Piston wear prediction for a motorcycle engine using PISDYN and FEARCE

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Introduction

Triumph evaluated PISDYN, an advanced three-dimensional simulation tool from Ricardo Software for predicting the dynamics of the piston and connecting rod assembly, to predict piston wear for a motorcycle engine.

As part of this process, Ricardo supported the evaluation to help carry out an analysis to simulating the behaviour of the piston. This resulted in a benchmark which summarized the most significant factors that play very important role in this field.

As this was a software test, Triumph provided only requested inputs without showing real piston wear patterns as determined from testing in order to verify whether PISDYN can correctly predict the piston wear patterns reliably, once the accurate input conditions are applied.

The main chapters from the benchmark are presented to show how Ricardo approached the analysis using the inputs.

Reliably predicting piston wear

Generally, a reliable analysis is based on a set of accurate data. In other words, inputs for the analysis.

In terms of PISDYN, some input parameters are obvious even for a final customer who admires a motorcycle from Triumph, a famous UK manufacturer producing distinctive stylish motorcycles as shown below.

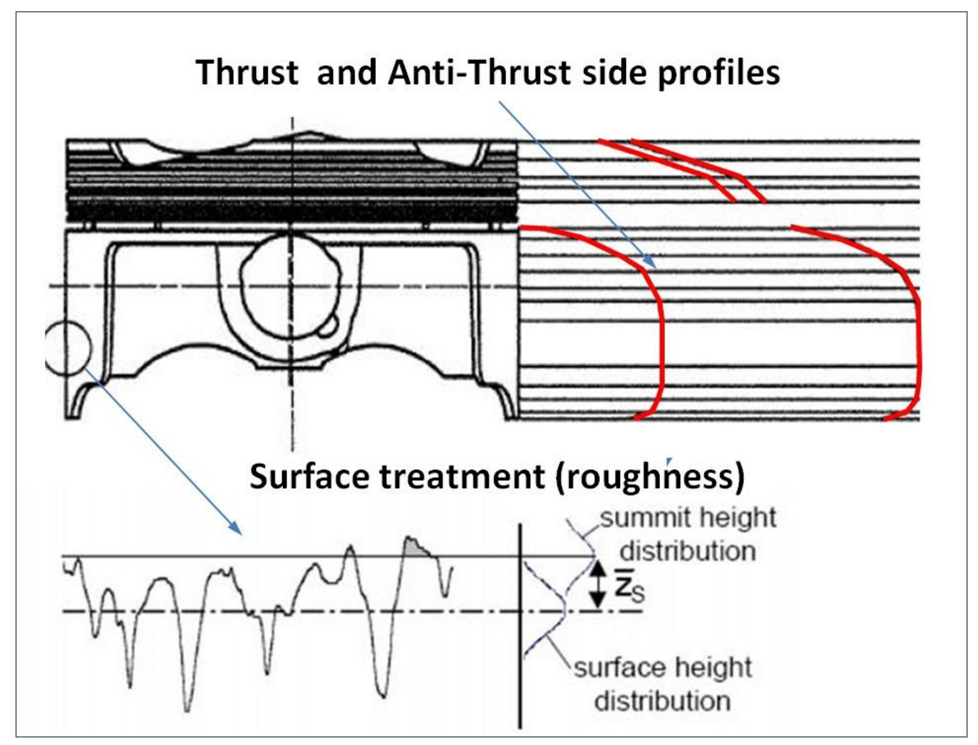
The base 4-stroke cylinder parameters are bore diameter of 74 mm, stroke of XX mm, connecting rod length of XX mm and crank throw of 26 mm operating at 11500 rev/min.

A more complicated input, which needs to be tested or predicted, is in-cylinder pressure that varies according to the crankshaft position with a peak of 82 bar. Triumph used the 1D gas dynamic software package WAVE from Ricardo Software for this prediction.

All mentioned parameters above set the engine performance which affects the basic kinematic and dynamic characteristics for each engine. However, this would not be sufficient for prediction of the piston wear as the piston's dynamic motion is more complex – involving 'secondary dynamics'. In other words, lateral motion characterized by tilting around a wrist pin axis and eccentricity - orthogonal to the wrist pin axis.

