Innovative Test Methods for Wax

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Blayson

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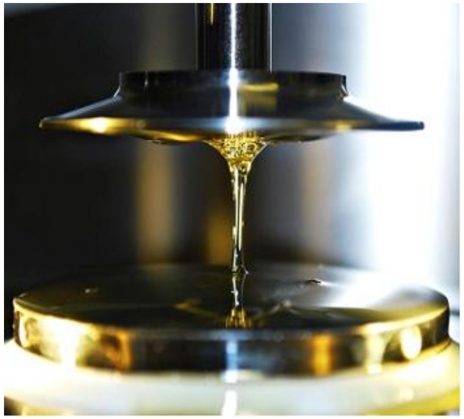
Agenda

- Traditional Wax Testing
- Specialist Wax Testing
- Process Based Testing
- Innovative Wax Testing
- Summary



Traditional Wax Testing

- Traditional wax test methods ensured batch to batch repeatability
- These tests were mostly derived from the petrochemical industry and involve tests such as
- Congealing point – This indicates the beginning of the transition from liquid to semi liquid
- Ash – This gives the percentage of non-combustibles within the material
- Penetration – An indication of surface hardness
- Ring and ball – Designates the softening point of the material
- Viscosity – An indication of the resistance to flow of the material and is generally specified at a fixed point

Specialist Wax Testing

- Specialist wax test methods have been introduced in recent years to map the use of wax materials and their behaviour throughout the investment casting process
- Rheometry – techniques used to assess the response of materials to applied forces in terms of flow and viscoelastic properties
- Differential scanning calorimetry (DSC) – The measurement of thermal properties of wax materials over a range of operating process temperatures
- Thermal mechanical analysis (TMA) – Highly sensitive equipment used to assess variables such as material expansion/contraction and mechanical changes with temperature
- DSC and TMA are linked to determine heat flow and physical changes within the wax material in relation to temperature change

Process Based Testing

- The aim of process based testing is to provide more meaningful data directly relating to the injection process
- Initial process based test methods included
- Free linear contraction – The percentage contraction of a wax material after injection under specific injection parameters
- Fluidity – Use of wax fluidity data which is representative of wax flow under controlled injection conditions
- This data can be used to predict
  - Possible turbulent flow conditions and associated defects such as air entrapment and flow lines
  - Minimum flow required to inject in an attempt to minimise the risk of core breakage

Innovative Wax Testing

- Innovation can be defined as a new idea, more effective device or process. It can be viewed as the application of better solutions to meet new requirements or existing market needs
- Innovative wax testing can be thought of as adapting current tests to meet increasing industry demands or designing new tests to model particular problems or situations
- Innovative wax test methods include
    - Fluidity spiral test
    - Pressure data logger
    - Wax memory
    - Wax distortion
    - Speed of melt

Fluidity Spiral Test

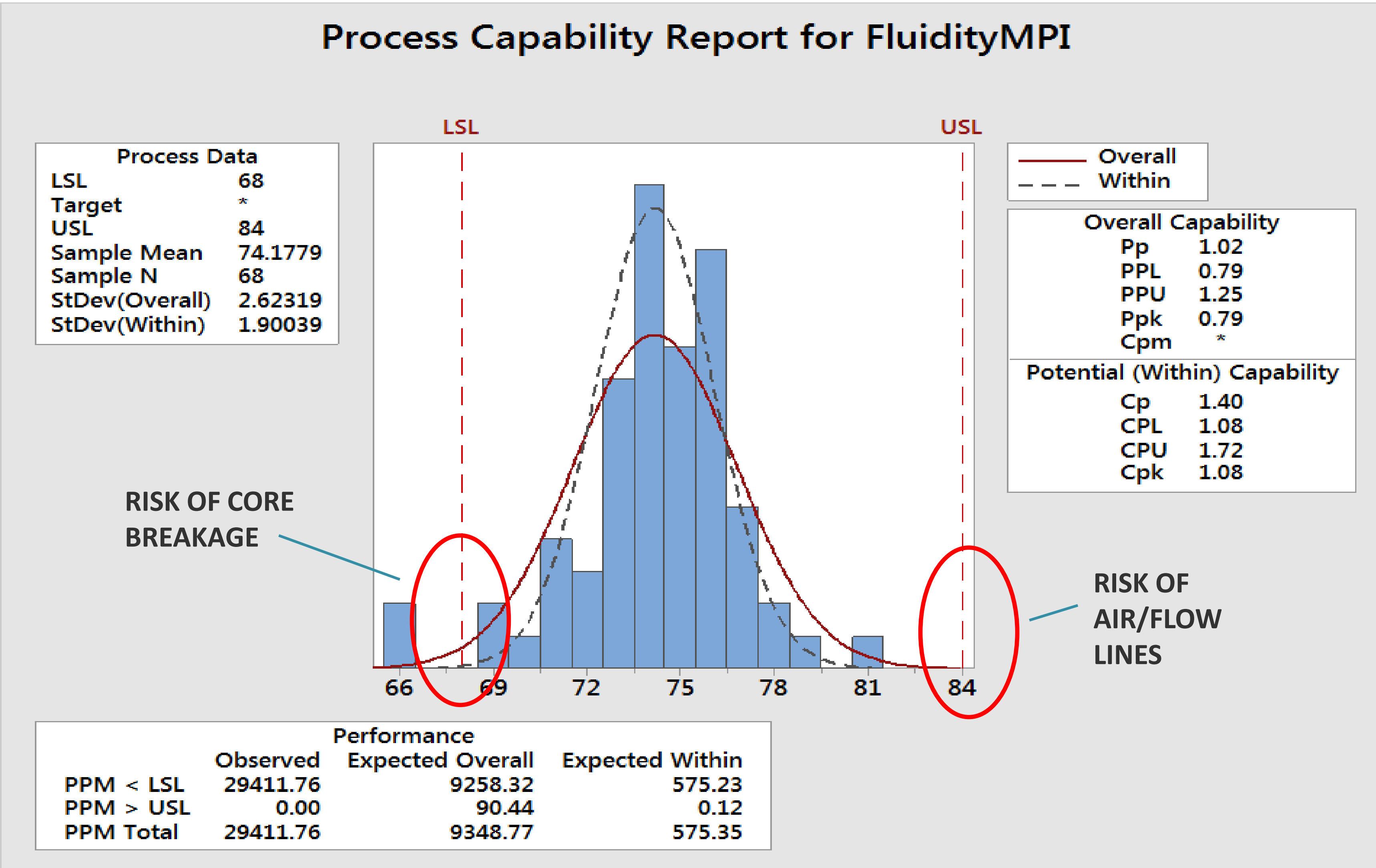
- Working together with European IC foundries to analyse ceramic core breakage we introduced the concept of the fluidity spiral test

- This was used to measure the flow rate of the wax and reduce the risk of core breakage. The wax was injected using the customers key injection parameters
  - Wax and die temperature
  - Pressure and flow

- The application of this test in conjunction with a close relationship with the customer allowed understanding of their process needs and the application of appropriate control limits

