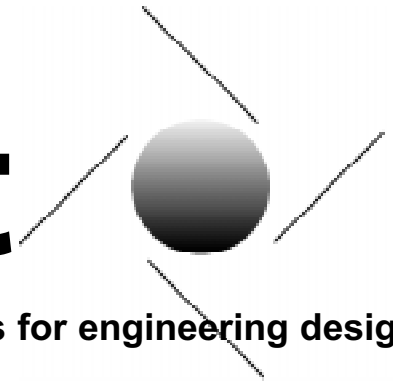# Datapoint

Reporting on developments in material properties for engineering design

Additions to test capabilities, staff, and partners program make for a notable year

One year has gone by since Datapoint Testing Services underwent an identity change to become DatapointLabs. It has been a year of exciting developments, both from a business and technical standpoint.

In response to customer requests, we expanded capability in the areas of creep, thermal analysis, dynamic mechanical analysis, moisture analysis and rheology.

To keep up with the demand, we increased our staff, adding people from varied backgrounds to provide you with the resources you needed.

We undertook development projects to obtain a better measure of properties such as biaxial extensional viscosity, no-flow temperature, viscous heating effects and the true yield point of polymers. There were advances in the development of hyperelastic models, particularly with the implementation of the Arruda-Boyce model. We are now implementing material models for crushable and resilient foams.

Finally, we developed close relationships with CAE software companies through our highly successful TestPaks Alliance Program. With eleven partners and 17 CAE programs in place, we are now the industry standard in properties for CAE.

Creep

Creep data has historically been very difficult to come by because of the excessive time needed to make these measurements. The non-linear nature of creep in plastics makes it necessary to perform tests at multiple stresses and temperatures. In 2000, we added 28 new creep frames. These instruments can span a wide range of loads, from 25 to 1200 N, and temperatures between 0 and 140°C, permitting development of detailed material models suitable for simulation. Measurements can be made in tension, compression and flexure.

Thermal Analysis

Thermal analysis involves the measurement of changes in material properties with temperature. DatapointLabs now has an complete line-up of thermal analysis instruments, including:
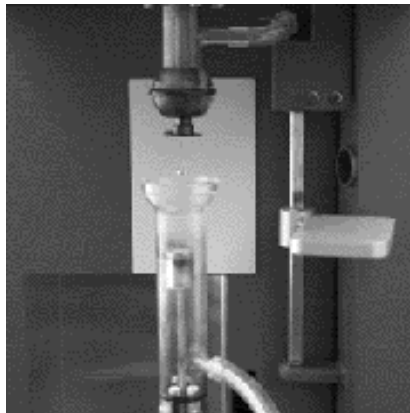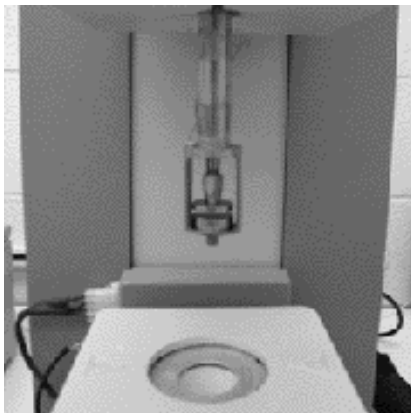
DSC: enthalpy and specific heat

TMA: linear and volumetric expansion

DMA: mechanical and visco-elastic properties including creep and stress relaxation.

Laser Flash: thermal diffusivity

TGA: weight loss due to evaporation or degradation.

Recent acquisitions include a Perkin Elmer DMA 7e (left) for creep, relaxation and visco-elastic characterizations and a TGA 7 (right), for degradation and other thermo-gravimetric studies.

FOCUS:

Novel techniques

DatapointLabs has seen a year of tremendous change and growth. We have a new name, but an unaltered focus on the product development community. In response to your need, we have extended our expertise to other materials. We remain the source for precision data for material modeling in the industry.

There is active discussion in the mold analysis area about the merits of the injection molding rheometer as compared to the capillary rheometer for viscosity measurement. We summarize findings in an article on Page 2.

