

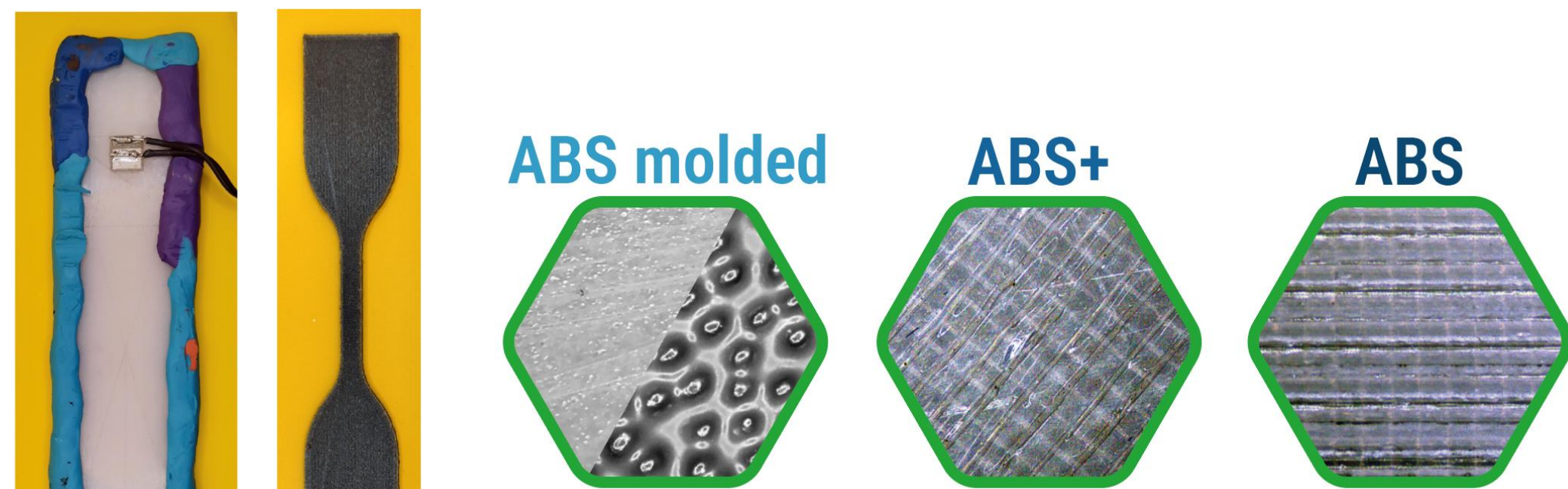
## TWO-STAGE METHOD FOR IDENTIFICATION OF ELASTIC MODULI IN FDM-PRINTED POLYMERS USING GUIDED WAVE DISPERSION

