Understanding Steel Behaviour - Building Safer Cars

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Introduction

There is a need to develop superior grades of material for the automotive industry which reduce the overall weight of the vehicle and yet enhance passenger safety by absorbing greater levels of energy during impact. One such example is that of TRIP steels which are increasing in popularity, exhibiting very high-strength and uniform-elongation (ductility). In TRIP steels, extensive work-hardening is induced due to a strain-induced martensitic phase transformation, shown in Figure-1. Here, the combination of the parent austenite and the transformed martensite phases behave as a composite material increasing the amount of energy the material can absorb before failure. Understanding how transformation strains are accommodated in each phase as a function of externally applied load, will help in fundamentally explaining the hardening behaviour of the steel.

Here, the TRIP-phenomenon in an austenitic stainless steel is investigated by mapping strain variation at a microstructural resolution during strain-induced martensitic transformations using digital image correlation.

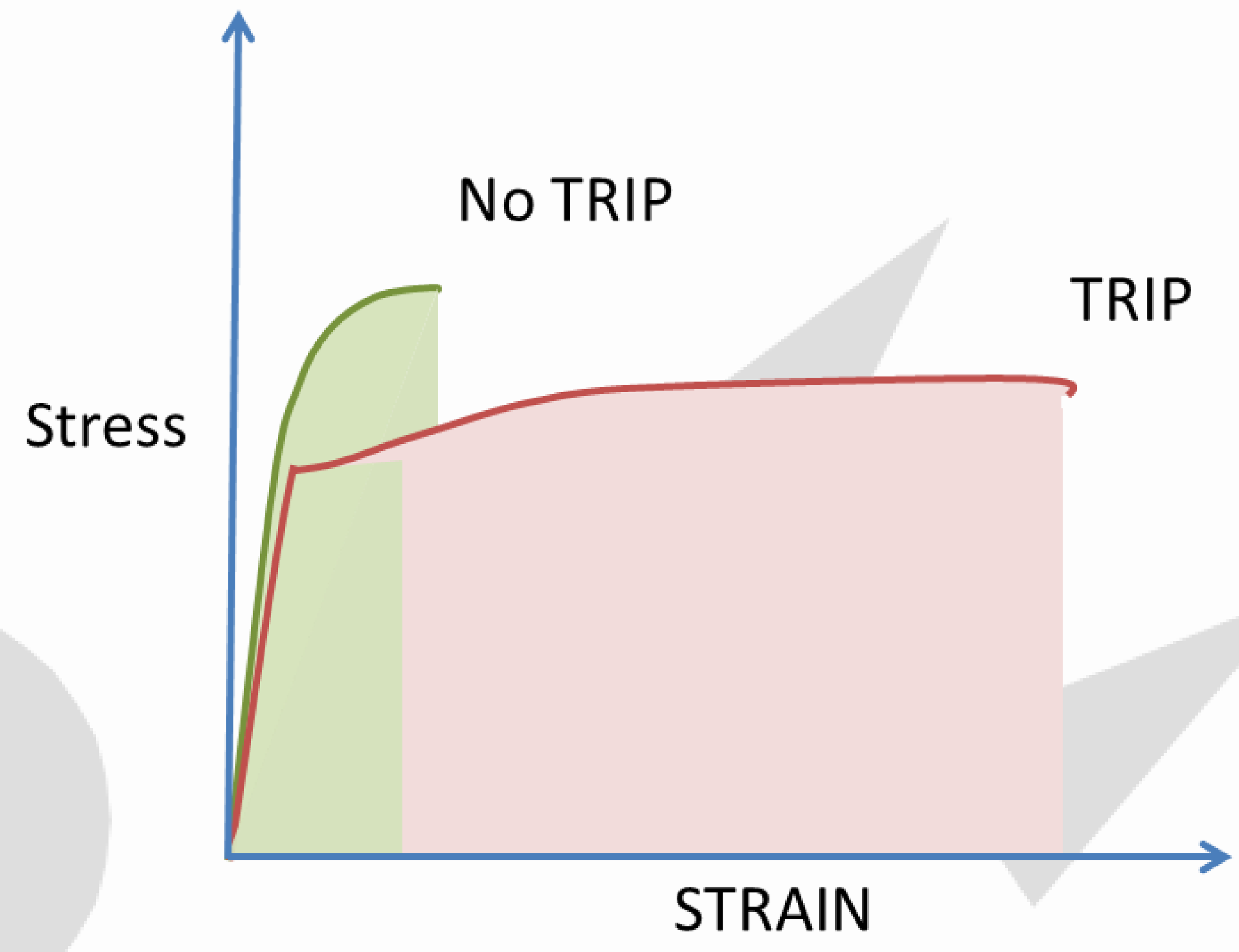

Figure-1

Digital Image Correlation (DIC)

