MECHANIKA ANALITYCZNA

Błędy modelowania

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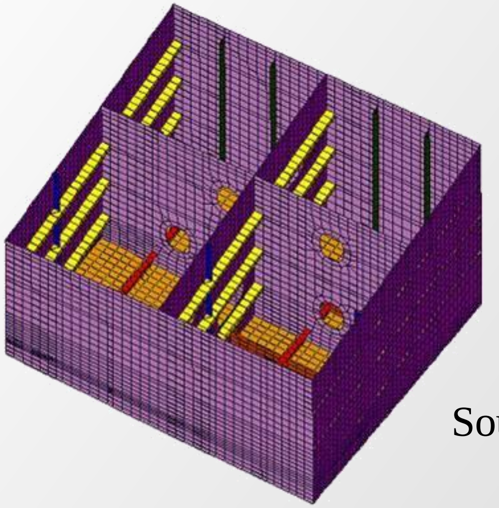
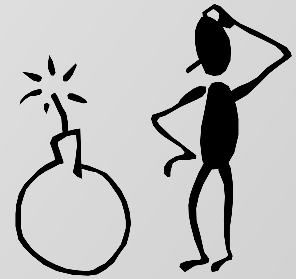
pok. A213

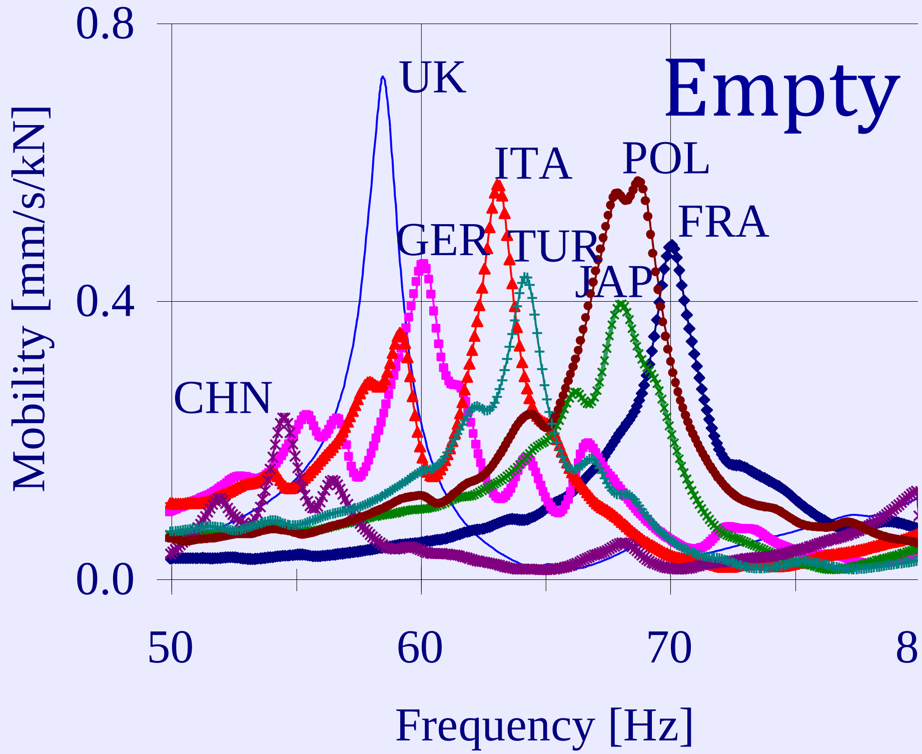
Benchmark

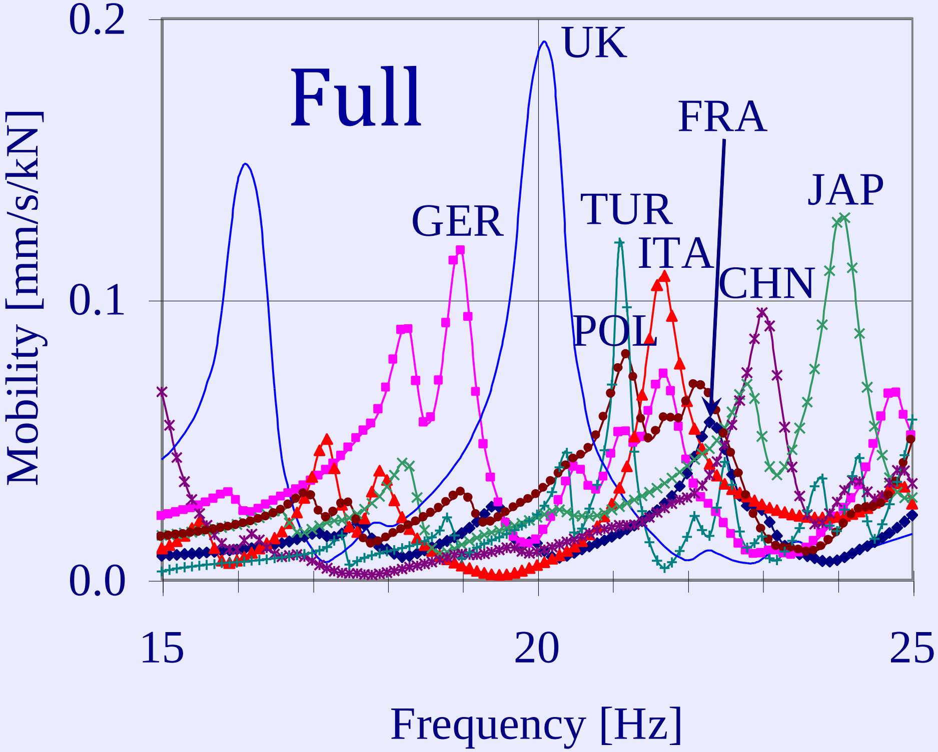


Source: ISSC

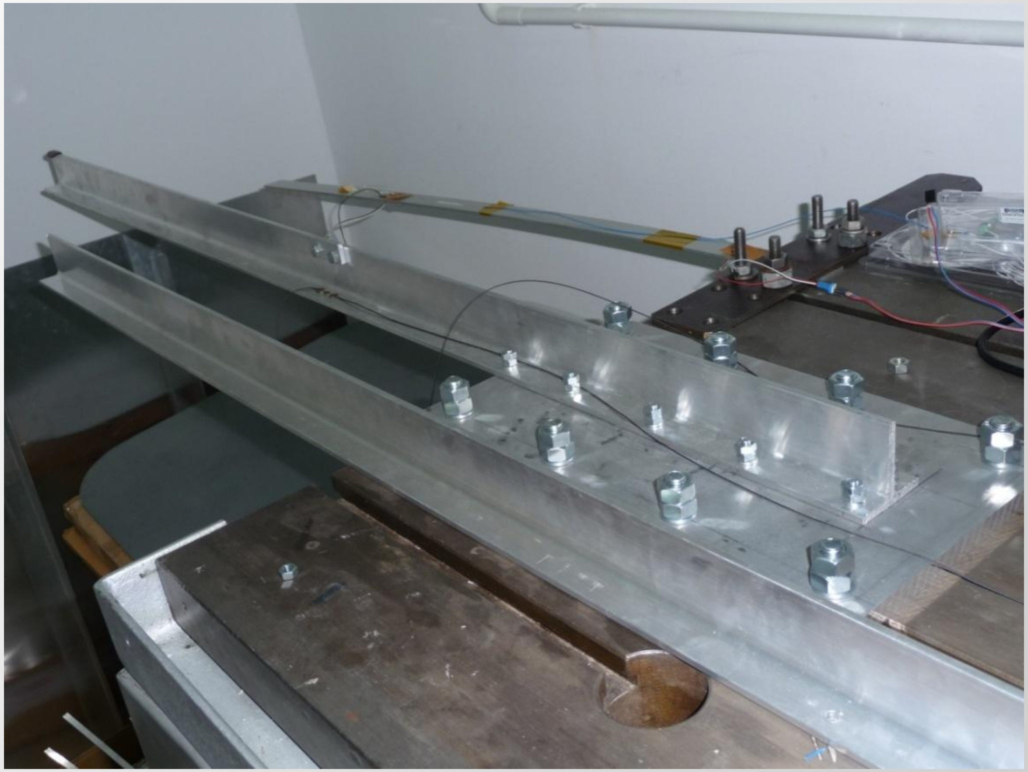


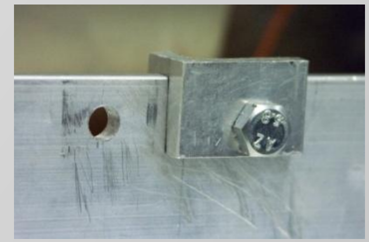
Wina obliczeń?

