Lightweight **Technologies Showcase**

Premium Vehicle Lightweight Technologies (PVLT)
Advanced Materials Forming
July 20th 2011

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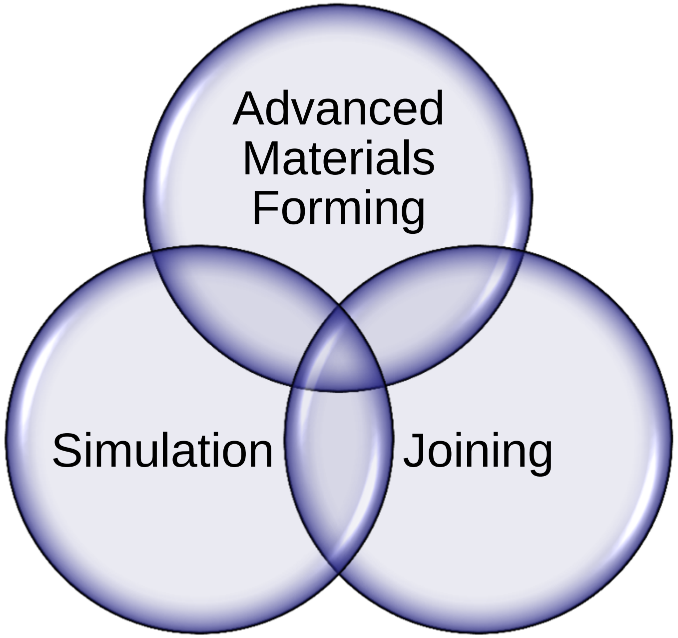
Content

- Overview of Work Area
- Workstream review:
  - Materials Characterisation – skins & structures
  - Sheet Hydroforming
  - Process Design for Optimised Material Utilisation
- Achievements & Conclusions

Premium Vehicle Lightweight Technologies (PVLT)

"To create a Centre that is renowned for its unique combination of collaborative R&D on lightweight materials with innovative simulation tools, forming technology, joining techniques for design, high impact capability and associated manufacturing processes."

"The strategic aim is to develop the competitiveness of the Body-In-White Cluster by building on the knowledge gained in the PARD Programme and helping to resolve the issues arising from the use of lightweight materials in the premium vehicle sector."



PVLT – Advanced Materials Forming

- Materials forming performance and process characterisation for a range of structural and cosmetic body panels
  - Mechanical testing
  - Forming assessments

- Desk top study into the technical and commercial opportunities offered by sheet hydroforming

- Investigation into the process considerations necessary to optimise materials utilisation during sheet metal forming

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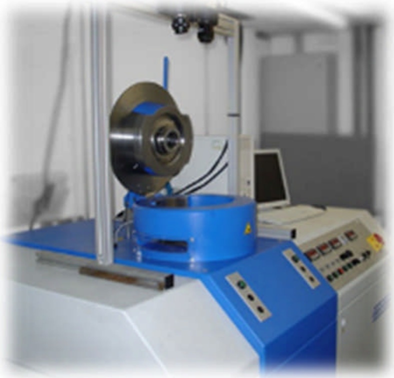
Facilities Developed - Testing



- Mechanical characterisation
  - Tensile/flexural/compression
  - Static/fatigue/dynamic
- Forming Limit Curves
- U-Profile / springback analysis
- Hole Expansion testing
- Fully instrumented press
- CMM
- Charpy impact tester
- Cross die tooling

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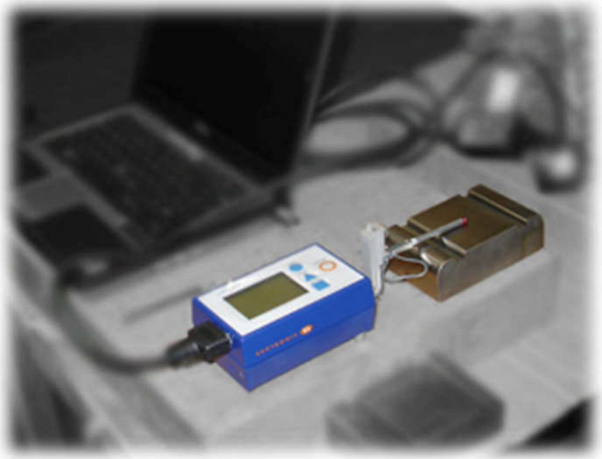
Facilities Developed - Analysis



- Metallographic preparation
- Microscopy (optical & electron)
- Electrical conductivity
- (micro)hardness testing
- Surface roughness
- Strain analysis/optical systems

Materials Characterisation - Industrial Context

- JLR needed a means of understanding the performance of new materials so that these alloys could be assessed for their formability, given that no bespoke facility existed in the UK at that time.

- BIW guild needed to understand the processing characteristics in advance of production and pre-production expectation.

Objective

- Develop a portfolio of tests that will assist the partners (JLR & BIW guild) in understanding the forming characteristics of new aluminium alloys and steel grades and generate recommendations for future design and manufacturing processes.

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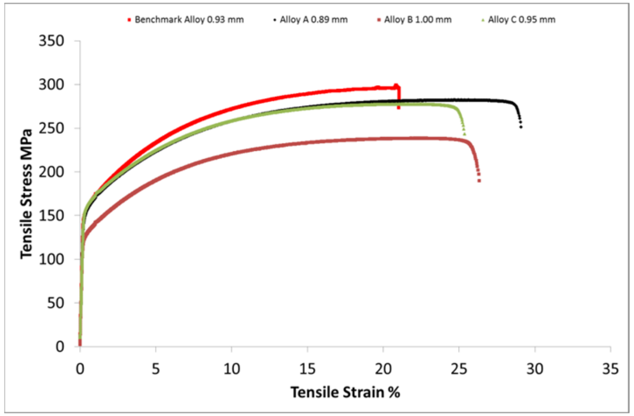
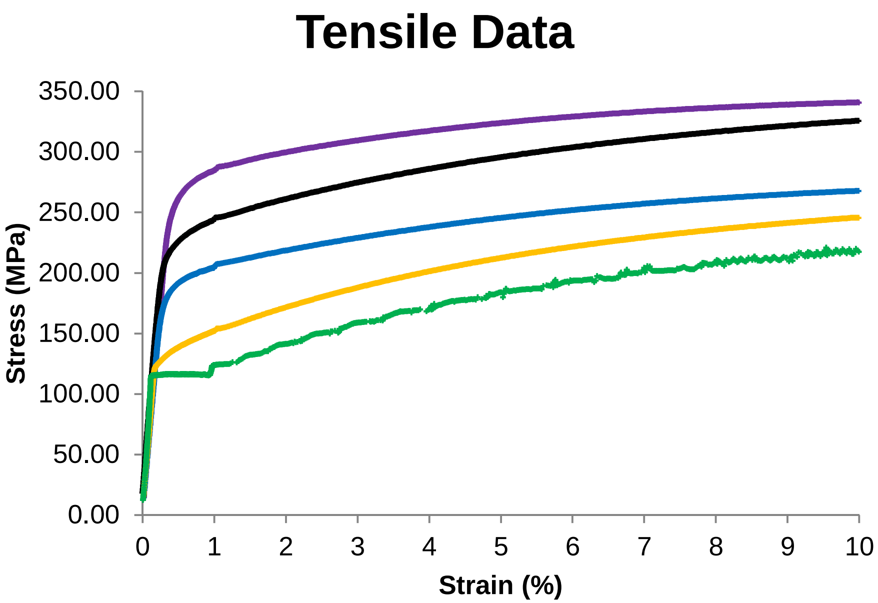
Mechanical characterisation

