Analytical, Experimental Study of Brake Squeal

Objective: predict brake squeal through analytical and experimental means; compare to squeal observed in the laboratory

- Finite Element models are validated through modal testing
- Experimental study of friction material mechanical properties
- Produce noise events with full scale brake system test rig

Stability analysis of the brake system correlates well to onset of squeal vibration
Modern reciprocating engines are expected to conform to strict efficiency standards. A key factor in achieving these standards is the minimization of parasitic loss due to friction. One of the major sources of friction in an internal combustion engine is the piston ring assembly, which by some estimates can account for 20-40% of engine frictional losses. A thorough understanding of the lubrication condition at the piston ring/cylinder liner interface is vital to determining sources of frictional loss.

Statistical models for mixed lubrication have been successfully applied to predict the frictional losses at the PRCL contact. However, a more advanced mixed lubrication model is being developed order to predict the tribological performance of a custom engineered surface where individual surface features must be resolved. With this tool, studies will be performed to determine an optimum surface pattern for friction reduction.

The complex dynamics of the lubricated slider-crank mechanism also play an important role in determining the frictional behavior of the piston ring and must be taken into account. For example, the piston motion is generally considered to be parallel to the axis of the cylinder. In operation the piston may also be slightly tilted and/or offset relative to the centerline of the cylinder. Models for the secondary motion of the piston have been developed to allow these effects to be included. Lubricated contacts are also found at the main bearings, connecting rod journal bearings, and the wrist pin. The overall goal of this project is to develop a coupled, multi-body, lubricated contact and frictional model for the slider-crank mechanism in internal combustion engines.
Preventive maintenance is a major cost in extending and preserving the life of an engine. Regular changing of engine oil and filters is the main method of preserving engine life. The purpose of oil changes is the removal of contaminants that collected over time. The interval of changes is dependant upon the build up of contamination. The frequency of such changes causes the increase in expenses for engine life extension. Effective cost savings requires the oil change interval to be increased while engine damage is decreased.

Several different types of contamination contribute to the deterioration of oil quality. A specific type of contamination contributes to the reduction of engine life through time, particulate sizes. Studies performed by SAE have shown a correlation between engine life and particulate size in engine oil. The studies have shown reduction in particulate size extends engine life as well as oil change intervals.

Effective methods of removal particulates have been developed by several corporations. The process used removes a portion of oil from the full flow to have a majority of particulates filtered, thus named by-pass filter. The purpose of this research is to validate the effectiveness of the by-pass filters on transportation diesel trucks. Performance of the by-pass filters will be tracked through a 12 month period through oil sample analysis. The analysis will provide insight into size of particulates removed, as well as oil chemistry. Data collected will provide an experimental solution to which by-pass filter has the best over-all performance rating.
Rolling element bearings have traditionally been designed on the basis of fatigue. Rolling element bearings operating under high speed conditions (i.e. in aircraft and gas turbines engines), the dynamic motion of the bearing elements becomes more significant. Under these conditions, the bearing may fail due to dynamically unstable cage motion or roller skidding and skewing. The aim of the current project is to simulate the motion of rolling element bearings to predict bearing performance for different geometries and operating conditions.

In the Mechanical Engineering Tribology Lab (METL), two approaches are being used. The first approach, called the Discrete Element Method, is used to model the behavior of bearings. The Discrete element bearing model was developed using the C programming language to analyze the bearing element interactions in terms of forces and moments, and then integrate them to simulate element motion over time.

In the second approach, bearing geometries are generated in 3-D CAD packages and then imported into the multi-body dynamics software, ADAMS®. Custom subroutines written in the FORTRAN programming language detect contacts and apply the resulting forces and moments. Bearing models in ADAMS® provide optimization techniques for bearing designers.

METL bearing models are currently being extended to investigate the influence of cage flexibility on bearing dynamics. Cage flexibility is being examined for its effects on cage instability, roller – cage pocket interaction, cage fatigue, roller positioning and bearing noise.
Water introduced into lubricant sumps often causes chemical decomposition of the lubricant. The effects of water on fluid film development is less understood. The objective of this study is to develop a basic and fundamental understanding of water contamination on heavily loaded lubricated contacts. The variation of water concentration through the contact and the film thickness generated are of key interest. Experimentally, film thickness is measured using interferometry. Results obtained experimentally are compared to the analytical results in the accompanying figures. These results represent the fluid film developed ball and disc in rolling contact. Below, the analytically predicted interference pattern (left) is very similar to the experimental interference pattern. To the right, the film thickness results are compared, the experimental results are shown in blue and the analytical results are in green. The upper image displays the film thickness across the rolling direction and the low image displays the film thickness along the rolling direction.
Friction at the piston ring cylinder liner (PRCL) interface accounts for approximately 30% of total engine friction. The objective of this research is to experimentally investigate the fundamental lubrication phenomenon at the PRCL interface and evaluate the effects that surface modifications have on the friction. A test rig was designed and constructed to reciprocate an OEM or modified cylinder liner segment under a stationary OEM or modified piston ring segment with a known normal force, lubricant, and RPM. The ring is connected to a piezo-electric force sensor to measure the friction force. Dimples approximately 100 µm in diameter by 5 µm deep were laser micro-machined into the surface of the piston ring to reduce friction near the ends of stroke where mixed lubrication occurs. Significant reductions in friction have been measured for the modified surfaces, and agreement with numeric simulations of the OEM case has been demonstrated. Future work includes simultaneous measurement of the lubricant film thickness and friction in the PRCL interface throughout the stroke on the current test rig plus the construction of two additional test rigs. The 2nd test rig will include the friction of the entire piston assembly, and the 3rd test rig will be a complete single-cylinder internal-combustion engine with the option to be motored electrically.