- **The result was a reduction in core cracking**

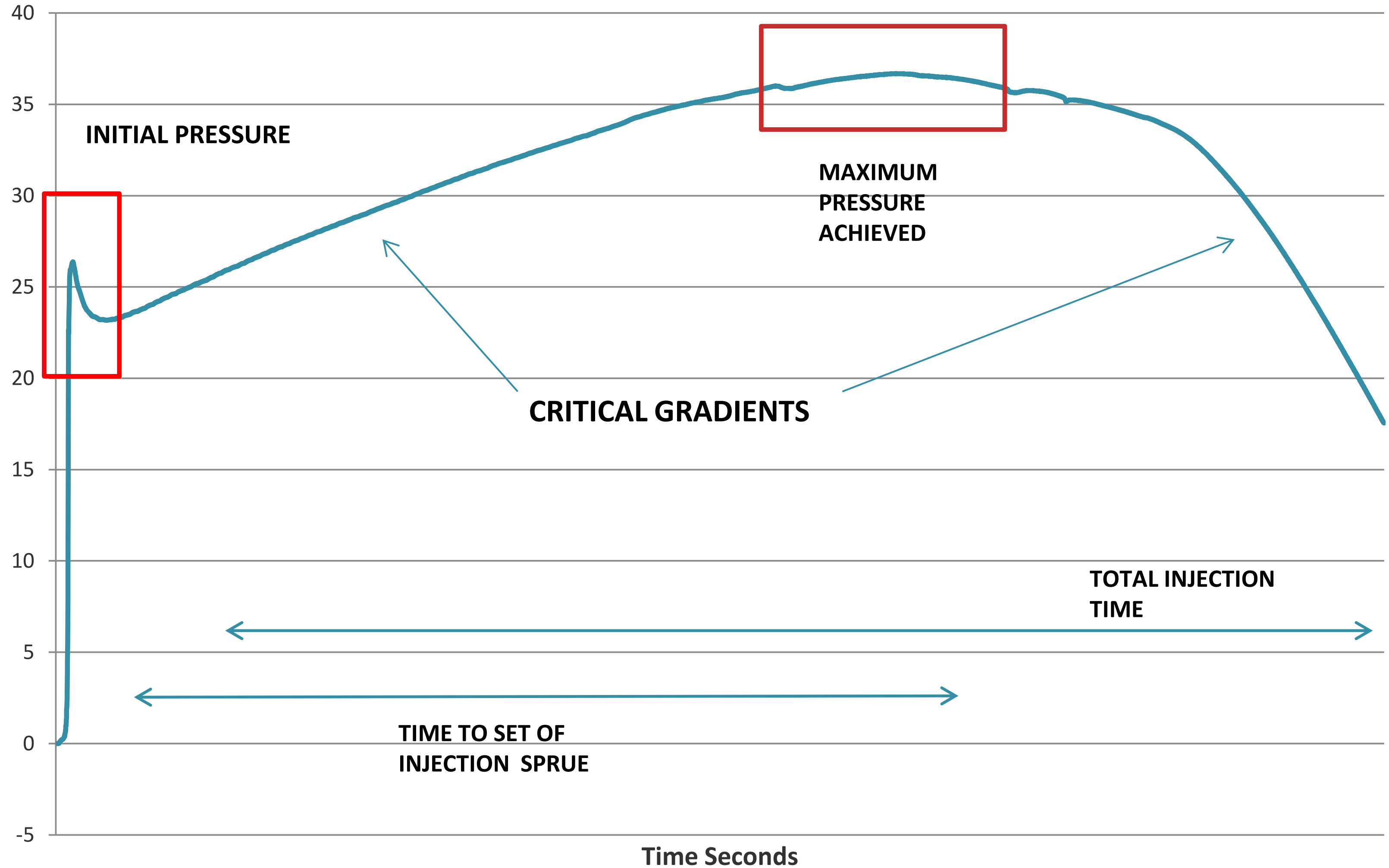
Analysis of Flow Using Fluidity Spiral Test



Pressure Data Logger

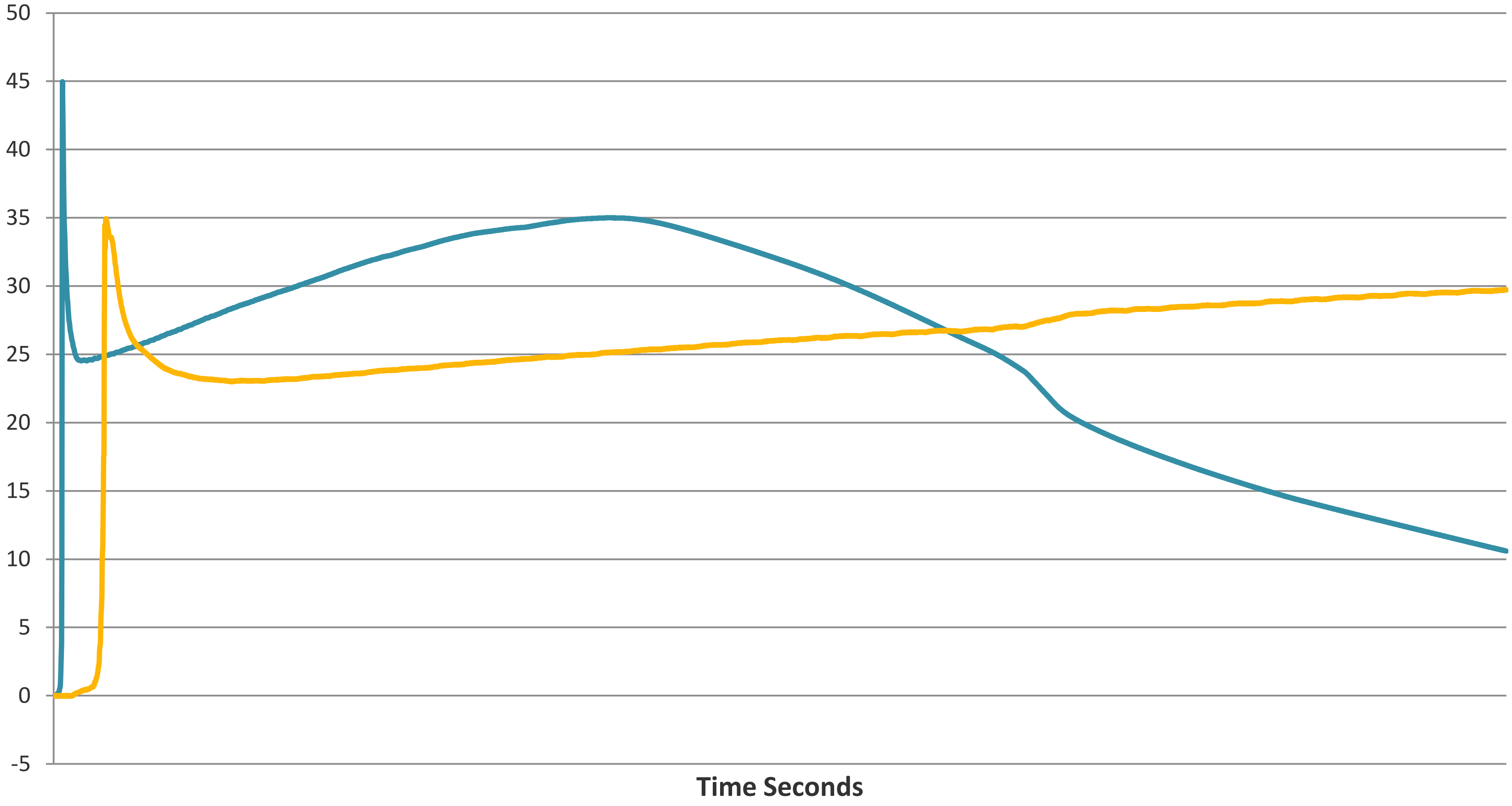
- The use of the piezoelectric probe to analyse pressurisation and apparent solidification has been part of our research and development programme for some time
- The use of this together with a pressure data logger has offered innovative data collection and real time injection information from within the die
- This further provides batch to batch analysis of wax solidification
- Measures wax pattern injection variability and any nonconforming wax patterns can be identified
- Generation of control parameters for wax injection
- **This has offered insight into the reasons why**