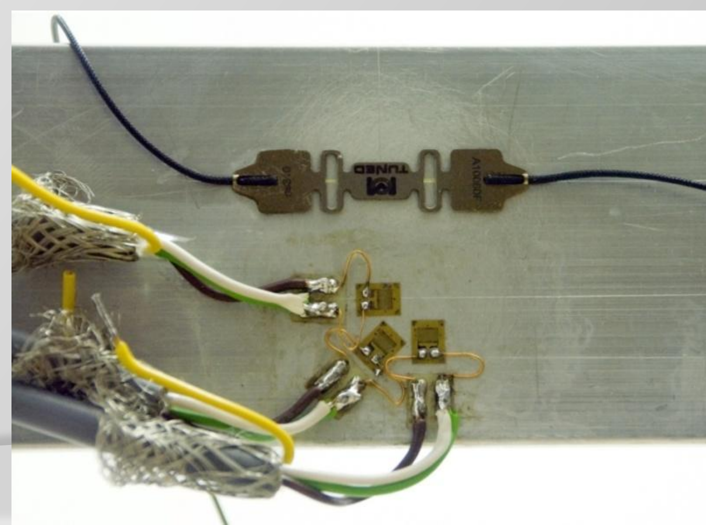




Przykład Belka z uszkodzeniami

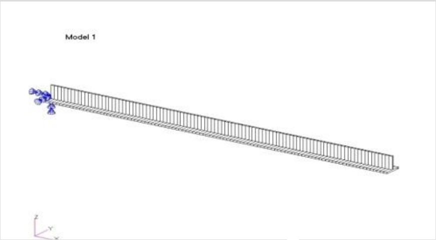


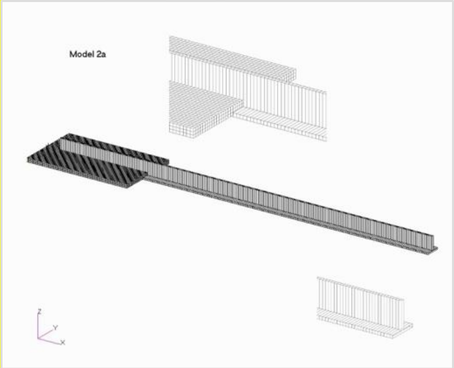


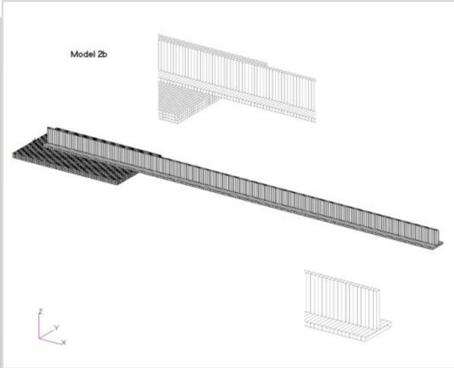


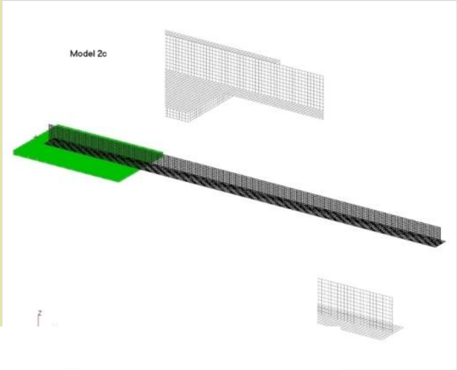
Jak liczyć tak prostą belkę?

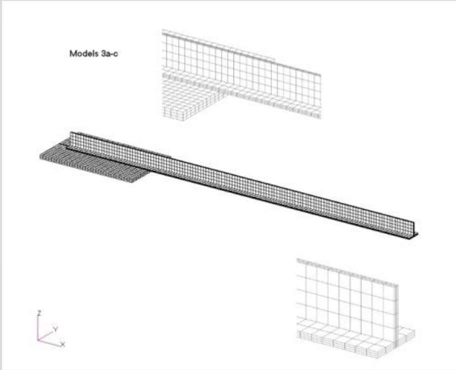
- **Model 1**: element belkowy **Bar2**, d.o.f. 600
- **Model 2a**: płyta mocująca – elementy trójwymiarowe **Hex8**, belka - **Bar2**, d.o.f. 30366
- **Model 2b** =**2a** + offset
- **Model 2c**: płyta mocująca – elementy trójwymiarowe **Hex8**, belka – elementy powłokowe **Quad4**, d.o.f. 27966
- **Model** $\mathbf{2c_m}$ = **2c** zagęszczony, d.o.f. 67638
- **Model 2d** = **2c** macierz mas rozproszona (coupled-lumped)
- **Model 3a** cały model: elementy trójwymiarowe **Hex8**, liczba stopni swobody 26664
- **Model** $\mathbf{3a_m}$ = **3a** zagęszczony, d.o.f. 107427
- **Model 3b**: = **3a**, aluminium **6061-T6**, d.o.f. 26664
- **Model 3c**: = **3a**, macierz mas rozproszona, d.o.f. 26664
- **Model 3d** cały model: elementy trójwymiarowe **Hex20**, liczba stopni swobody 13803
- **Model** $\mathbf{3d_m}$ = **3d** zagęszczony, d.o.f. 47640
- **Model 3e** = **3a** rozrzedzony (jeden elem. na grubość), liczba stopni swobody 15120
- **Model 2cU** = **2c** belka z uszkodzeniem

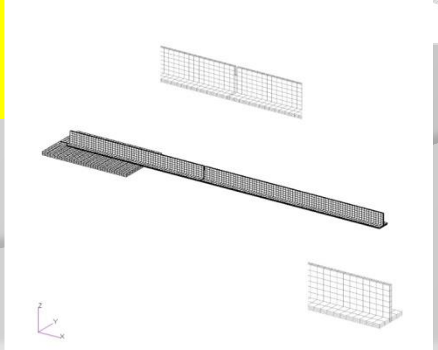












Wyniki obliczeń belki

		Częstotliwości drgań własnych [Hz]								
Postać \ Model	**1**	**2a**	**2b**	**2c**	**2d**	**3a**	**3b**	**3c**	**3d$_m$**	**3e**
1	29.159	29.159	29.159	27.557	27.558	28.279	29.429	28.281	28.223	28.294
2	42.623	42.621	42.621	41.445	41.446	39.808	41.426	39.81	39.756	39.836
3	181.13	181.09	181.09	112.31	112.89	119.04	123.88	122.16	117.52	118.81
4	261.68	261.53	261.53	168.64	168.77	173.98	181.05	174.58	173.25	174.04
5	500.21	499.85	499.85	254.95	254.97	245.51	255.49	245.61	245.11	245.71
6	710.11	708.93	708.93	330.59	331.85	350.9	365.17	357.81	346.7	350.48
7	961.26	959.82	959.82	433.14	434.51	452.84	471.25	459.46	448.42	452.56
8	1246.2	1200.4	1200.4	575.51	577.14	613.05	637.98	622.45	605.75	612.65
9	1333.6	1329.4	1329.4	690.37	690.51	667.69	694.83	668.3	666.2	668.35
10	1551	1547.1	1547.1	740.86	744.15	766.25	797.4	783.24	760.2	764.77