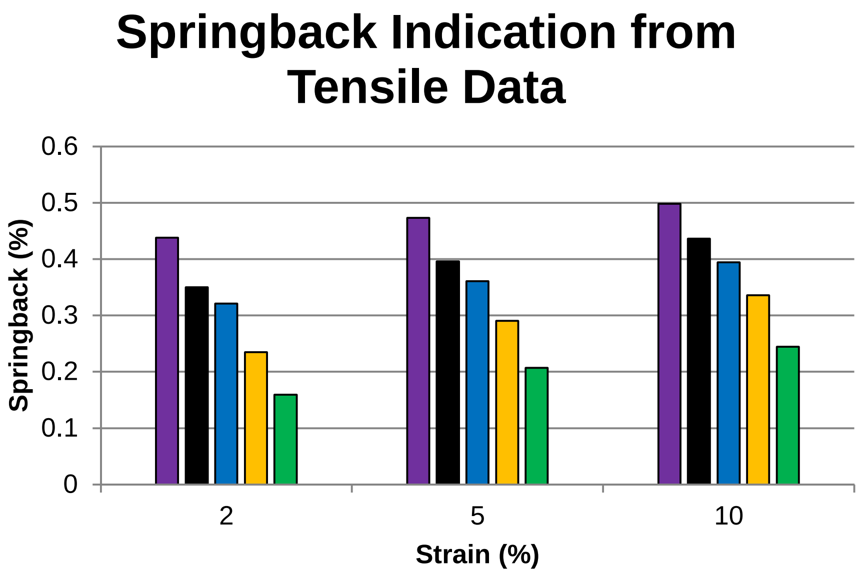
- Tensile testing
- Forming limit curves
- Springback characterisation
- Hole expansion tests
- Associated tests
  - Cross die assessment
  - Erichsen Cupping tests
  - Optical and SEM microscopy

Characterisation of Aluminium alloys



- The benchmark alloy shows high UTS
- Alloy A shows higher elongation for failure
- Alloy B has the lowest 0.2% proof and UTS
- The higher the Proof Stress, the higher the resulting springback for the same gauge





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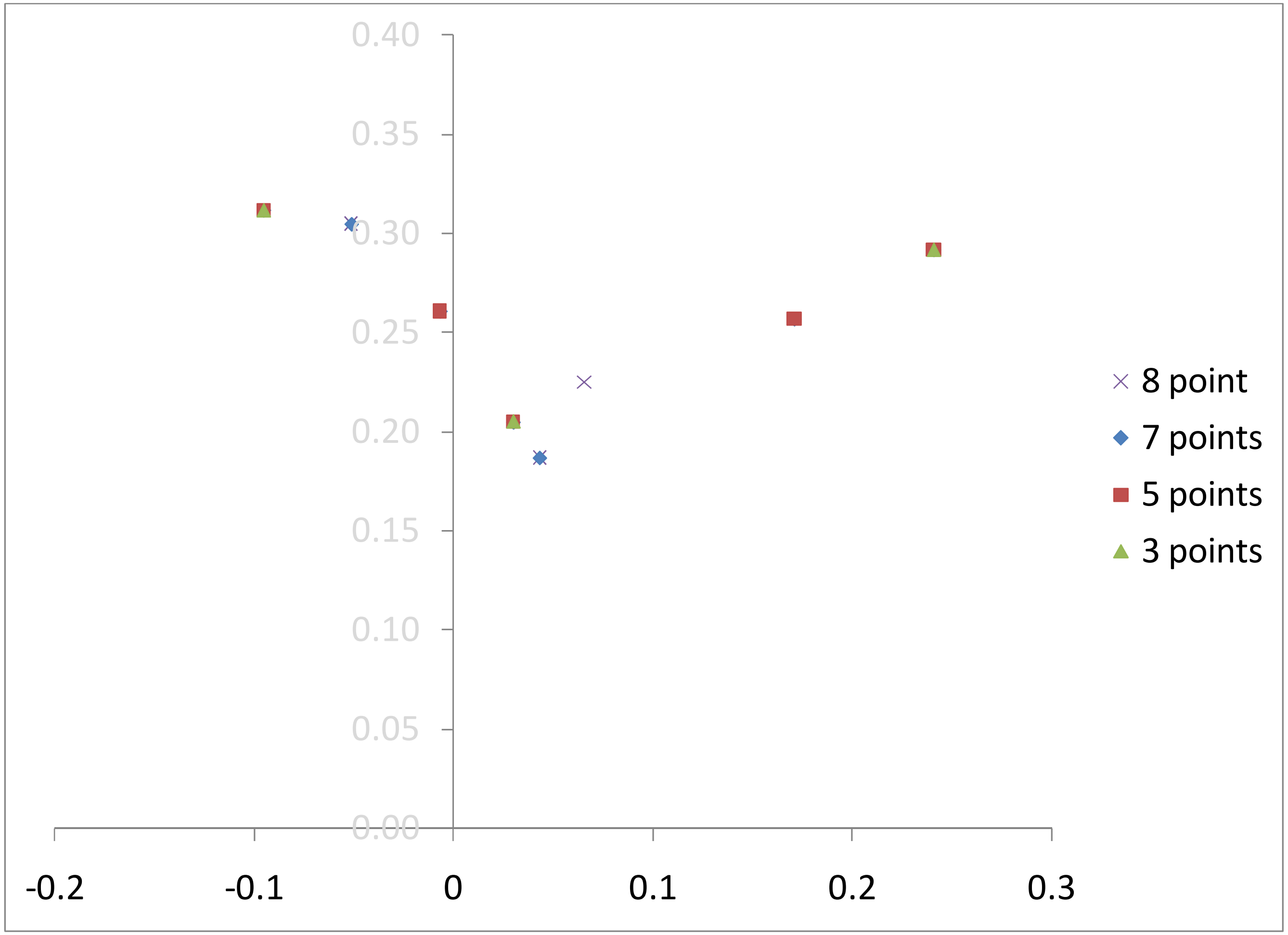
Procedures – FLCs

- Critical to define plane strain position, and associated geometry.
- Want to avoid testing too many different geometries due to large amounts of material that would be required, and time to process results.