Data Logger Output



Injection Profile Overlay

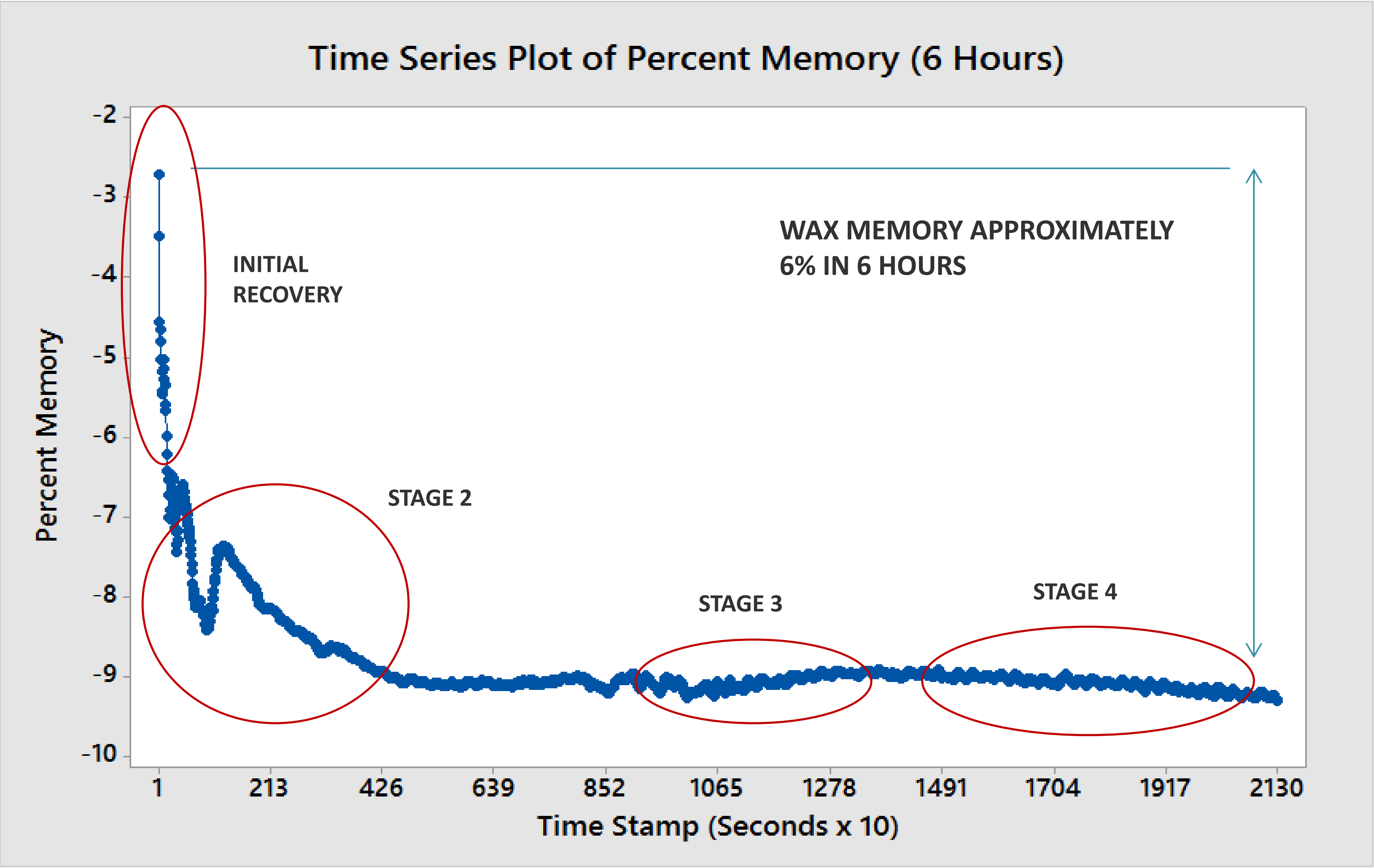
The traces below relate to two consecutive injections of the same wax



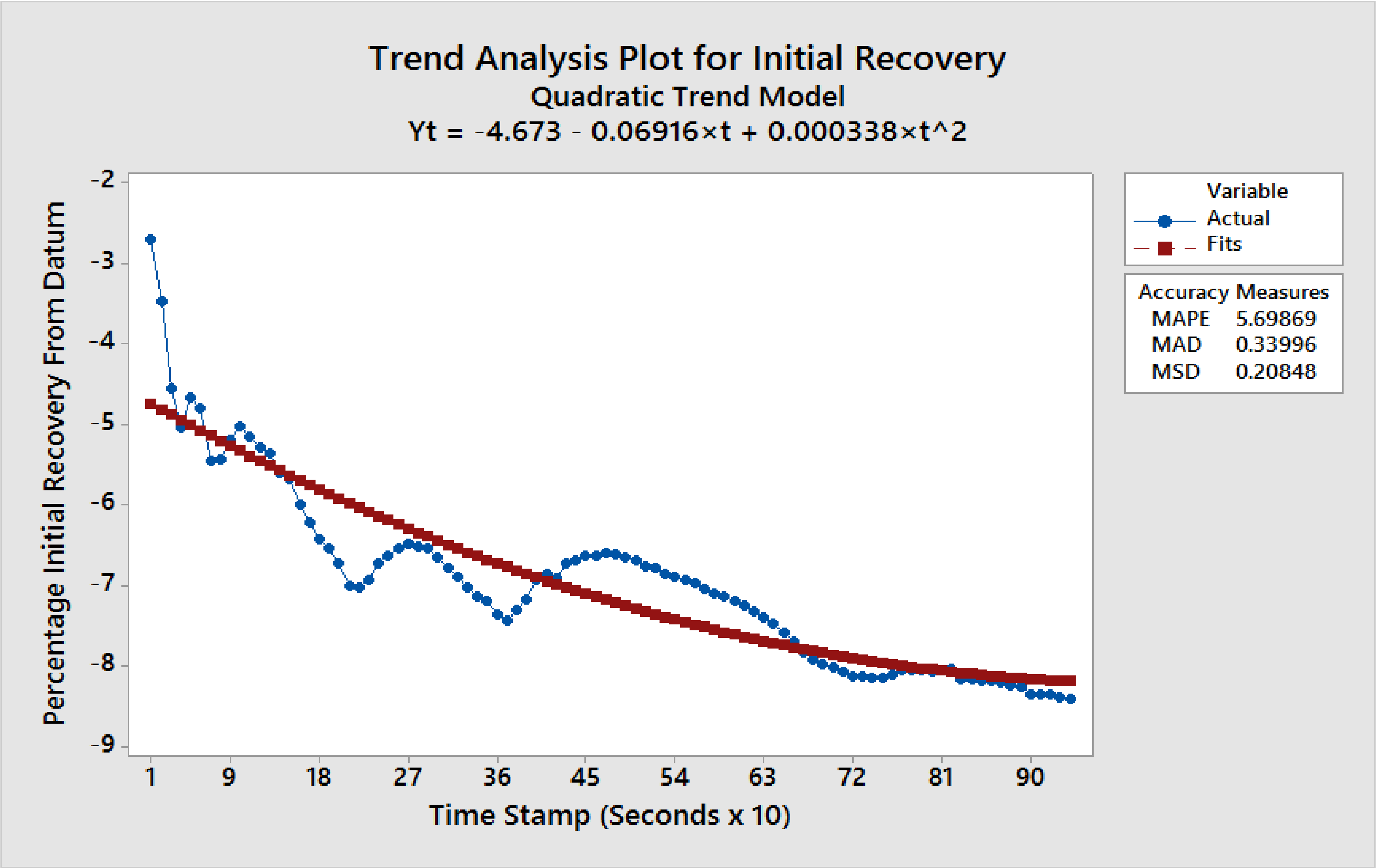
Innovative use of Laser Measurement

- This project involved working with European IC foundries who reported that ceramic cores were cracking 24 hours after injection
- There was no evidence that core cracking occurred immediately after injection
- A detailed DOE took place to identify possible variables and wax memory was identified as a possibility
- A development programme was designed to investigate further using a standard injected test piece
- Contact measurement had an influence on the results, therefore laser measurement was used as an innovative test method
- This technique provided detailed information of wax behaviour and led to the development of materials capable of minimising the effect of wax memory
- **This work earned Blayson the UK CMF innovation award 2014**