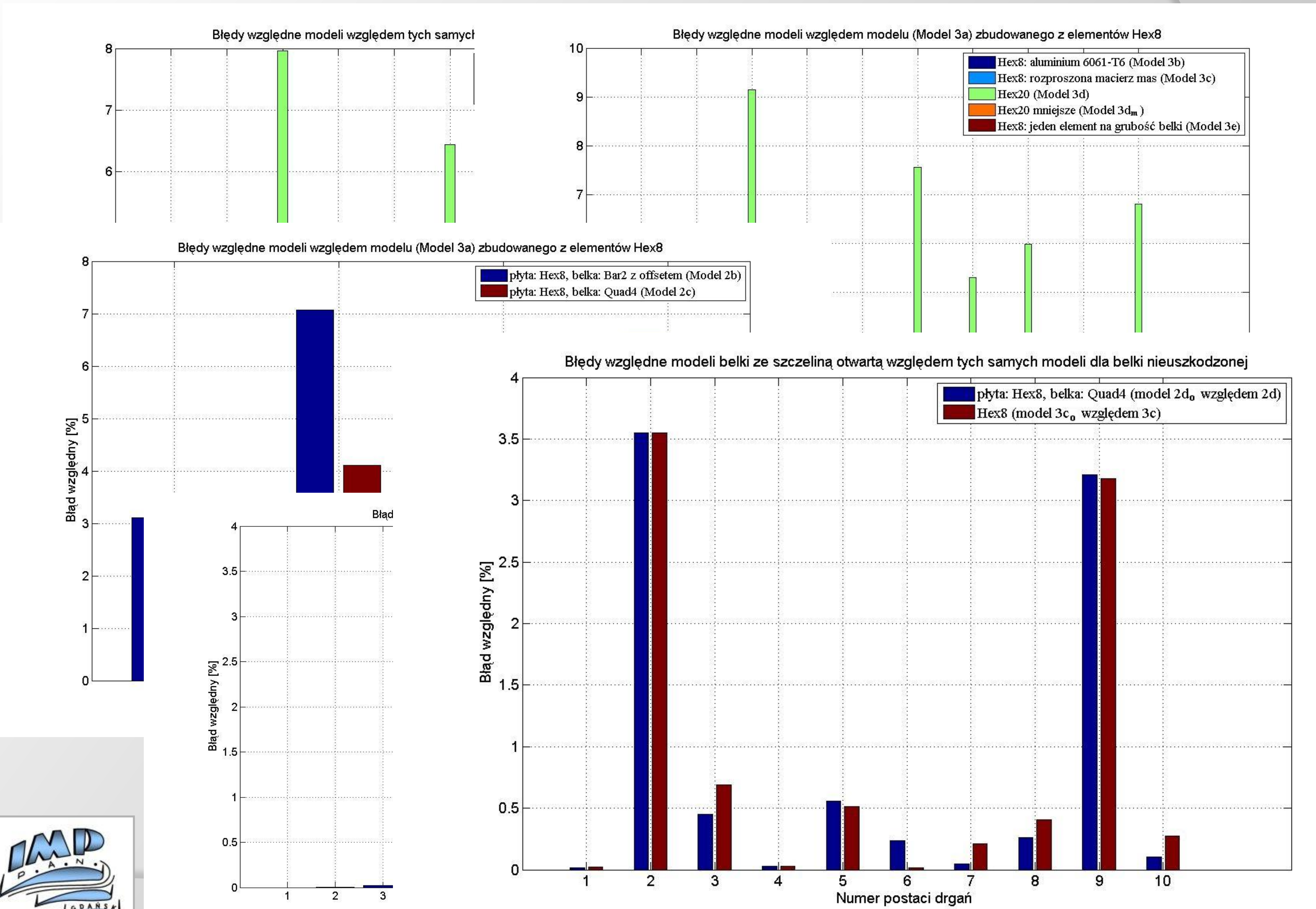
Wyniki obliczeń belki

	Częstotliwości drgań własnych [Hz]					
Postać \ Model	**2c**	**$2c_m$**	**3a**	**$3a_m$**	**3d**	**$3d_m$**
1	27.557	27.556	28.279	28.237	28.278	28.223
2	41.445	41.455	39.808	39.759	39.837	39.756
3	112.31	111.91	119.04	119.8	108.16	117.52
4	168.64	168.53	173.98	173.81	171.83	173.25
5	254.95	254.95	245.51	245.19	245.41	245.11
6	330.59	329.57	350.9	351.97	324.39	346.7
7	433.14	432.15	452.84	453.68	428.84	448.42
8	575.51	573.83	613.05	613.2	576.38	605.75
9	690.37	690.38	667.69	666.66	666.37	666.2
10	740.86	739.7	766.25	771.51	714.1	760.2

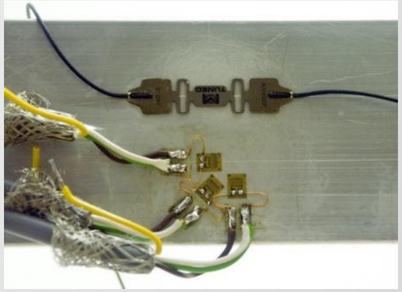
Wyniki obliczeń belki

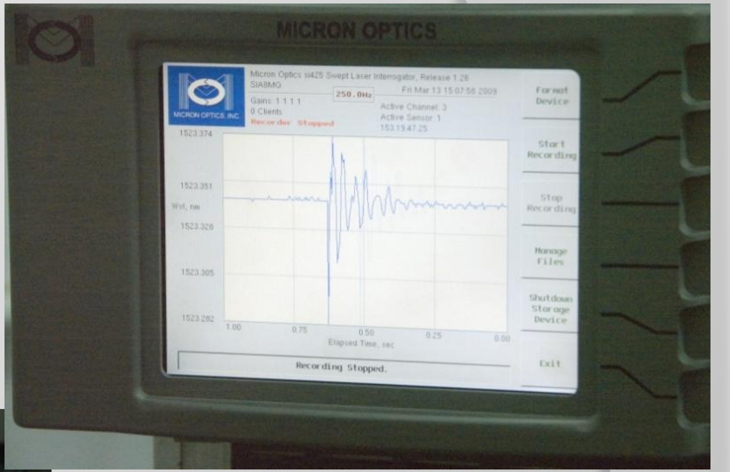
	Częstotliwości drgań własnych [Hz]			
Postać \ Model	**$3c_o$**	**3c**	**$2d_o$**	**2d**
1	28.274	28.281	27.553	27.558
2	38.396	39.81	39.975	41.446
3	121.32	122.16	112.38	112.89
4	174.53	174.58	168.82	168.77
5	244.35	245.61	253.55	254.97
6	357.76	357.81	332.64	331.85
7	458.5	459.46	434.3	434.51
8	619.94	622.45	575.64	577.14
9	647.05	668.3	668.37	690.51
10	781.1	783.24	743.36	744.15