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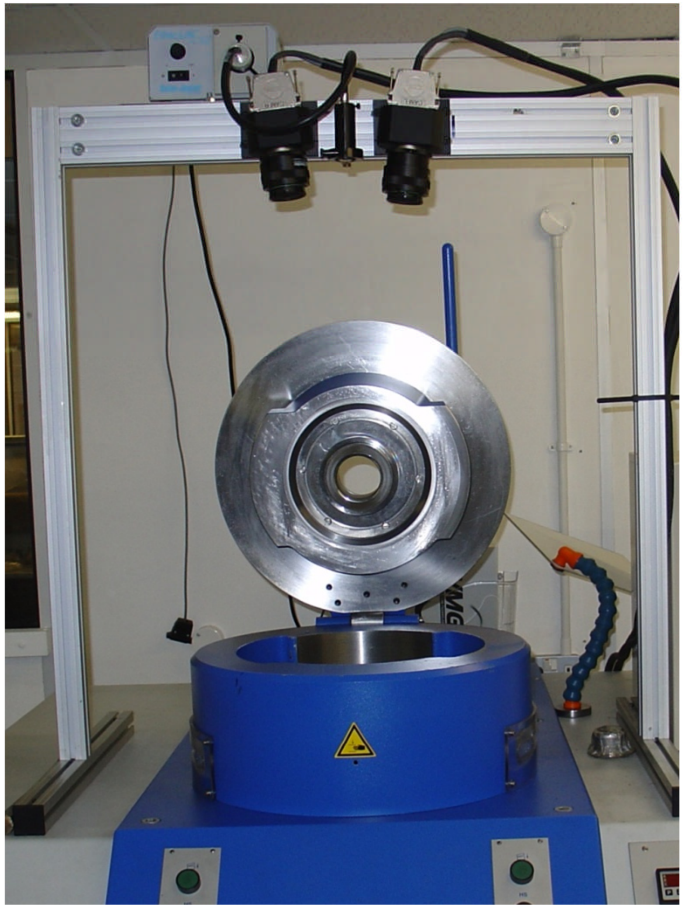
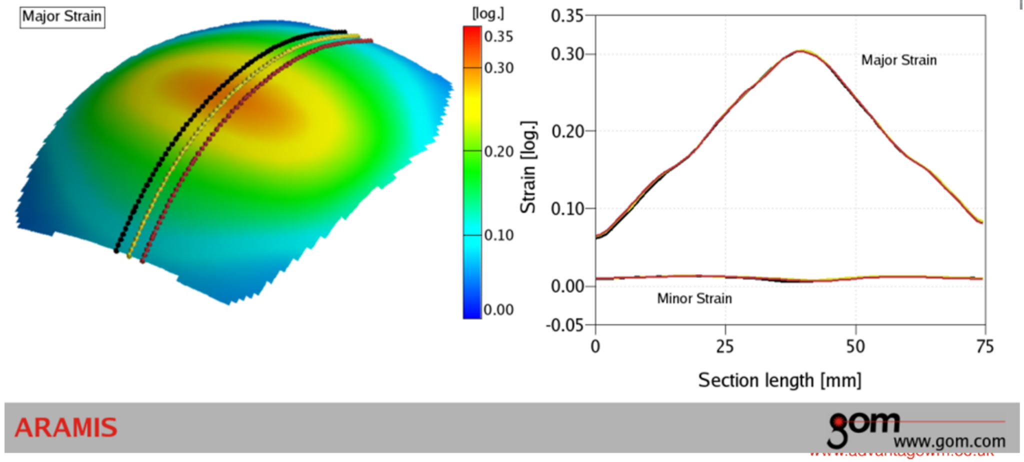
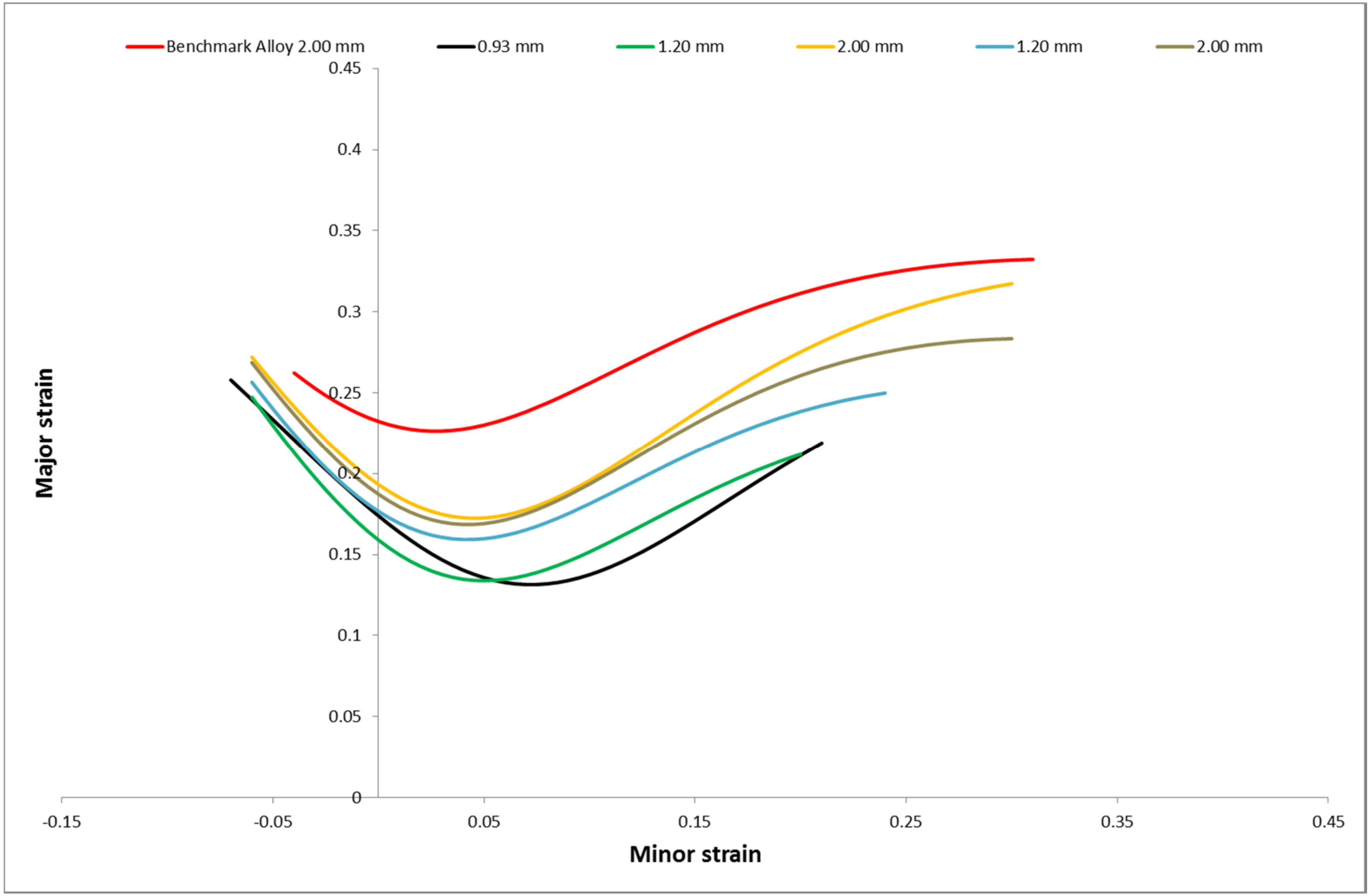
Forming Limit Curve Determination

