Effects of a fracture on ultrasonic wave velocity and attenuation of a homogeneous medium

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Outline

- Introduction
- Problem statement and objective
- Background
- Methodology and materials
- Results
- Conclusions

Introduction

https://photosalmagundi.wordpress.com

- Ultrasonic pulse velocity (UPV) method (*ASTM reference*) is used for damage detection

- Velocity is not sensitive

- Wave attenuation is sensitive

Problem statement and objective

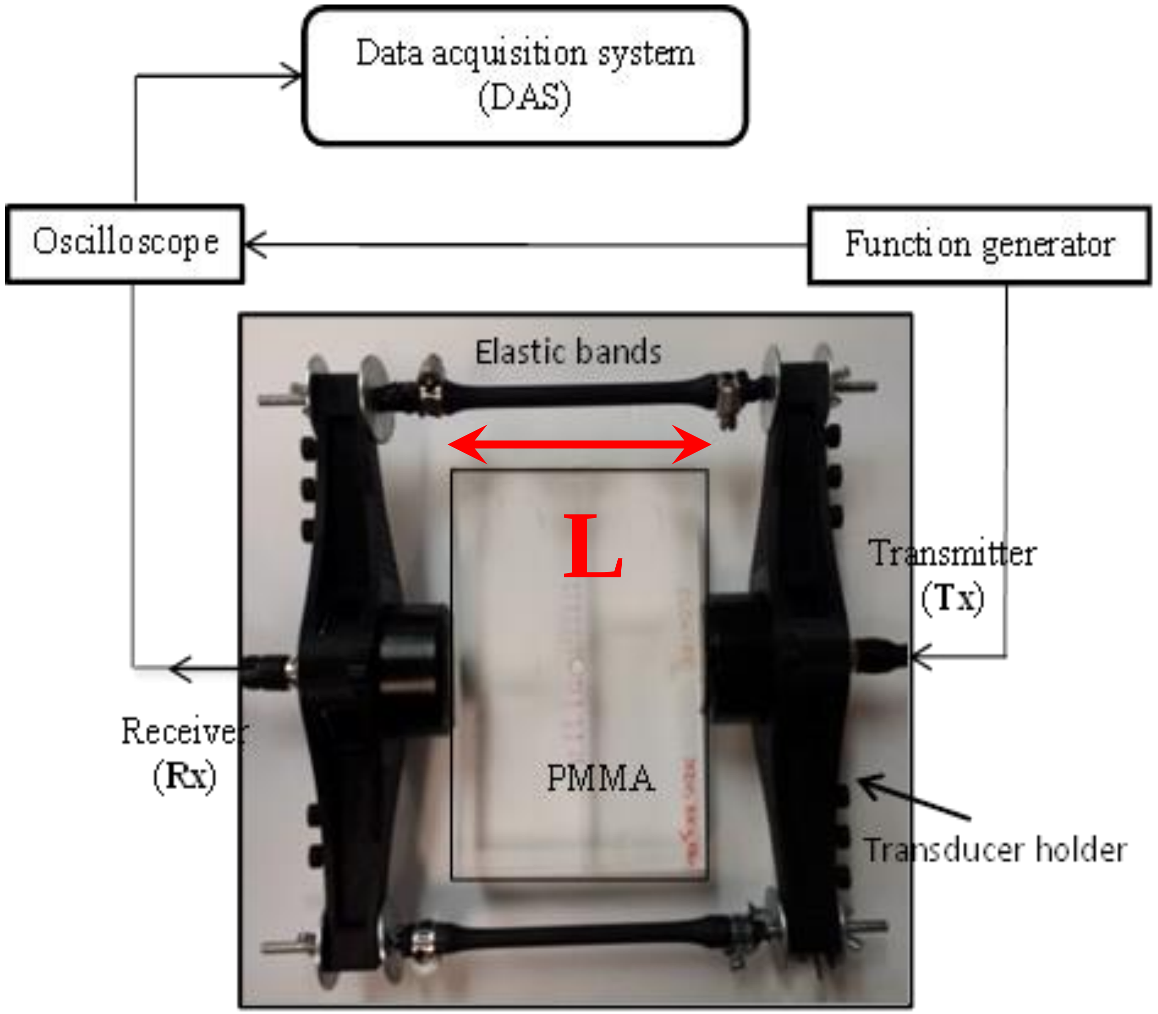
- Problem statement
  - Damage detection is performed using wave velocity alone.

- Objective
  - Detection of damage using wave velocity **and attenuation** in UPV testing.

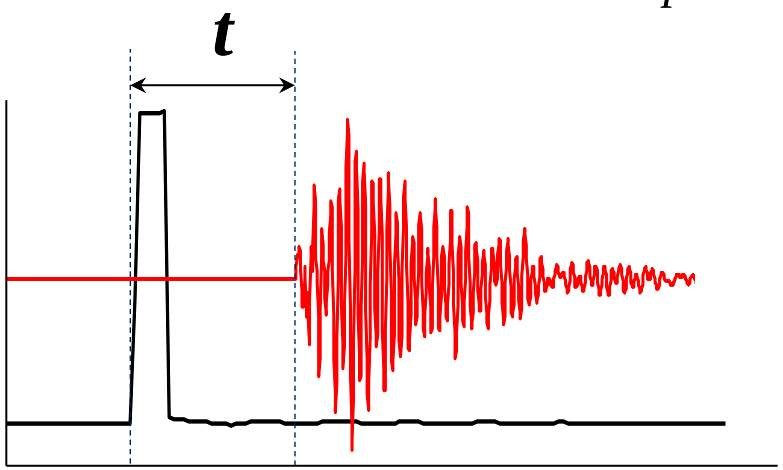
Tasks to achieve the objectives

- ❖ Assessment of fracture propagation in a homogenous material (PMMA) using UPV method.
- ❖ Correlation of fracture length with changes in wave parameters (velocity and attenuation).

UPV method

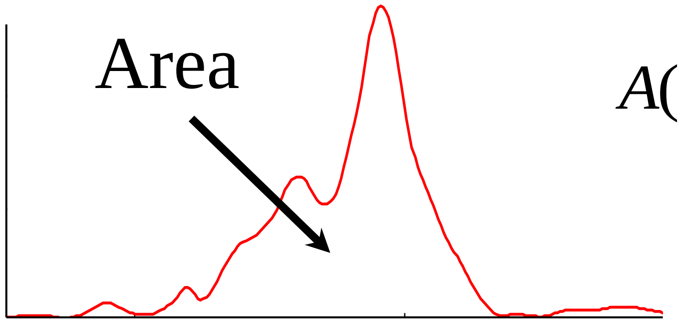


Wave velocity (V_p)



$$V_p = \frac{L}{t}$$

Attenuation (A)



$$A(\omega, x) = A_o(\omega) e^{-\alpha(\omega)x}$$

Methodology

PMMA Specimens (19)

Case I (15)
Intact, hole and fractured

PMMA Annealed (15)
- Thickness = 25.4 mm (8)
- Thickness = 12.7 mm (7)

