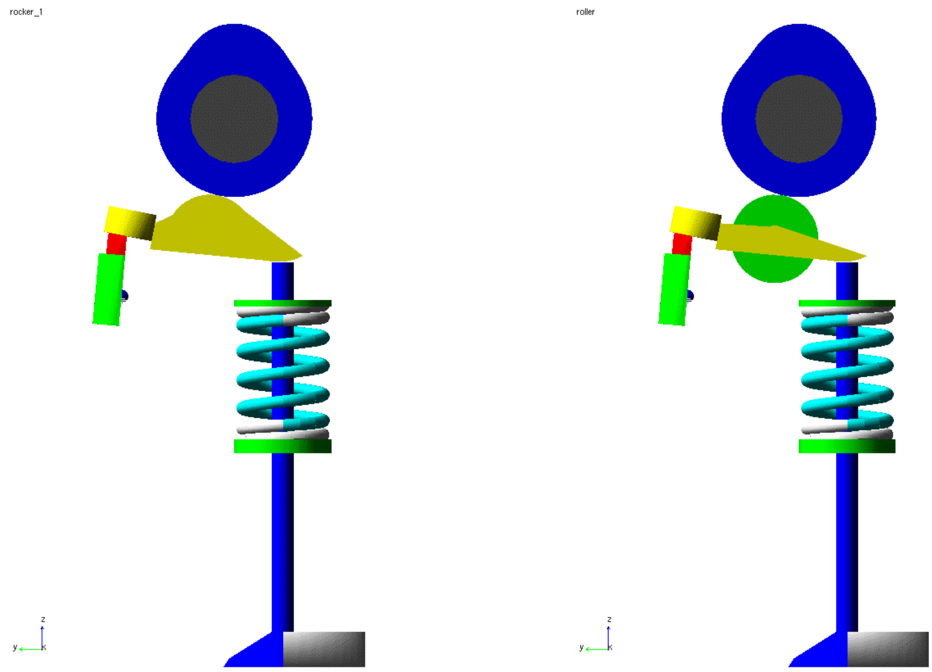

Fig.2: Rocker with radii and rocker with roller and radius.

To create the second one, a rocker with a roller and a radius, it's only necessary to attach a roller to the standard rocker with two radii. In this case the contact is built between the cam and the roller instead of the radius of the rocker.

The last one is the aforementioned rocker. This rocker is moved by two cams and acts on three valves. The rocker is created with a general part and several attachments. The hydraulic lash adjusters are fixed to the arms of the rocker. (front page and Fig.3)

At this time the choice of the parameters is important because it has a strong influence on the comfort of getting the correct data. In trial calculations, experience has to be gained as to which elements can be used to tune the single-valve-train. An example of such an element is the contact between the cam and the roller.

Experience is gained by creating and calculating several different valve-trains and comparing the results with test data. It is an aim to produce a set of standard parameters to do first calculations of new valve-trains in advance. Some standard values of these tuning parameters are given in the program but it's necessary to figure out whether these values fit to requirements of the user.

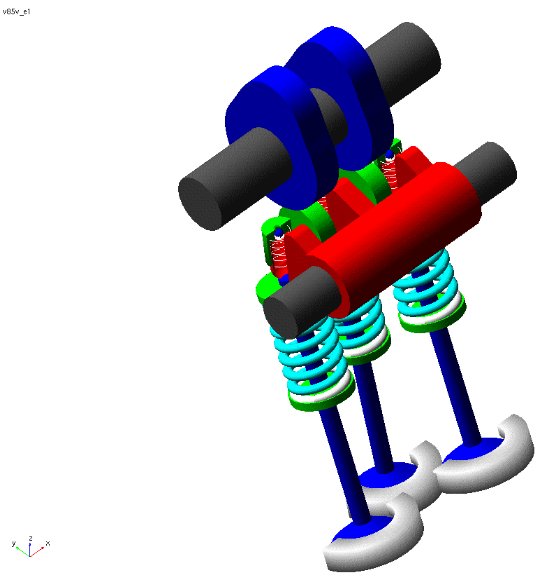

Fig.3: Rocker with two cams and three valves

4. Complete-Valve-Train Assembly

After the tuning of the single-valve-train, complete-valve-trains are assembled. First, with a rigid cam shaft, in order to overlap the required torque at the pulley.