- DIC is a technique where a digital camera or in our case scanning electron microscope (SEM) is used to image a surface of material during deformation
- It gives a full field strain measurement map to sub-pixel accuracy by correlating digital images before and after deformation (shown in Figure-2).
- For 2D DIC, test specimen should be in plane with imaging system for entire test duration
- A good surface pattern is required to get good spatial resolution and strain measurements.
- The first challenge is to create a speckle pattern viewable in the SEM because traditional methods using paint are not suitable to be imaged with an SEM or at the spatial resolution required

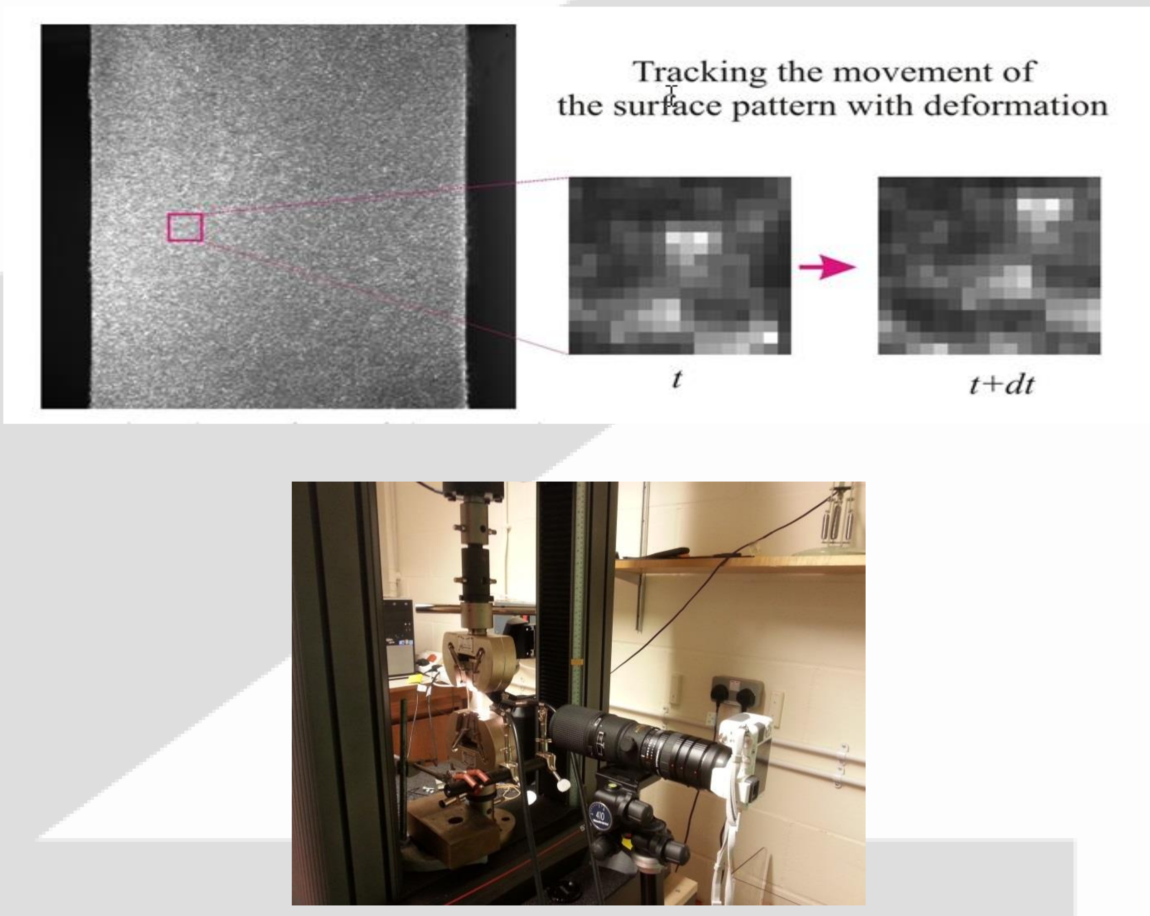

Figure-2

DIC at Microstructural Level – Inside an SEM

- Speckle Pattern needs to be conductive – We're using Gold
- Sputtering gold on a well polished sample and placing it in humidifying chamber gives random nano-sized speckles of gold which give excellent contrast in the back scattered mode (atomic number contrast imaging) in the SEM refer Figure-3