Case II (4)
Uniaxial compression test

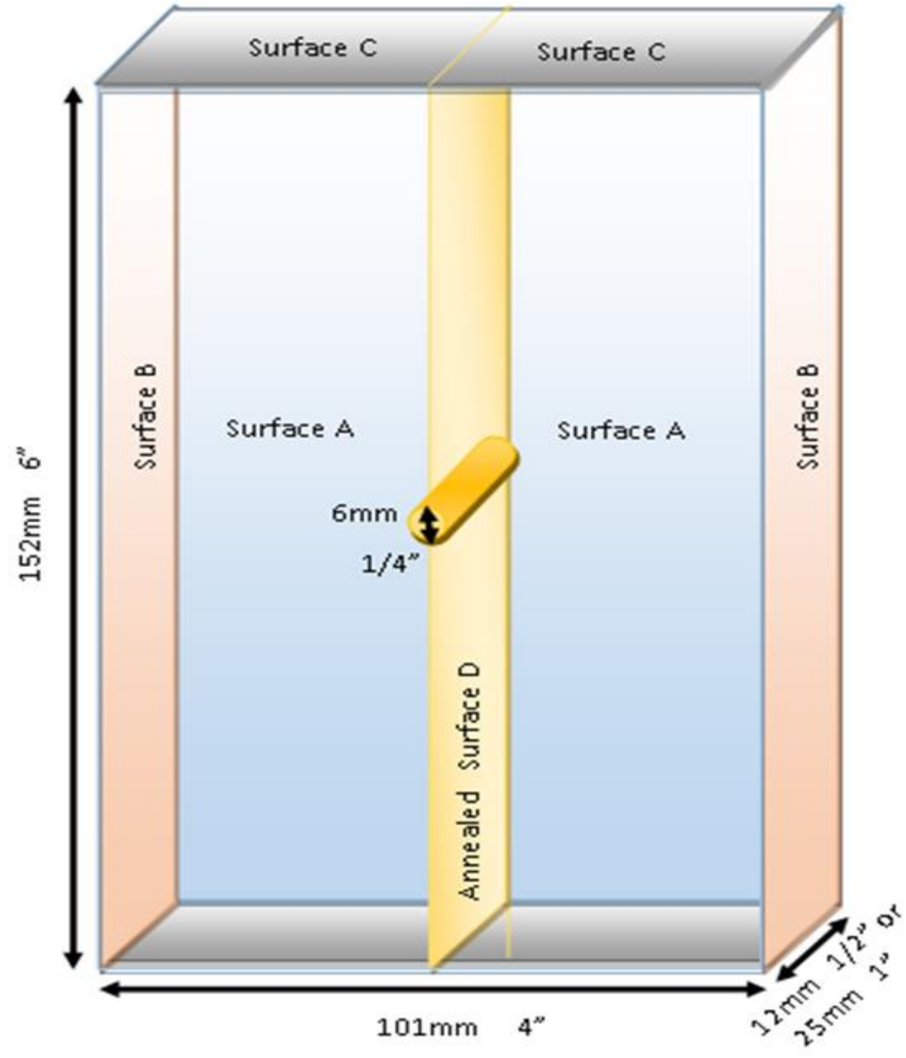
PMMA Solid (2) & Annealed (2)
Thickness = 25.4 mm

Comparison of velocity and attenuation

Materials – testing scheme

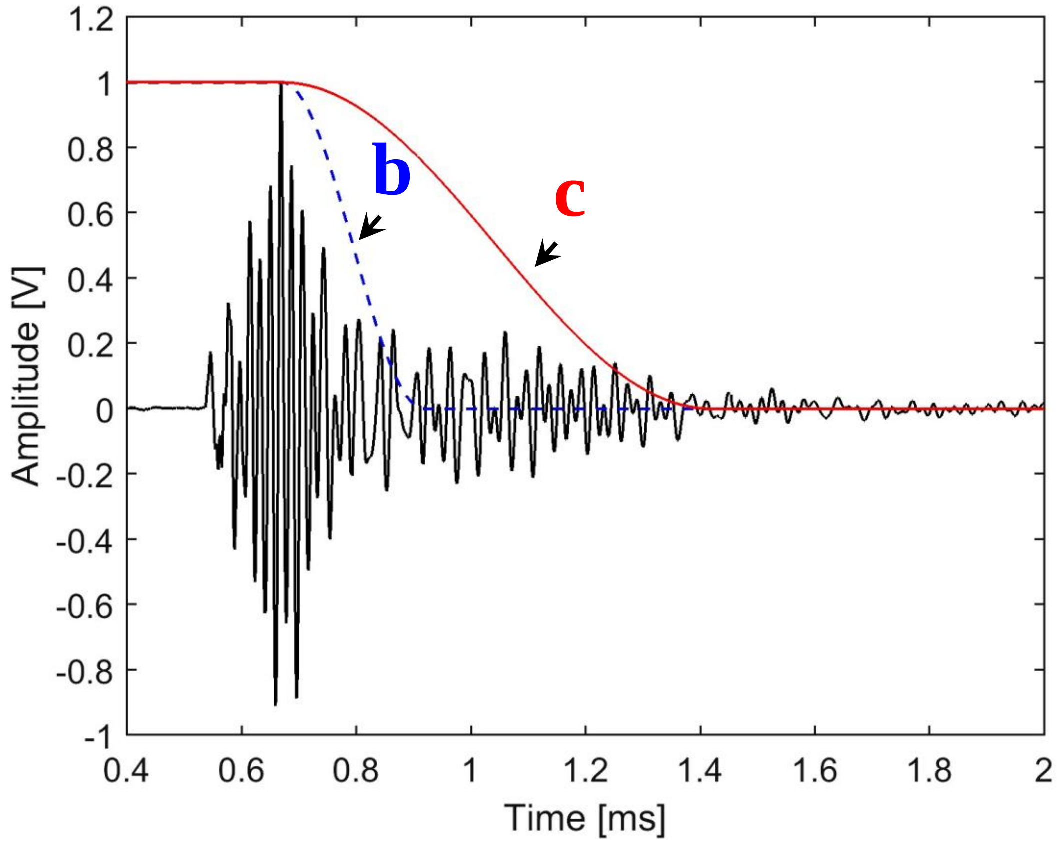
PMMA specimens

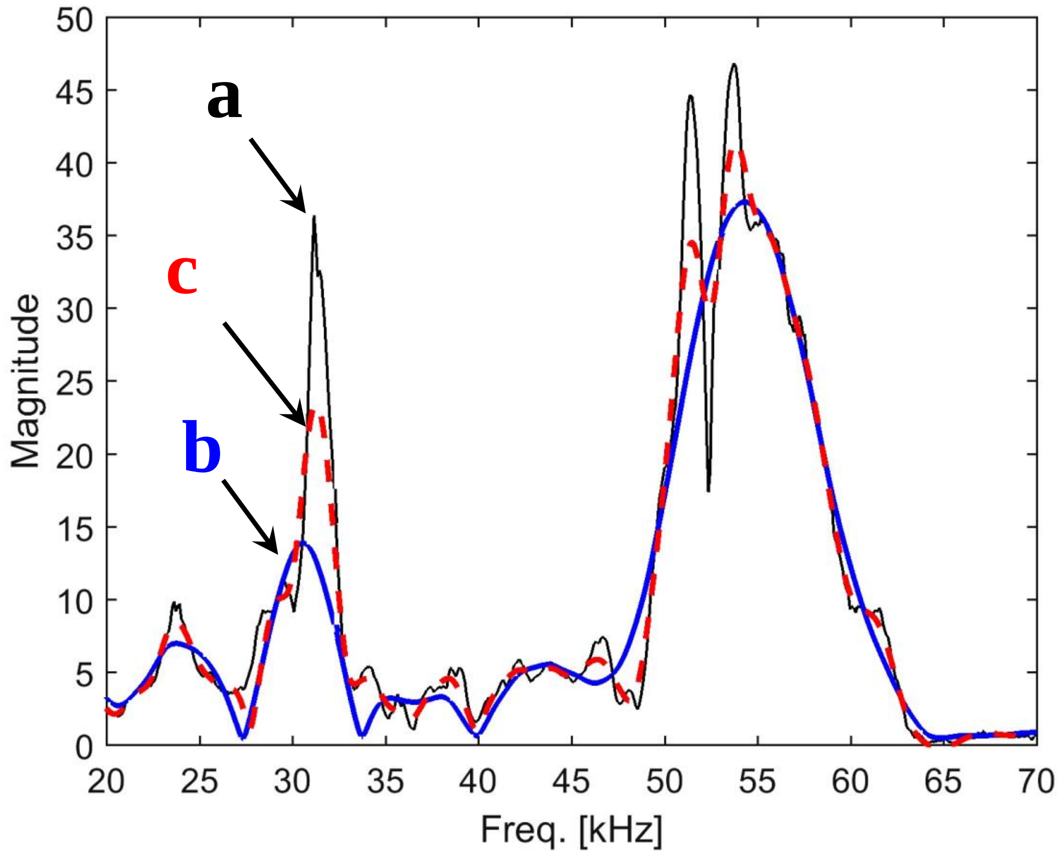
Specimen #	Type	Thick. (mm)	Fabrication conditions of PMMA: Temperature (C⁰)	Fabrication conditions of PMMA: Pressure (KPa)
PA-(1-4)	Annealed	25.4	150	24
PA-(5-8)	Annealed	25.4	150	12
PA-(9-10)	Annealed	25.4	150	6
PA-(11-13)	Annealed	12.7	150	12
PA-(14-16)	Annealed	12.7	177	6
PA-17	Annealed	12.7	177	12
PS-(1-2)	Solid	25.4	-	-