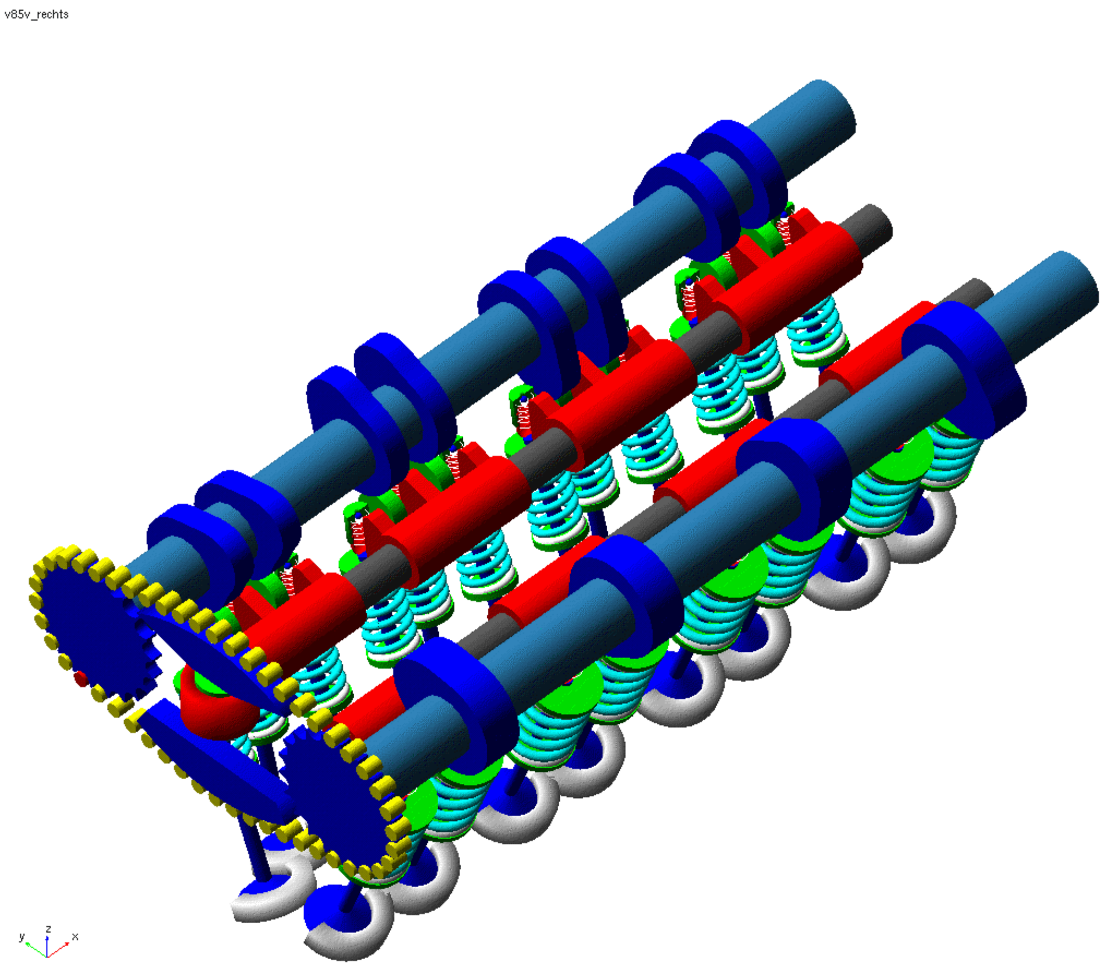

Fig.4: Complete-valve-train with two cam shafts

Further on, two camshafts are joined together e.g. with a short chain-drive, like the cylinder head of AUDIs V8 engine(Fig.4). The last step is the assembling of a complete timing mechanism with belts or chains.

Outlook

The current development state of ADAMS/Engine provides a very good tool to carry out valve-train dynamic analysis. However, the development of ADAMS/Engine is not finished yet and will be continued with the generation of modules for the crank-train, the accessory-drive and the gear-drive.
Another great step forward would be the development of a relational data model to realize an implementation of a relational database management system. It makes the use much easier, if the user can store and maintain different components and subsystems in a relational database management system. In this case, the data don't have to be typed in by hand or copied and pasted in the file systems. Additionally, the same data can be used for the kinetostatic calculation and the dynamic analysis.
First steps have been done to describe the data model by creating an entity relationship diagram. However there is still a long way to go.