

Grading of sawn timber using the vibration technique

Locating imperfections based on flexural mode shapes

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Outlines

- Introduction
- Finite Element modeling
- Experimental studies
- Error analysis
- Conclusions



Introduction

- Strength grading of timber
 - MOE => MOR
 - Inhomogeneous material
 - Local variation of MOE



- Aim
 - Investigate the potential of using mode shape or Mode Shape Curvature (MSC) for locating natural defects in wooden beams

$$MSC = \frac{d^2(U)}{dx^2}$$

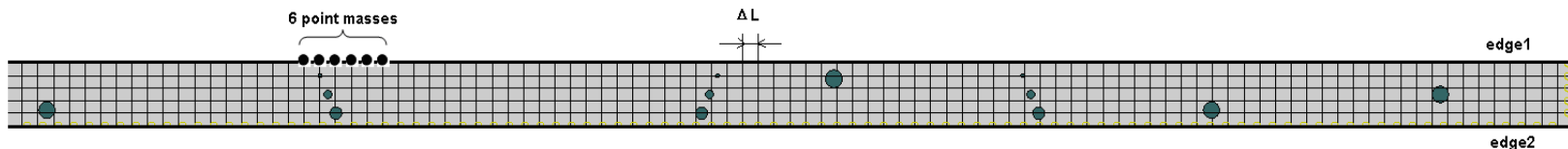
U – the mode shape vector



FE modeling

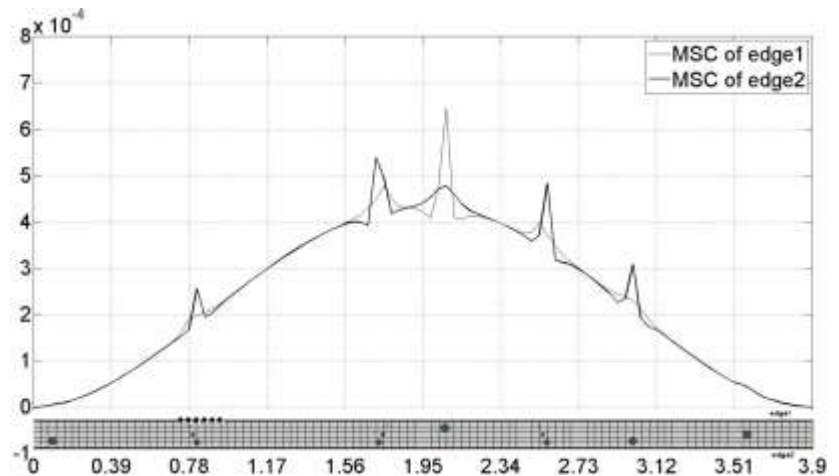
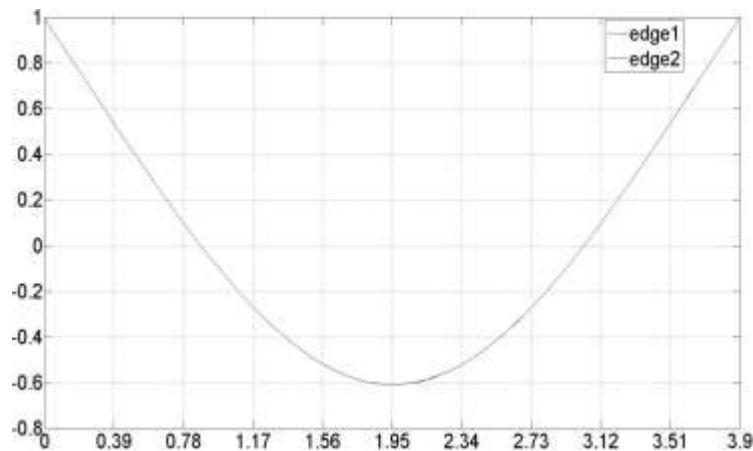
- 50x150x3900 mm
- ‘Knots’ - size, position
- Material properties
- Partitions
- Mode shape of edge1&2
- Flatwise and edgewise