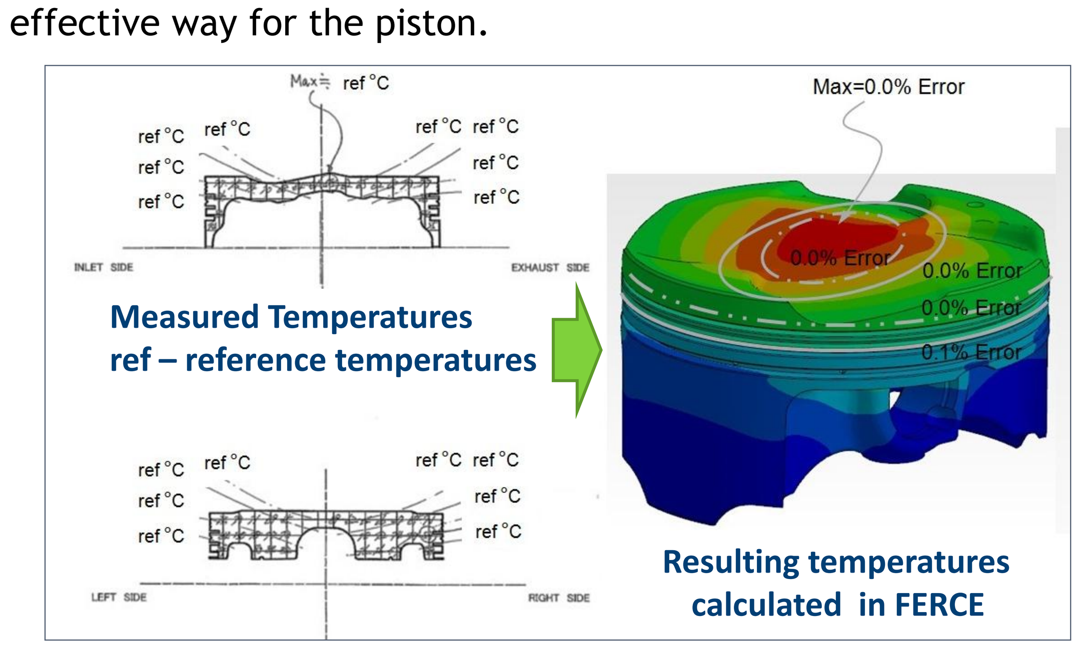
The analysis approach

Complete piston and connecting rod geometry are necessary inputs for PYSDYN, allowing proper modelling of piston secondary dynamics – this includes the detailed description of component shapes. Very detailed geometrical information, such as profile of a piston and its surface treatment, is often available in engineering drawings. The piston profile varies in the axial (shown in the picture below) and circumferential directions.

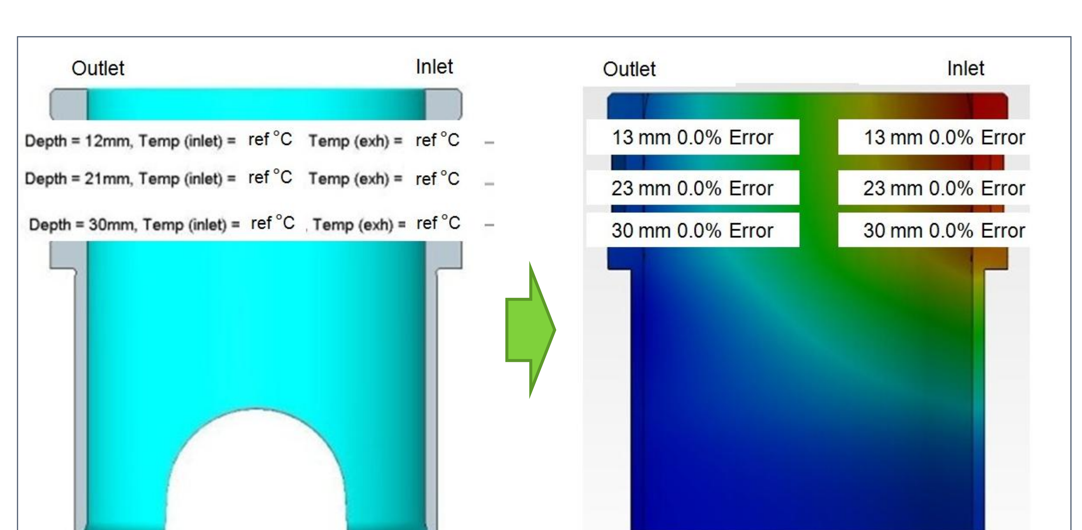


Pistons and cylinders are compliant and deformable due to thermal expansion as well as mutual interaction between the components. For this reasons, a thermal analysis using Finite Element (FE) methods often has to be performed. In this case, no CFD data for the thermal analysis was available, but Triumph kindly provided measured temperatures for the components instead.

Ricardo performed a simple thermal analysis using FEARCE, a unique FE software product with advanced pre- and post-processing functions in order to receive the similar temperature fields at tested. The pre-processing functions allowed analysts to correlate FE temperatures with the measured data in a very effective way for the piston.