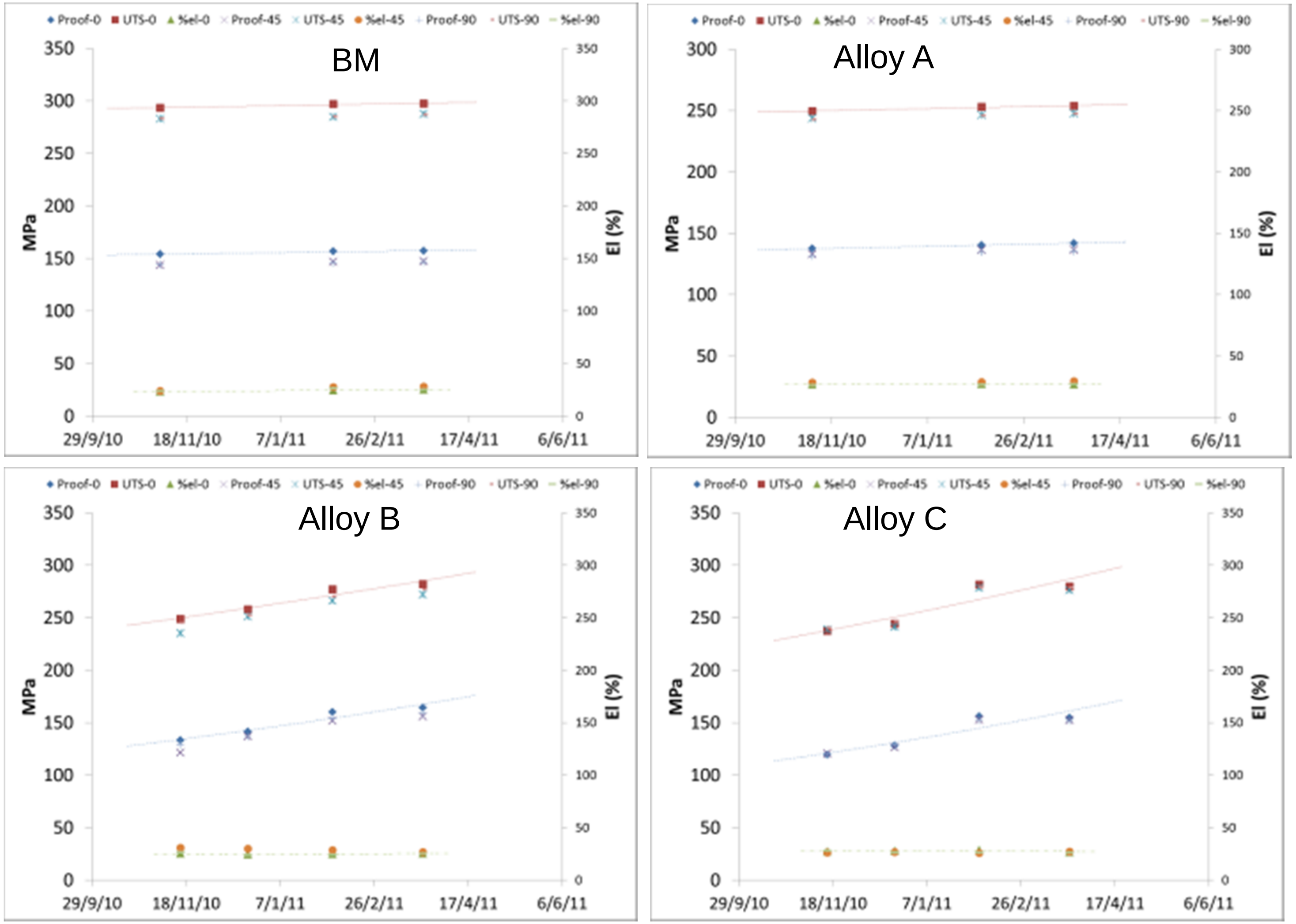




FLC - Examples



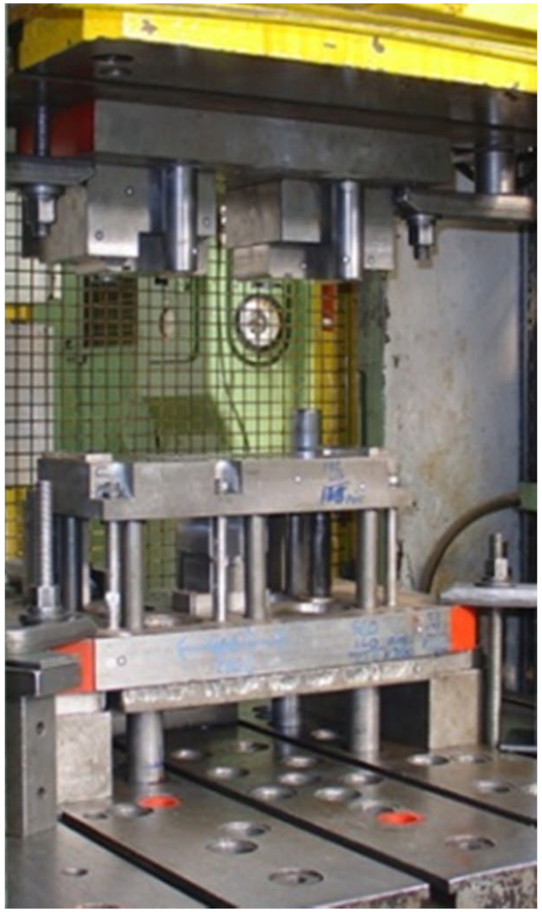
Skin Alloys – Natural Ageing



Indicates importance of validating materials properties at time of character-isation (e.g. When conducting U-Profile tests on different days and/or locations)

Springback Studies

U-Channel Tool



Parameters

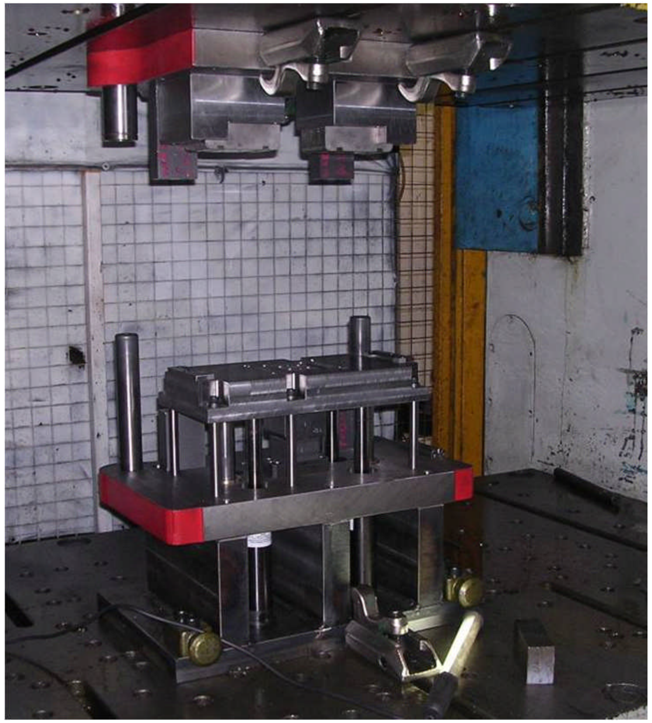
- Draw depths
  - 50 & 75 mm
- Die Radii
  - 8 & 12 mm
- Punch Radius
  - 12 mm
- Drawbead
  - 1 mm

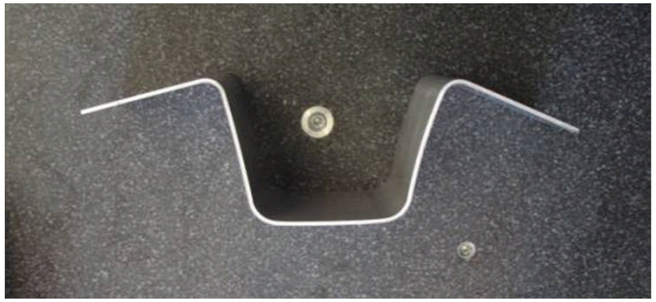
Nominal Punch Die clearance: 10% of sheet thickness