	E [GPa]	ρ [kg/m ³]	ν [-]
Clear wood	12	500	0.3
Knots	2	500	0.3



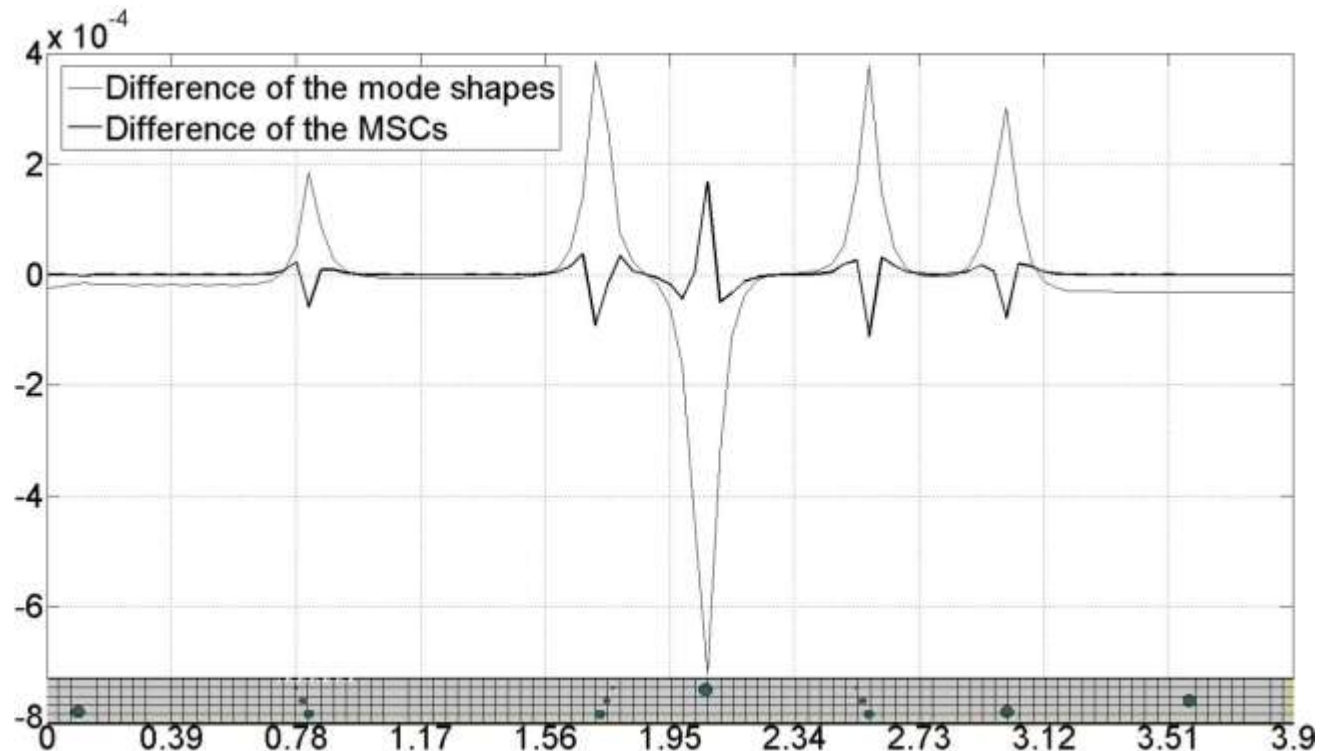
FE results- the 1st flatwise mode

The mode shapes (*left*); the MSCs (*right*)



FE results- the 1st flatwise mode

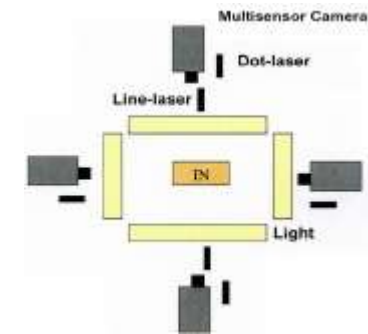
The difference between the mode shapes and the MSCs