Francois Barthelat's article below, on determination of the true yield point of plastics is a 'must read' for plastics structural analysts.

STRUCTURAL ANALYSIS

Measuring true yield point of plastics

Plastic deformations can cause irreversible damage in plastic parts well before the traditional yield point. In order to design good parts, it is vital to know at what point these deformations start to be significant.

A common mechanical test for plastics is the tensile test. A specimen is stretched at a constant speed, and the forces are recorded. A stress-strain curve can then be derived. Often the yield point–i.e., the point at which plastic deformation begins– is assumed to be at the maximum of the stress strain curve, when the force starts to decrease. This concept is known to be erroneous, as it has been shown that plastic flow starts before this point. This maximum on the curve actually corresponds to the point where the specimen becomes unstable and a neck forms.

The stress-strain curve can be decomposed into the following regions as suggested by Courtney [1], and illustrated in Fig.1:

INJECTION MOLDING CAE

Viscosity measurement techniques: Injection molding vs capillary rheometers

Viscosity data are among the most critical of all the material properties used in mold filling analysis. Consequently, it is not surprising that there has been controversy from the beginning about the best way to measure this important property. Capillary rheometers have been used historically for such measurements and these continue to provide greater than 90% of the viscosity data in the world today. Capillary rheometers were chosen over other techniques such as cone and plate rheology because they came closest to the kind of flow regime that is seen in injection molding.

Questions about suitability of capillary rheometer data have continued to exist, however. In an attempt to bring the data closer to the 'real life scenario', attempts were made to use an injection molding machine as a rheometer. The work of Tseng [1] reflects these early efforts. The authors found good comparability with capillary rheometer data for polypropylene. Polystyrene did not fare as well. Further, while they obtained data at high shear rates, the lack of low shear data compromised the development of a good viscosity model. These factors placed doubts about whether the injection molding technique had advantages over capillary rheometry.

Last year, Amano et al [2] published results from a novel injection molding rheometer, capable of very high shear rates. According to the authors, their primary reasons for using the instrument was to provide the right shear history and to have a ready source of melt for the very high shear rate measurements. This instrument again showed viscosity data comparable with capillary rheology. It is not in widespread use due to the high cost associated with the acquisition and use of the instrument.

More recently, Newman[3] showed comparison data between capillary rheology and the Moldflow injection molding rheometer. In this work, a number of materials were tested including filled and unfilled materials. The work showed good comparison between the instruments for most materials, showing once again that capillary viscosity data is indeed acceptable for injection molding simulation. There were two exceptions: 1) The injection molding rheometer data was lower than the capillary rheometer data for highly filled materials. This finding suggests that highly filled materials undergo greater breakage in the injection molding machine than they do in the capillary rheometer. The finding is explained by the shearing action of the screw which is not present in the piston driven capillary rheometer. Indeed, capillary rheology experiments at DatapointLabs using injection-molded specimens instead of pellets substantiate these findings for highly filled materials.

2) The injection molding rheometer shows higher viscosity than the capillary rheometer for thermally unstable materials. Nylon 4,6, some LCPs and other thermally unstable materials cannot withstand the long residence times seen in a capillary rheometer. They can undergo thermal degradation lowering the observed viscosity in the capillary rheometer.

Conclusions

Recent studies have shown that the capillary rheometer is suitable for the measurement of viscosity for injection molding CAE. It produces data comparable to the injection molding rheometer for almost all materials. It provides accurate low shear rate data which is vital for robust viscosity model construction. Accurate viscosity of highly filled materials can be obtained using the capillary rheometer provided the material used for the test has already been through an injection molding history.

The only exceptional cases are those of thermally unstable materials which are best characterized using injection molding rheometry.

In general, considering the high cost of injection molding rheology, little advantage is gained from its use for routine testing.

References

1. "Analysis of Rheological Data from an Automated-Injection Molding Capillary Rheometer", H. C. Tseng et al. SPE ANTEC Proceedings (1985), p. 716-719

2. "Pressure Dependent Viscosity of Polymer Melts", O. Amano, SPE ANTEC Proceedings, 2000, p. 885

3. "Technical Presentation" R. Newman, Moldflow User's Conference, 2000.

