ROI overlaps of 80 %.

3.2.4 Model Validation Using a Commercially Available Phantom

Utilizing a CIRS Elasticity QA Phantom model 049, a subset of the results obtained from the finite-element simulations and numerical characterizations were compared against their physical phantom equivalents. The phantom mimics acoustically homogeneous soft tissue with embedded lesions which vary in depth, size, and mechanical stiffness. Nominal mechanical properties of the phantom as given by manufacturer specifications are summarized in Table 3.2. Pre- and post- compression b-mode ultrasound images were obtained of lesions in the phantom and the resulting strain ratios for each lesion were compared to the simulated strain ratios for the specific combination of parameters. Specifically, lesions at a depth of 3.5 cm, a diameter of 2.0 cm, and with true stiffness ratios of 0.56, 1.80, and 3.20 were examined. Surface indentation was performed manually with the transducer indenting approximately 0.5 cm (6.25 %) at the surface. The detailed experimental protocol that was followed for these validations is given in Section C.1 in Appendix C.

Table 3.2: CIRS phantom model mechanical properties

Property	Symbol	Value	Units
Nominal basal elastic modulus	E_{tissue}	25	kPa
Lesion elastic modulus	E_{lesion}	8, 14, 45, 80	kPa
Speed of sound	c_0	1540	$\mathrm{m\,s^{-1}}$
Acoustic attenuation	α	0.5	$\mathrm{dB\,cm^{-1}\,MHz^{-1}}$
Lesion diameter	$\varnothing S$	10 and 20	mm
Lesion depth	d	15 and 35	mm

3.3 Results and Discussion

Following the procedure outlined in Section 3.2, finite-element models of ultrasonic b-mode image formation and tissue deformation were synthesized. The results of these models were then fed into the local strain estimation algorithm described in Section 3.2.3. The resulting numerical characterizations of the relationship between measured and true strain ratios in the simulated tissue and their dependence on the various lesion parameters given in Table 3.1 were examined. Finally, the local strain estimation algorithm was carried out on a physical phantom and compared against a subset of the simulated cases.

3.3.1 Finite Element Models of Ultrasound and Deformation

Sample images generated using both the acoustic and deformation finite-element models are given in Figs. 3.4c – 3.4d. In Fig. 3.4c, a sample generated b-mode ultrasound scan is given. Fig. 3.4a shows the lateral displacement field generated by the deformation finite-element model while Fig. 3.4b shows the axial displacement field. The entire top surface of the model has been displaced axially by 6.25 mm (5 %), which caused deformation of both the soft tissue and embedded lesion within. Since the lesion was modelled as being 3.2 times stiffer than the surrounding tissue, the lesion underwent less strain which consequently resulted in the lesser displacement depicted. Fig. 3.4d shows the resultant b-mode image generated by applying the displacement field given in Figs. 3.4a and 3.4b to the tissue and embedded scattering centres used to create Fig. 3.4c. What results is a locally scaled and translated version of

Fig. 3.4c that corresponds to indenting the surface of the skin above a stiff lesion. The large anechoic region located at the bottom of the domain is tissue that was not modelled in the pre-compression image as it was outside of the original domain. This area represents the region of tissue that is undetectable with the strain-estimation algorithm given in Section 3.2.3 as the information contained there is only available in one of the two input images and so is considered incomplete data. Sample source code for generating the b-mode images seen in Fig. 3.4 is given in listing B.1 in Appendix B.