Experimental studies

WoodEye scanning – delivering a defect list

- Type
- Size
- Position



For example: one side of one board



Experimental modal analysis

Experimental configurations

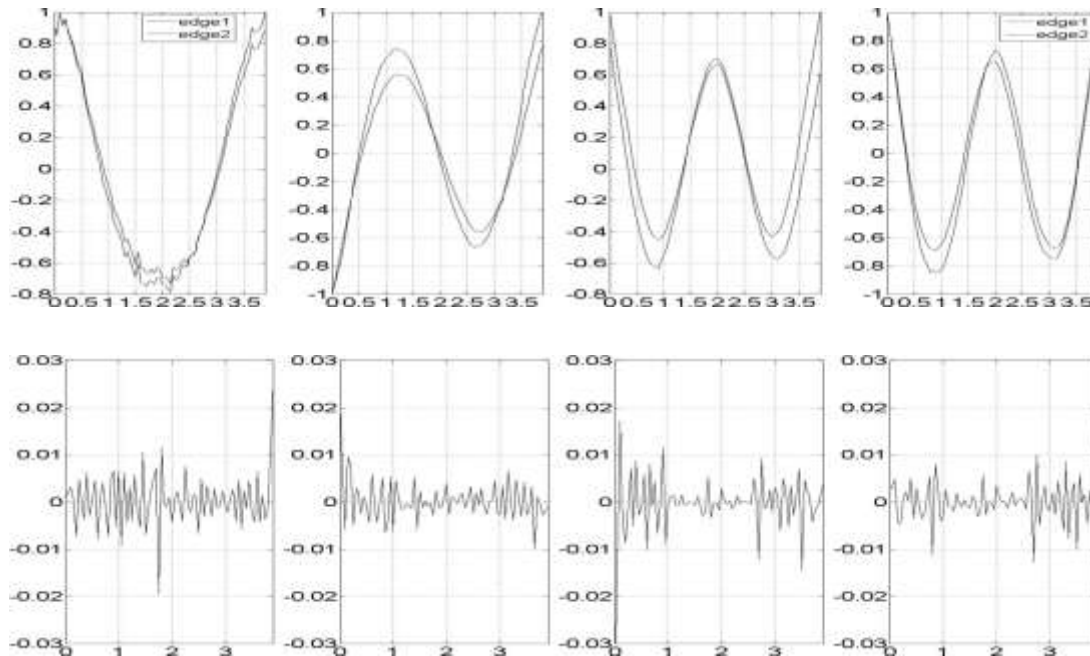
	Susp.	Exci. mthod	Meas.p. no.	No. accs	Flatw.	Edgew.
M1	Hor.	Hammer impulse	27	14	Y	Y
M2	Ver.	Shaker - pseudo r.	391	14	N	N
M3	Ver.	Shaker – pseudo r.	131	1	N	Y
M4	Hor.	Shaker - random	79	2	Y	N



Results M4:

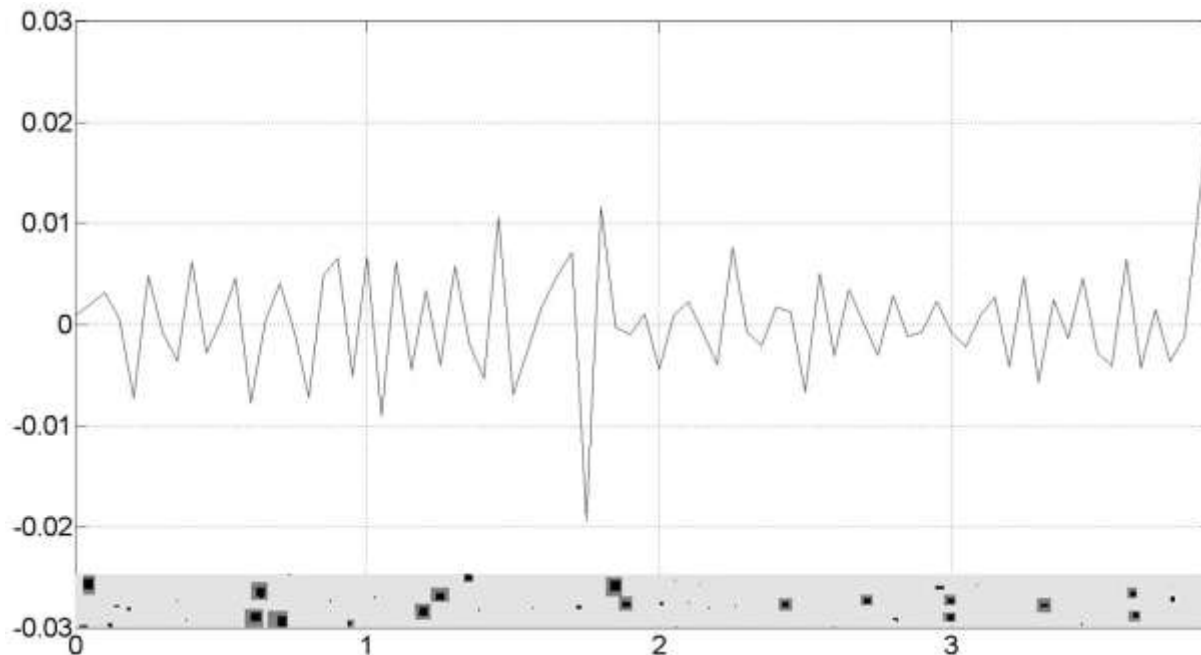
M4	Hor.	Shaker - random	79	2
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The mode shapes of two edges (*up*), the difference of the MSCs (*down*)