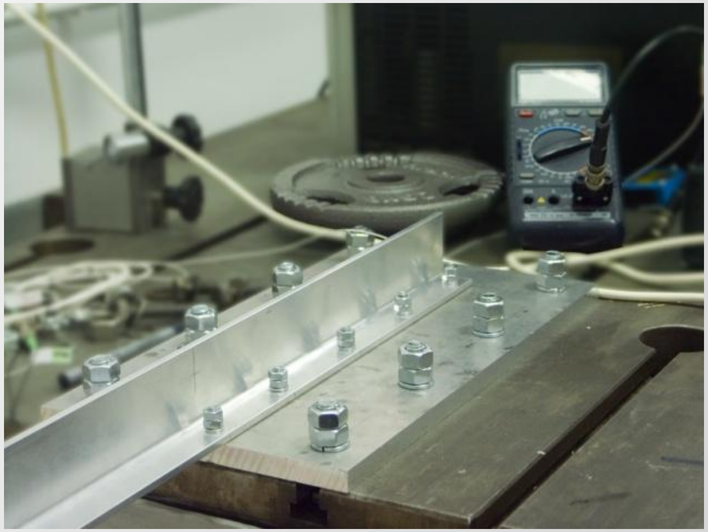
Błędy obliczeniowe

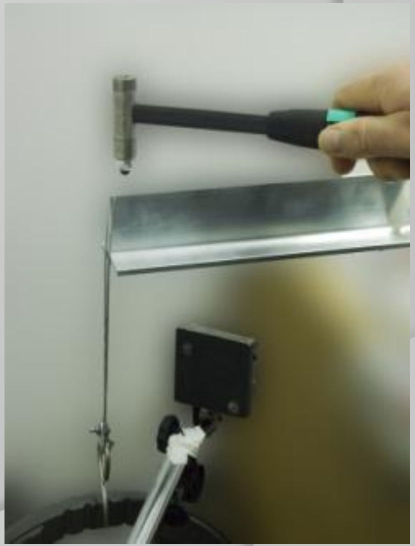


Pomiary belki



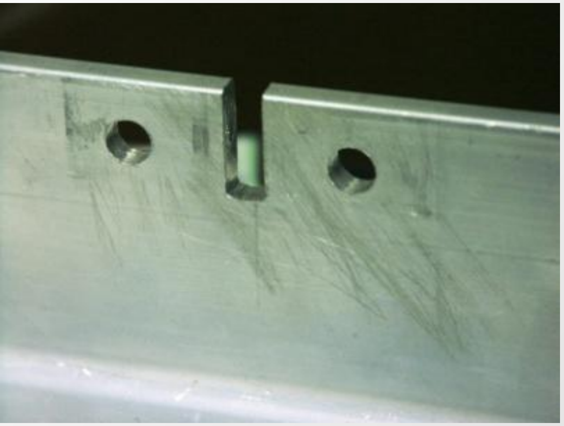


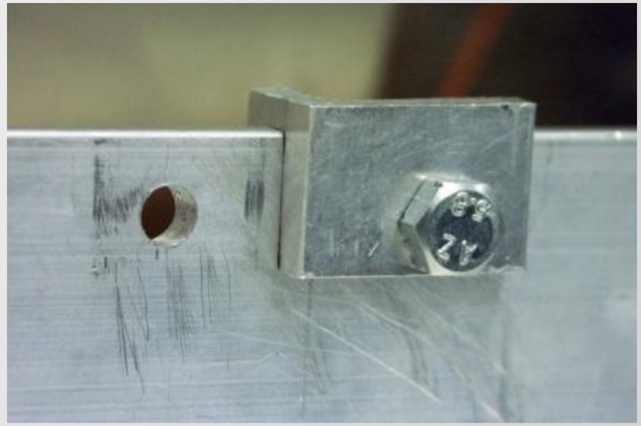


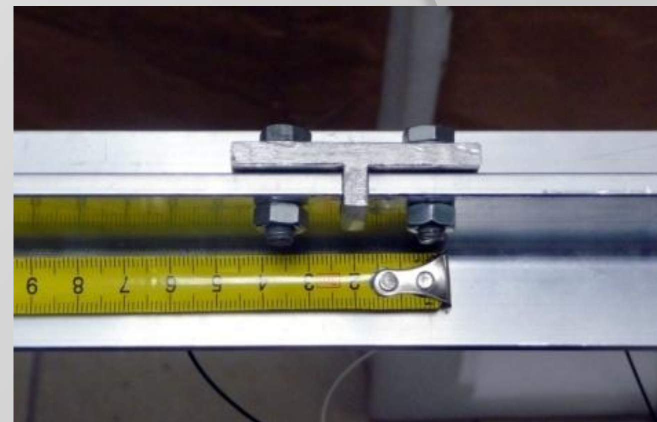


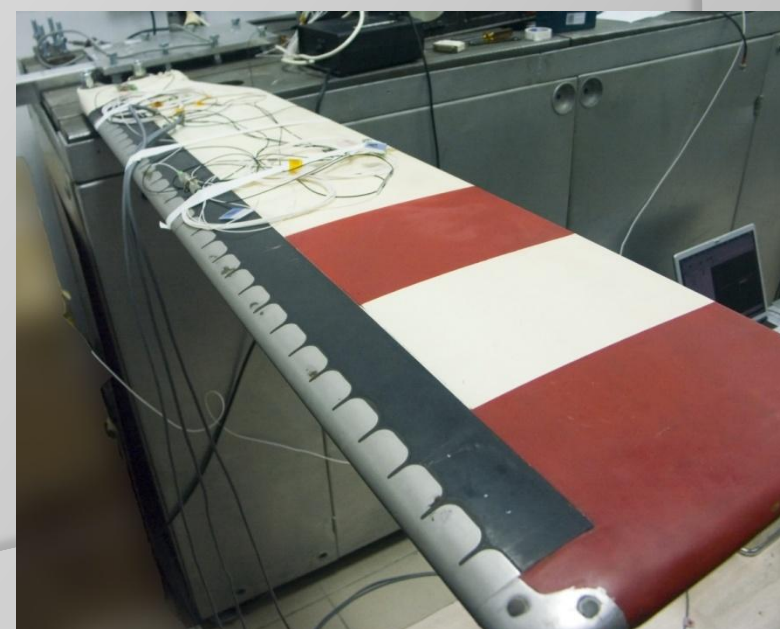
Badania laboratoryjne – wirnik helikoptera + usztywnienie konstrukcji