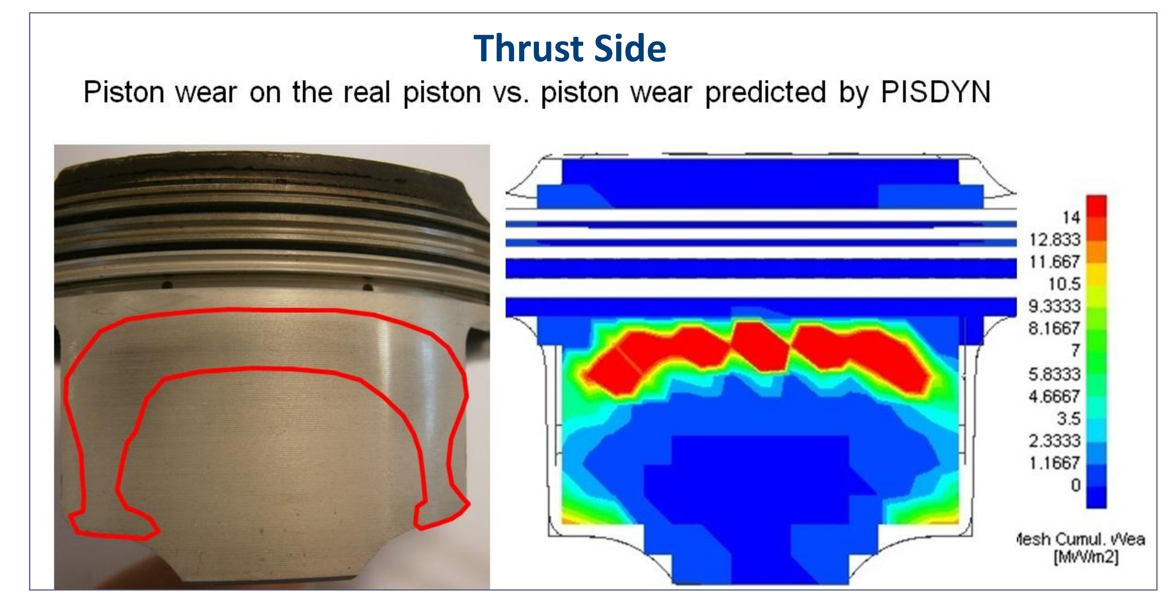
A similar approach was used for the cylinder liner temperature distribution.



PISDYN analysis and piston wear results

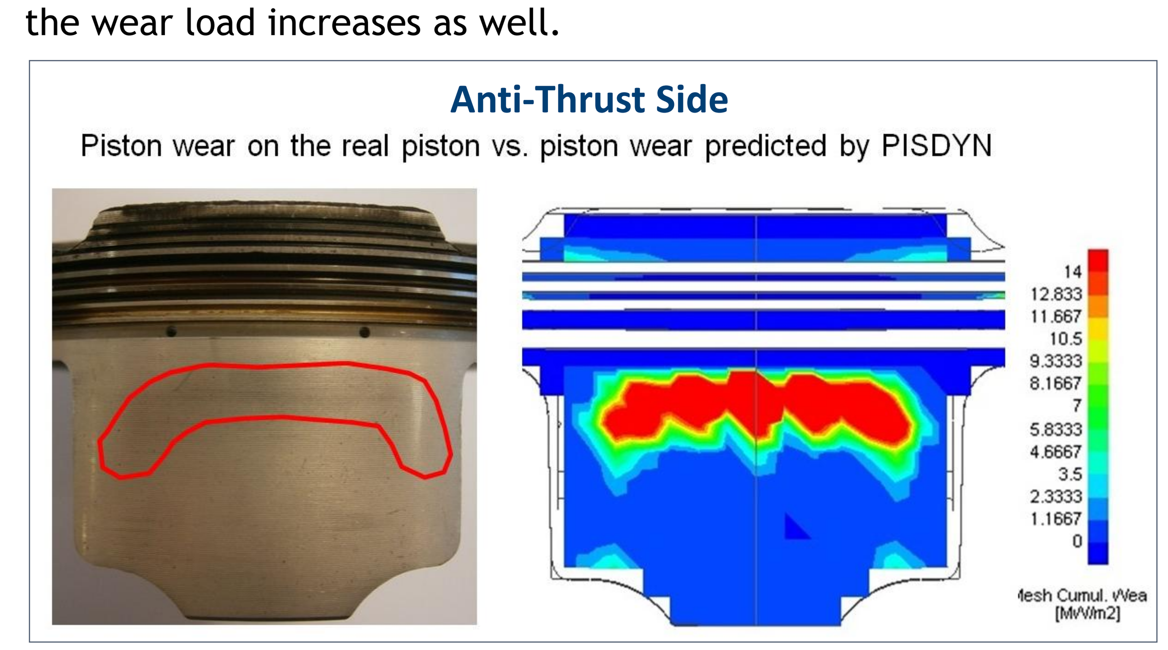
Once the temperature fields were calculated, the thermal expansion of the components was automatically assessed by PISDYN. Taking into account all geometrical parameters as well as the lubricant behaviour, an elasto-hydrodynamic analysis was carried out – involving the elastic piston and liner components with lubricant in-between.