Heating and pressurizing time: 6 hours

Signal windowing

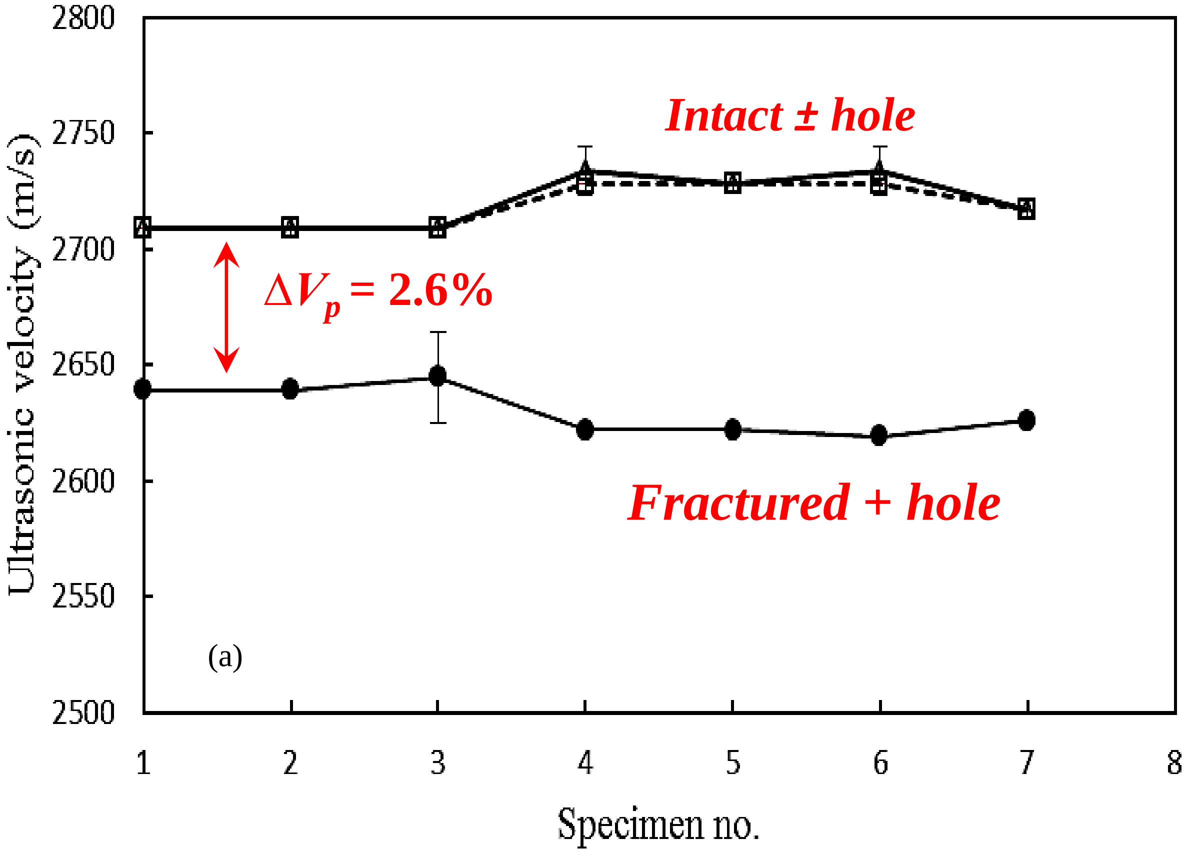




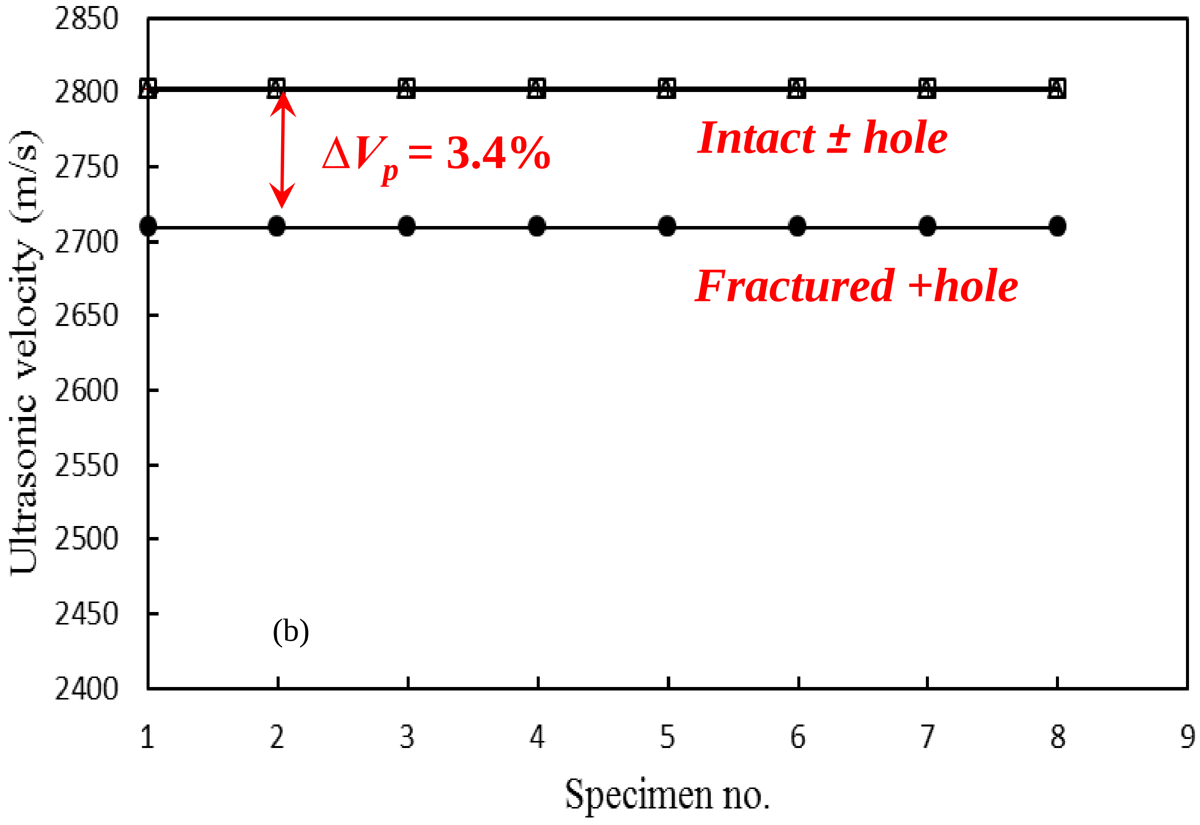
a – original signal b – window factor (0.1) c – window factor (0.3)