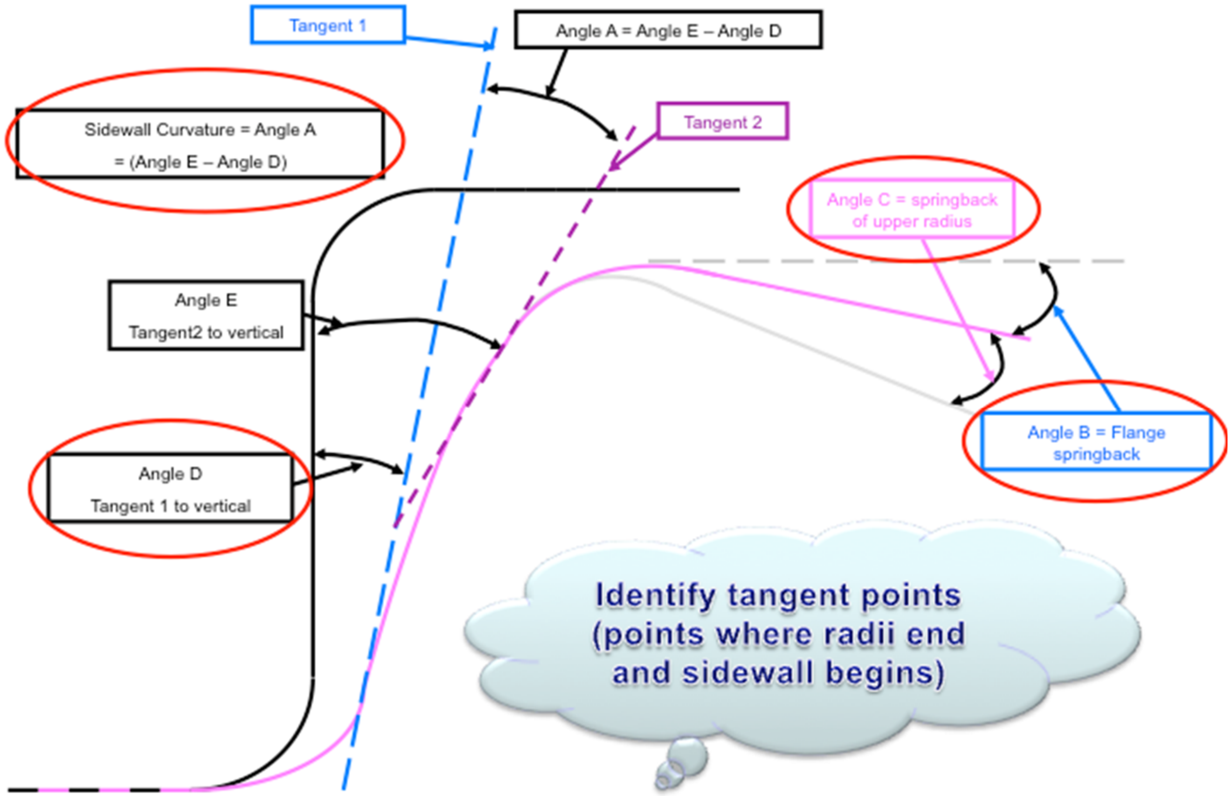
5 samples/condition for repeatability

PVLT– Advanced Materials Forming

Investigation of Springback Using Simple U-Profile Tool

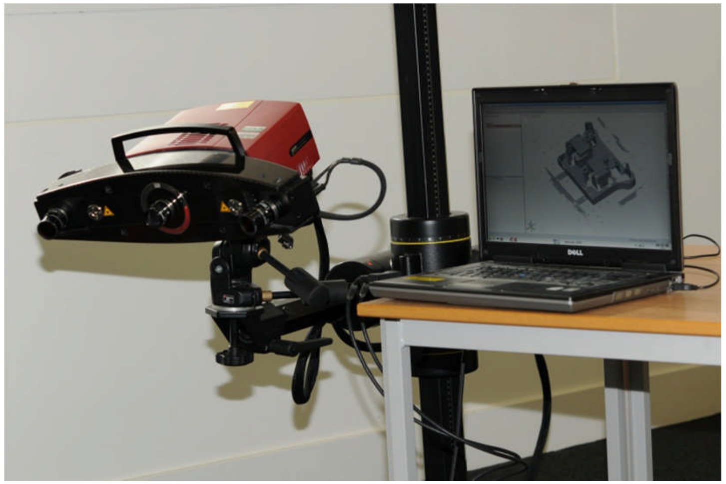




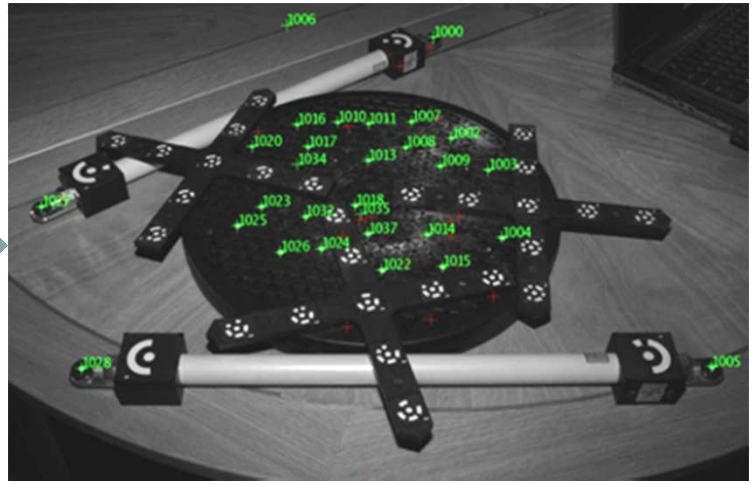


Optical measurement process

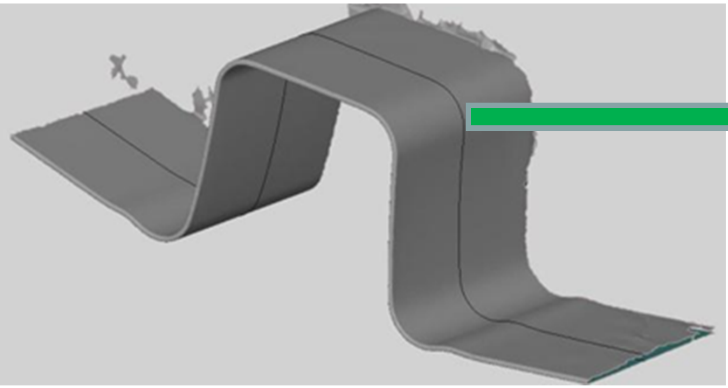
GOM ATOS System



Reference system



Full surface scan



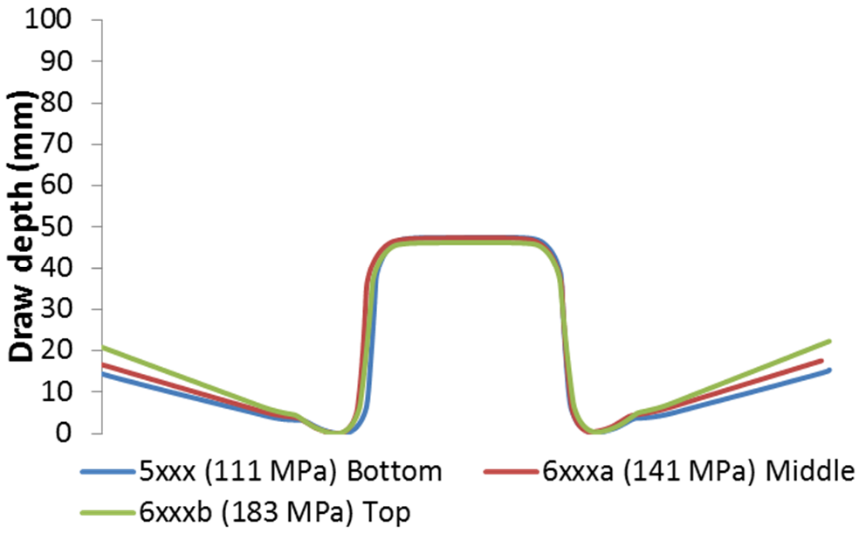
IGES Import

Mid plane line scan

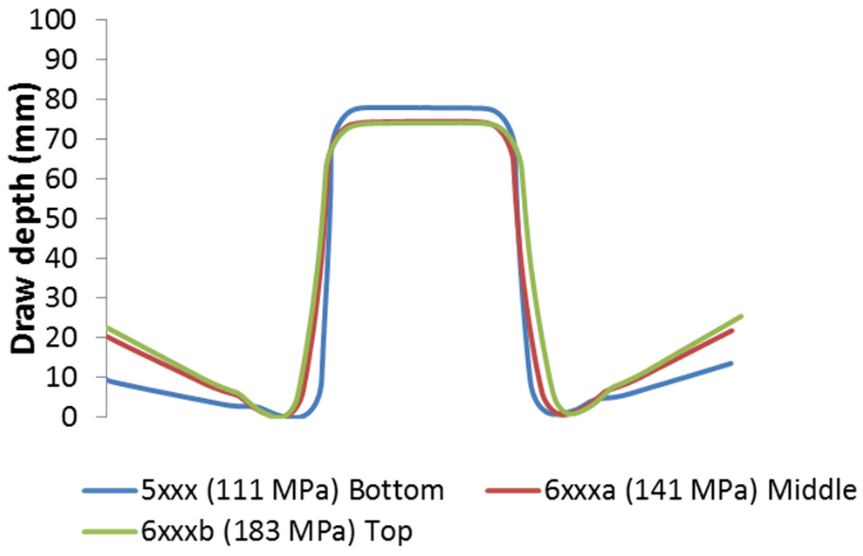
Datum ?

Springback Results (8 mm Die Radius)

50 mm Draw Depth



75 mm Draw Depth



- Higher 0.2% proof strength shows higher Flange Springback.
- Both the 6xxx alloys show similar springback characteristics.