Hubert Lobo is President, DatapointLabs

Make your point.

We welcome your comments and invite submissions for future issues. Please call us at 1-888-DATA-4-CAE or visit our website: www.datapointlabs.com.

ANNOUNCEMENTS

DatapointLabs adds Sales/Mktg Director and technical staff

We are proud to announce the appointment of S. Scott Kumpf to the position of Director, Sales and Marketing. Scott has had a distinguished career as co-founder and former president of Ithaca Peripherals Inc., now Transact Technologies (NASDAQ: TACT), a manufacturer of transaction based printers and related products.

New technical personnel

Shan Wo has joined DatapointLabs as an Associate Engineer, working in the area of rheology, data analysis and support for our clients who perform CAE. Shan holds a B.S. degree in mechanical engineering from Cornell University. Shan's hobbies include rock climbing and caving.

We would like to introduce Brian Lussier and Jamie Antosh, who have joined our staff as Laboratory Technicians. Jamie is a regional BMX biking champion, winning second place in the New York State 2000 championship. Brian has specialized in the measurement of mechanical properties; Jamie, in PVT and creep.

Laboratory passes A2LA audit

DatapointLabs has once again passed its ISO Guide 25 audit through A2LA. (Here's what our A2LA assessor said about us this year: "It is rare to see a lab where the personnel have such an in-depth understanding of what they are doing".)

ISO Guide 25 is being replaced this year with ISO 17025, which aligns the requirements for laboratory accreditation with those of the ISO 9000 quality system series. DatapointLabs has set in place a plan to ensure our compliance with this new standard before the end of the year.

Download a copy of our scope of accreditation at our brand new web-site: www.datapointlabs.com/qualitysystem.asp

Upcoming events

NDES '01: Meet S. Scott Kumpf and Gary Timpe at the ANSYS booth, #7500. March 5 - 8, Chicago, IL.

SAE Week. March 5-8, Detroit, MI.**SAE Week.** March 5-8, Detroit, MI.

ANTEC'01: Meet Hubert Lobo and S. Scott Kumpf at Booth #222. May 7-10, Dallas, TX.

ABAQUS User's Conference. May 30-June 1, Maastricht, The Netherlands.

TestPaks Alliance Program grows

DatapointLabs' *TestPaks* Alliance Program has seen significant growth in the last year. Strong alliances have permitted the company to offer a very high level of connectivity in terms of properties and material models for the simulation programs of its alliance partners. 'Load & Go' capability has been added to *TestPaks* for a number of programs including ABAQUS, ANSYS, HyperExtrude LS-Dyna, MSC.MARC, T-Sim and B-Sim.

Each *TestPak* contains all the measurements required to characterize a material according to a particular material model. The resulting data is supplied both in a written report and electronically, ready to load into the CAE package.

TestPaks are available for:

Injection Molding
C-MOLD
Moldex
Moldflow
TMConcept
Extrusion/CFD
EXTRUD
FIDAP
Flow 2000
HyperExtrude
Polycad
Polyflow
Thermoforming & Blow-molding
Polyflow
T-SIM / B-SIM
Structural Analysis
ABAQUS
ANSYS
LS-Dyna
MSC.MARC
MSC.NASTRAN

Year 2000 in review

Continued from p. 1.

Rheology

Viscosity data are essential to the understanding of processing phenomena. To meet the needs of our research clients and TAP partners, we acquired capability to perform melt tensile tests using a Goettfert Rheotens, laser die swell measurements, slit die capability, viscous heating measurements, and a comprehensive collection of rheometry dies that permit the investigation of phenomena such as slip, entrance and exit effects and ultrahigh shear rate viscosity.

Biaxial extensional viscosity measurements are made using a lubricated squeezing technique, yielding input data for the KBKZ and G'Sell models.

True yield point determination of plastics

Continued from p. 1

• The first region corresponds to viscoelastic (recoverable) deformations.