Time Line of Wax Memory



Detailed Overview of Wax Memory



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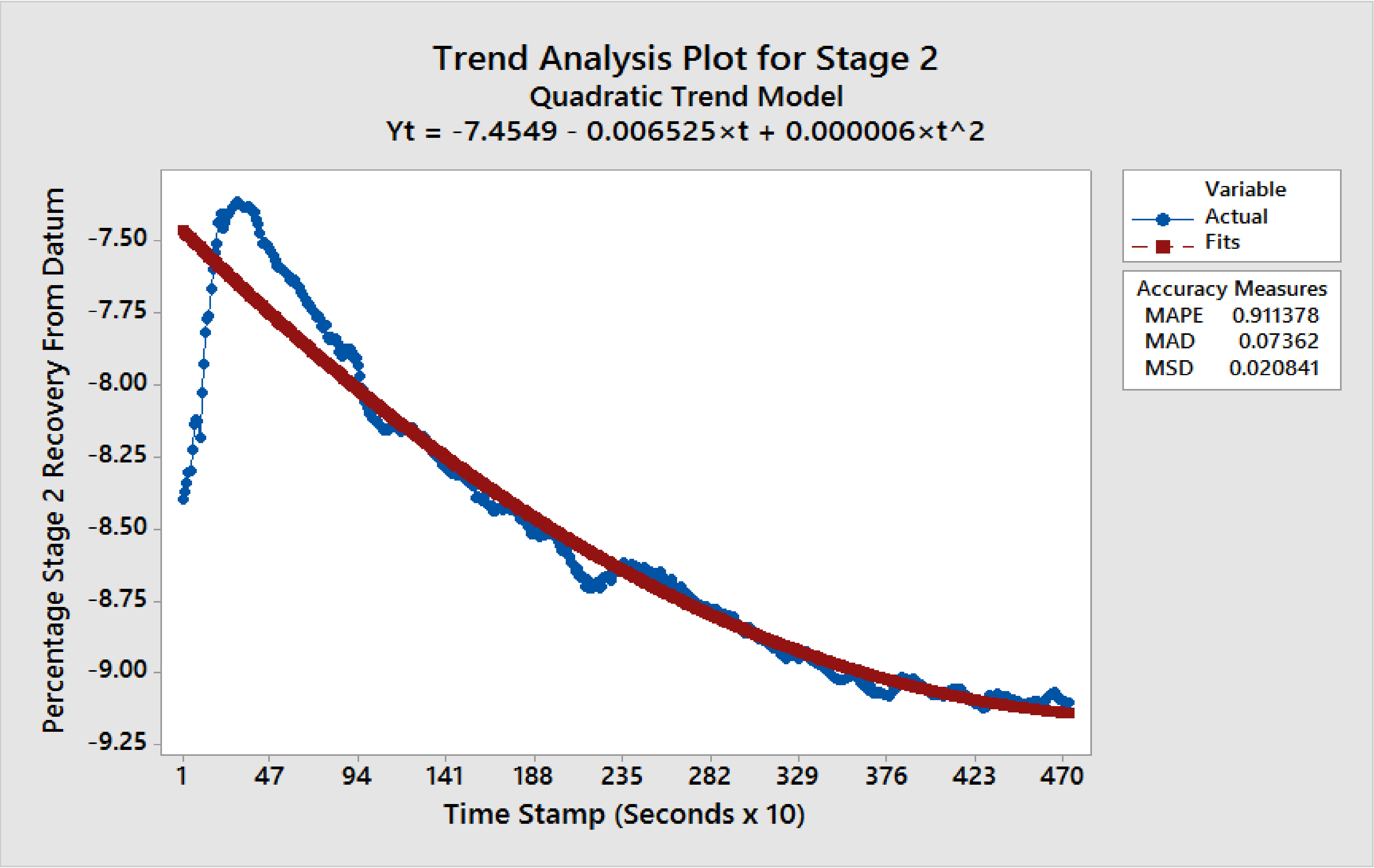

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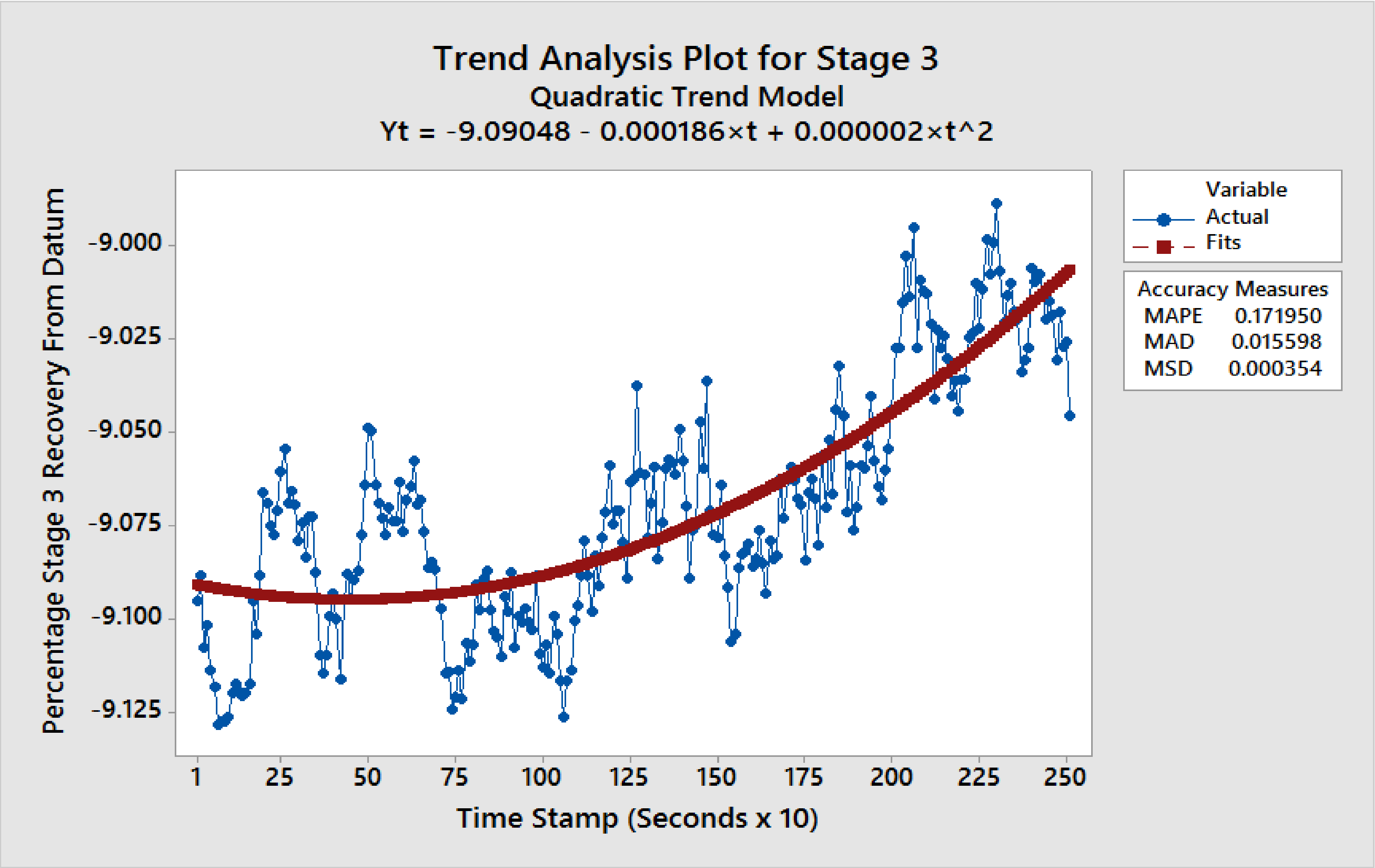