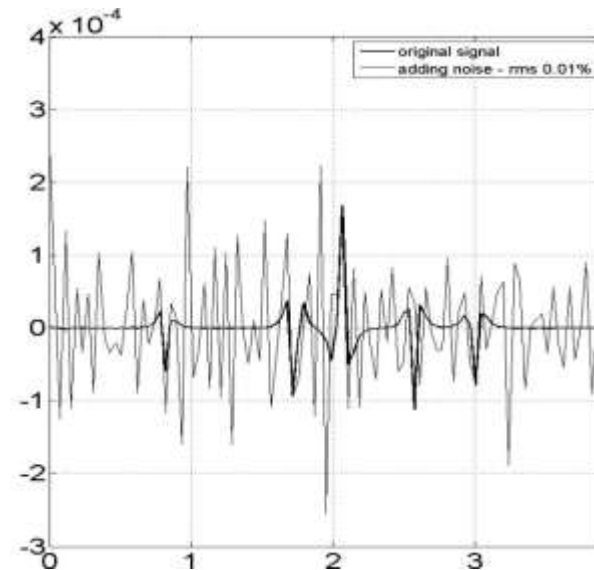
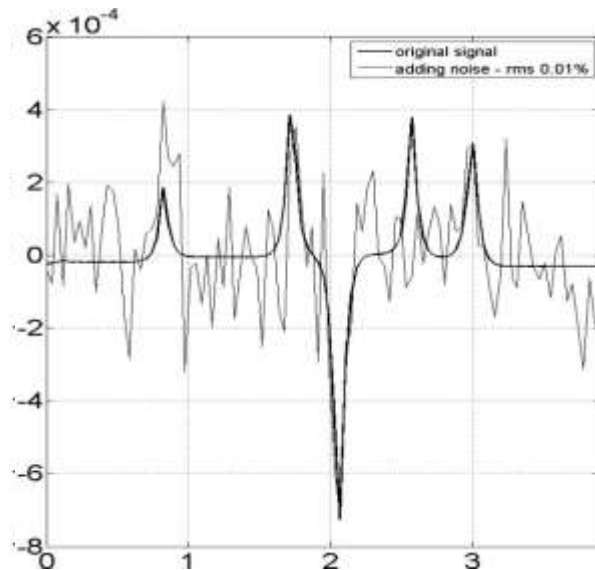
Result – the 1st flatwise M4