Badania laboratoryjne różnych typów uszkodzeń konstrukcji



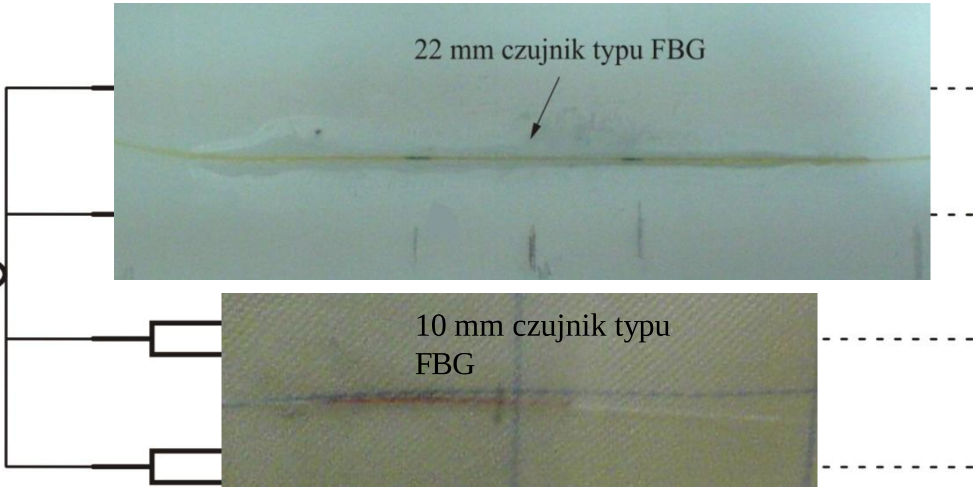




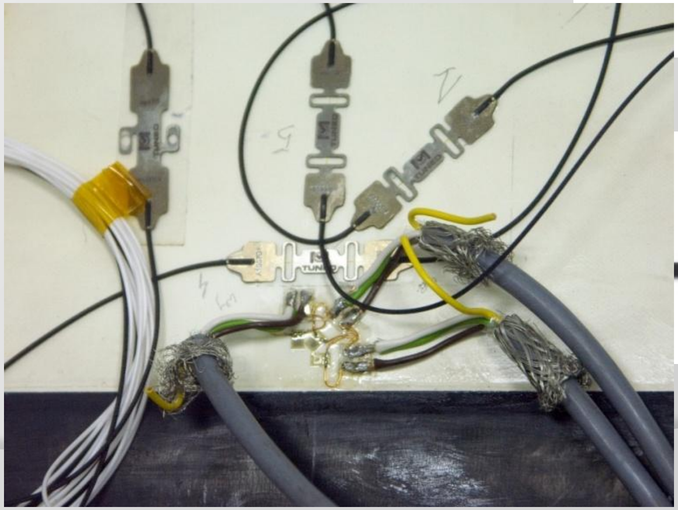


Nowe techniki pomiarowe

czujniki FBG



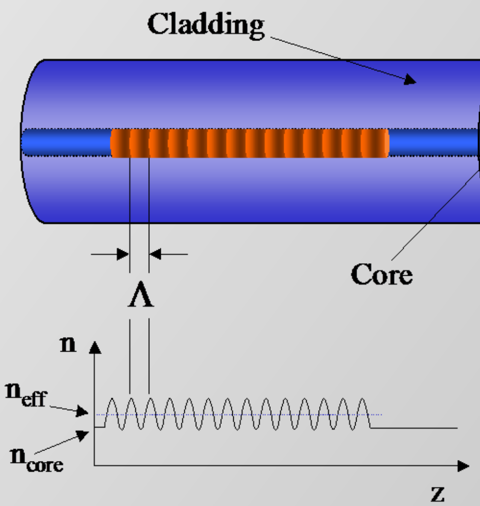
os3100 Optical Strain Gage



os4100 Temperature Compensation Sensor

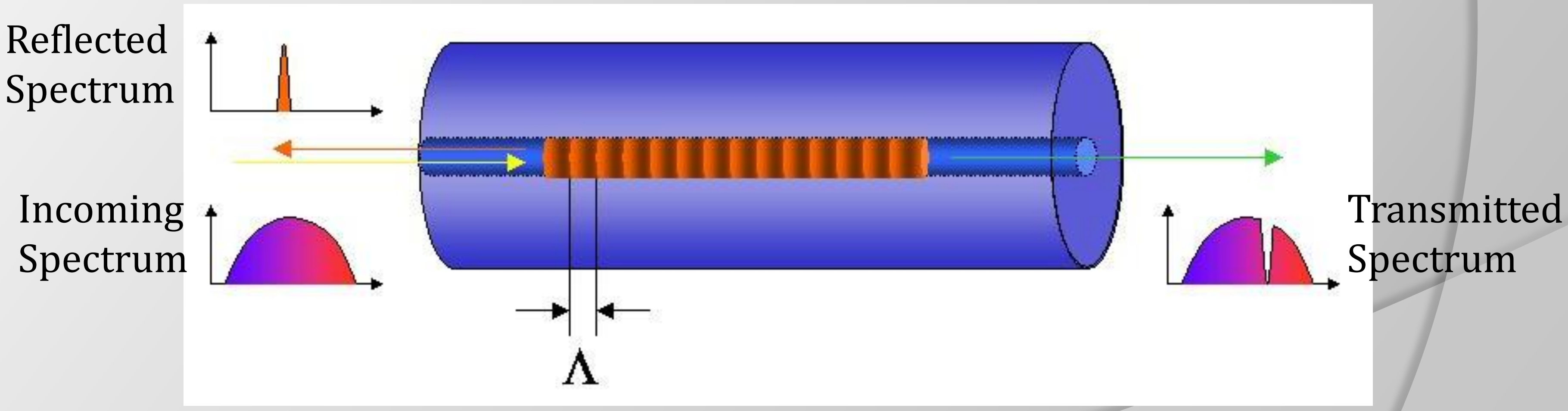
Czujnik typu FBG

FBG is made by periodically changing the refraction index in the glass core of a fibre.

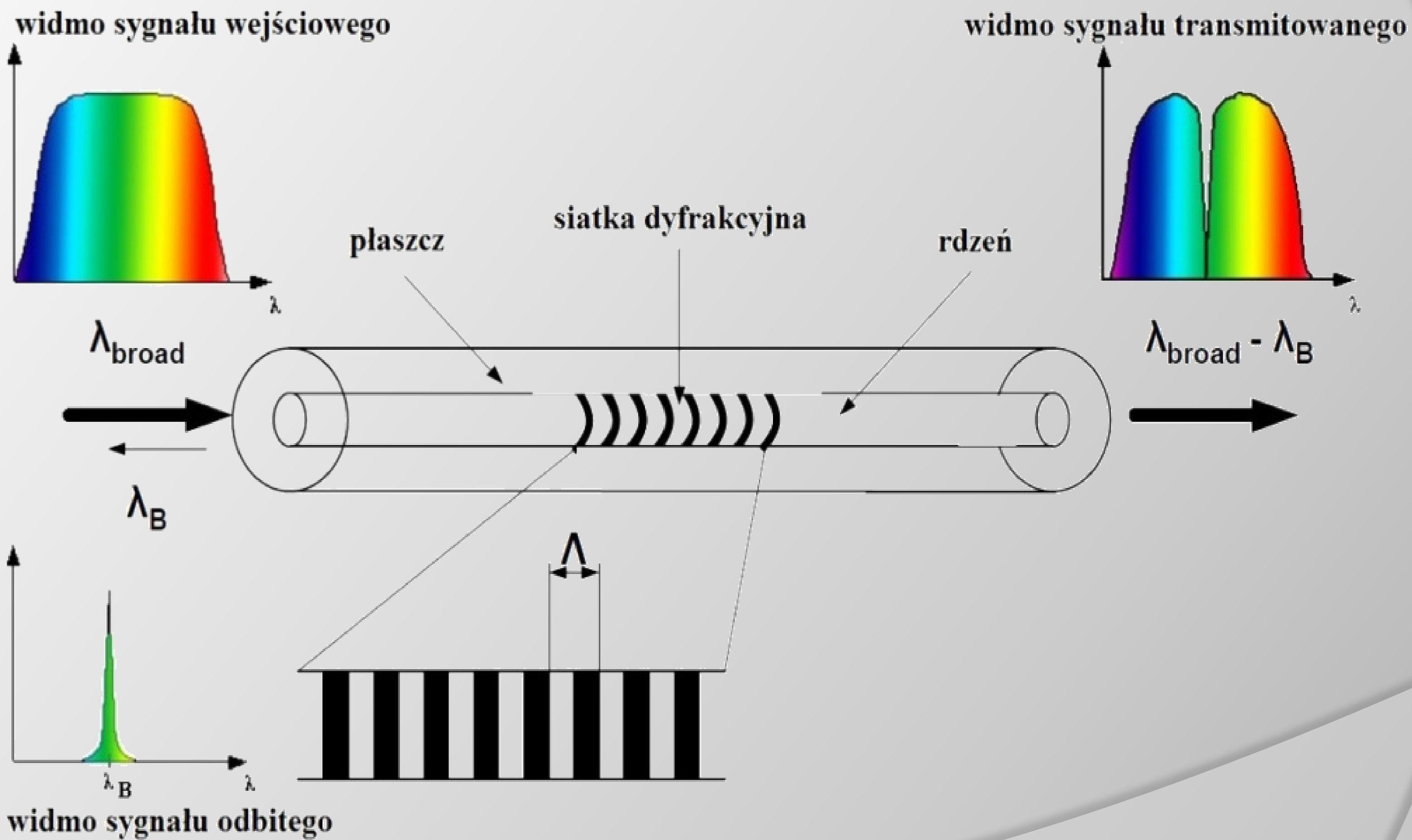


$$\lambda_B = 2n_e\Lambda$$

$$\Delta\lambda_B/\lambda_B = (1 - \rho_\varepsilon)\,\varepsilon + (\alpha + \zeta)\,T$$



Zasada działania



Dobór konstrukcji do analizy

HLJV Innovation

Długość całkowita:

