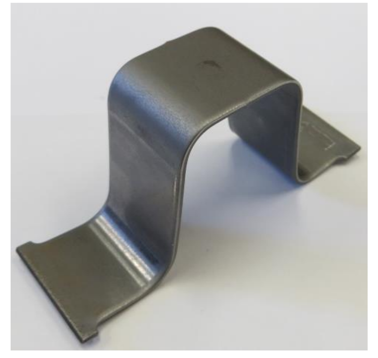
Automated Identification of Tool Wear in Sheet Metal Stamping



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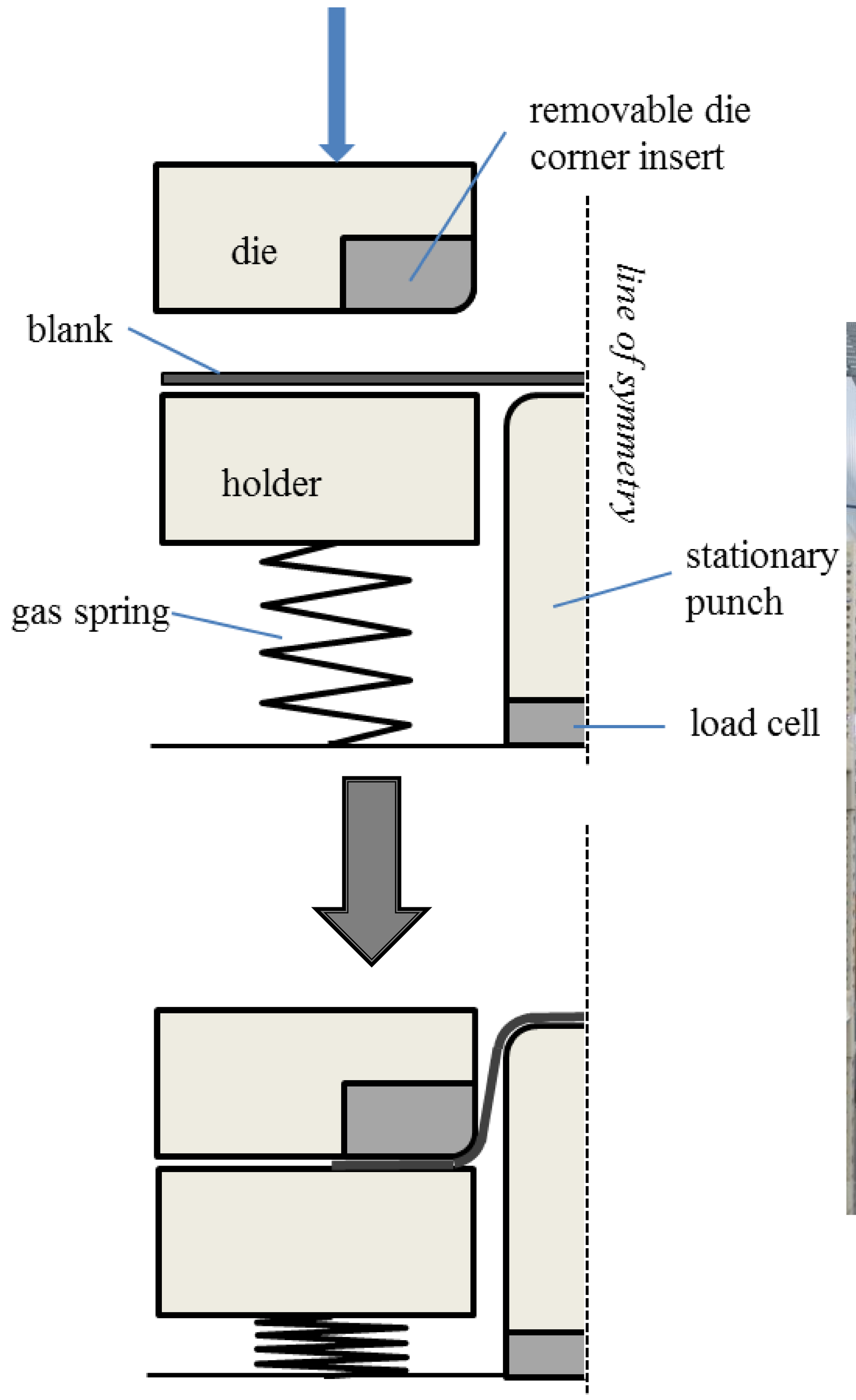
The Problem: Tool wear in sheet metal forming continues to be an issue in the automotive manufacture industry, particularly with the recent introduction of high strength steels to reduce vehicle weight. A process monitoring technique that is capable of monitoring the onset of tool wear will assist with maintenance regimes and reduce costs for the industry.



