6. Conclusions and Recommendations

6.1 Conclusions

In this study, the effects of manufacturing errors on the dynamics of high speed valve trains were investigated. This investigation was conducted for both rocker and computer numerical control cam grinders. In addition, valve train dynamics were investigated using a combination of experimentation and dynamic simulation. Specifically, the following was accomplished:

- A new rocker mechanism analysis that only requires the lift curve instead of the lift curve and higher order derivatives was developed.
- Experimental results of high speed valve trains indicate that dynamics are not affected by tolerances that are on the order of typical shop standards.
- Simulated results were presented that matched well with the experimental results. In addition, the simulated results also show no appreciable change in valve train dynamics when typical shop tolerances are applied to the cam profile.
- A modular camshaft was developed to test prototype cams in high speed valve trains.

6.2 Implications of the Study

This section will further discuss the impact of the work on cam related manufacturing. The first conclusion states that only the curve required for input to the rocker mechanism model is the lift curve instead this curve and a number of its derivatives. This allows for more complex cam curves to be analyzed as easily as simple curves whether the original design curves are available or not. For example, other rocker models were relegated to simple cam shapes [17] [12]. However, the theoretical cam curves presented in Chapter 3 are made of 10 polynomials [100]. This model accurately predicted the derivatives without using the design functions. In addition, it was able to accurately predict the errors on this complex profile quickly.

The rocker mechanism was used to predict cam errors due to errors in the kinematic loop of the mechanism. The errors that were investigated varied in magnitude and overall shape. Since the grinding wheel size error would be the most common, it was decided to produce cams with the predicted error from the model. Several of these cams were run in a test rig and compared to base line results of an actual camshaft and to each other. This provided two conclusions:

- The modular cam can accurately predict valve train behavior.
- Typical shop tolerances may be adequate for producing cams (with respect to dynamics).

Based upon this work, the modular cam is now being used in industry to predict the behavior of high speed big block valve trains and to rapidly test design changes to the cam lobe for valve train dynamic instability.

The simulated results match well with the experimental results. These results indicate that the numerical simulation was accurate in predicting upsets in the valve train due to changes in the cam profile. Using this information, cam profiles that were synthesized by changing the rocker length and vertical grinding wheel position of the rocker mechanism were investigated using the simulation only. Again it was found that these errors had little impact on the dynamics of a high speed valve train. A potential use for this simulation code is to implement new cam designs numerically instead of using trial and error testing on the test rig. By doing this, cams can be tested by simulation first and then by prototyping the better designs.

The investigation of the errors resulting from the CNC cam grinding process was performed by using actual error traces from cams produced on this type of machinery. Even though the errors selected for this investigation were extreme for this type of machinery, the resulting effects on the valve train were minimal. The errors were then doubled and additional simulations were performed. These simulations again showed that the effect of the errors were minimal with respect to valve train dynamics.

In addition to the investigation of the upset in valve train dynamics due to manufacturing error, a new method of testing valve train dynamics using a roller cam was developed. This method used a stub shaft outfitted with an edm cut cam lobe. This method is superior to manufacturing an entire camshaft since it saves time and money for experimental work as it requires only the production of a new plate cam instead of several cam lobes.

6.3 Recommendations

Further investigations of production errors on the performance of automotive camshafts are required. Even though the dynamics of high speed valve trains were not largely effected by cam errors on the order of thousandths of an inch, other engine functions may be adversely effected. For example, engine combustion may be severely impacted by this amount of error. Simply put, an engine depends on the cam to provide the proper fuel quantity to the combustion chamber and this in turn depends on the lobe area of the cam. The cam lobe area is the area under the lift curve of the cam in question. Since the lift curve is changed due to the machine used to manufacture the cam, the cam lobe area is also changed. In order to investigate how these changes in lobe area effect the combustion process, camshafts containing the desired amount of error must be produced. These cams can then be placed in fully functioning engines and tested on a dynamometer. In addition, both carburetor and fuel injected type engines can be tested. Changes in the overall performance can then be monitored to obtain further information as to the proper tolerances of camshafts.