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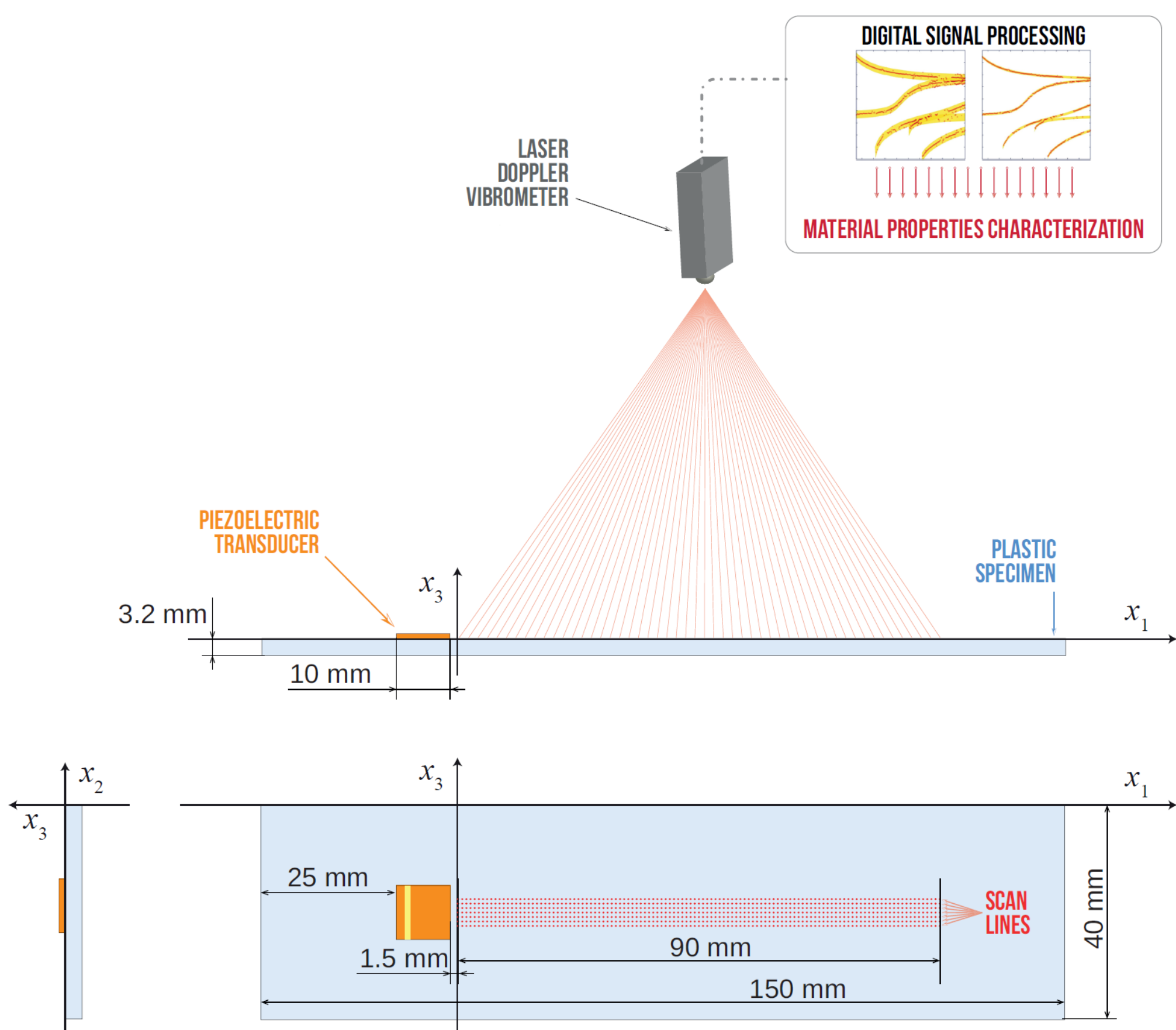
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### INTRODUCTION & AIM

Additive manufacturing is increasingly adopted in engineering practice for producing geometrically complex structures with high precision. However, predicting the mechanical behavior of polymer-based components remains challenging due to insufficiently accurate data on their elastic moduli, particularly under dynamic loading. Classical experimental mechanics methods primarily based on quasi-static tests are often unsuitable for accurately characterizing dynamic elastic properties. This study proposes a two-stage algorithm to solve an inverse coefficient problem for determining the elastic moduli of specimens fabricated from polymeric materials via fused deposition modeling (FDM), leveraging experimental dispersion characteristics of guided elastic waves.