Method: A series of trials were conducted on a mechanical press set for drawing channel parts, and punch force was recorded for each part formed using a load cell located in the base of the punch [1]. Four distinct trials were conducted where tool wear level and lubrication type was varied. These trials allowed for the analysis technique to be tested with distinct changes in tool wear level and lubrication. Signatures for each trial were collected and then compared in a series of comparisons looking to distinguish between distinct changes in tool wear levels and lubrication types, and also to see if it was possible to distinguish between the two situations.

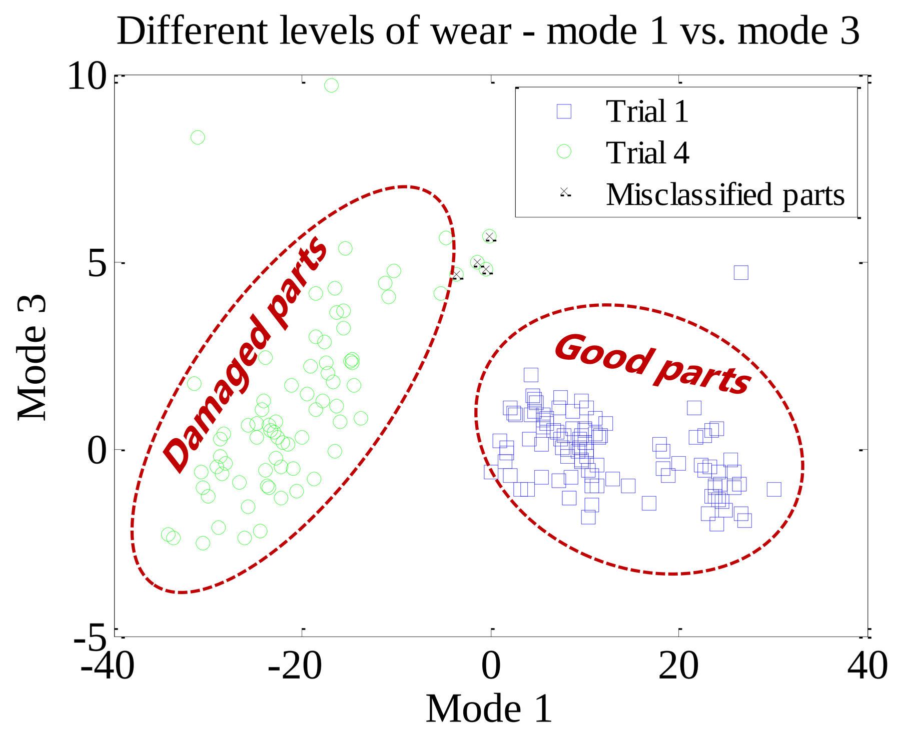
Trial	Tool wear level	Lubricant
1	Low	Mill Oil
2	Low	Dry
3	Low	Ionic Liquid
4	High	Mill Oil

Comparison	Trials included
Wear	1, 4
Lubrication	1, 2, 3
Wear versus lubrication	1, 2, 4