188,70 m

Szerokość: 42 m

Wysokość konstrukcyjna

11 m

Wyporność: 22313 t

Statek do montażu elektrowni wiatrowych

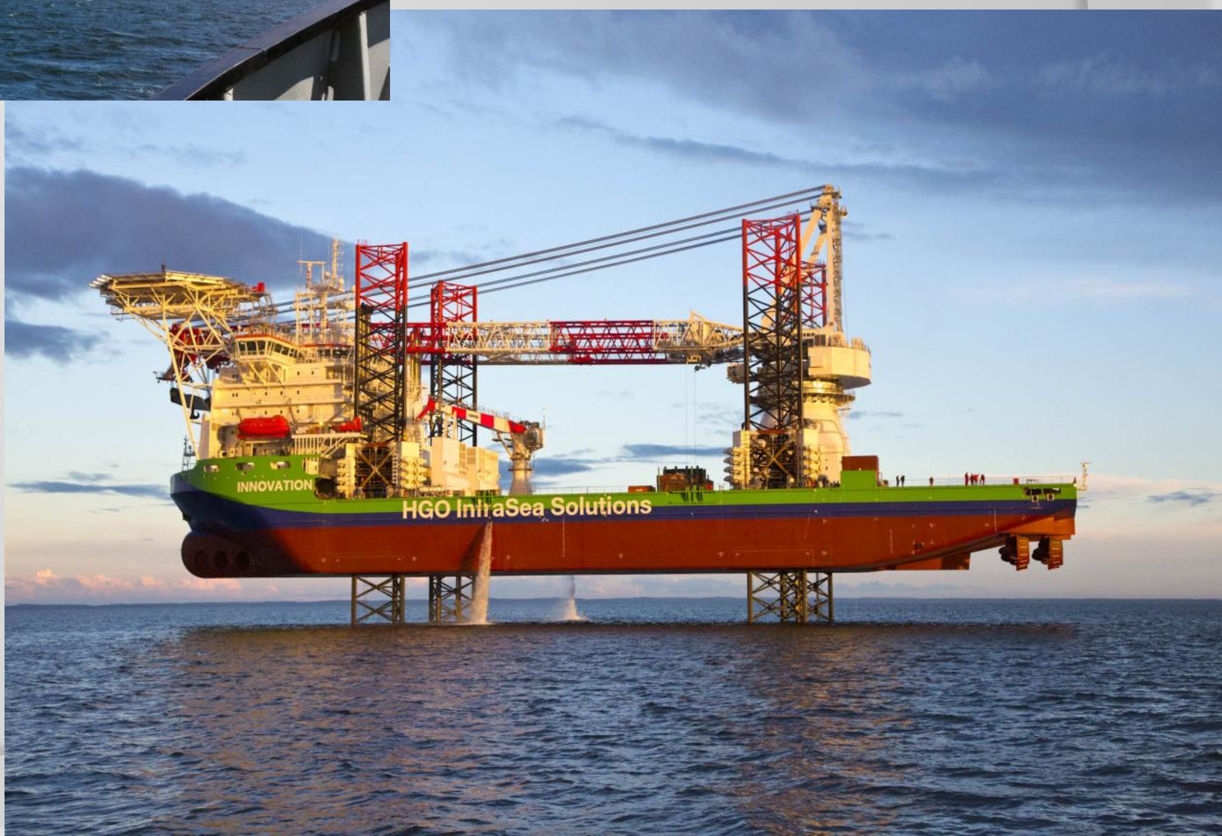
HLJV Innovation

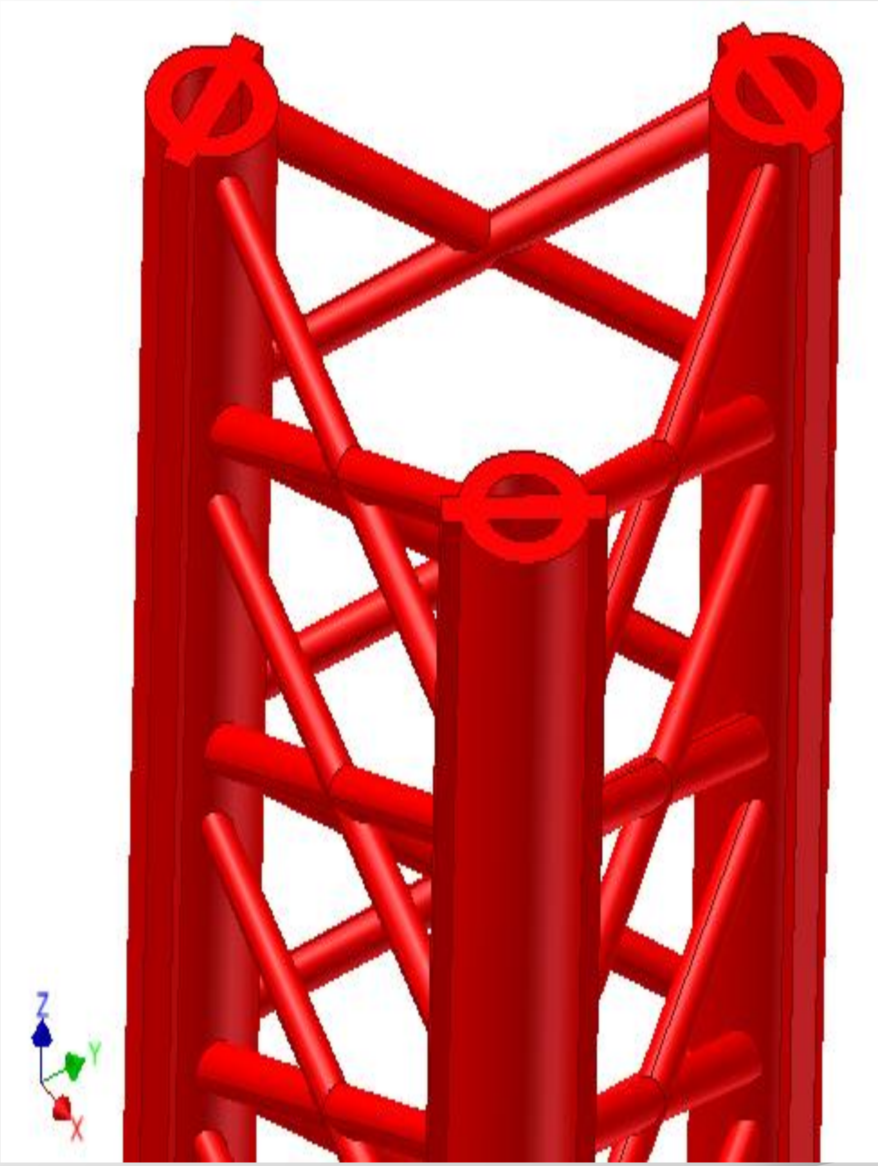
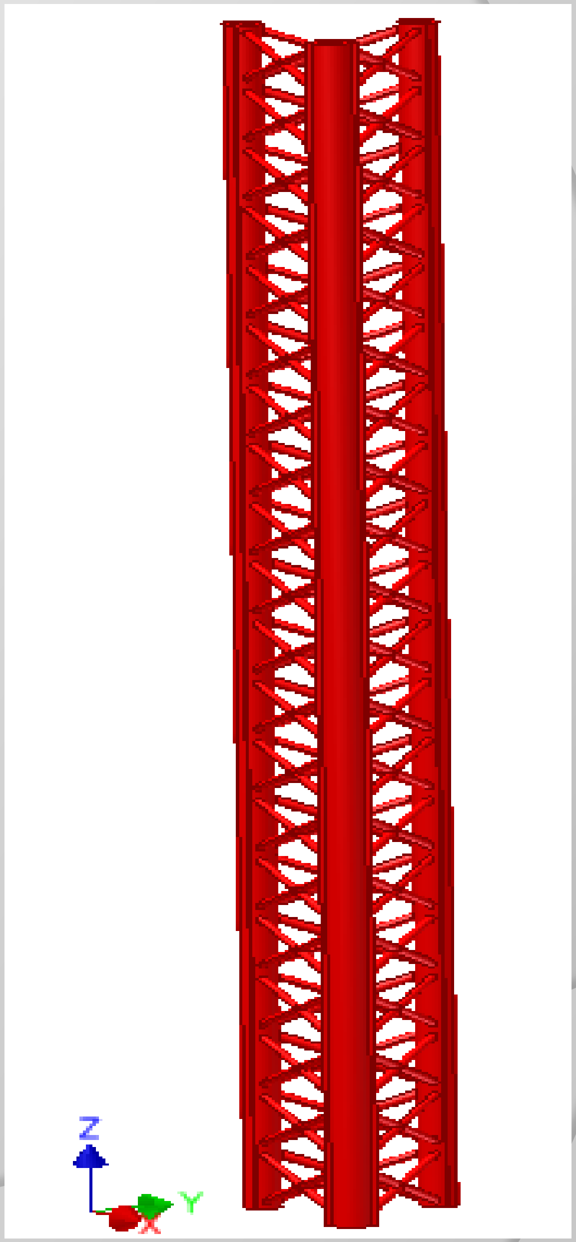
Długość całkowita: 188,70 m

