Image correlation analysis를 이용한 종이의 재료역학적 특성에 관한 연구 I

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1. Introduction

Paper is not really homogeneous, but at the macroscopic level it can be reasonably modeled as a homogeneous material. It is also known that paper behavior is strongly anisotropic. Paper can be modeled as an elastic material when the stress level is low and when the load duration is short. Paper can be also modeled as nonlinear, time-independent, when the stress level is high, but the load duration is short.

Paper mechanical behavior is often determined by a uniaxial tensile test with stress levels from zero to failure [1]. Tensile tests are done with a short-term loading (Tappi Standard T 494 om-88). Tensile tests show that paper behavior is very nonlinear when stress levels exceed the elastic range. Edgewise uniaxial compression tests have also been carried out. A variety of different test methods have been developed for measuring the compressive behavior [2]. Since the compression methods typically require lateral support of the specimen to prevent sample buckling, it is difficult to provide instrumentation to measure the pure value of strain and stress. It appears that the best method, from the point of view of obtaining pure compressive loading without need for restraining supports, is the cylinder test method discussed in detail by Uesaka [3]. The principal difficulty with this method arises from difficulties in maintaining a uniform field of stress and strain around the circumference of the sample.

Overall objective is to investigate how paper behaves when in-plane loading is high enough for non-linear effects. Strain components around the circular hole (especially along lines leading from the hole edge along the longitudinal and lateral axes), will be obtained using image correlation analysis at several load levels. In this study, only elastic behavior of paper material was investigated using image correlation analysis in elastic regime.

2. Material and method

2.1 Material

The paper material selected for this study is a machine made medium density paper that might be used as a greeting card paper. As such, this paper has a basis weight of 122 g/m^2, a density of approximately 676 kg/m^3, and exhibits a strongly anisotropic and nonlinear behavior.

2.2 Digital camcorder

A SONY DCR-TRV 730 digital video camera recorder was used to acquire digital images of the surfaces of undeformed and deformed paper specimens. The use of the digital camcorder is advantageous, since it eliminates the need for a frame grabber option that converts the camera signal from analog to digital form for computer processing. In practice, the digitizing process can cause the gray-value at any pixel to vary from image to image as the frame grabber converts the camera signal from analog to digital form.

2.3 Image correlation software

VIC_2D (Beta 3.0.3 version) image acquisition software developed at the University of South Carolina was used. The digital camcorder was set up approximately 152.4 cm from the specimen in order to compensate for any "out of plane motion" of the specimen. This gave a field of view of approximately 4 square inches at the maximum zoom-in of the digital camcorder. A standard photographic tripod was used for a camera mount in this research. Special care was taken to ensure that the image plane of the camera was exactly parallel with the test specimen surface.

2.4 Testing machine

All experiments were carried out using a 50kN capacity Instron Model 4204 electromechanical universal testing machine. This machine is designed for testing materials in tension, compression, shear, and flexure from 0.1 N to 50 kN. The test machine is composed of loading frame components and control console components. The Model 4204 incorporates a microprocessor controlled, closed-loop, and servo drive system with an optical encoder feedback assuring accurate and constant crosshead speed. Thus speeds are independent of the voltage, frequency, or applied force (with rating).

3. Results and Discussions

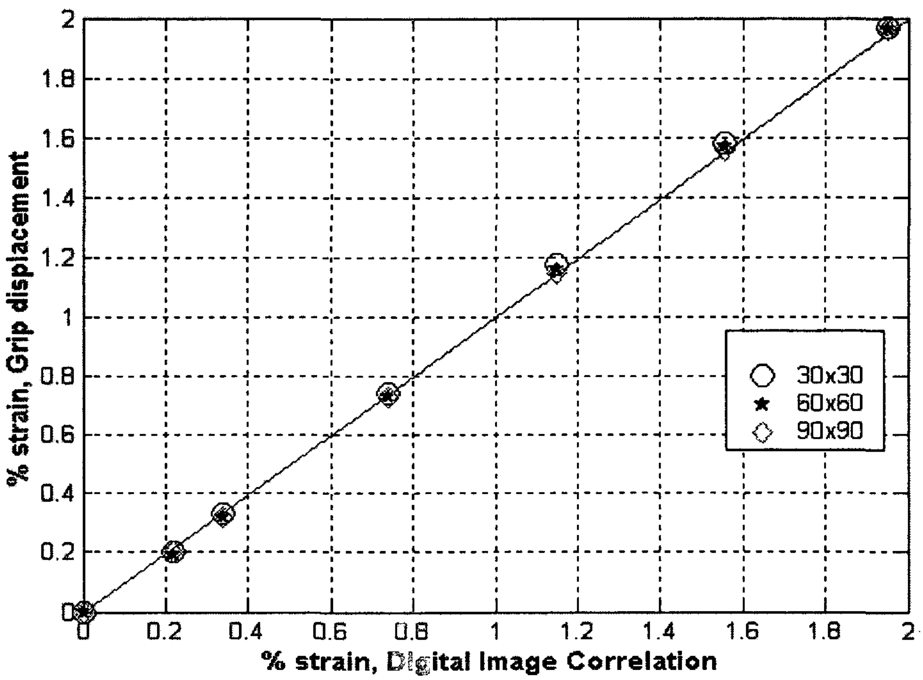

Figure 1. Comparison of % strain for MD test specimen. Displacements measured at center of the specimen. marked hexagonal.