Change in V_p

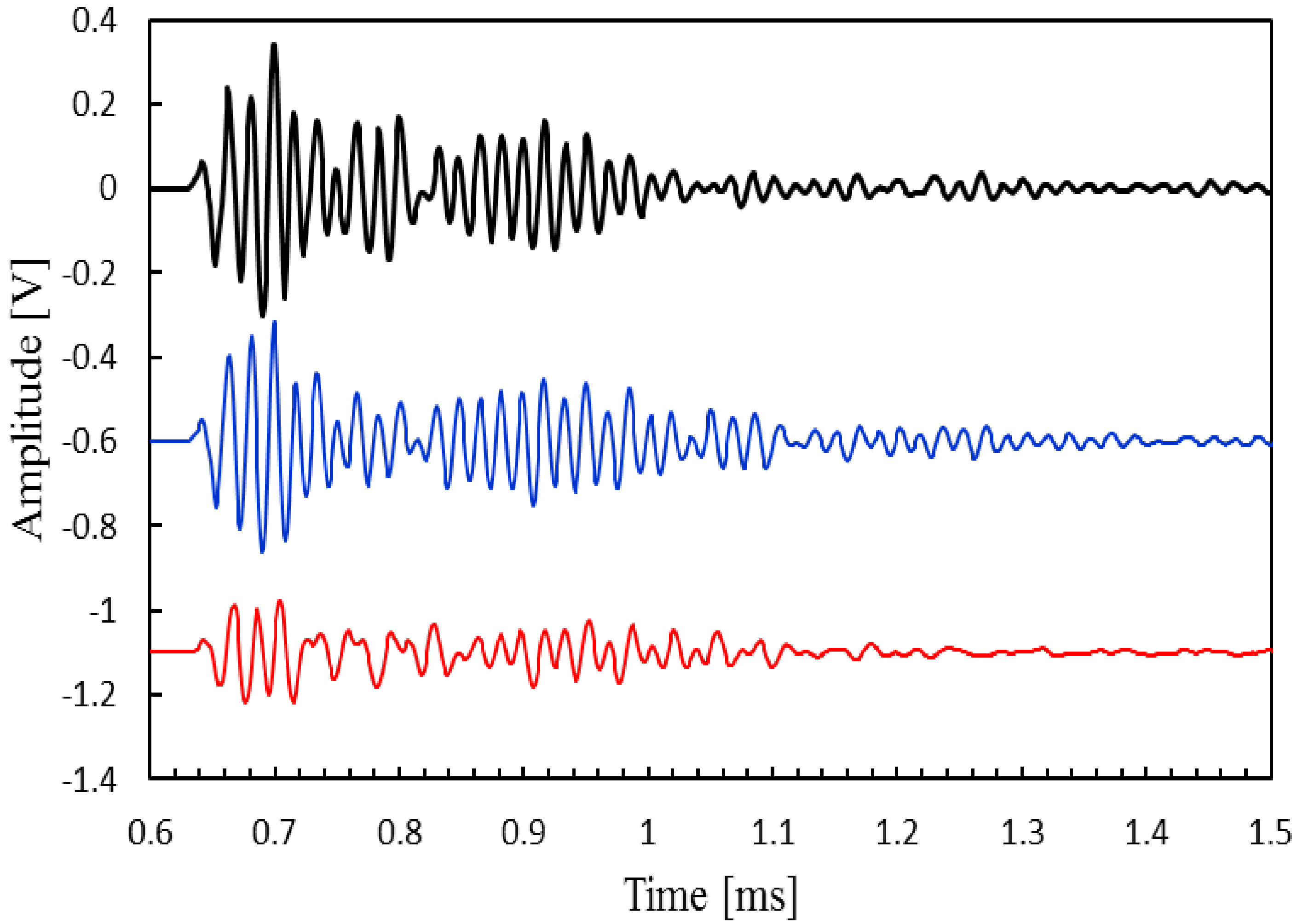
d = 12.7 mm



d = 25.4 mm



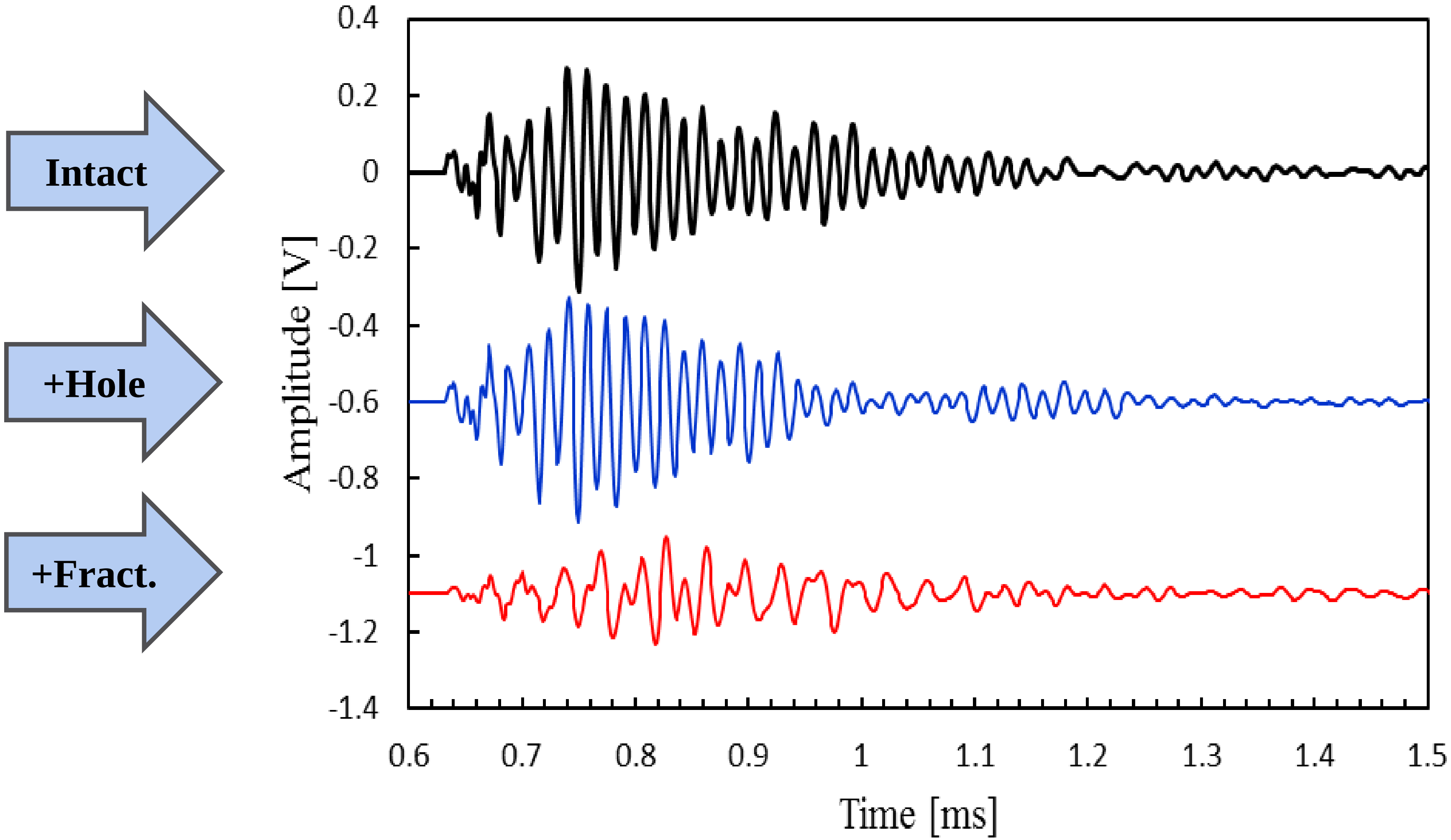
Thickness = 12.7 mm



	V_p%	% A
Intact	**100%**	**100%**
+Hole	**100%**	**87%**
+Fract.	**97.4%**	**38%**