Szerokość: 42 m

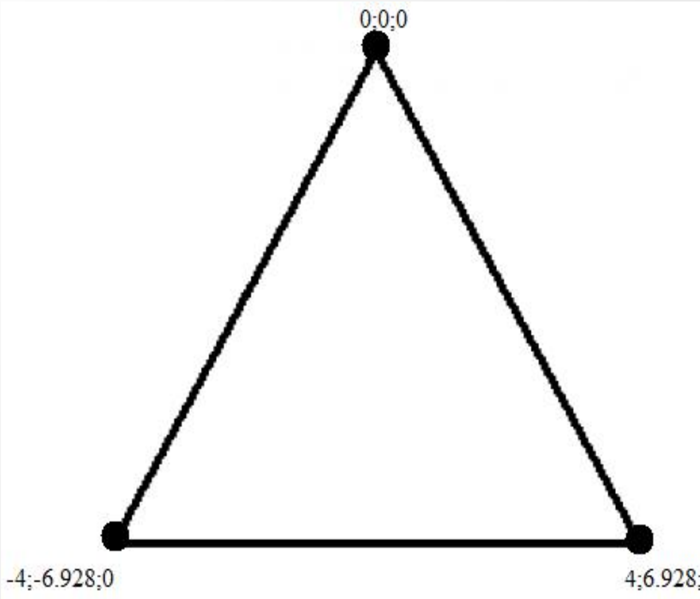
Wysokość konstrukcyjna: 11 m

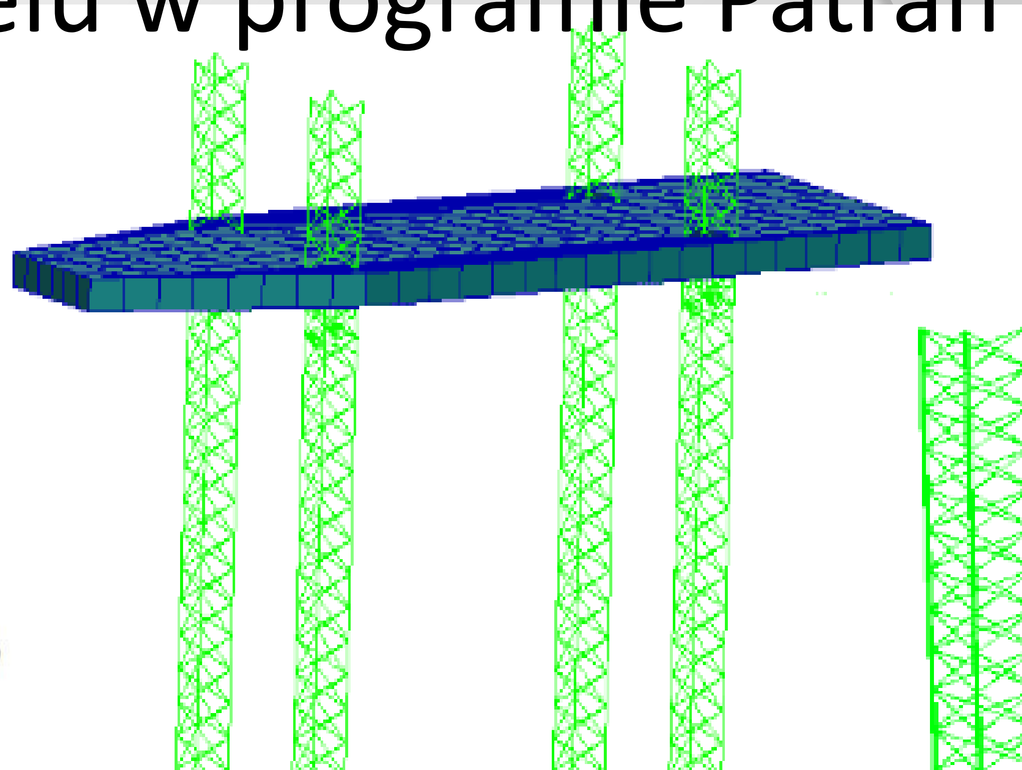
Wyporność: 22313 t

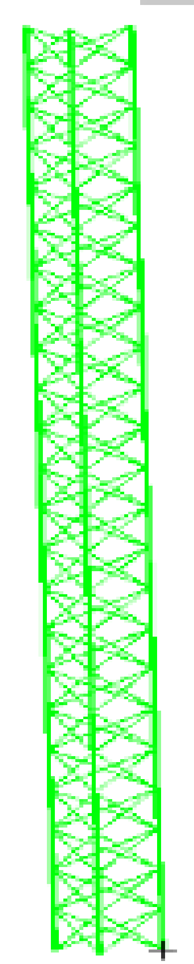


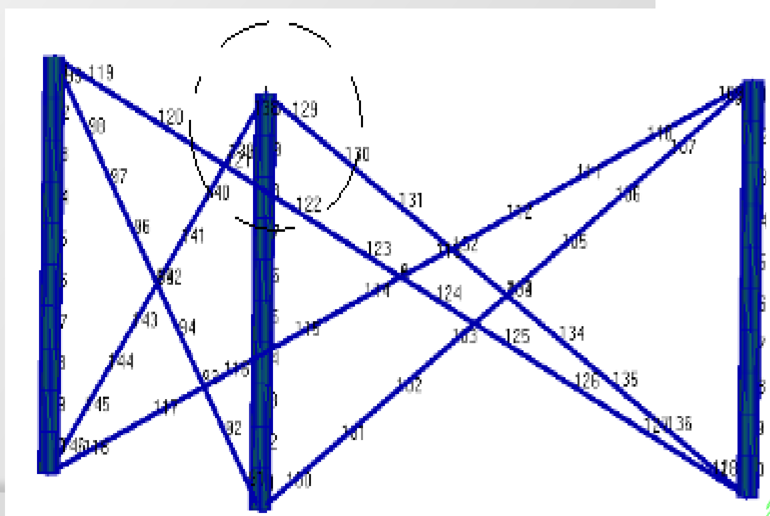

Z
Y
X

Z
Y
X