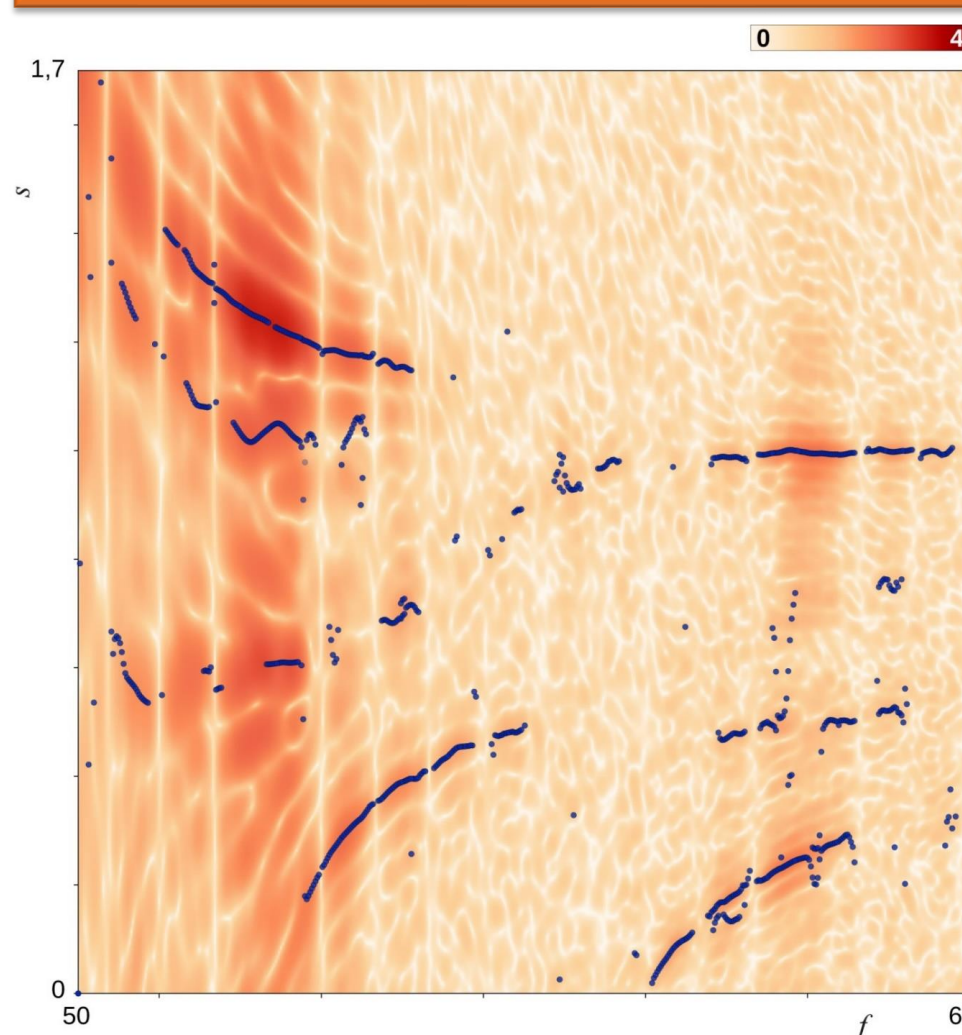
### METHOD



Surface out-of-plane velocities, measured using laser Doppler vibrometry, are processed with the matrix pencil method to extract dispersion curves. In the first stage, a fast method based on the Fourier transform of the waveguide's Green's matrix provides an initial approximation of the elastic moduli. This estimate is refined in the second stage by minimizing the discrepancy between theoretical and experimental dispersion relations; the objective function selectively weights experimental points in proximity to the current theoretical prediction, which improves convergence robustness.

### RESULTS & DISCUSSION

#### Matrix pencil method



Experimental validation on FDM-printed specimens shows strong correlation between the identified Young's modulus and reference values obtained from standard uniaxial tensile tests, confirming the method's applicability for non-destructive dynamic characterization of additively manufactured polymers.