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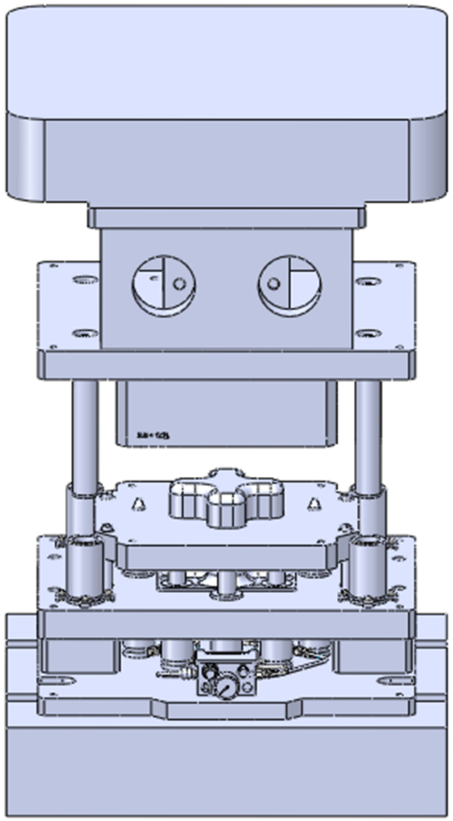
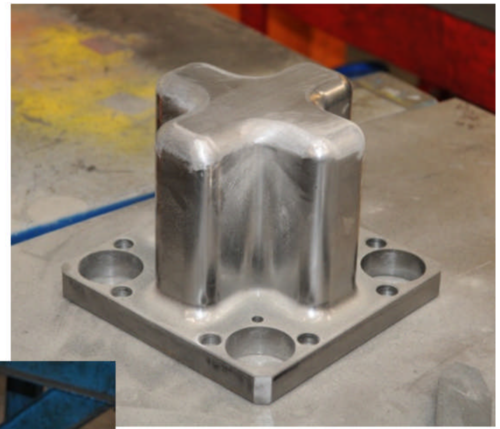
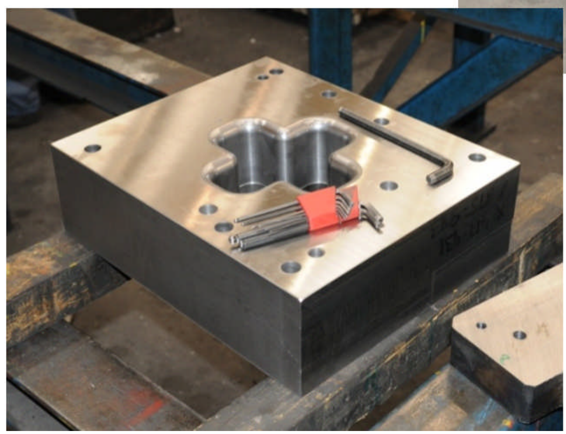
Cross Die for Complex Drawing Assessment







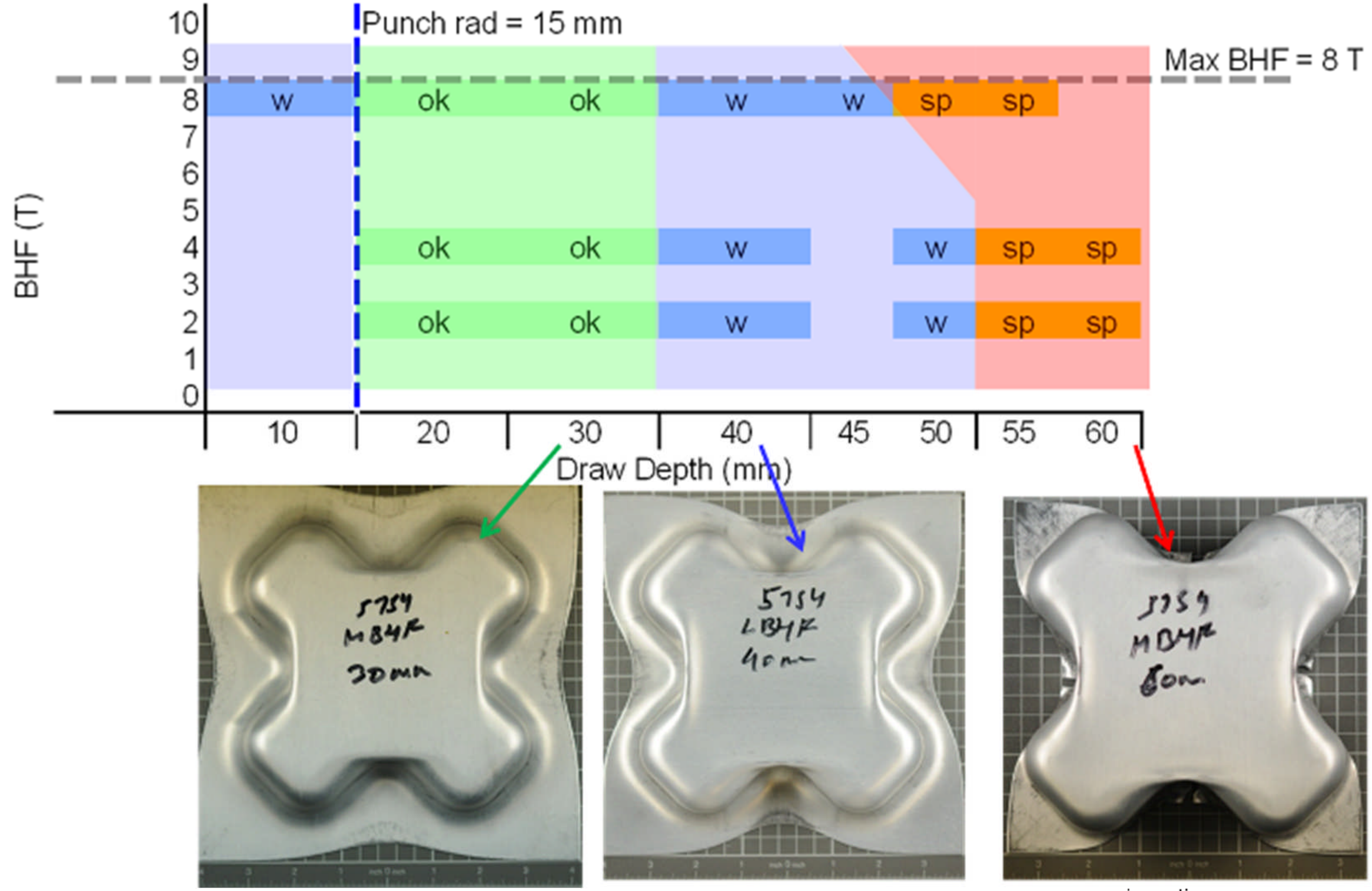
8 gas springs to provide up to 10 T blankholder force

3 die sets to accommodate 0.9, 2.0 & 2.5 mm (=10% clearance)

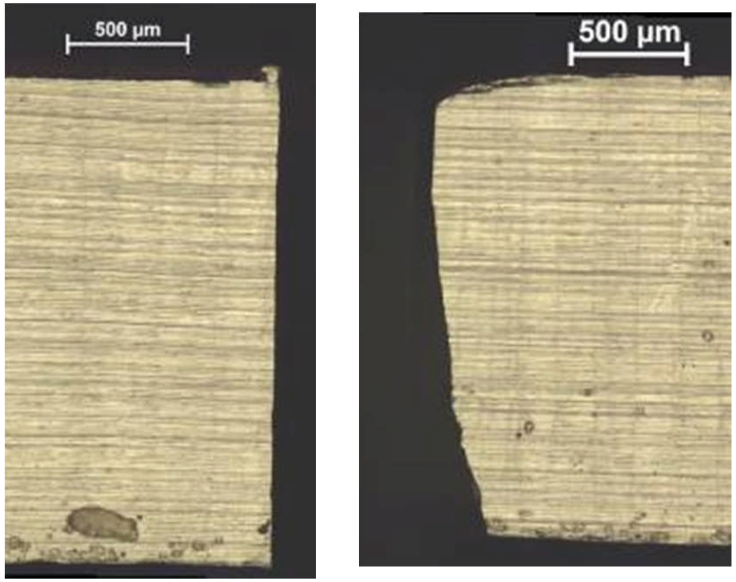
Upper pad and gas spring (1 T)