Case – I - Comparison of V_p and A

Thickness = 25.4 mm

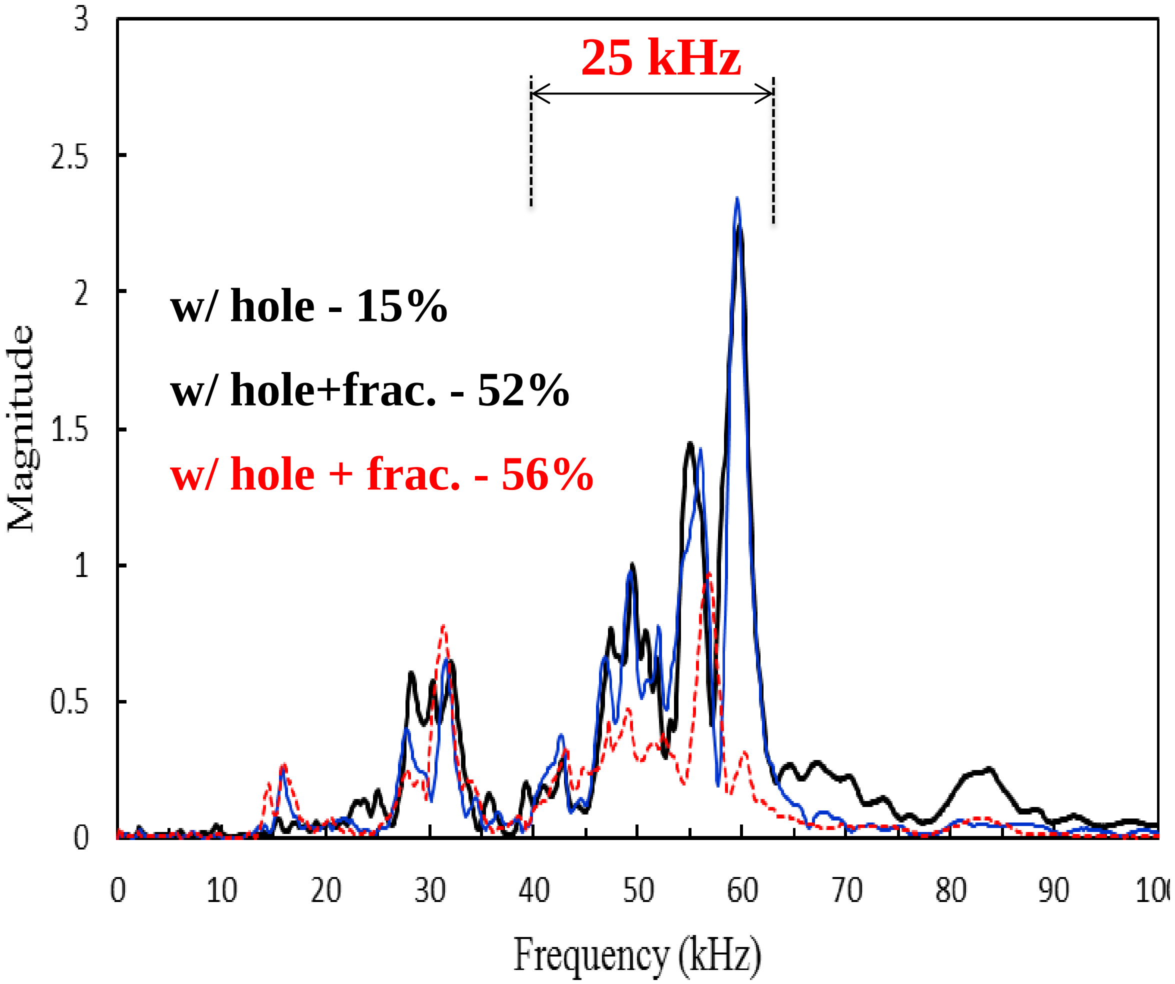


	V_p%	%A
Intact	100%	100%
+Hole	100%	87%
+Fract.	96.6%	55%

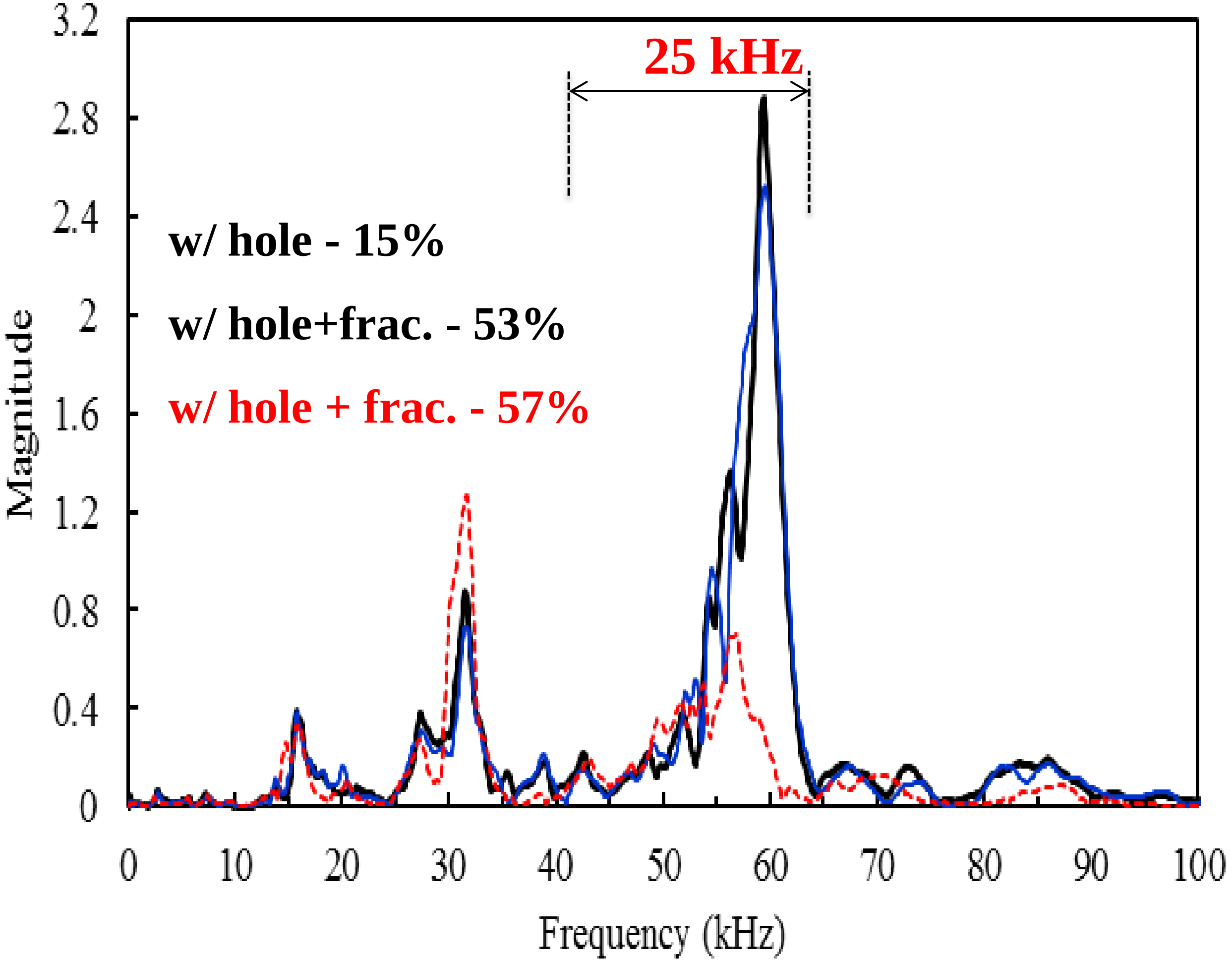
Case - I – Frequency spectra

% difference in spectrum area

Thickness = 12.7 mm



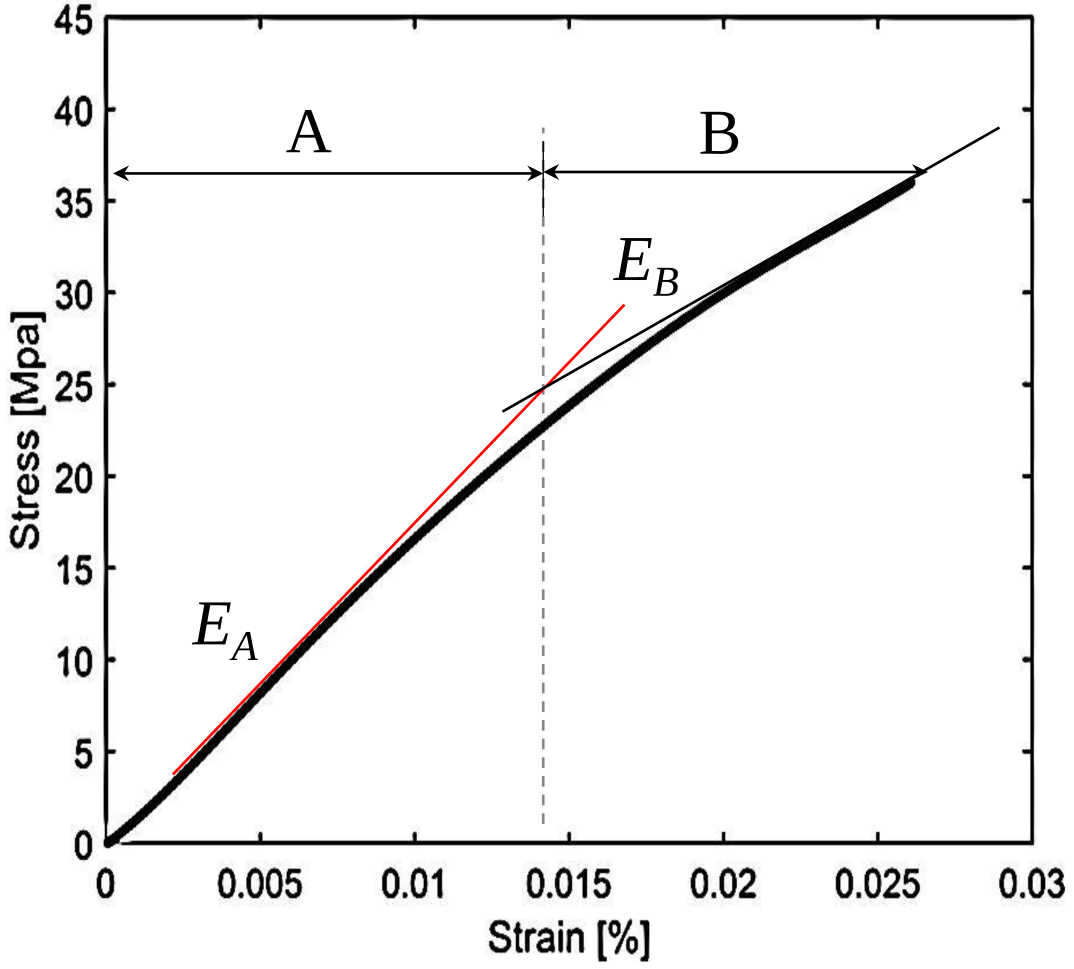
Thickness = 25.4 mm