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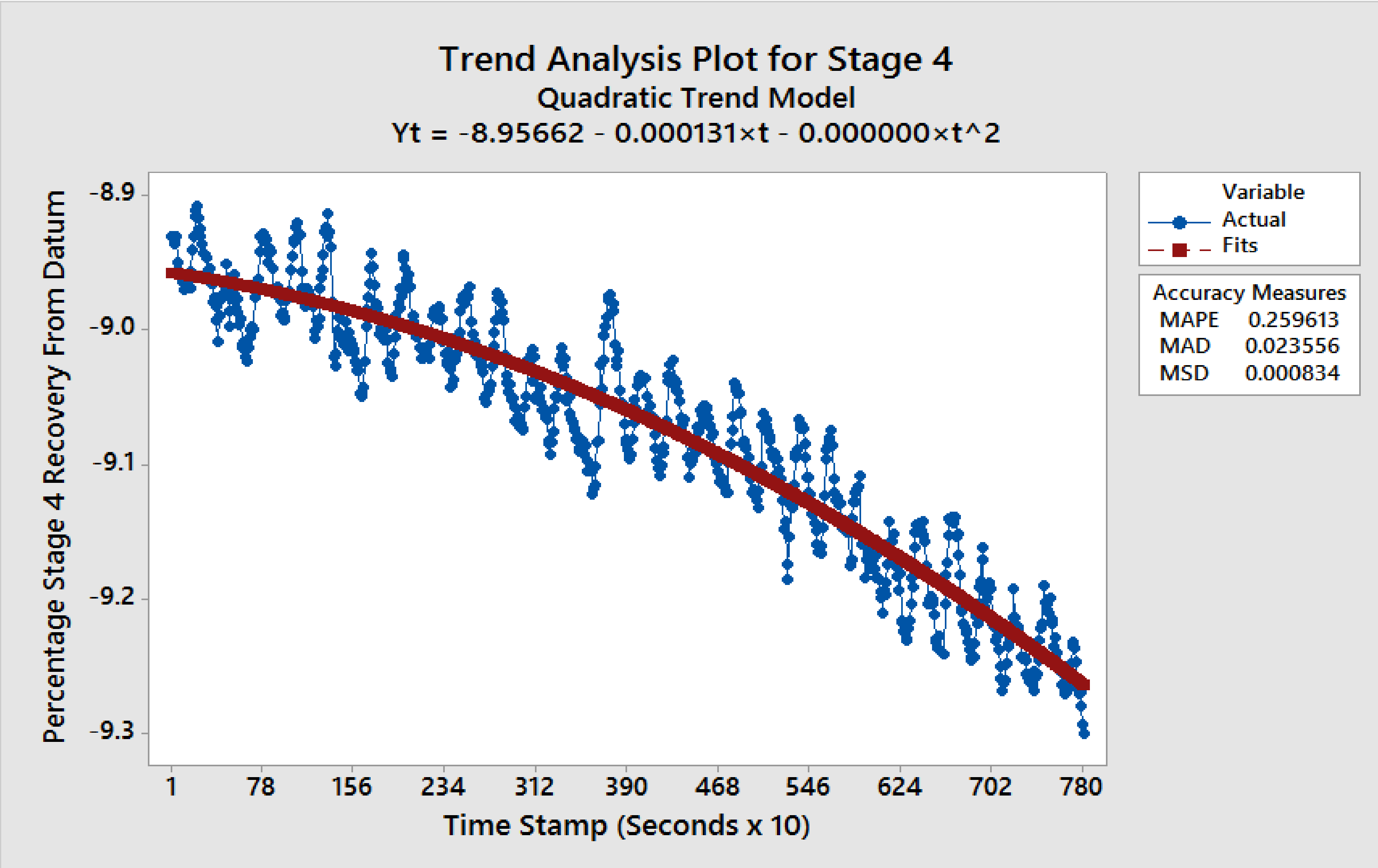
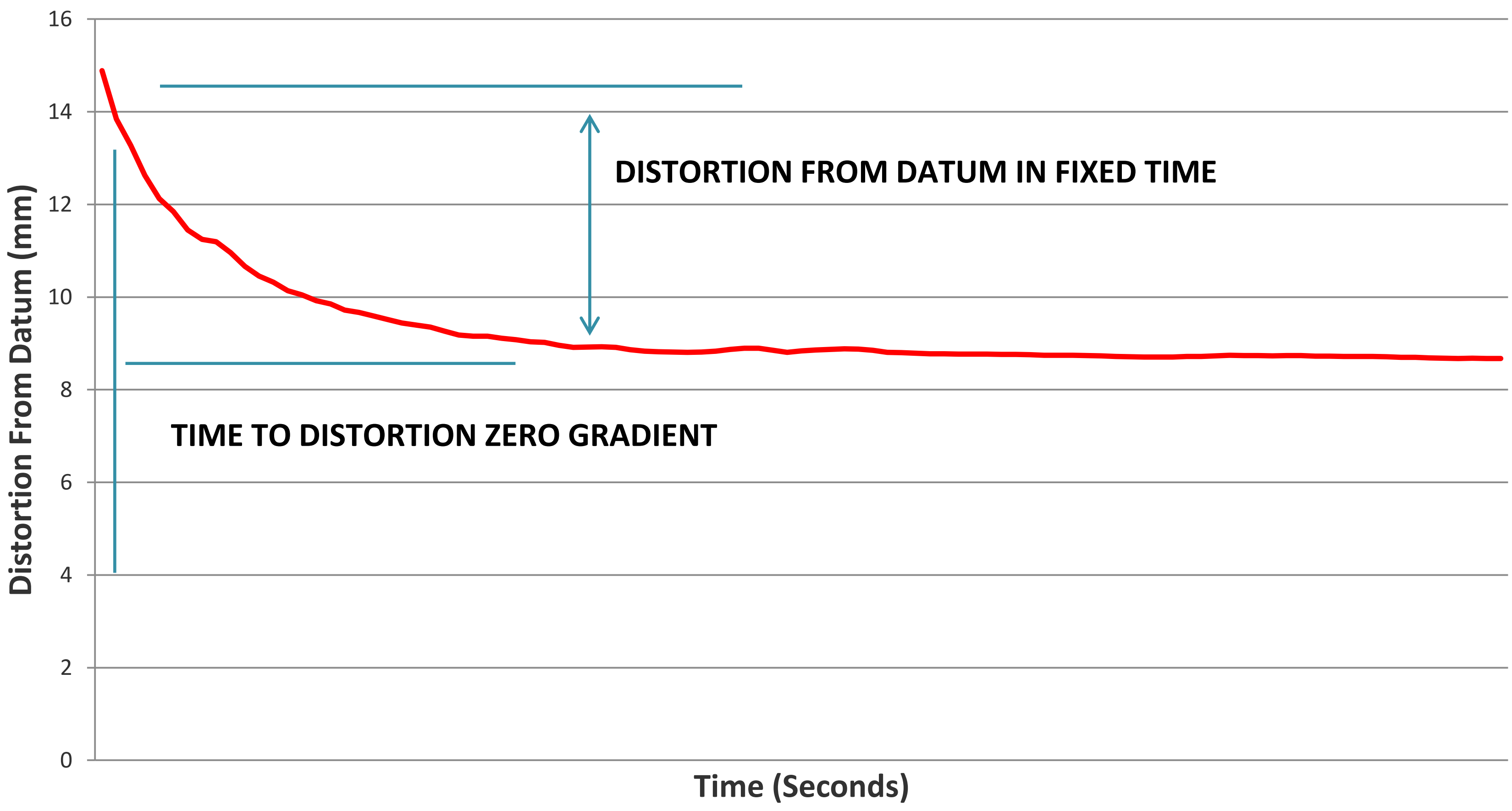