Structural Alloys – Cross-Die Trials

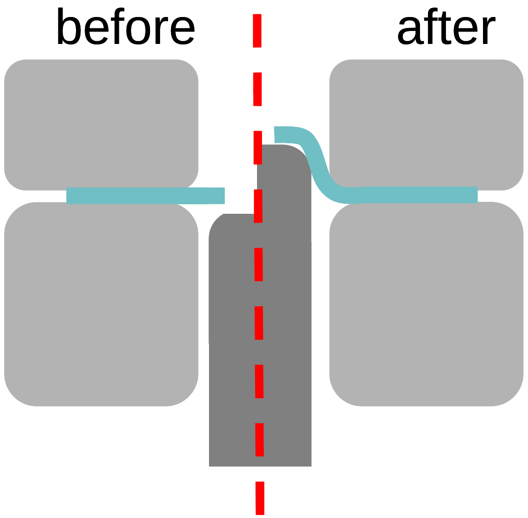
w = wrinkles ok = forms sp = splits

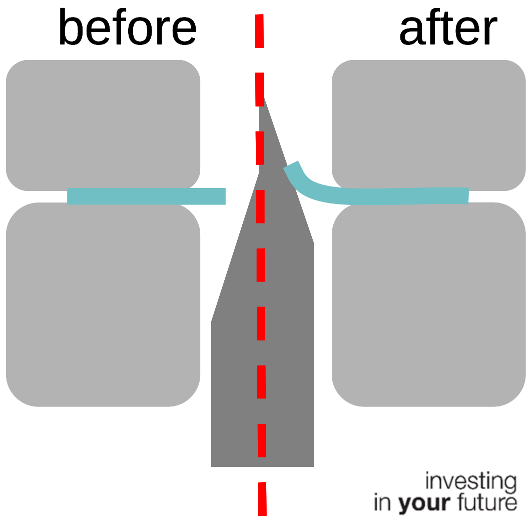


HE - Sample Preparation & Testing

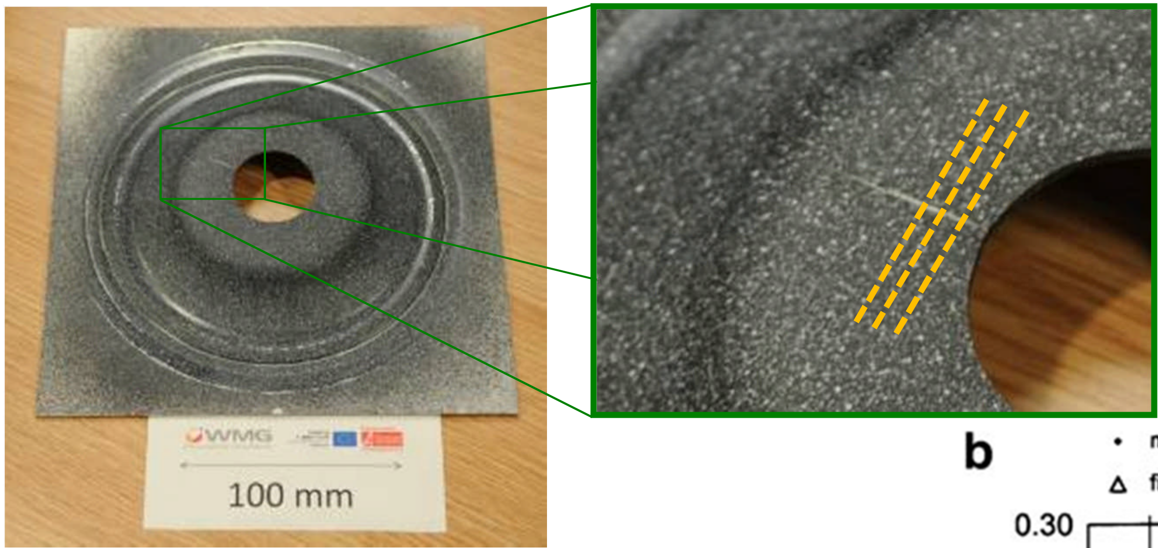


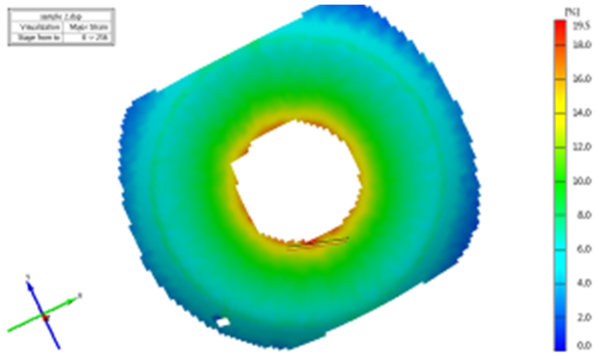
- Hole of 10 mm diameter introduced by drilling & reaming or punching
- Hole expanded using a conical punch
- 30 mm hole CNC'd then expanded with a flat-topped punch (one sample punched: 6xxx T4 a)

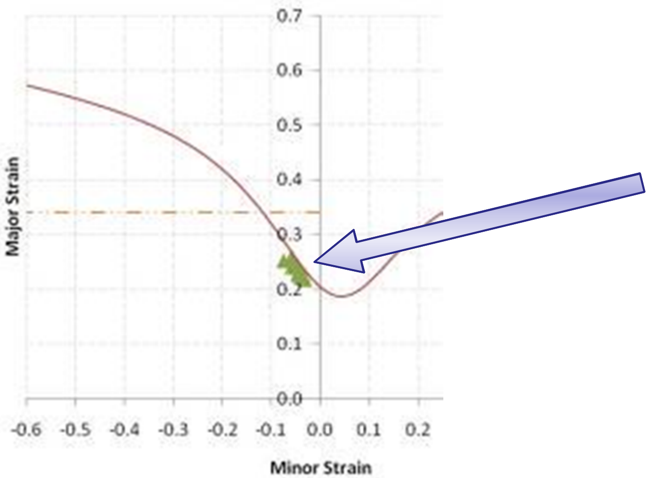


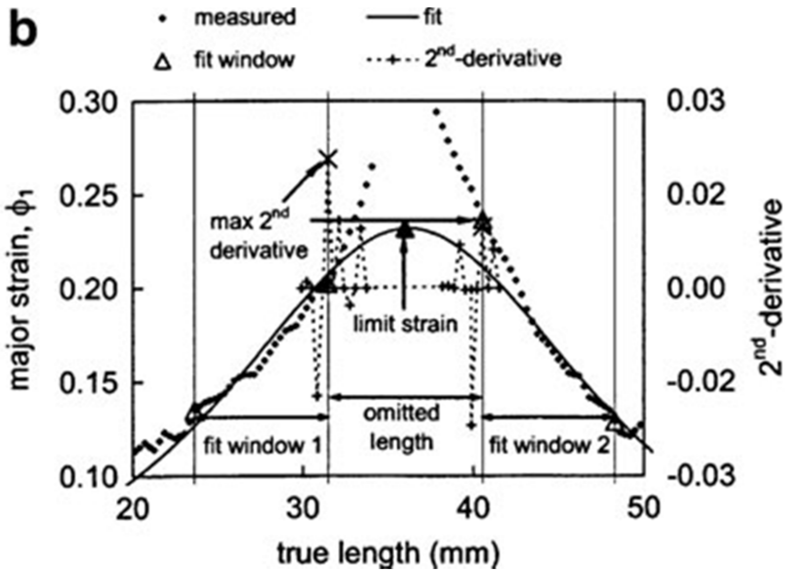


Hole Expansion Strain Data









Int J Mater Form (2010) 3:165–189

Sheet Hydroforming

Objective:

- Clarify the business case uncertainties to support investment decisions in a UK sheet hydroforming facility
- If outcome is positive, develop proposal to introduce technology to UK/West Midlands

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Claimed Benefits

- **Complicated part capability**
  - Process provides increased formability giving greater design freedom
  - cost of rework built into current programmes could be eliminated

- **Reduced number of operations**
  - With the ability to make more complicated shapes it is possible to reduce the number of draw and re-strike operations normally required

- **Low tooling investment**
  - Up to 70% cost reduction due to absence of lower half, reduced maintenance and reduced time consuming tool spotting and matching

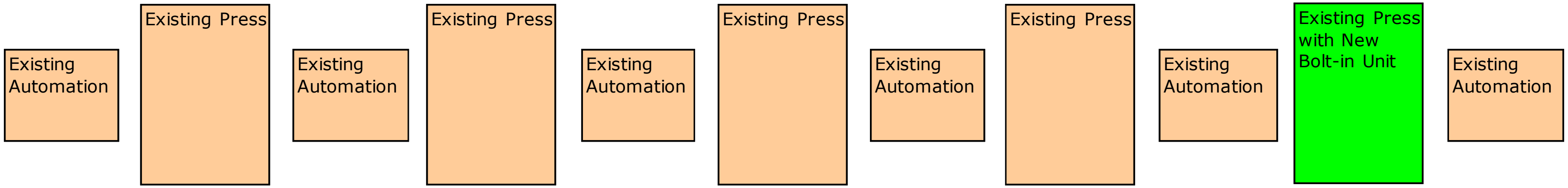
- **Uniform wall thickness**
  - Thinning is more uniform over the whole part as the sheet metal is pushed firmly onto the punch during forming