Intact **+Hole** **+Fracture**

Case – II – Elastic moduli

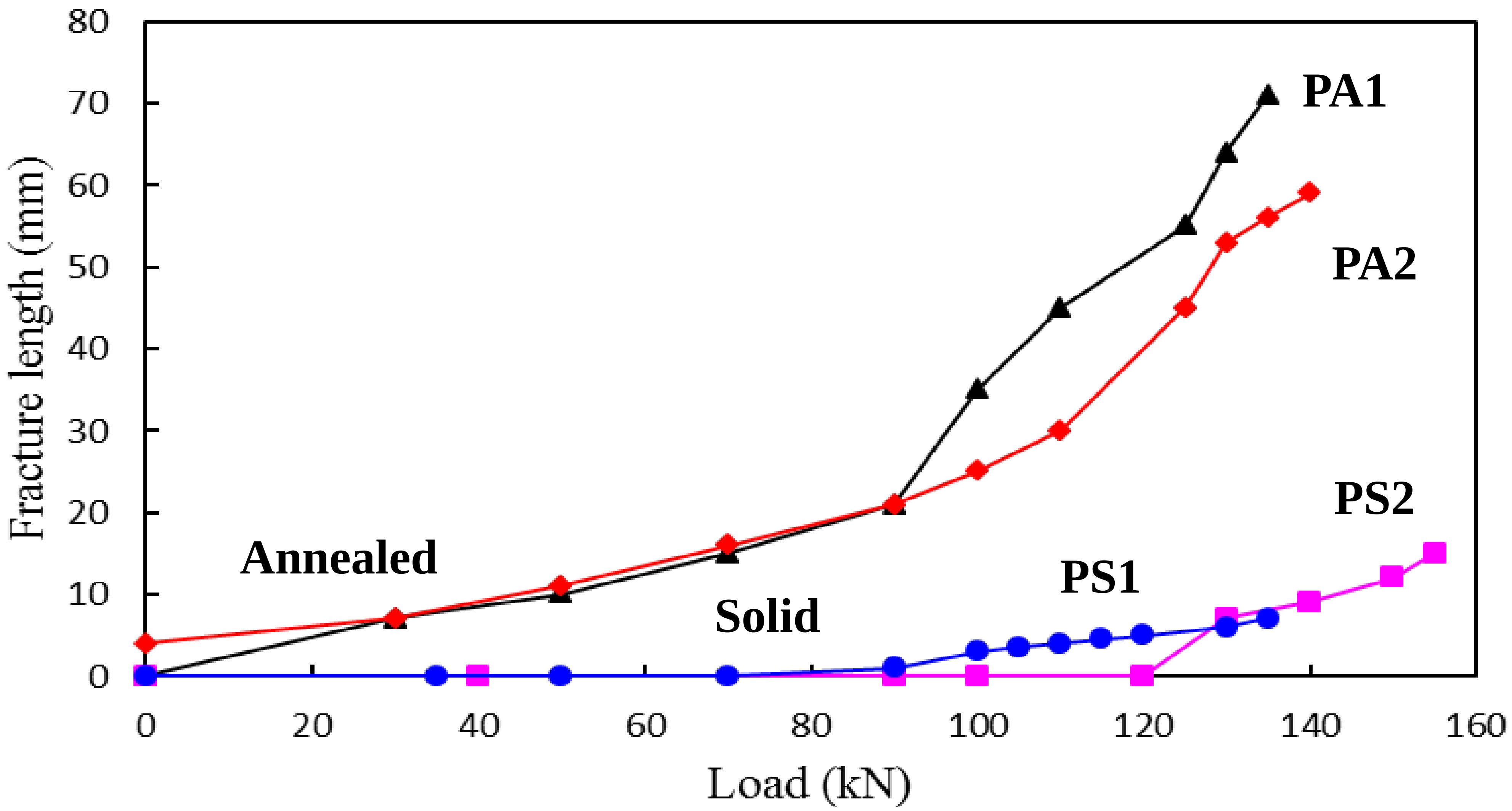
Stress-strain from compression test



	PA-1	PA-2	PS-1	PS-2
E_A[GPa]	1.69	1.85	1.87	1.80
E_B[GPa]	0.86	1.07	1.05	0.93
E_d[GPa]	4.96	4.96	4.66	4.66

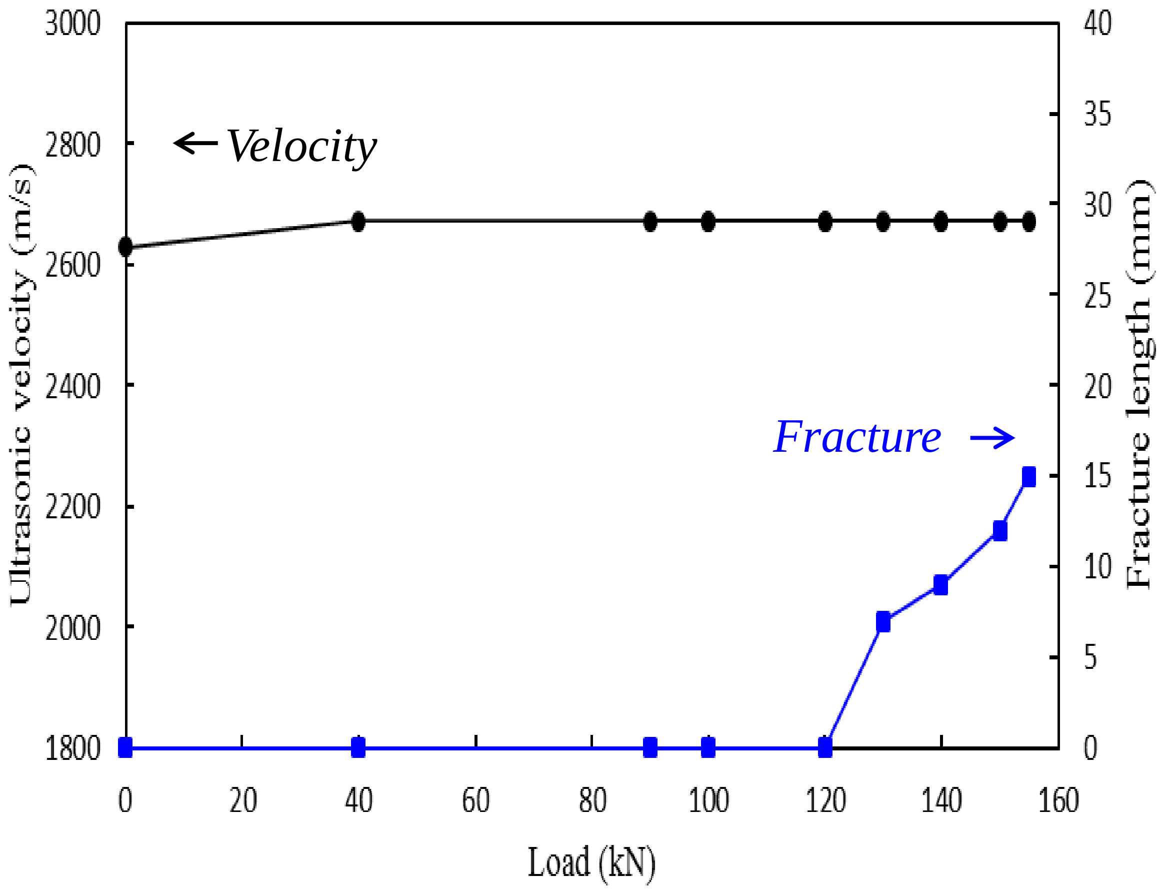
E_A - initial
E_B – final
E_d – dynamic using wave paramters