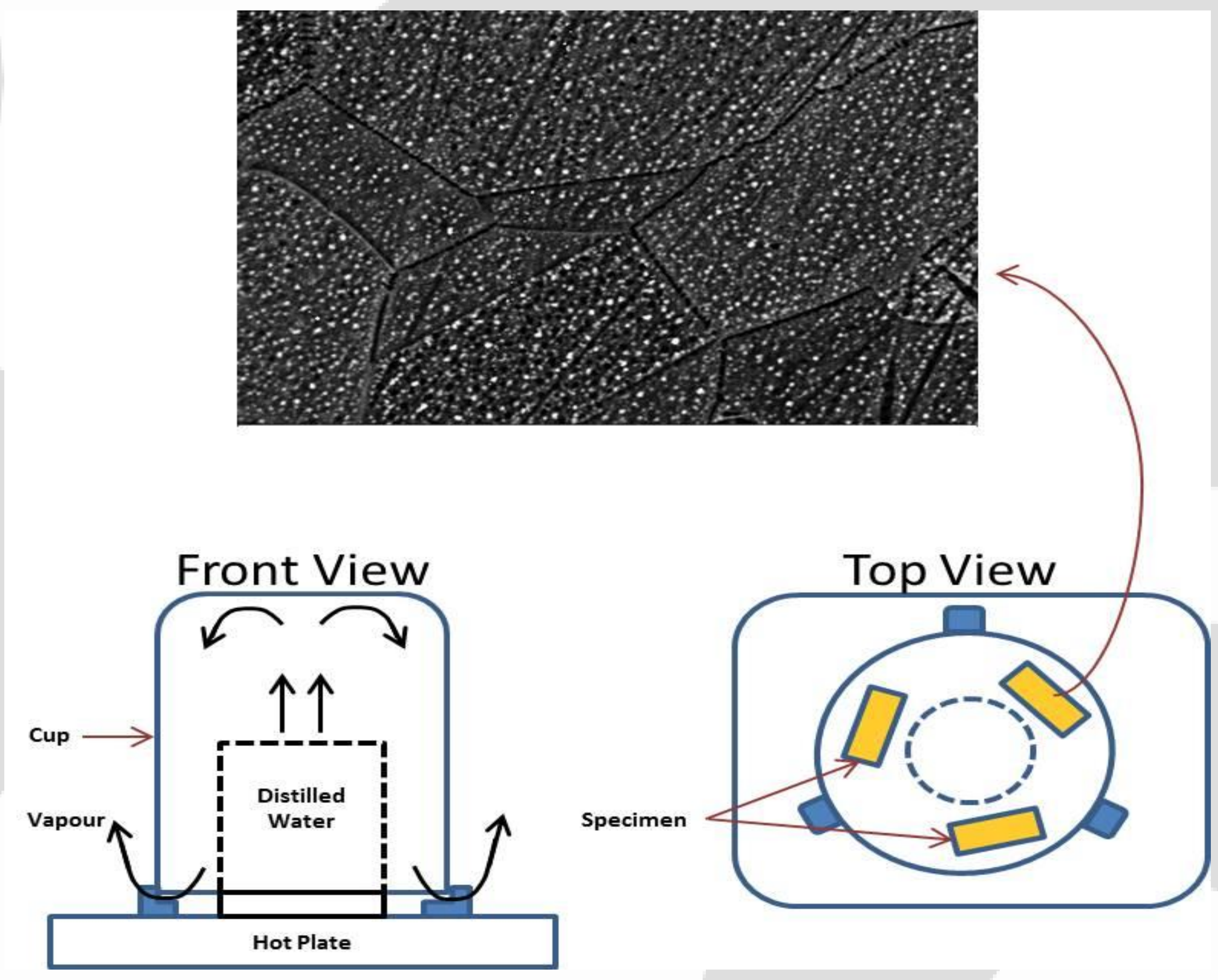

Figure-3

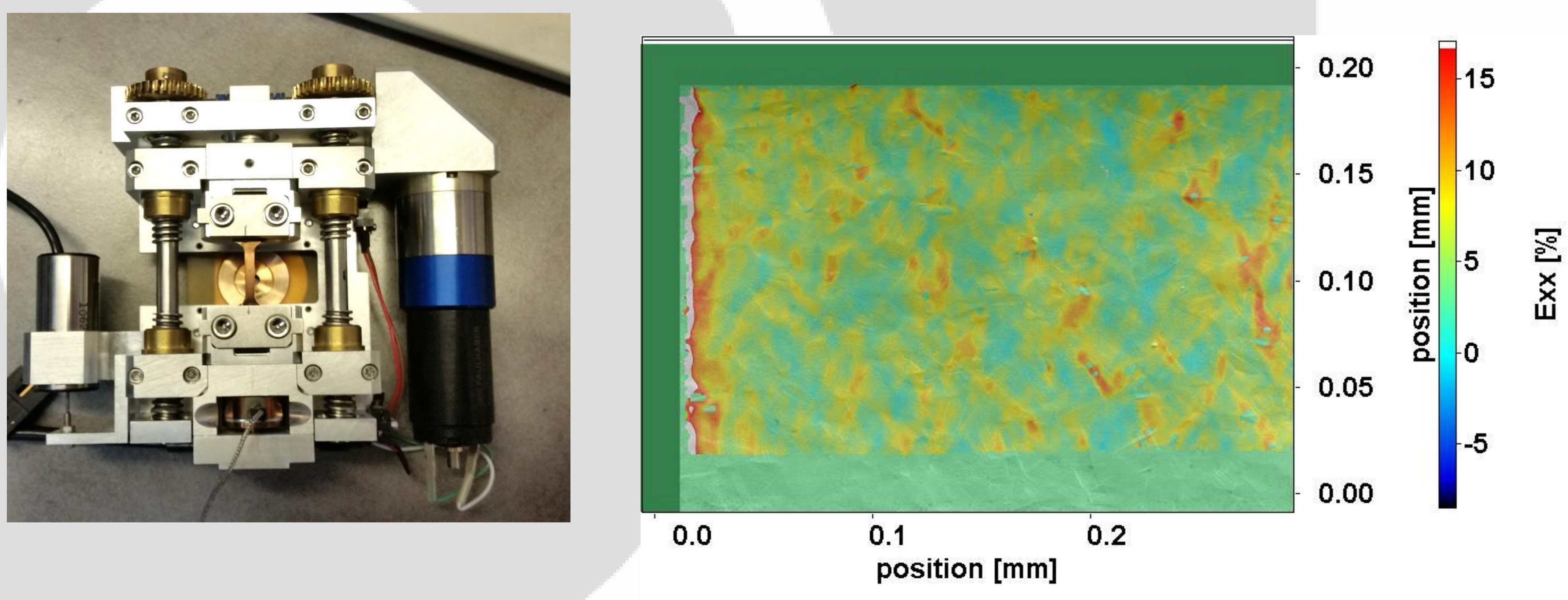

Figure-4

Experiments

Specimen was tested in a mini tensile test machine that fits inside the SEM chamber(Figure-4)

Imaging for DIC was taken using back scattered mode which gives an excellent contrast between the tiny-bright gold speckles particles and the dark steel background

The image correlation algorithm determines how far and in what direction each of the gold speckles moves during deformation

Results

Although the specimen is strained to approximately 10 %, it is seen that local strain is far from uniform. Strain appears to accumulate around transformation sites.

From the Strain map (figure 4) it is clear that there is very high strain accumulation (>20%) in certain areas which is the expected value from martensite transformation theory

Conclusions

- DIC has been used for the first time to map strain accommodation in TRIP steel
- It clearly shows that the externally applied load is accommodated very efficiently in the material around potential martensite transformation sites.