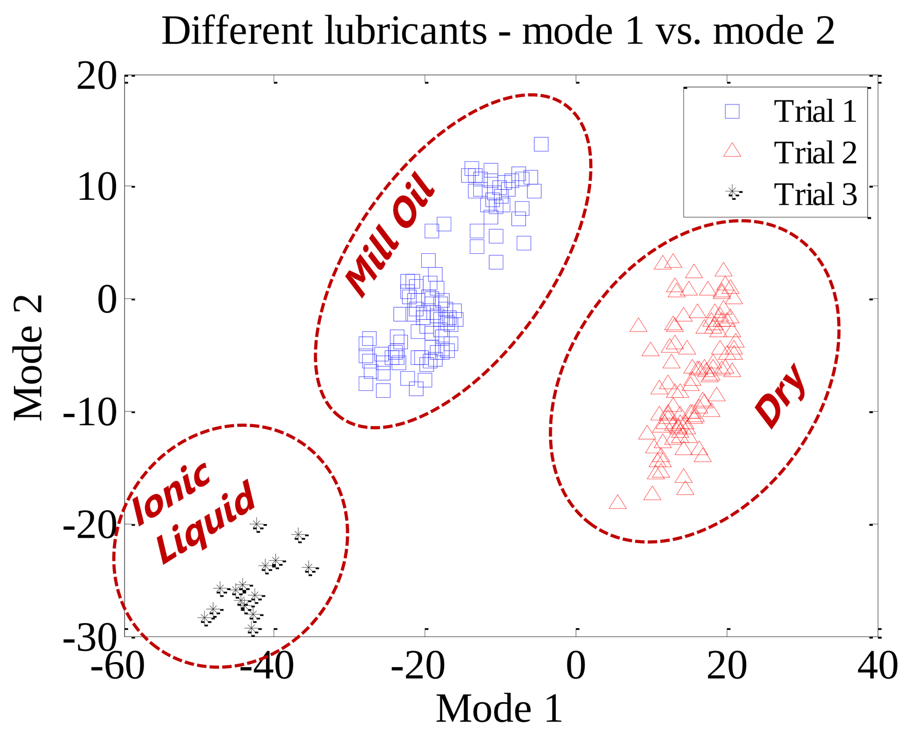
This Project: This project has focused on using Point Distribution Models to analyse stamping punch force signatures in order to detect changes in tool wear levels and lubrication types in the deep drawing process, with view to detecting and monitoring the onset of tool wear and changes in lubrication.

Results:

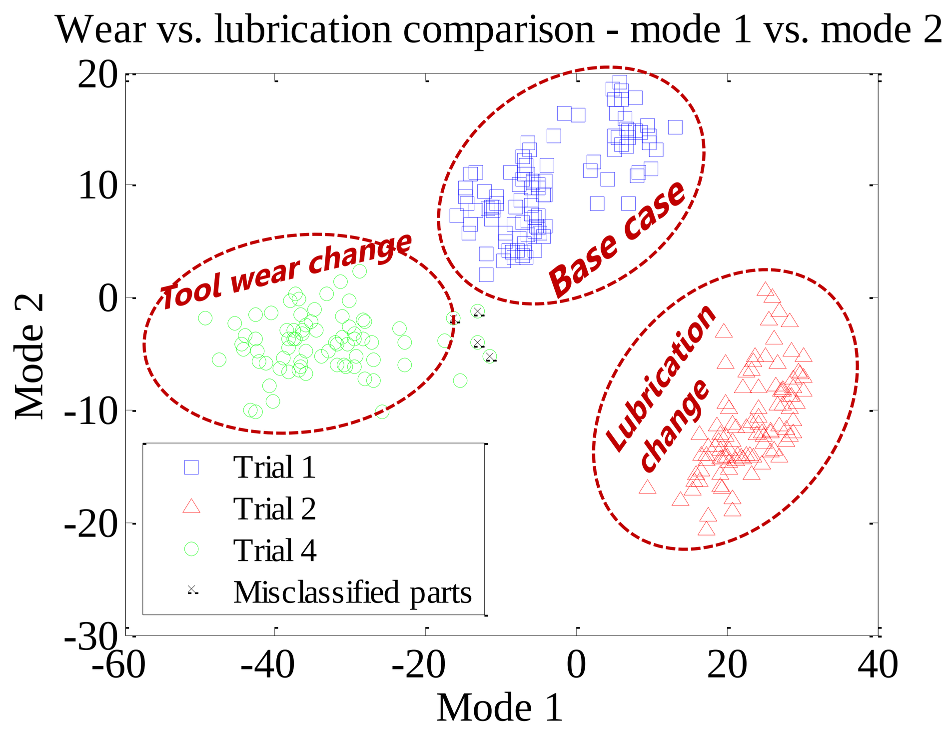
Different levels of tool wear classified with 98% accuracy.