Case – II - Fracture growth

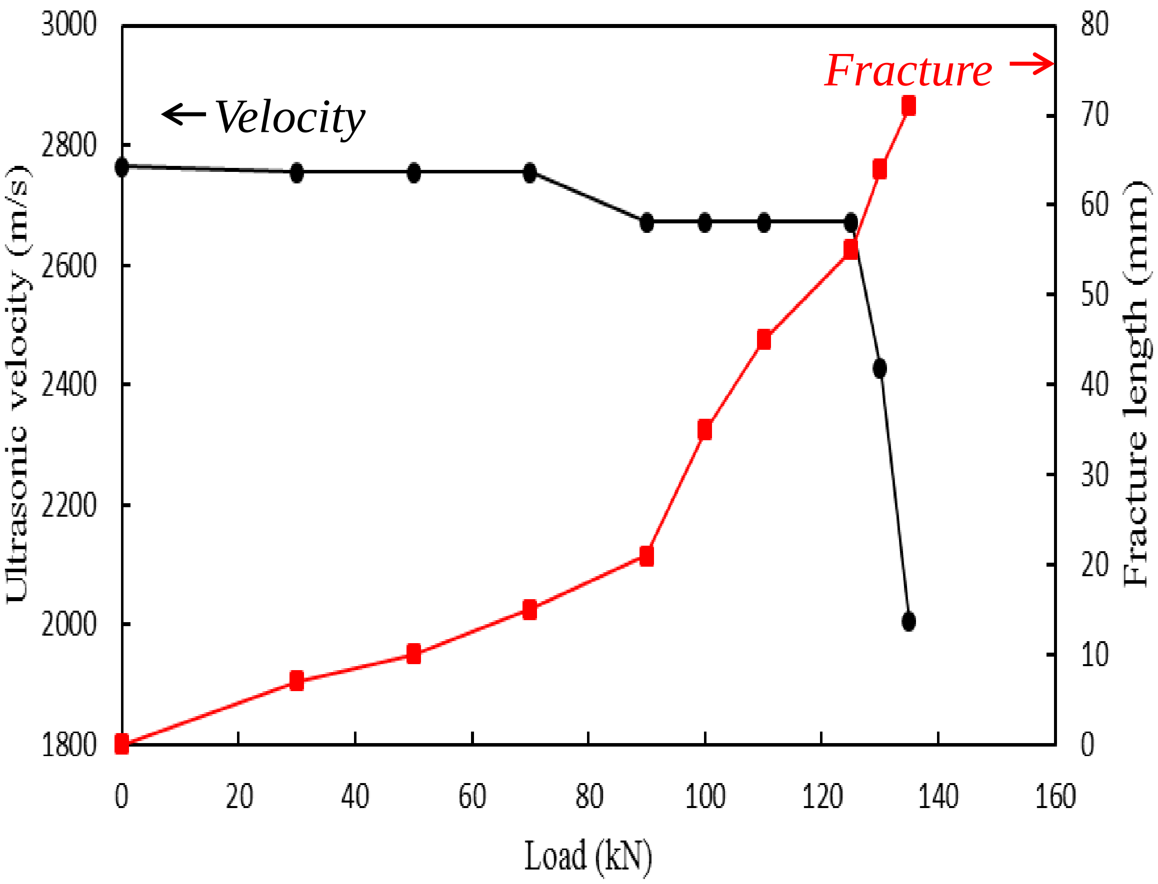


Case – II - V_p and fracture vs load

Solid PMMA

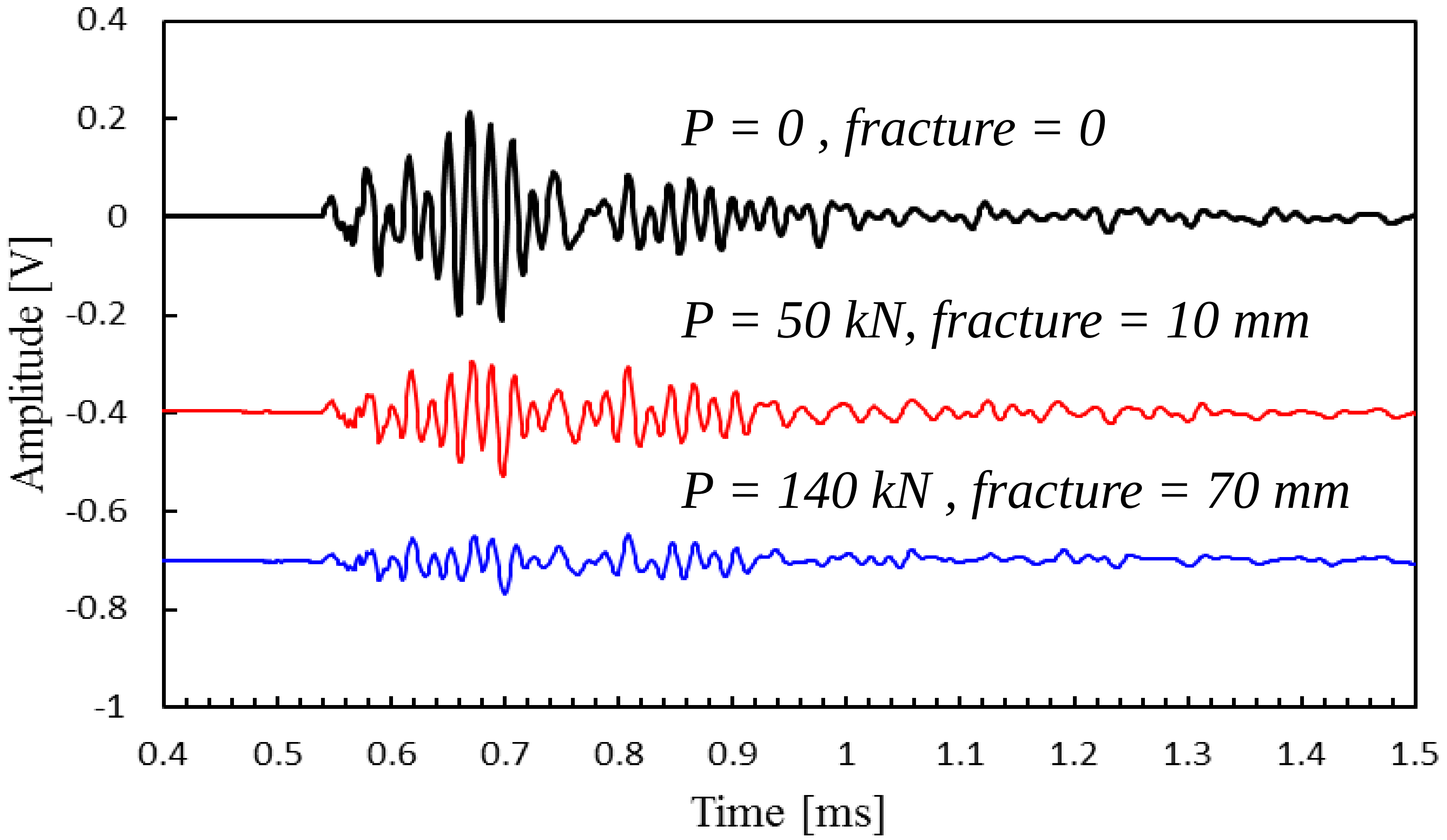


Annealed PMMA



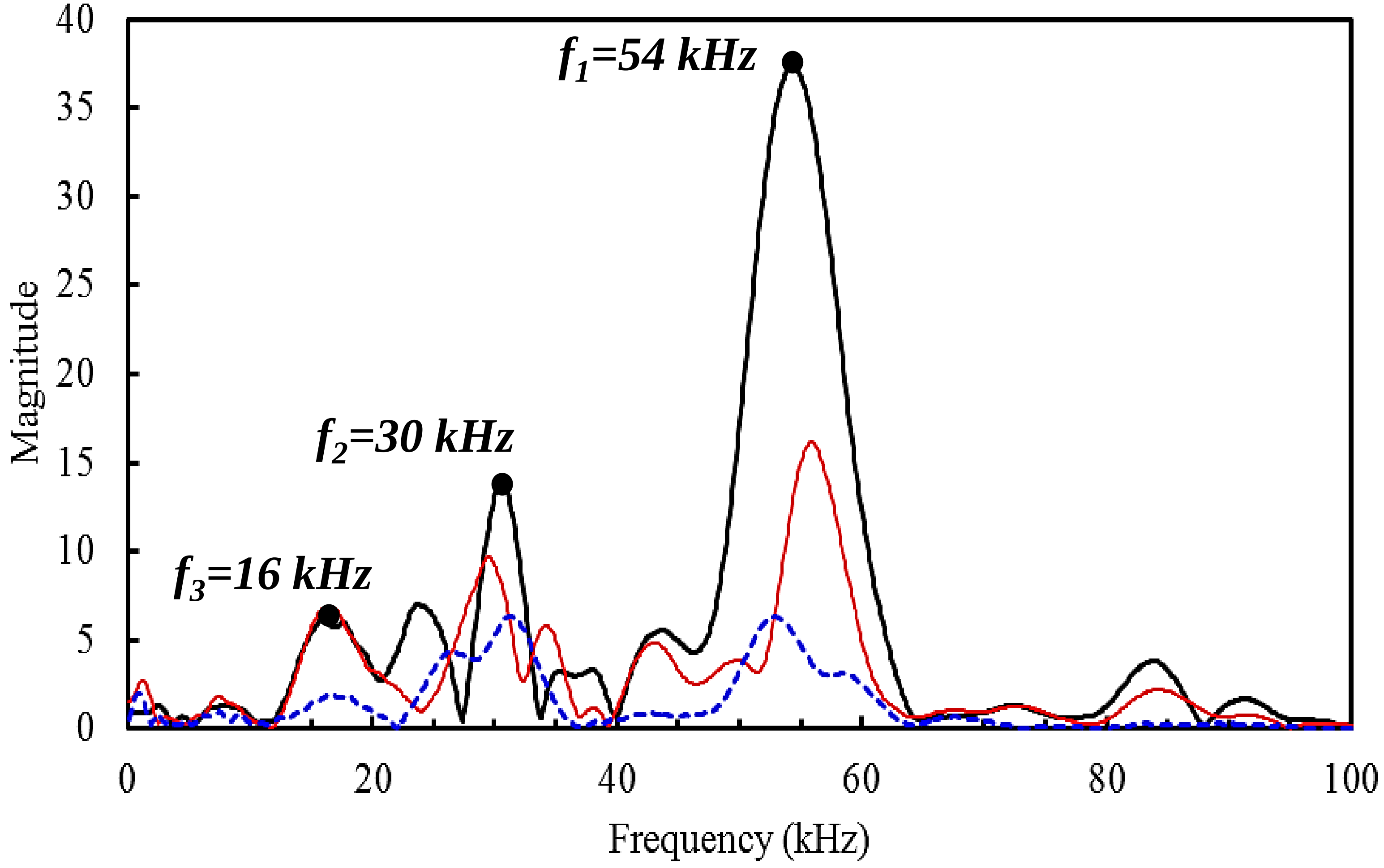
Case – II - Comparison of V_p and A

Typical annealed PMMA



V_p%	% A
100%	**100%**
100%	**64%**
96.4%	**32%**

Typical annealed PMMA

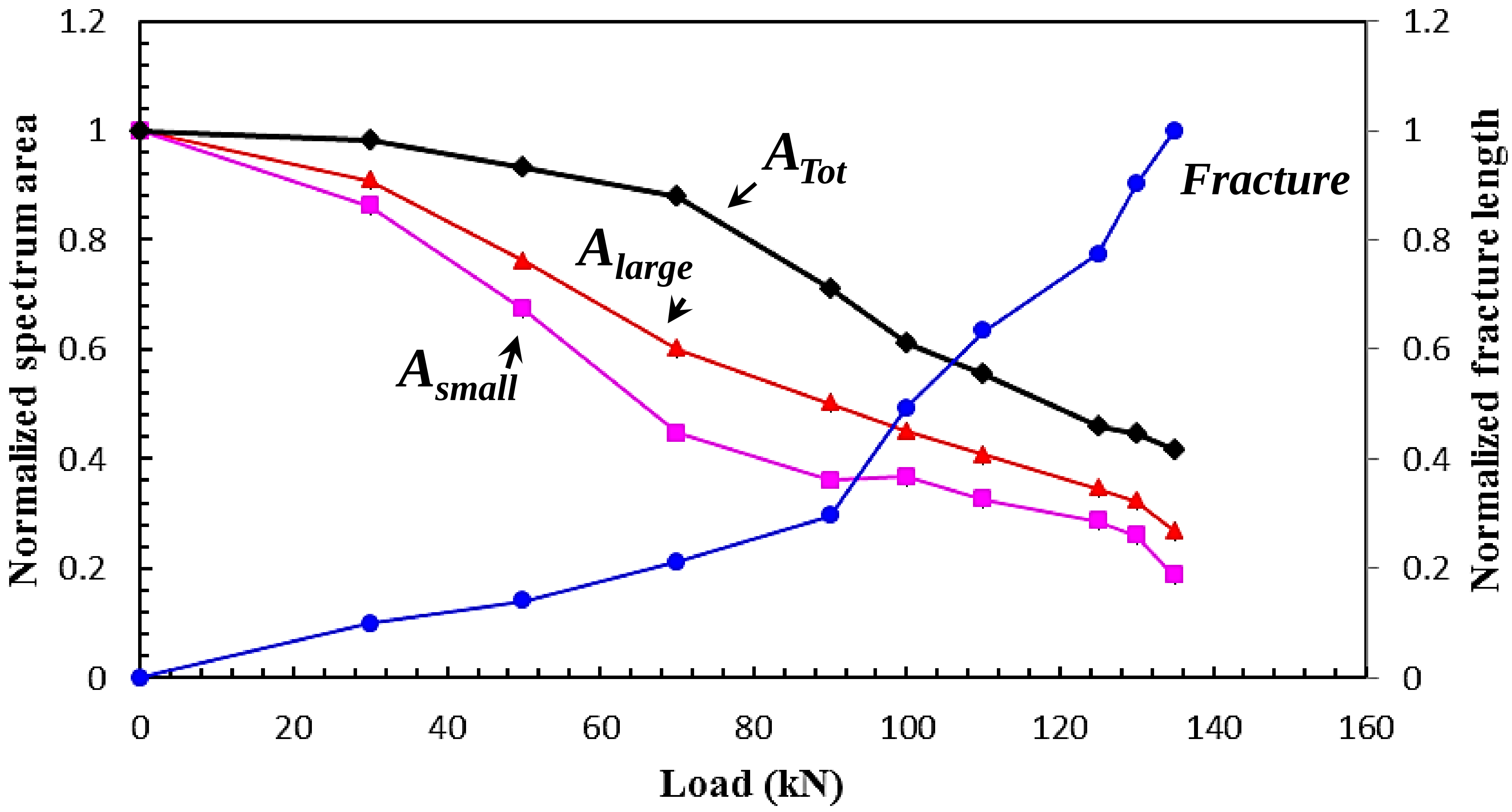


Fracture %	% Area
0%	100%
14%	76%
100%	27%

— P=0 — P= 50 kN --- P = 140 kN

Case – II – Effect of frequency bandwidth

Typical annealed PMMA



Conclusions

- Wave velocity shows extremely low sensitivity to fracture length (≈ 3 %).
- Wave attenuation is much more sensitive
  - Effect of fracture length on wave amplitudes: Case – I ≈ 45 %, Case – II ≈ 70 %
  - Effect of fracture length on spectrum area: Case – I ≈ 53 %, Case – II ≈ 70 %
- Areas calculated using smaller frequency ranges are more sensitive than larger frequency ranges

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Thank you for your listening