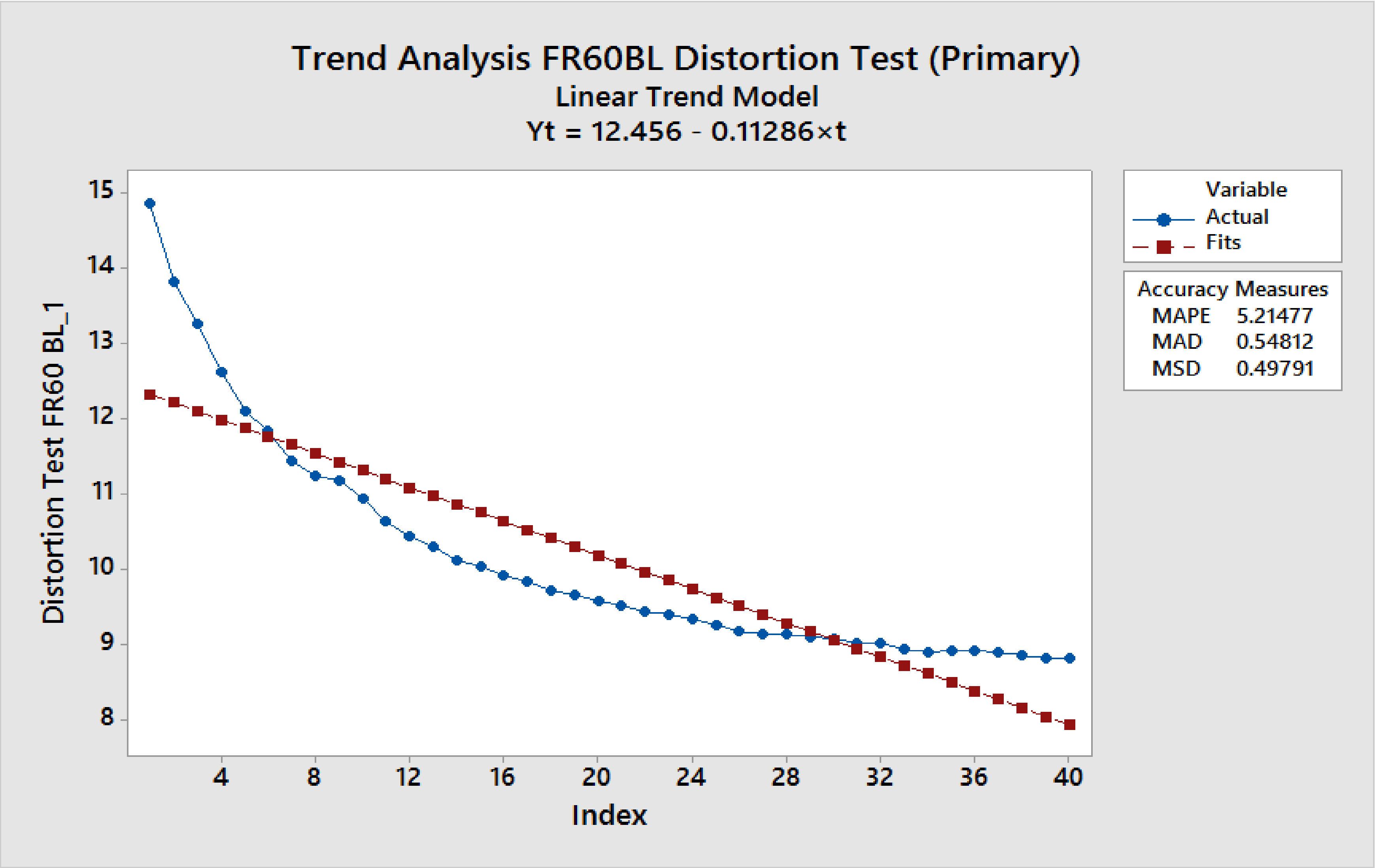
Further use of Laser Measurement

- In a second application of this technique we worked closely with another European IC foundry to design a test that could model the distortion that occurs on removal of a wax pattern from the die
- The foundry had found that this was a key issue influencing the dimensional variability of wax patterns
- The technique developed involved measuring the extent of distortion inherent within a wax immediately after injection
- **This technique assisted in the development and design of wax materials that resisted distortion**

Distortion Test Plot Area



Distortion Test Trend Analysis



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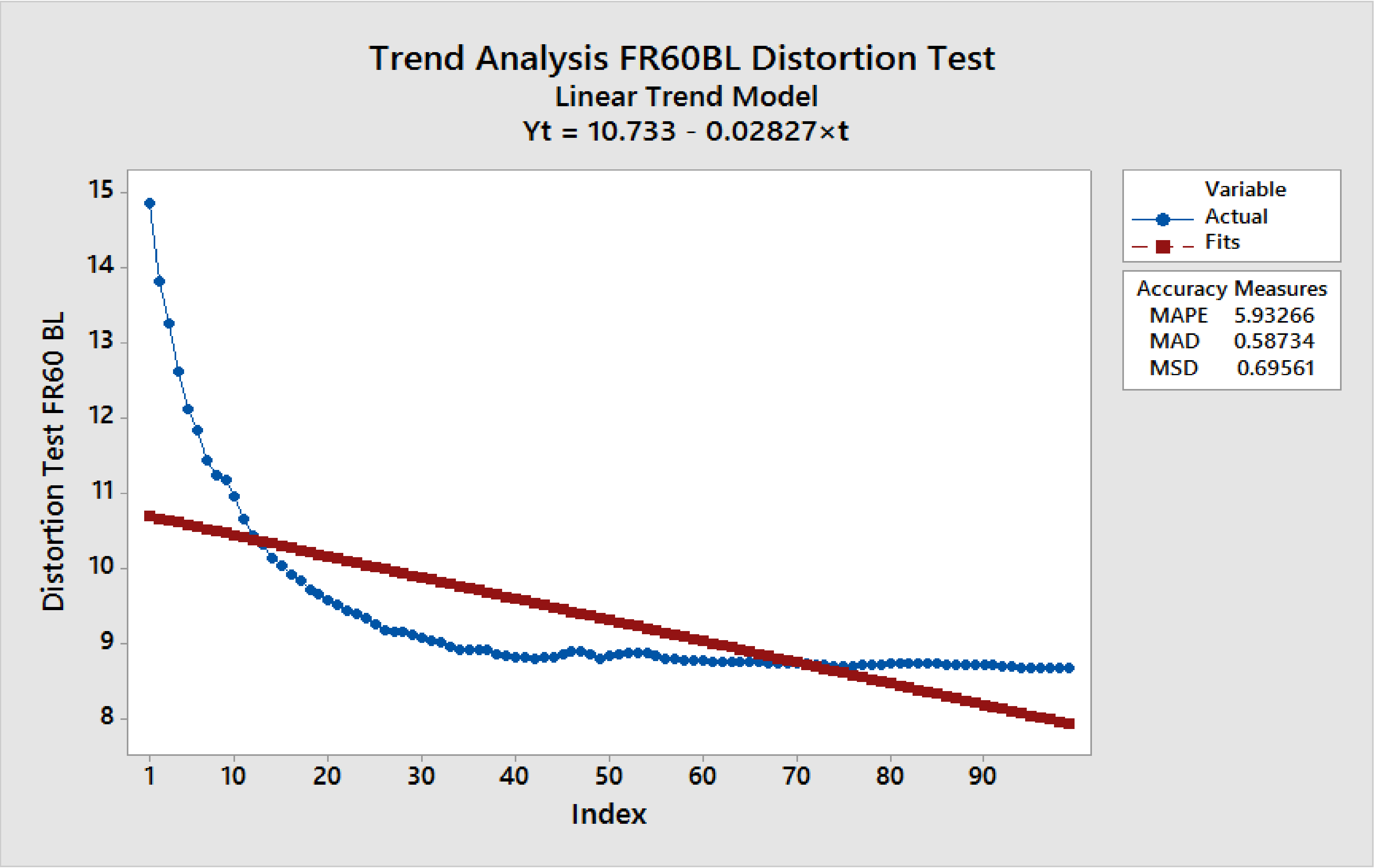
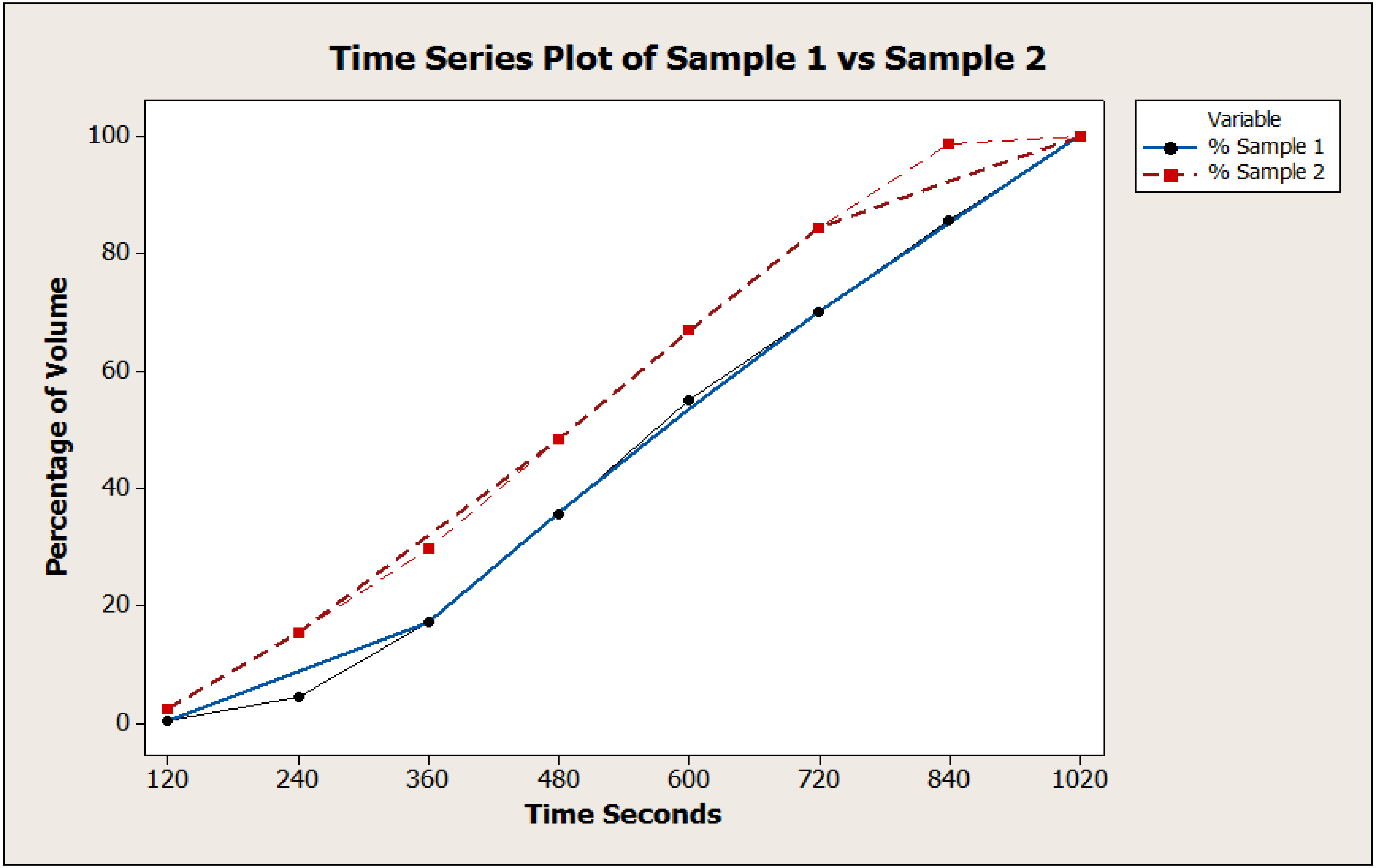