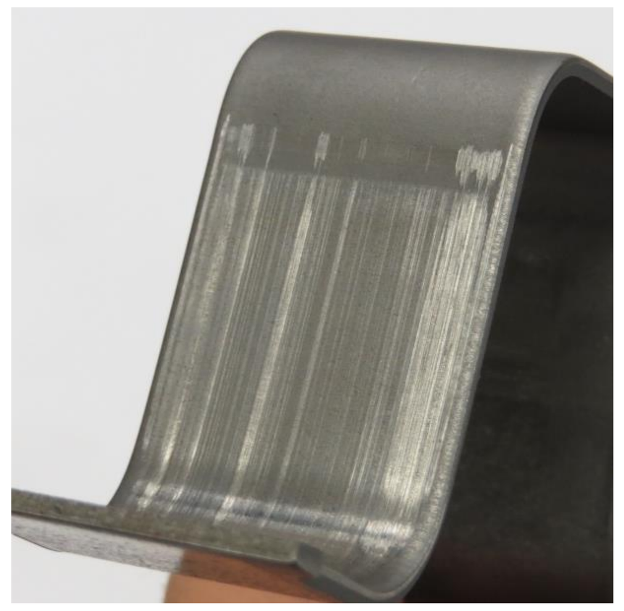
Different lubrications types classified with 100% accuracy.



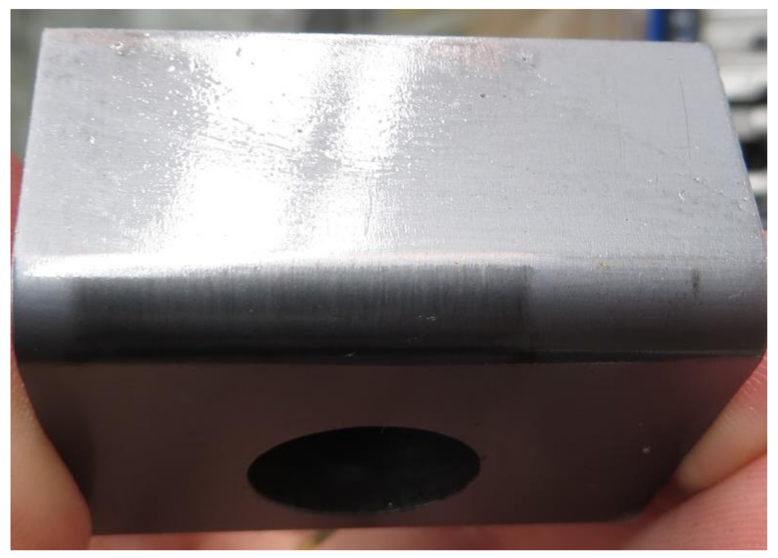
Change in lubricant and wear classified as distinct from base case with 99% accuracy.