• The second region starts at what we will now call the true yield point of the material. Plastic deformations become significant, through craze formation and/or homogeneous flow (shear bands).

• The third region corresponds to the formation of a neck in the specimen. The deformation is dominated by a massive homogeneous flow in the drawing regions.

The purpose of the true yield point test is to determine the location of the actual yield point on the stress-strain curve. The general idea of the procedure is to load the specimen, let it relax and measure the residual deformation after a fixed period of time. This procedure has been used before [2,3] with success on PMMA, PS and PC. Here, several samples were deformed up to different strain levels, and then unloaded and measured after a given recovery time. The residual strains could then be plotted as a function of the initially applied strains. When the initial deformation exceeded the plastic limit of the material, a dramatic increase of residual strain was observed. It has also been shown [2] that this limit is independent of the time allowed to the material to recover. This

property has been used in this present procedure to reduce the duration of the test.

The residual extensions after the first couple of cycles are low and linearly increasing (Figure 2). These residual deformations correspond to residual viscoelastic strains. For larger imposed extensions (around 4-5 mm), the residual deformations become much larger, as some plastic residual strains are also accumulated.

To measure the true yield point from the curve, an onset or an intercept type construction may be applied. Of these, the onset construction presents a more conservative picture of this phenomenon.

References

1. "Mechanical behavior of materials", Thomas H. Courtney, McGraw-Hill Series in Material Science and Engineering (1990).

2. "Components of non-elastic deformation in amorphous glassy polymers", R. Quinson, J. Perez, Journal of Material Science 31 (1996) p. 4387-4394

3. "Yield criteria for amorphous glassy polymers", R. Quinson, J. Perez, Journal of Material Science 32 (1997) p. 1371-1379

Francois Barthelat holds an MS in Mechanical Engineering. He is currently pursuing a Ph.D at the Univ. of Illinois.
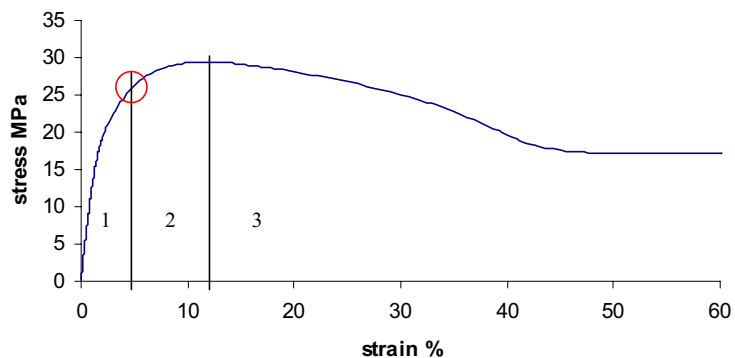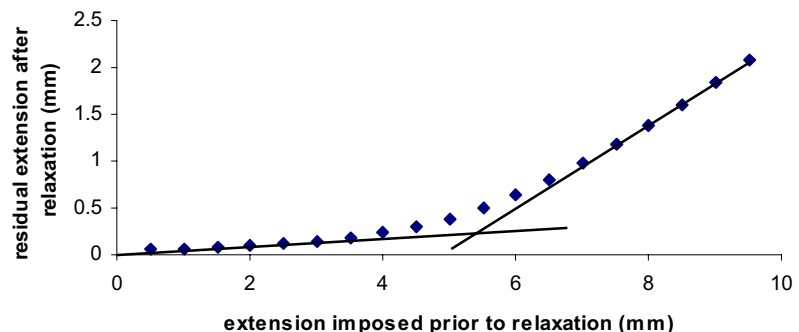

Figure 1. Stress strain curve showing the 3 different regions. The true yield point is circled.

Figure 2. Plot of residual extension vs initial applied extension.

DatapointLabs
95 Brown Rd #164
Ithaca, NY 14850

Datapoint

Reporting on developments in material properties for engineering design

Visit us at

ANTEC '01, Dallas

May 7-10, Booth# 222

datapointlabs.com