Speed of Melt

- A further project involved working to investigate minimising shell cracking on thin shells for aluminium castings
- Properties such as fluidity, expansion, melting point and mechanical strength had been evaluated and tested without success
- A model was designed to evaluate how wax melted and flowed
- A test was developed using a Ford viscosity cup heated to a fixed temperature
- In addition to flow data the test also provided wax weight loss information over time at fixed temperature
- The technique showed subtle differences between wax types which correlated with the degree of shell cracking experienced during the development programme
- **Achieves cost savings through reduction in shell coats required**

Comparison of Samples Speed of Melt



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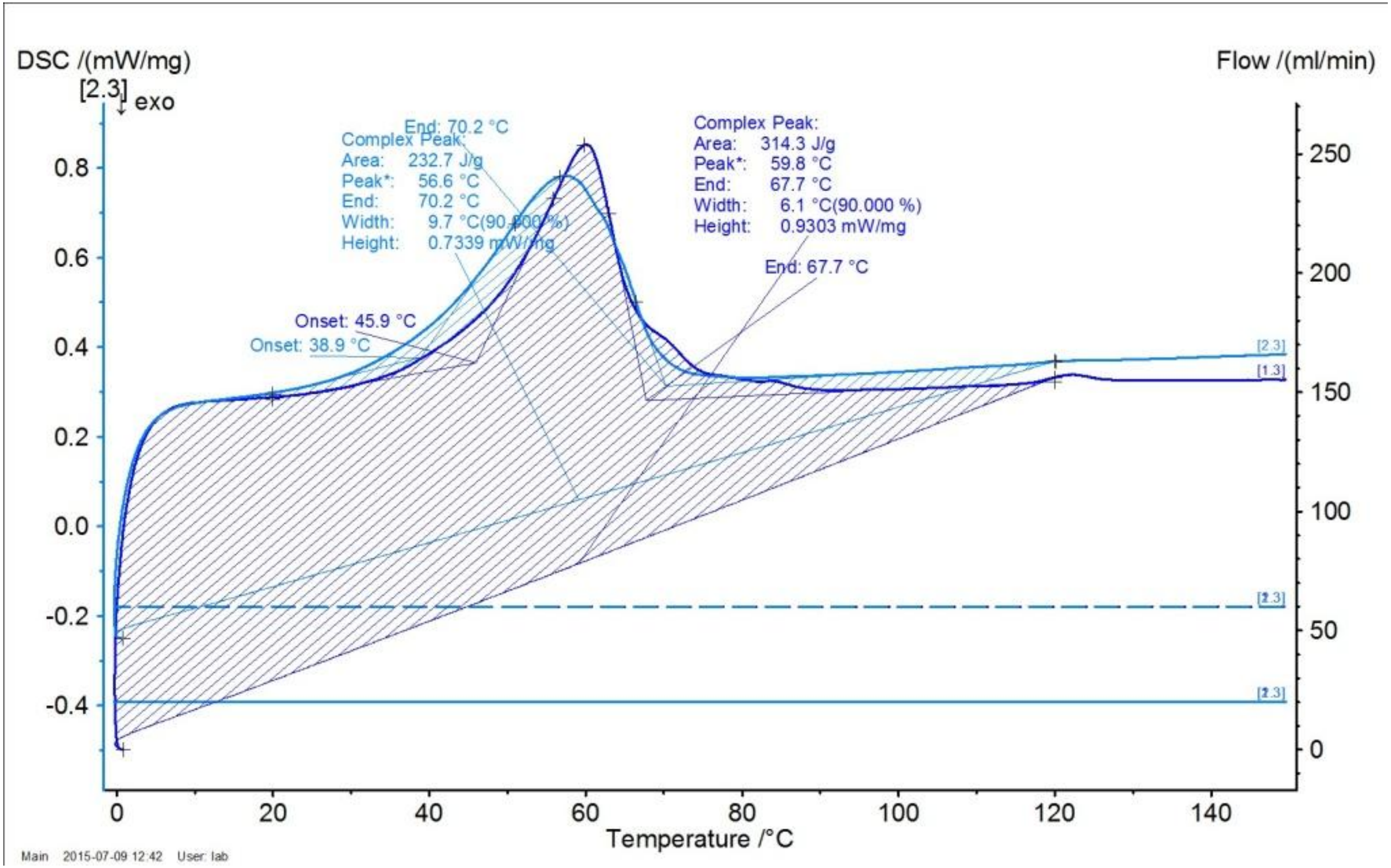
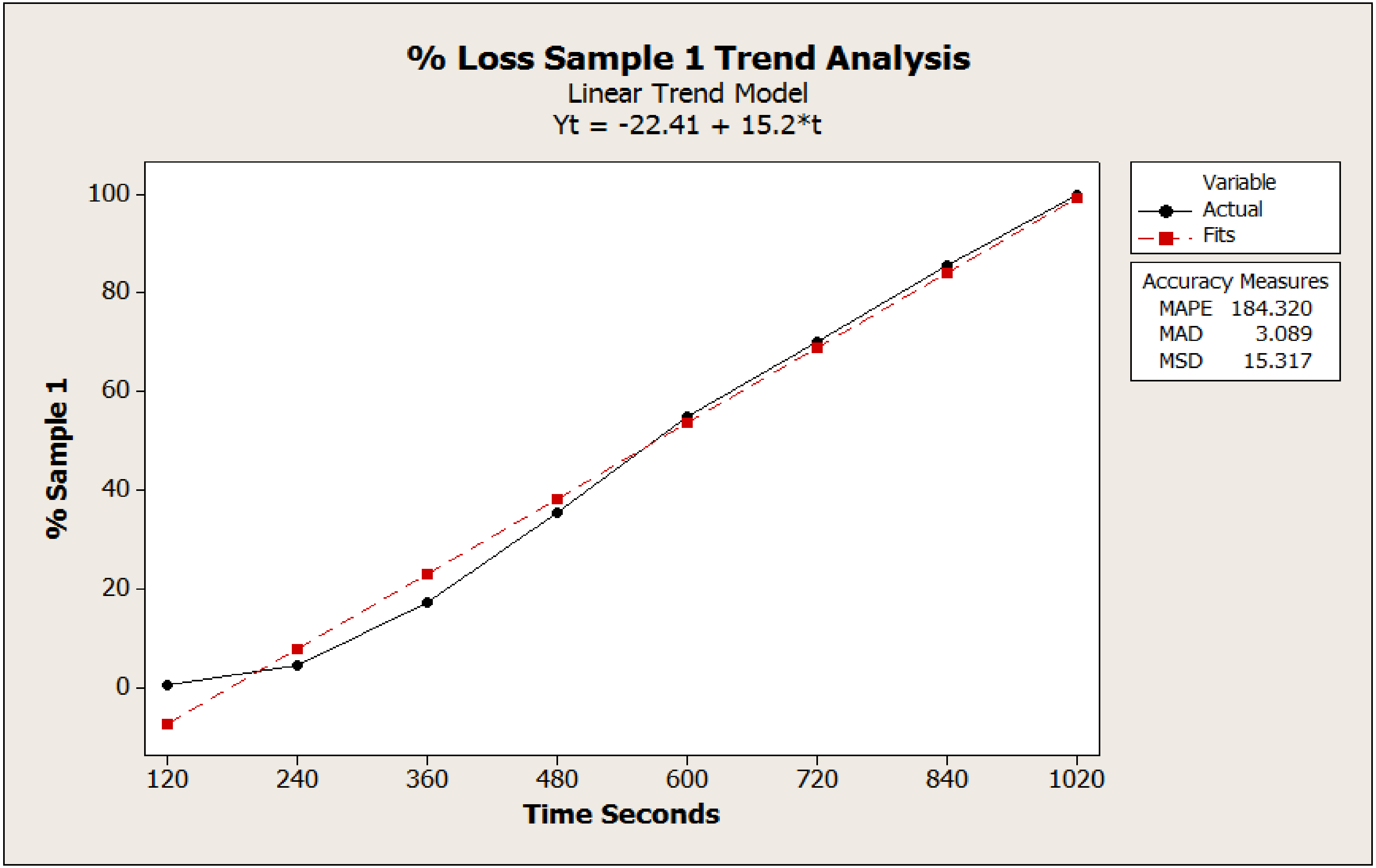