Damaged part



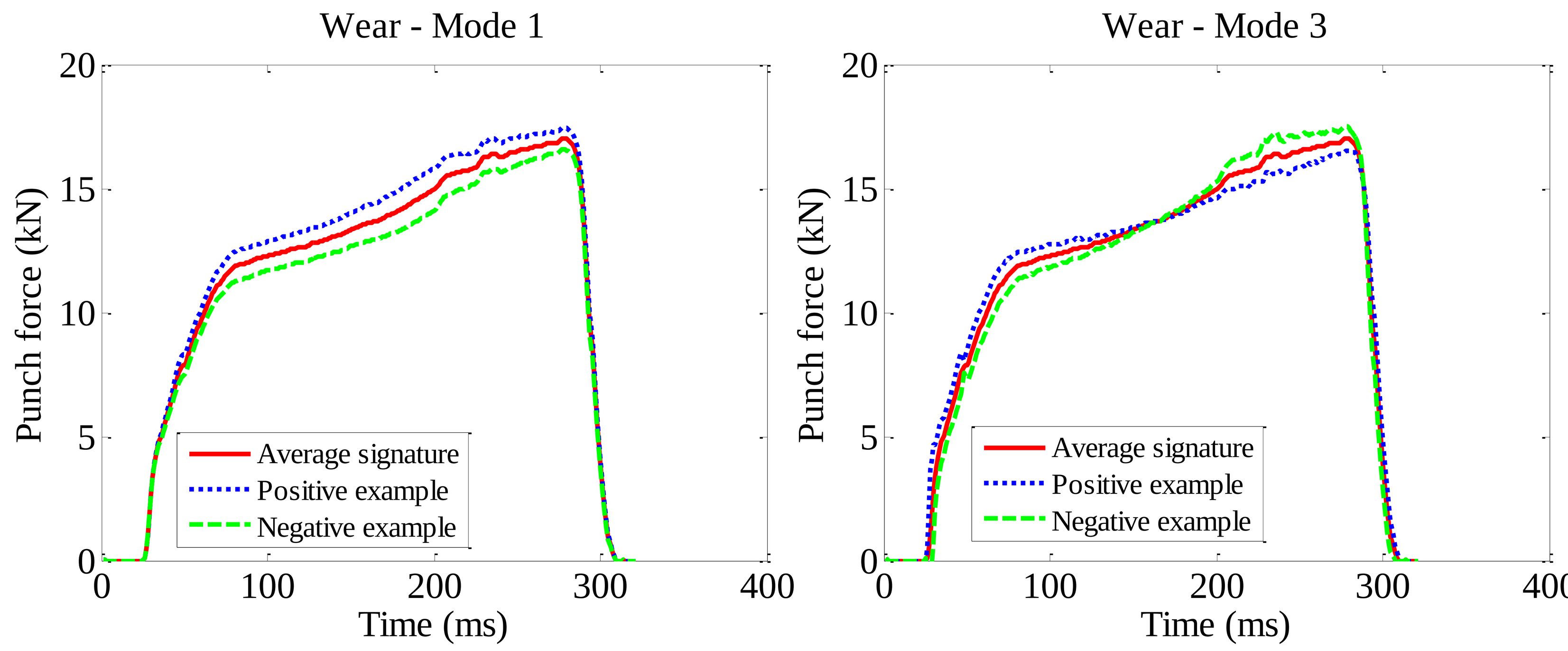
Low tool wear



High tool wear

Analysis: Point Distribution Models are used to determine the key modes of signature shape variation in a training set of signatures from each comparison. Signatures from the comparison are then characterized in terms of these modes of variation. Each signature is then plotted in 2D spaced based on the characteristic values for the two most significant modes of variation [2]. K-means clustering algorithm is then used to classify signatures.

Discussion and Conclusion: These have results shown that it is possible to distinguish between tool wear and changes in lubrication using the Point Distribution Model technique on punch force signatures. The technique also allows for investigation into punch force signatures and their characteristic shapes. Giving it a clear advantage over other process monitoring techniques that are unable to detect small process changes like tool wear or do not reveal information about the underlying process. With further application this method has the potential for significant saving for the auto industry.



Example modes of signature shape variation

Next steps:

- Full industrial trials:
  - Applied to more complex parts.
  - Different sensor locations.
- Investigate tool wear development:
  - Apply improved classification methods.

References:

[1] Pereira M. P., Yan Y., Rolfe B. F., *Sliding distance, contact pressure and wear in sheet metal stamping.* Wear, 268: 1275-1284, 2010.
[2] Doolan M., Hodgson P., Kalyanasundaram S., Cardew-Hall M.: *Use of Image Recognition Techniques in the Analysis of Sheet Metal Forming Force Signature Curves*. J. Manuf. Sci. Eng., 125(2): 363-368, 2003.

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