As a result, the piston wear pattern shows the most significant wear load in the upper halves of the skirt on both thrust and anti-thrust sides.

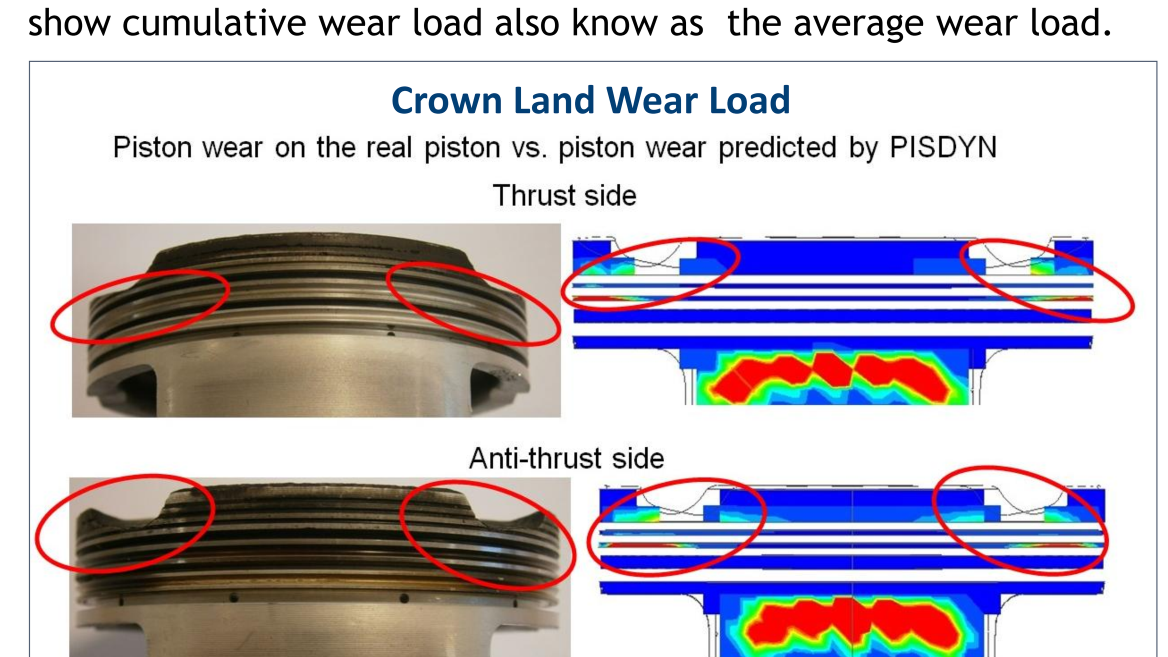


Engineering surfaces are not perfectly smooth. Often, pressure generated by hydrodynamic lubrication is not sufficient to prevent contact of asperities between the metallic surfaces. In this case, the asperity contact pressure is calculated using the Greenwood-Tripp model. This model considers cone shaped asperities with random heights.

The peaks of these cones are assumed to be rounded. As the clearance between the surfaces diminishes, both the number of contacting asperities and the degree of interference between the asperities increase. As a result, the asperity contact increases and the wear load increases as well.



Some asperity contact was detected on lands. PISDYN figures show cumulative wear load also know as the average wear load.



Conclusions

Comparison of the results shows very good correlation between PISDYN's predictions and test. These results were obtained without the test results available – the comparison was done after the simulations were finished.

The piston wear pattern shows the most significant wear load in the upper halves of the skirt on both thrust and anti-thrust sides. At the same time, wear load is detected on some crown lands.

It is expected that PISDYN predicts piston wear results at a high level of accuracy as far as sensible inputs are imposed. It has been shown how FEARCE contributes to the modelling process in a very effective way when calculating important input conditions for PISDYN.

As a results of this evaluation, Triumph decided to purchase both PISDYN and FEARCE to carry out similar analyses in the future.

References

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