The difference of the MSCs



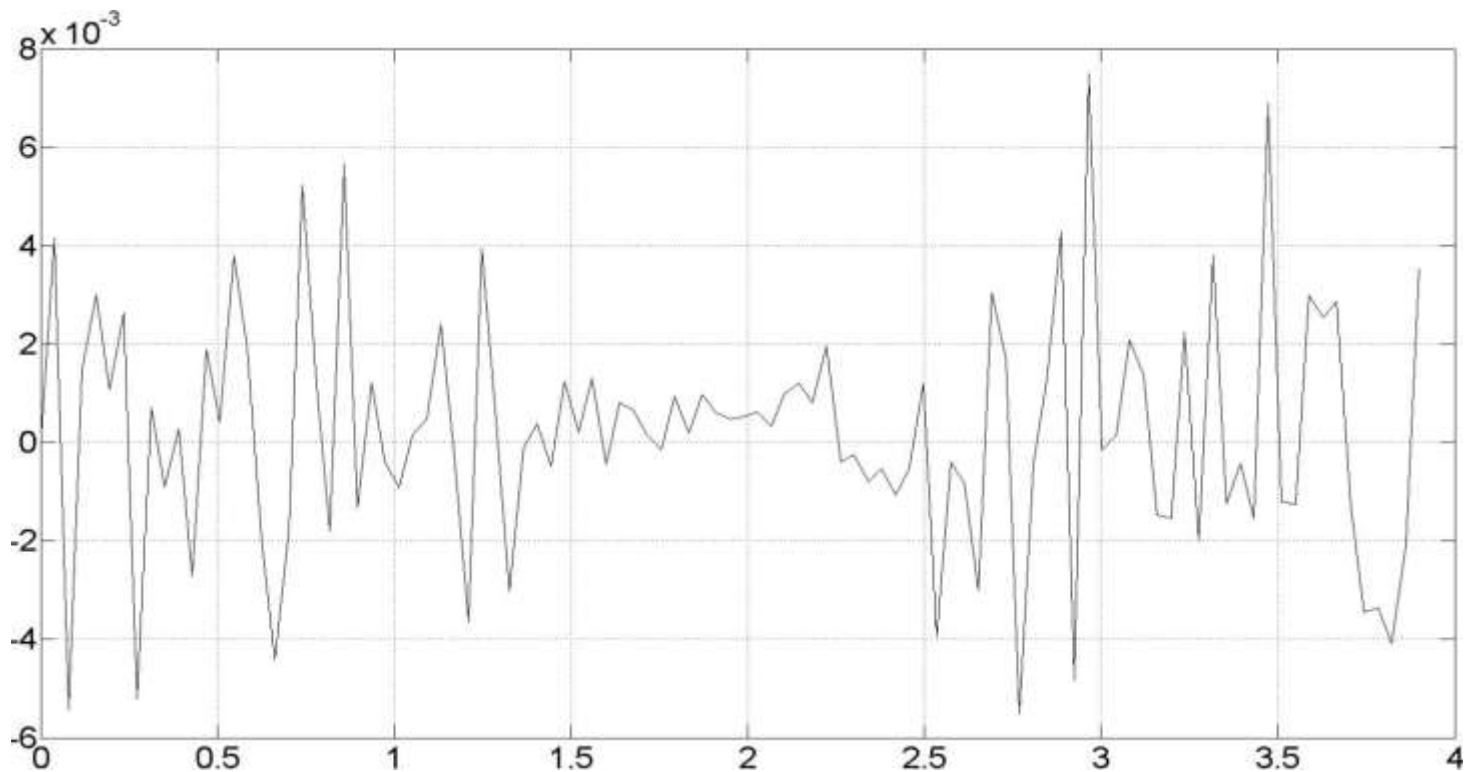
Error analysis

Influence of the random error of RMS 0.01%: the difference of the mode shapes (*left*) and MSCs (*right*)



