Development of novel testing equipment for mechanical characterization of complex materials

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INTRODUCTION

Understanding the mechanical properties of diverse materials, including metals, adhesives and soft polymers an, is crucial for developing robust models that enable efficient and safe design, accident prediction, and innovative product creation. Determining these properties requires specialized testing methodologies beyond conventional standards. This work details the design principles and functionalities of custom-built apparatuses designed to probe and characterize specific mechanical behaviour relevant to their performance.

HIGH STRAIN RATE PERFORMANCE OF MATERIALS

Multiple materials exhibit high strain rate dependence (Figure 1a), requiring the development of specific testing systems that enable the application of load at very high rates. One such device constructed was a drop-weight apparatus, designed for 5 m/s and with a custom control system, equipped with rebound catching arms (Figure 1)

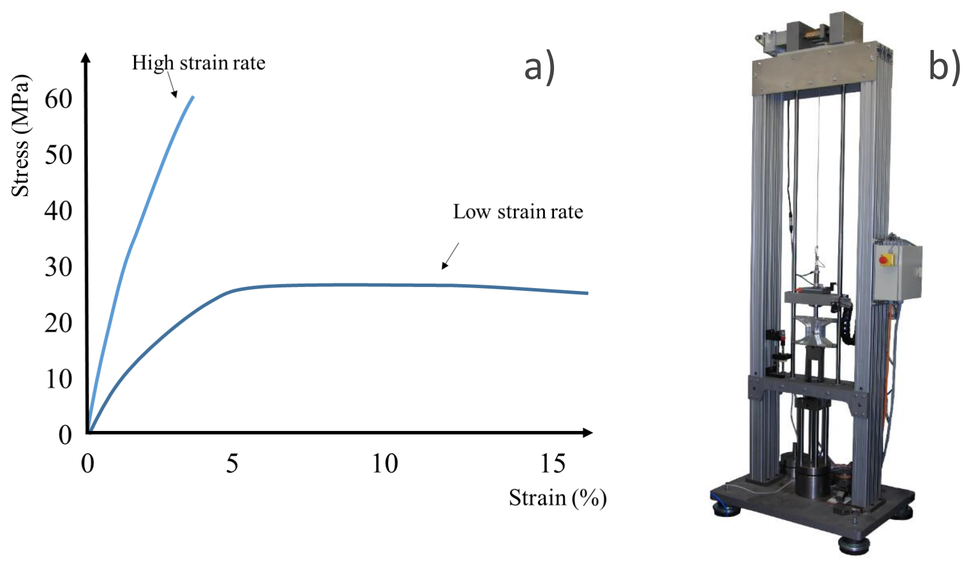

Figure 1 – a) Polymer behavior at high strain rates, b) designed drop weight apparatus

An alternative device is the well-know split Hopkinson pressure bar (SHPB) apparatus. The proposed design we have created makes use of a compression/traction capable configuration, which can be switched by controlling a novel pneumatic actuator design, as shown in Figure 2.

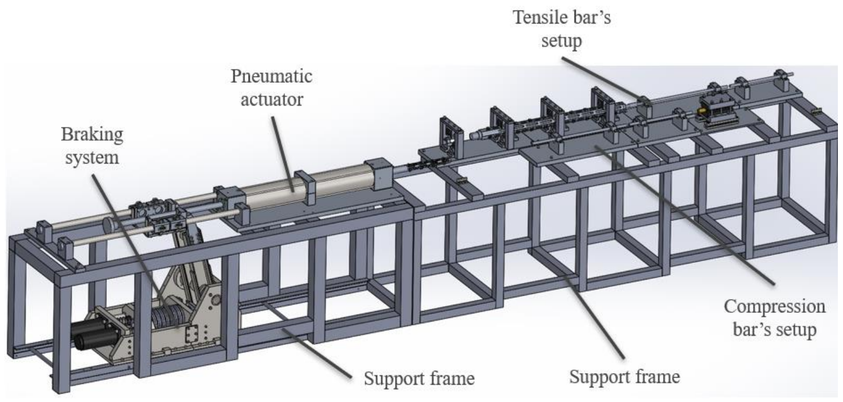

Figure 2 – Compression/traction SHPB apparatus

Furthermore, a device was designed for the determination of fracture envelope of adhesives under multiple mode angles as a function of strain rate (Figure 3). This novel mixed mode apparatus controls the loading angle on the upper and lower arms of the specimen, generating different loading angles. This enables the extraction of fracture envelopes (Figure 4).

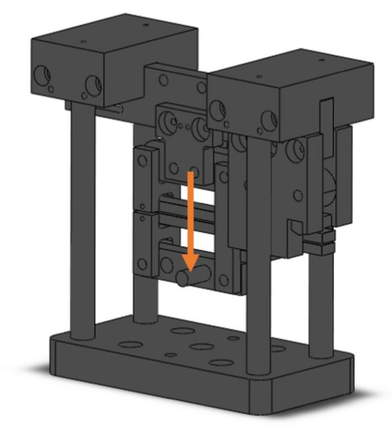

Figure 3 – Numerical and experimental response comparison

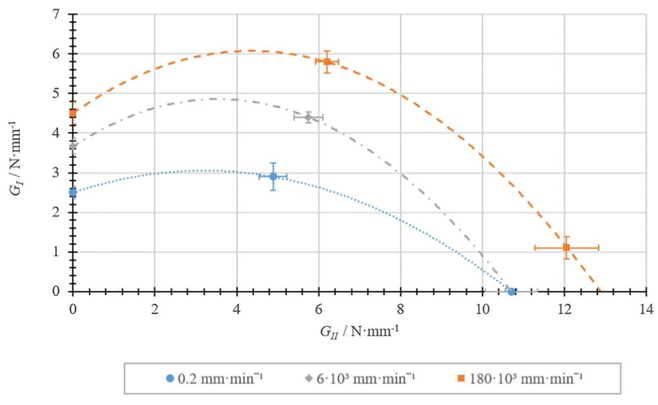

Figure 4 – Failure mode and numerical model geometry

CREEP PERFORMANCE OF MATERIALS

Creep testing systems have also been devised, with the use of systems able to provide low mechanical loads for short period of time.