- **Dimensional stability**
  - The process results in an even strain distribution resulting in lower springback
  - Less movement of the material over the punch giving parts with better dimensional accuracy

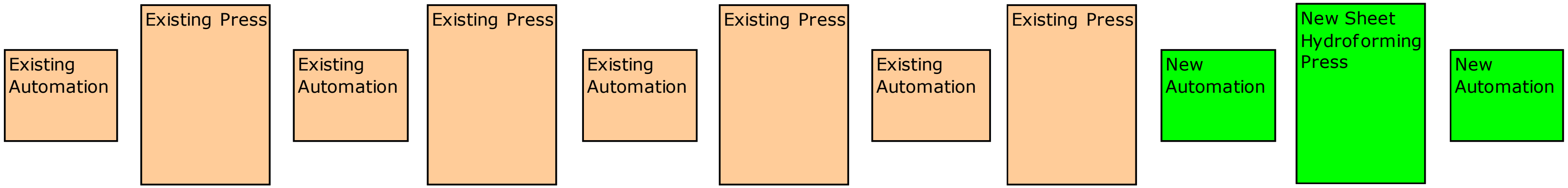
- **Surface quality**
  - As fluid acts as the female half, there are less tool marks, slip lines and other markings
  - With greater uniform strain, highs/lows and other distortions are less evident

Sheet Hydroforming Options

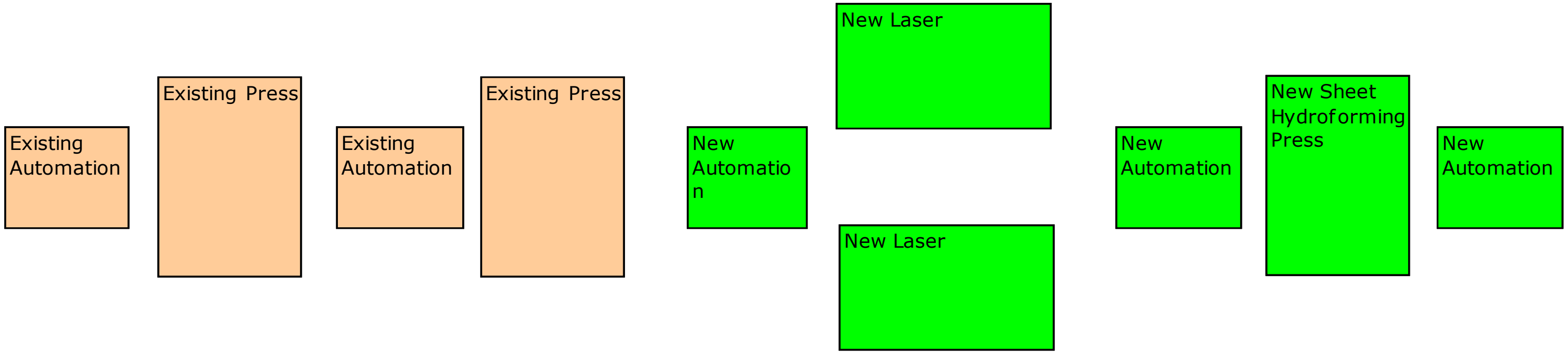
Option 1. Bolt in unit in existing press



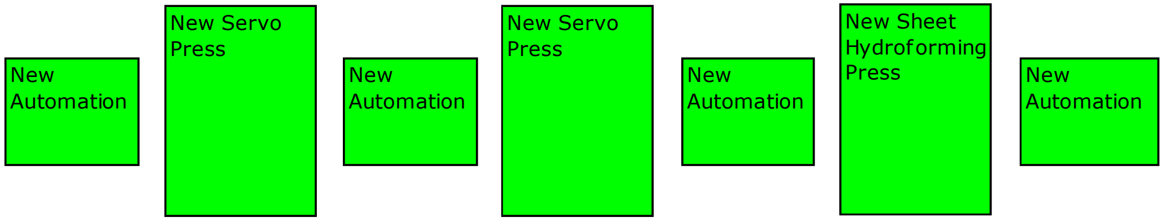
Option 2 . New Sheet Hydoforming Press



Option 3. Flexible Manufacturing Cell



Option 4. Totally New Press Line



Key assumptions for Make Vs Buy study

- Zero rework applied to hydroformed components
- Hydroformed XK deckid is proposed as integrated, one piece outer on the assumption of no design compromise from Styling
- Energy costs based on standard hydroforming hydraulic unit
- Rework levels apply to all components manufactured conventionally
- Calculations based on 4 inner and 4 outer hood panels
- Initial assessment based on comparison of draw dies only
- Full assessment based on each business case option as supplied or manufactured in house
- Similar exercise conducted for a decklid

Key conclusions from study

- Business case viability could not be established or bonnet
  - additional work performed confirmed findings

- Approx 8 components with annual volumes no more than 40k needed to fully utilise facility

- Claimed benefits of complicated part capability, reduced number of operations and low tooling investment <u>not clearly demonstrated</u>

- A number of other OEMs have explored the technology but not committed to production

Key Trigger Points for New Investigation

- New facility established in the UK
- Reduced cost of capital equipment
- High number of feature specific or re-work intense components running at approx 40k p.a.
- Proven ability to consistently manufacture components without process concerns such as leakages etc.

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Achievements

- Detailed business case analysis conducted on sheet hydroforming process to advise JLR manufacturing strategy decisions.
- Comprehensive materials characterisation test portfolio established supported by detailed procedures and state of the facilities.
- Alloy characterisation facilitated the introduction of a number of new alloys onto JLR future models
- Deeper understanding on new alloy performance and manufacturing complexities achieved within core JLR team and key personnel from BIW Guild members.
- Process design recommendations arising from PDfOMU study will yield significant savings.
- Culture of trust and cooperation established between all partners.

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Publications

- M. Stanton, R. Bhattacharya, G. Williams, I. Dargue, **The production and examination of u-profiles for assessing springback**, in 7th International Conference on Manufacturing Research 2009, P.D. Ceglarek, Editor. 2009, University of Warwick: University of Warwick. pp. 371-375.
- R. Bhattacharya, M. Stanton, I. Dargue, G. Williams, ***Materials characterization of Aluminium alloys for use in automotive structures***, in 7th International Conference on Manufacturing Research 2009, P.D. Ceglarek, Editor. 2009, University of Warwick: University of Warwick. pp. 366-370.
- M. Stanton, I. Masters, R. Bhattacharya, I. Dargue, R. Aylmore, G. Williams, ***Modelling and Validation of Springback in Aluminium U-Profiles***, International Journal of Material Forming, 2010, 3, 163-166.
- R. Bhattacharya, M. Stanton, I. Dargue, G. Williams, R. Aylmore, ***Forming limit studies on different thickness aluminium 6xxx series alloys used in automotive applications***, International Journal of Material Forming, 2010, 3, 267-270.
- R. Bhattacharya, M. Stanton, I. Dargue, R. Aylmore, and G. Williams, ***Experimental Evaluation of Springback in Aluminium Alloys Using Optical Measurement and Numerical Analysis***, AIP Conf. Proc. 1353, 241 (2011)
- M. Stanton, R. Bhattacharya, I. Dargue, R. Aylmore, and G. Williams, ***Hole Expansion of Aluminum Alloys for the Automotive Industry***, AIP Conf. Proc. 1353, 1488 (2011)
- R. Bhattacharya, M. Stanton, I. Dargue, R. Aylmore, G. Williams, ***A Study on The Springback Behaviour of Automotive Aluminium Alloys***, Accepted for publication at ICTP 2011, Aachen.
- M. Stanton, R. Bhattacharya, G. Williams, I. Dargue, ***Investigation of Materials Springback Using a Simple U-Profile***, GOM UK Deformation Workshop, Presentation 8, Nov. 2009. (invited speaker)

Acknowledgements

- Industrial Partner: Jaguar Land Rover

JAGUAR | LAND ROVER

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ANY QUESTIONS?

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