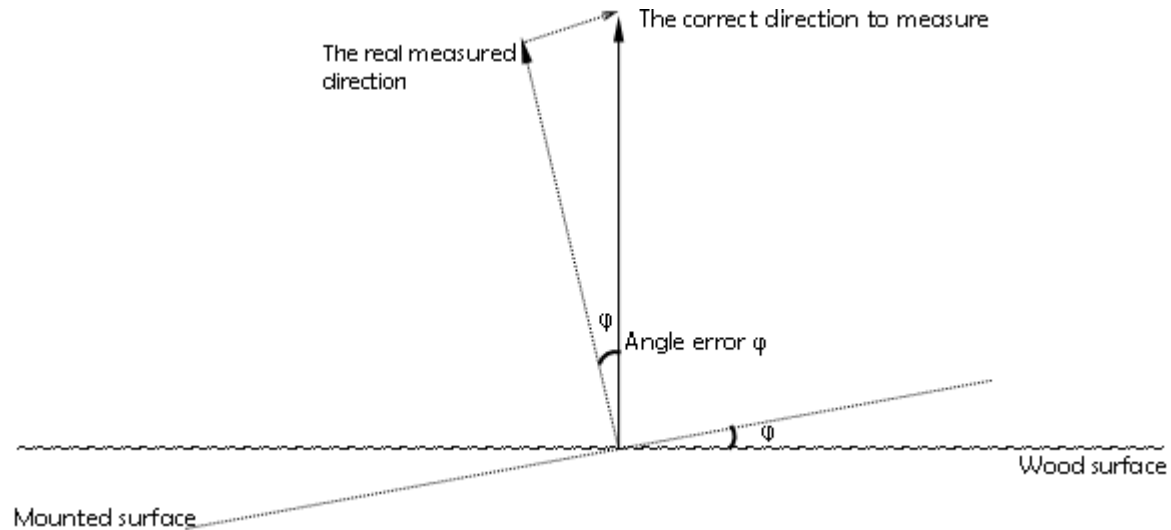
Position error

Mode shape error induced by 0.5mm position error – RMS 0.24%



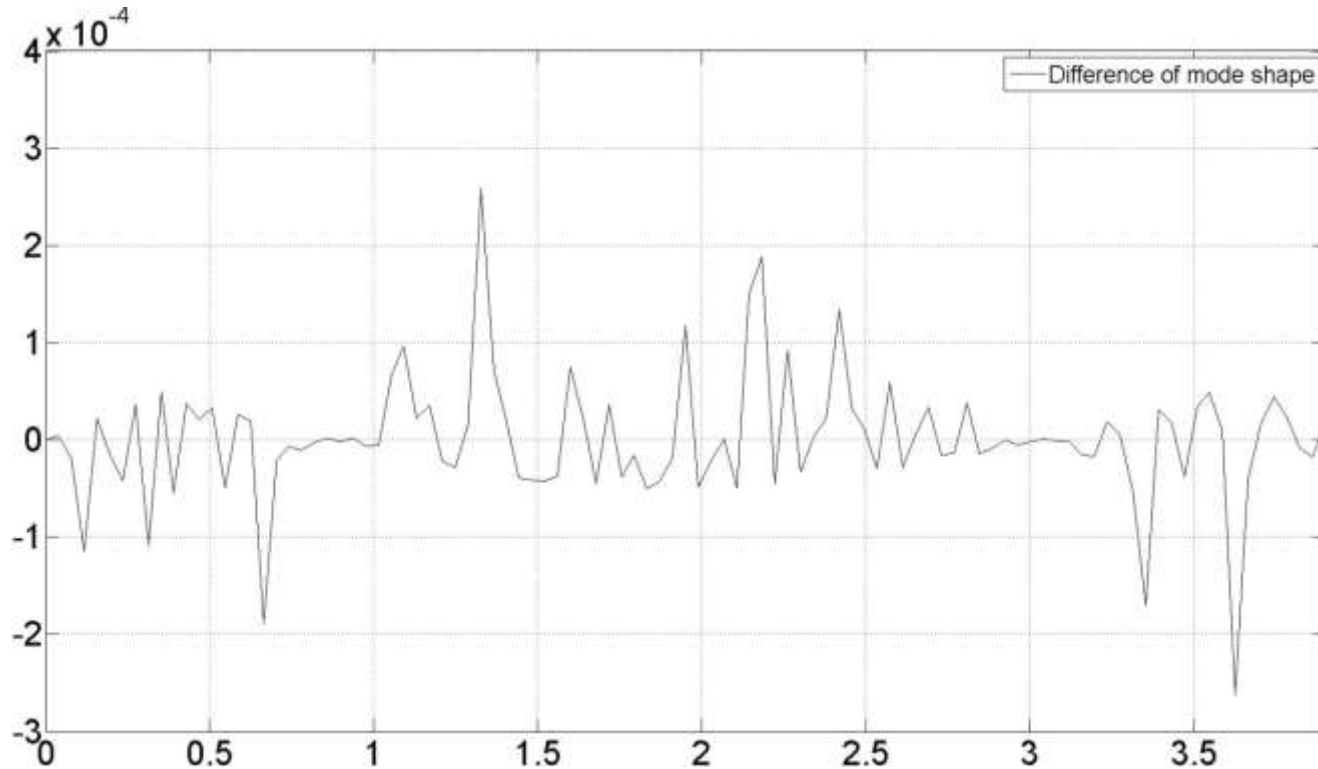
Angle error

A simple sketch to explain angle error



Angle error

Mode shape error induced by RMS 1° position error – RMS 0.012%



Summary of error analysis

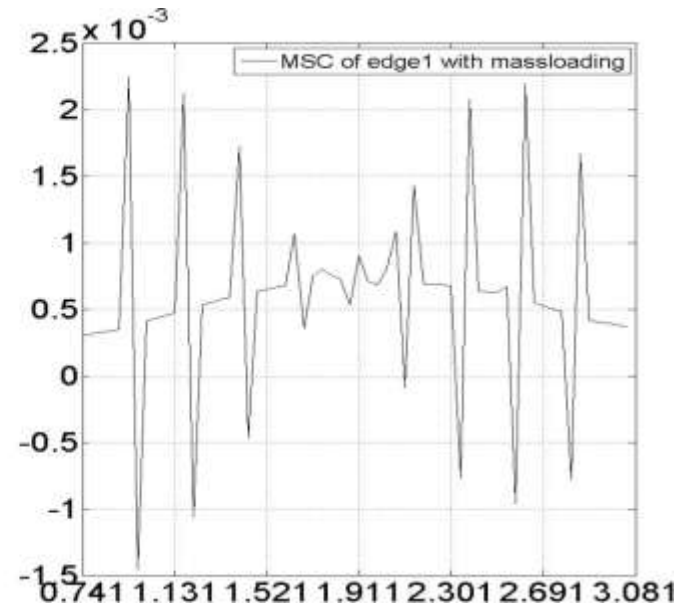
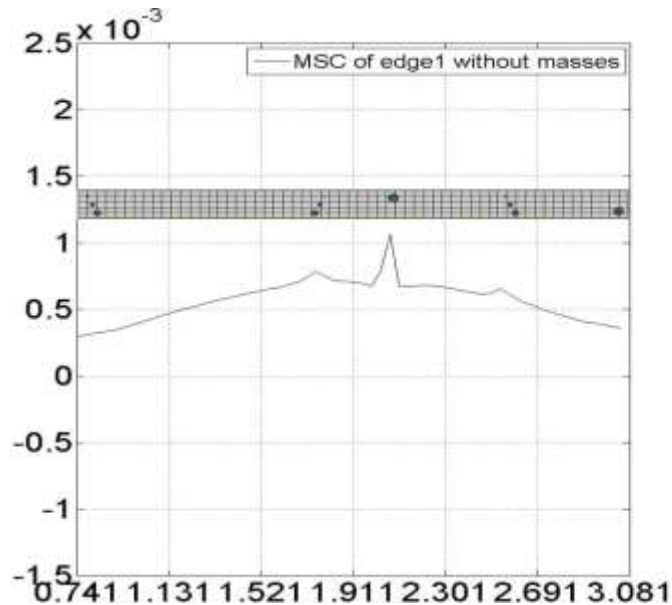
- Total error must be: $< 0.01\%$
- The position error: 0.24%
- The angle error: 0.012%
- Both of them are beyond 0.01%



Other error sources...

...which are difficult to estimate the size: mass loading effect, parameter estimation error etc.

Influence of mass loading on MSC



Conclusions

- Mode shape/MSC shows a good potential
- Sensitive to errors - accurate mode shape
- Difficult to achieve using accelerometers
- A new way of measuring - SLDV for example
- Use other dynamic parameters
 - Resonance frequency
 - Modal damping



Thank you for your attention!

Questions??



Result –1st flatwise, M1