One such device developed is shown in Figure 5

This system uses a simple pneumatic based actuator system and special gripping system, to avoid the introduction of spurious loads.

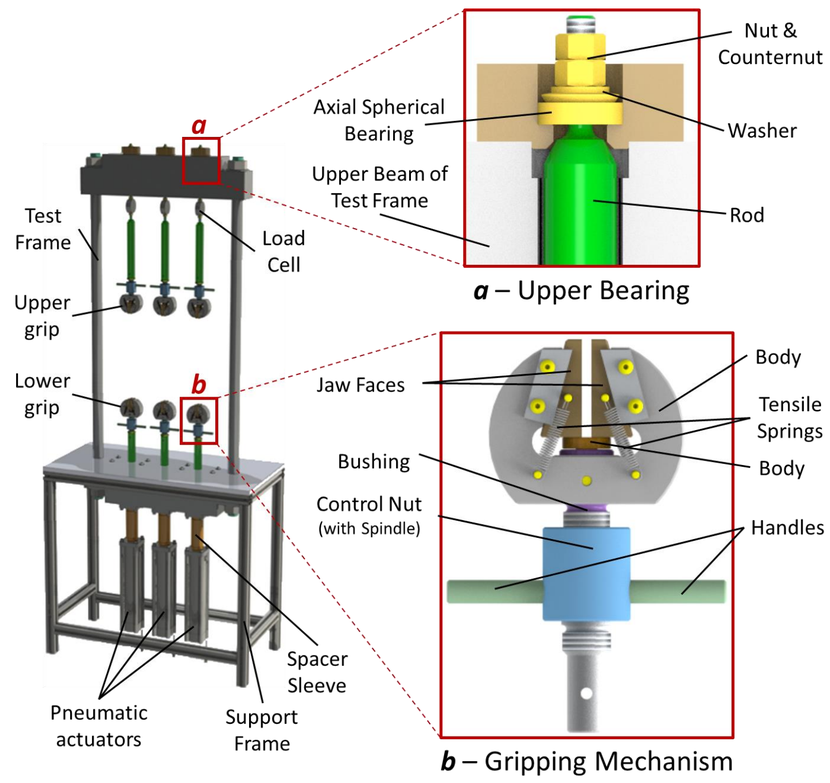

Figure 5 – Pneumatic creep testing system, highlighting the upper bearing (a) and the gripping mechanisms (b).

MULTI PROPERTY TESTING OF ADHESIVES

Finally, a system for testing multiple properties of adhesives using a single specimen configuration has been created, using a novel specimen design and step-loading actuator, able to reproduce four separate tests, shown in Figure 6 (traction, shear, fracture toughness in mode I and mode II).

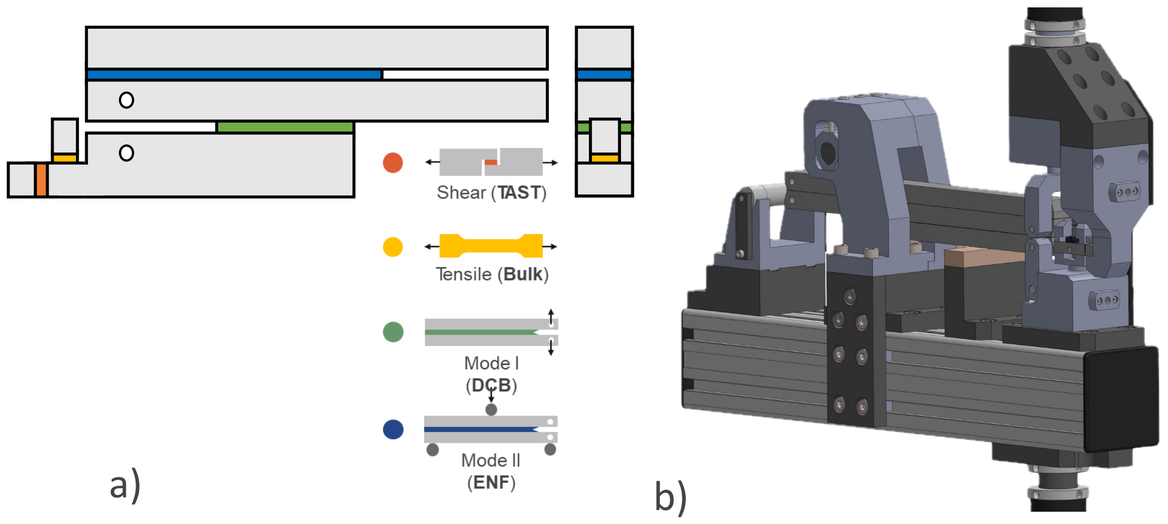

Figure 6 – a) Specimen design, highlighting the different loading modes and their location in the specimen and the step loader device

CONCLUSIONS

Experimental results obtained using these specialized devices have shown their ability to provide unique insights into the mechanical characteristics of these complex materials, ultimately enhancing design and reliability in advanced joining technologies and related fields.

ACKNOWLEDGEMENTS

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