The result of verification test for image correlation analysis is shown in Fig. 1. Fig. 1 shows the direct comparison of the strains of the machine direction (MD) specimen calculated from the grip displacement and the strains of the MD specimen experimentally determined from digital image correlation at several load levels. The maximum difference between the measurements is less than 0.029.

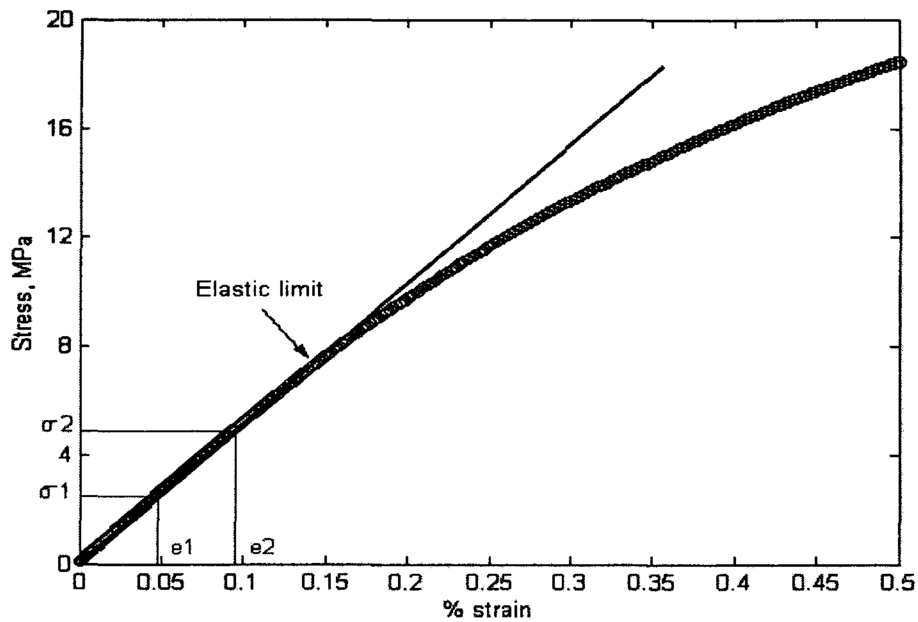

Figure 2. Illustration of the procedure for the determination of the modulus of elasticity using the initial slope

Table 1. Young's moduli of MD paper specimens.

Specimen No.	Initial slope (Gpa)	Polynomial regression analyses (Gpa)		
		6^{th} degree	7^{th} degree	8^{th} degree
M3_9S7	5.57	5.85	5.48	5.33
M3_9S8	5.37	5.70	5.35	5.15
M3_9S9	5.45	5.74	5.38	5.12
M3_9S10	5.45	5.58	5.23	5.06
M3_9S11	5.28	5.68	5.27	4.95

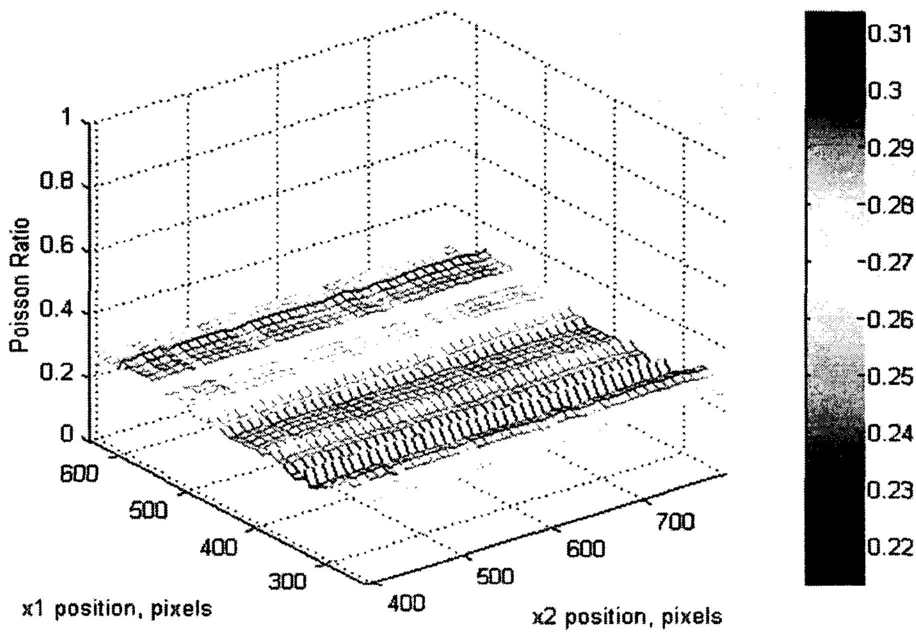

Figure 3. Contour plot of the full-field Poisson ratio of the CD specimen

Table 2 In-plane shear modulus of the paper specimen

Specimen	Subset size		
	30 30	60 60	90 90
A3_9S11	1.03	1.13	1.03
A3_9S12	1.12	1.12	1.12
A3_9S13	1.07	1.12	1.07
A3_9S14	1.07	1.13	1.12
A3_9S15	1.07	1.03	1.07
Average	1.069	1.103	1.079
Standard deviation	0.030	0.044	0.038

4. Conclusion

Elastic constants (Young's modulus, poisson ratio, shear modulus for both MD and CD specimens) are successfully determined using image correlation analysis.

5. References

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