Individual Trend Analysis of Melt Speed



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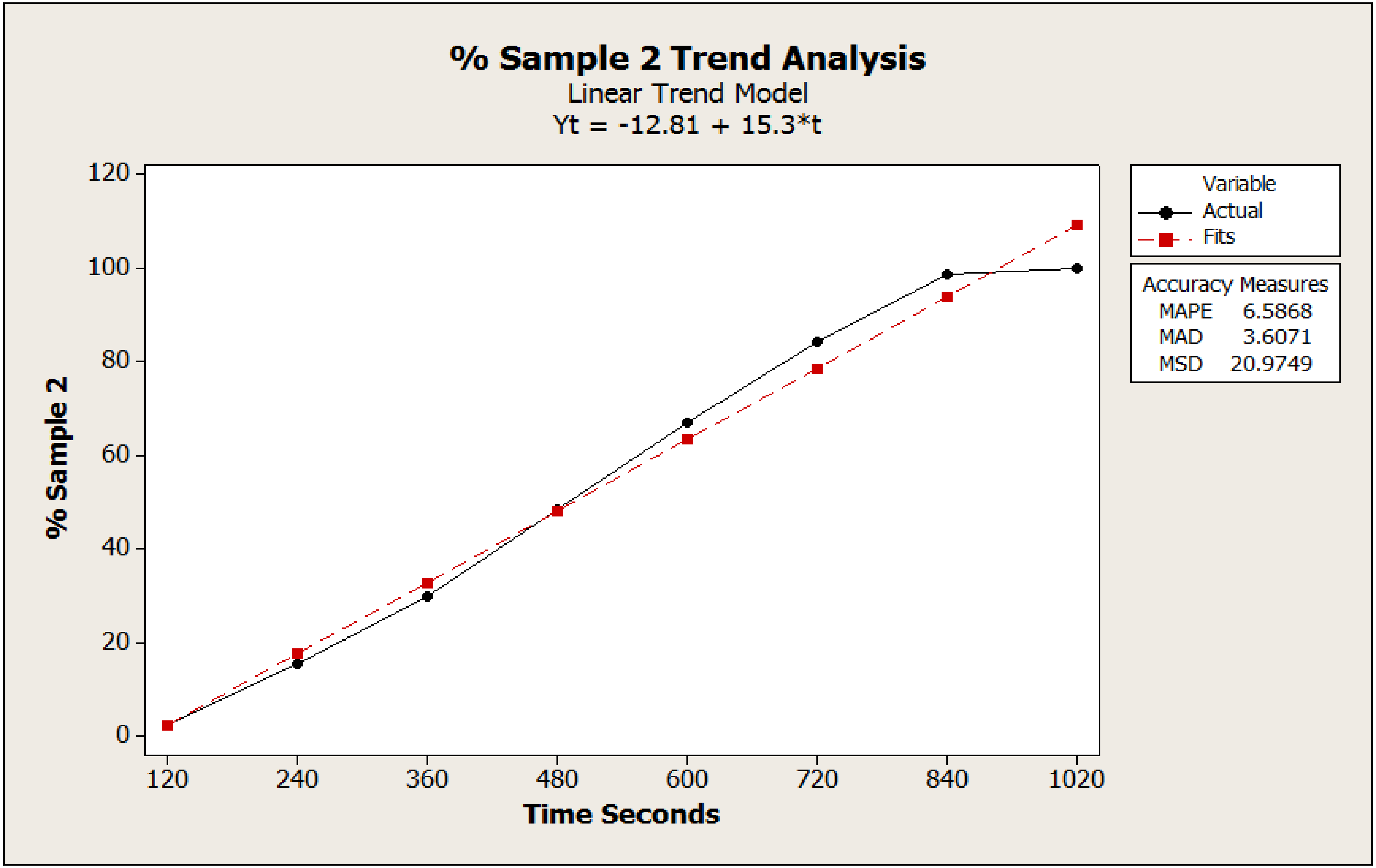

Summary

- The paper has reviewed numerous wax testing methods both historical and innovative
- The use of state of the art test equipment has furthered our knowledge and understanding of wax testing
- However there are times when modelling certain situations requires blue sky thinking
- We have demonstrated that with innovative thought and close supplier and customer partnerships significant opportunities exist for designing tests and wax products that enhance wax pattern production and productivity

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