#### Post-processing algorithm:

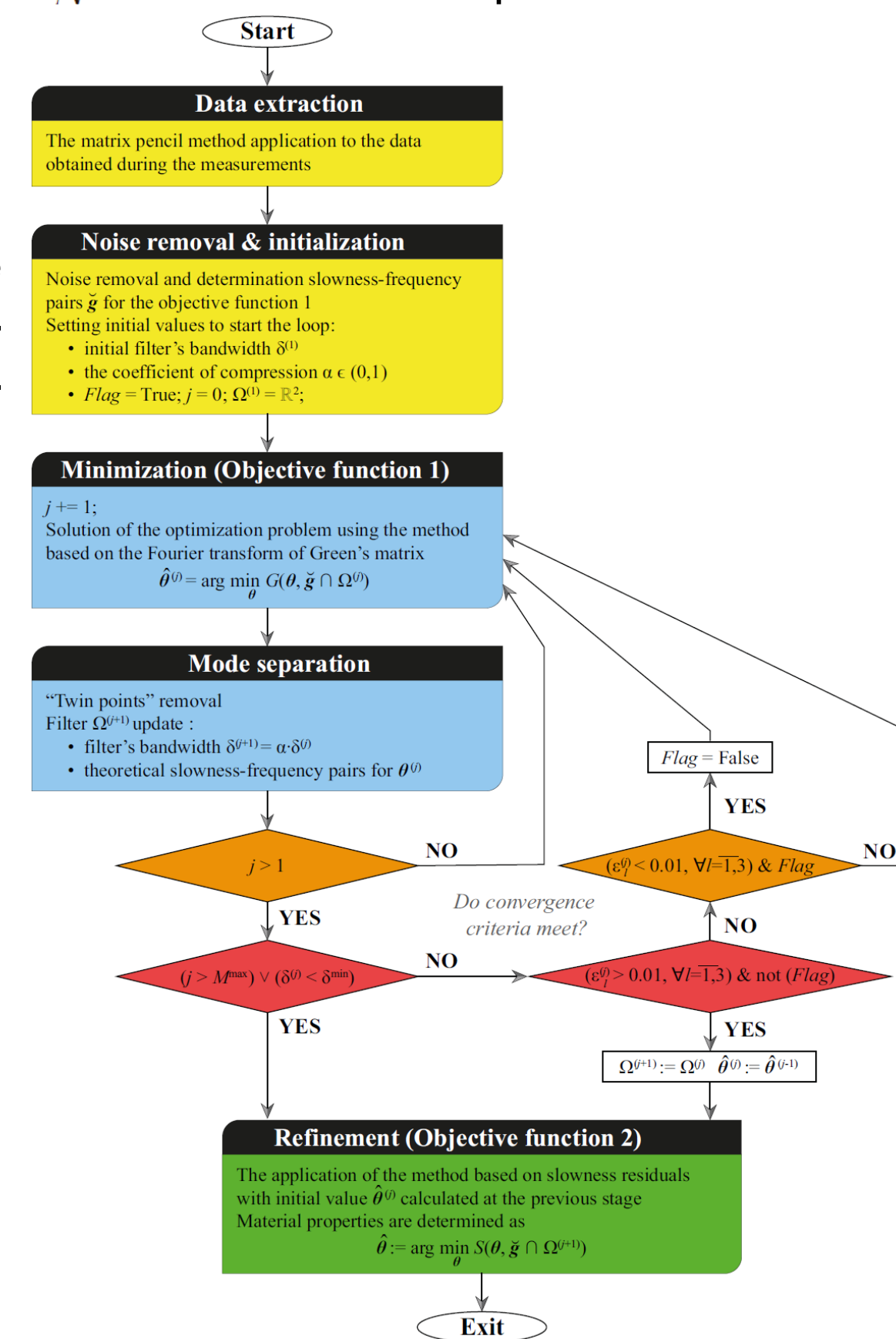
1. Scanning along  $N$  lines for each line separately
2. Processing scan data
3. Inverse coefficient problem
4. Removing outliers across multiple estimates
5. Determination of 4 basic core metrics in total (across all lines)
6. Removing lines as outlier
7. Determination of 4 basic core metrics (all data that was not removed)

#### Multi-Stage Algorithm for material properties Characterization

##### Loss function

$$F(\theta, \check{\theta}) = \frac{1}{N} \sum_{n=1}^{N_f} \sum_{k \in \mathcal{P}_n} \|\check{s}_k(\check{\theta}, f_n) - s_k(\theta, f_n)\|$$

$\theta$  – model vector of parameters,  
 $\check{\theta}$  – vector of parameter estimates,  
 $s_k$  – theoretical slowness,  
 $\check{s}_k$  – experimental slowness,  
 $k$  – index of experimentally found data  $\mathcal{P}_n = \{k | \exists \check{s}_k(\check{\theta}, f_n), n = \overline{1, N_f}\}$ ,  
for a certain frequency  $f_n$ ,  
 $N_f$  – total number of frequencies,  
 $N$  – total number of pairs.



### CONCLUSION

	ABS molded	ABS+	ABS
<b>Ultrasonic</b>			
Density, kg/m <sup>3</sup>	1000.5	1017.4	1012.5
Poisson's ratio	0.400	0.372	0.336
Young's modulus, GPa	2.001	2.301	2.187
<b>Tensile</b>			
Young's modulus, GPa	1.65	2.133	2.105

### REFERENCES & FUNDING

Golub M.V., Doroshenko O.V., Arsenov M.A., Eremin A.A., Gu Y., Bareiko I.A. *Computation*, 2022, Vol. 10(6), 93.

The research is carried out with the financial support of the Kuban Science Foundation, Ortho-Market LLC (Project Num. NTIP-25.1/8).