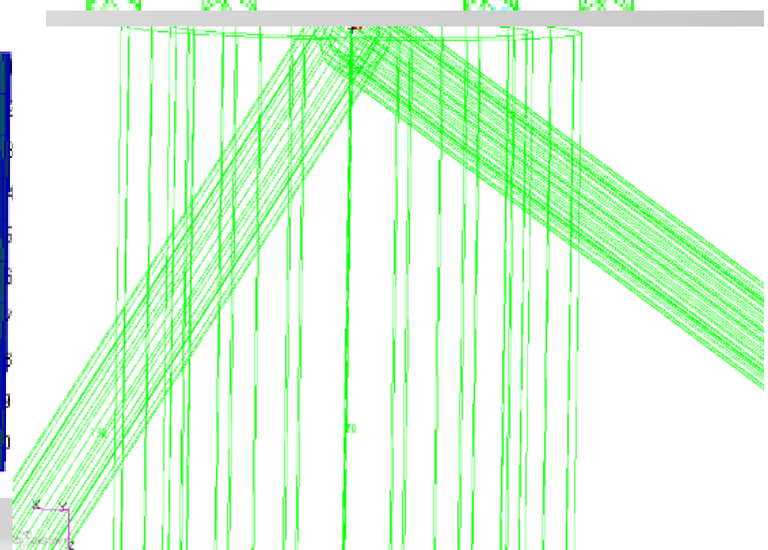
Budowa modelu w programie Patran



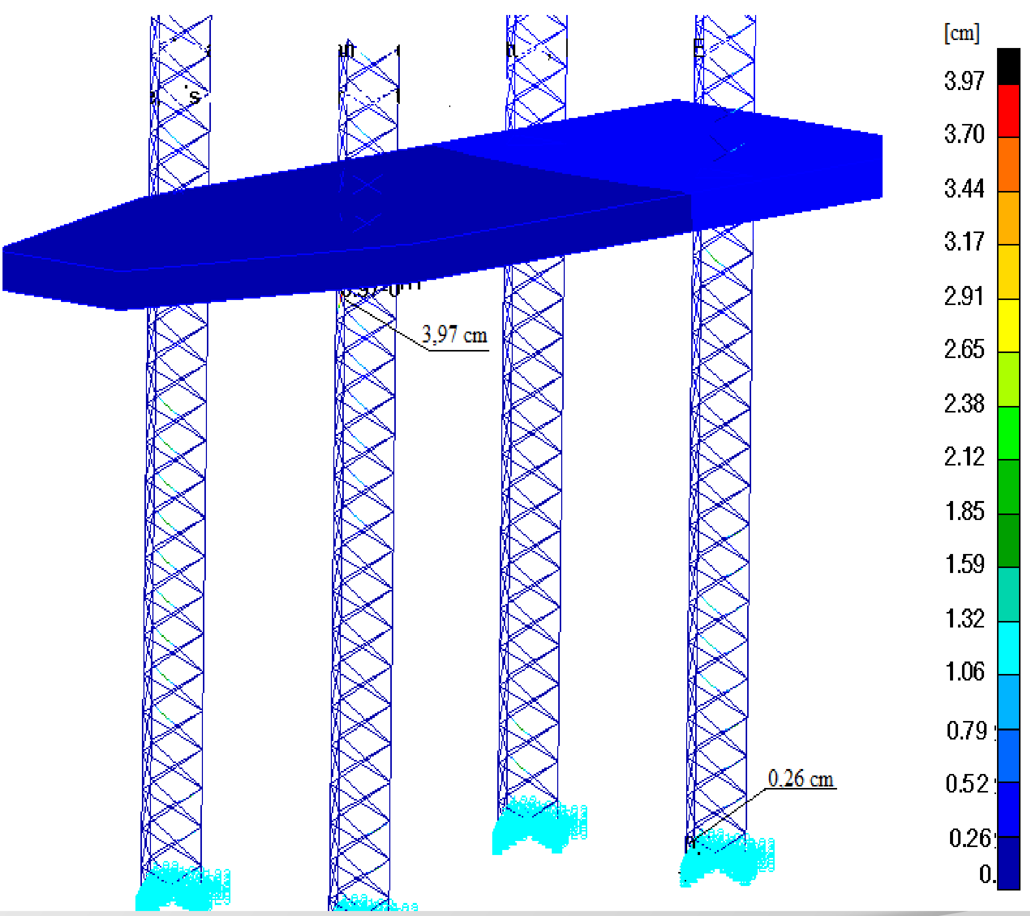


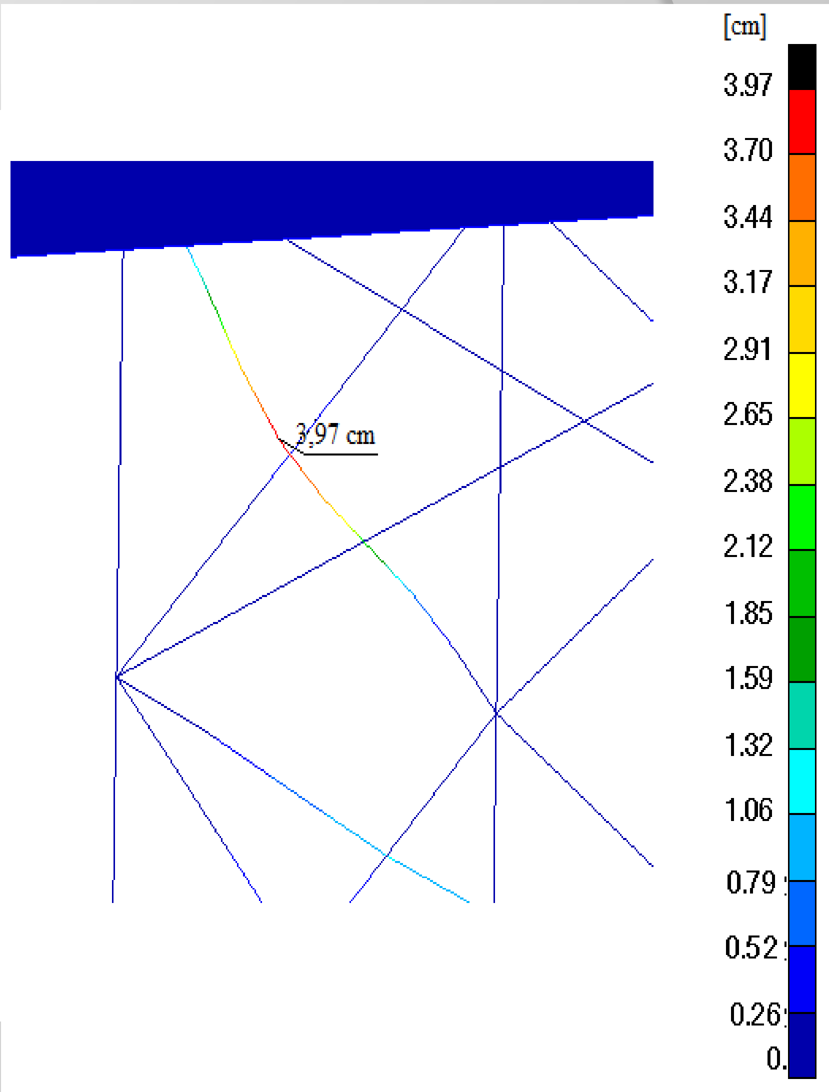




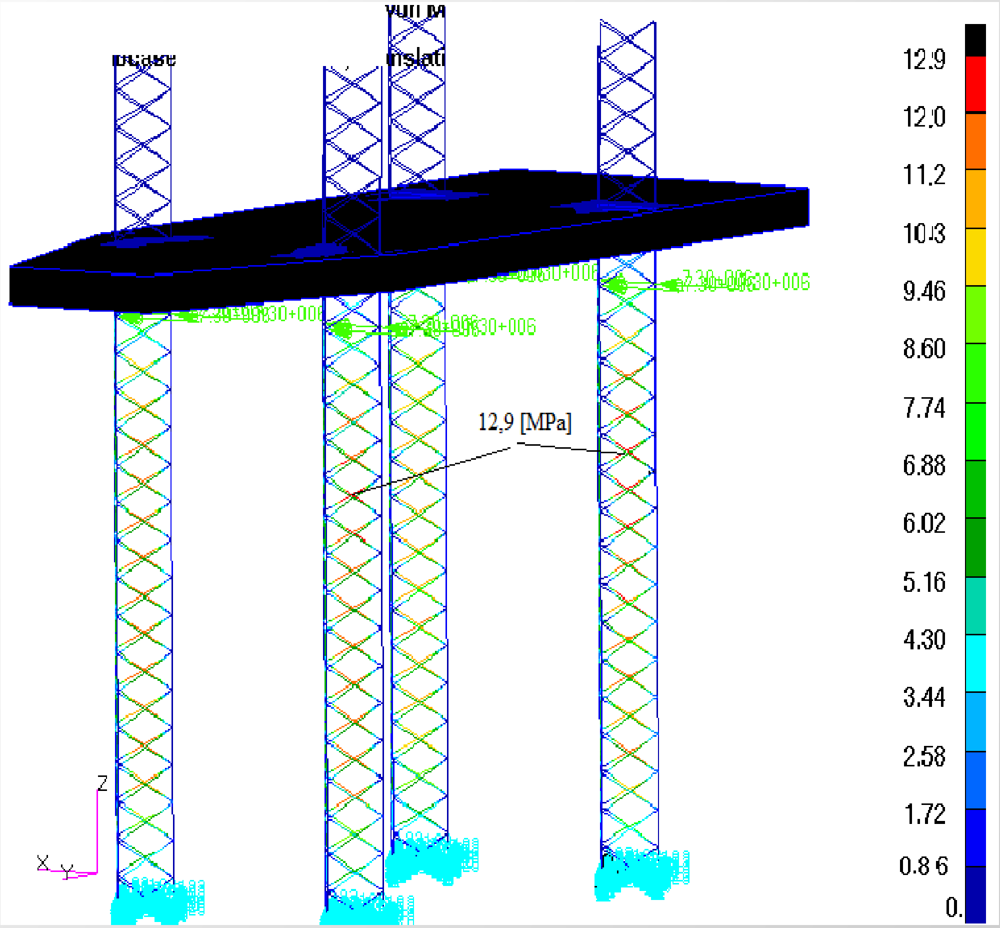


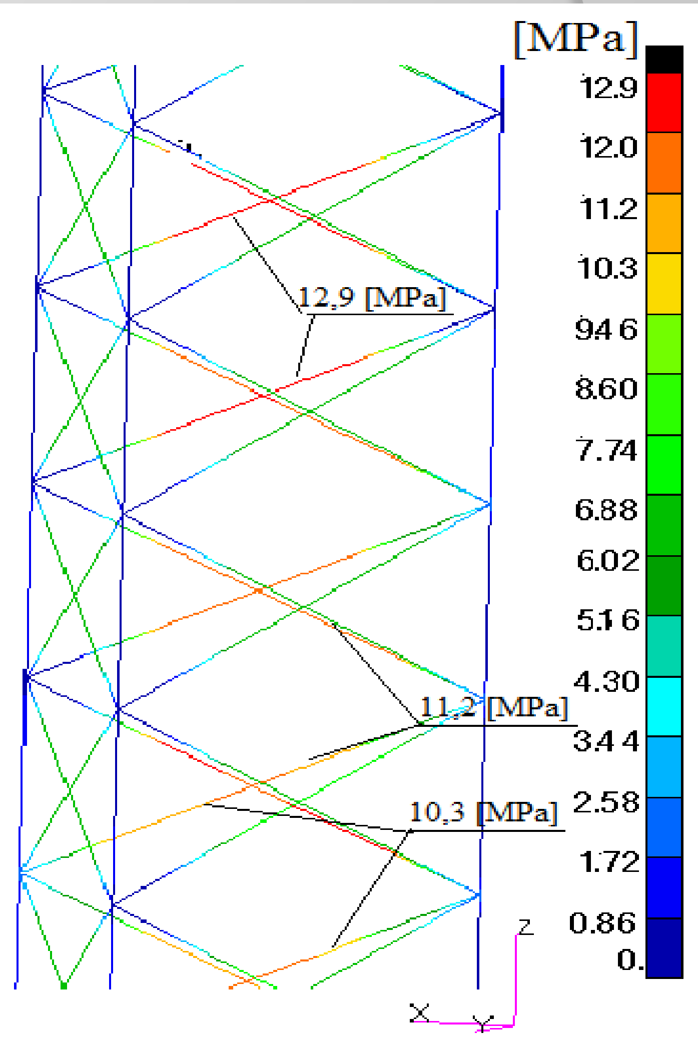
Analiza przemieszczeń



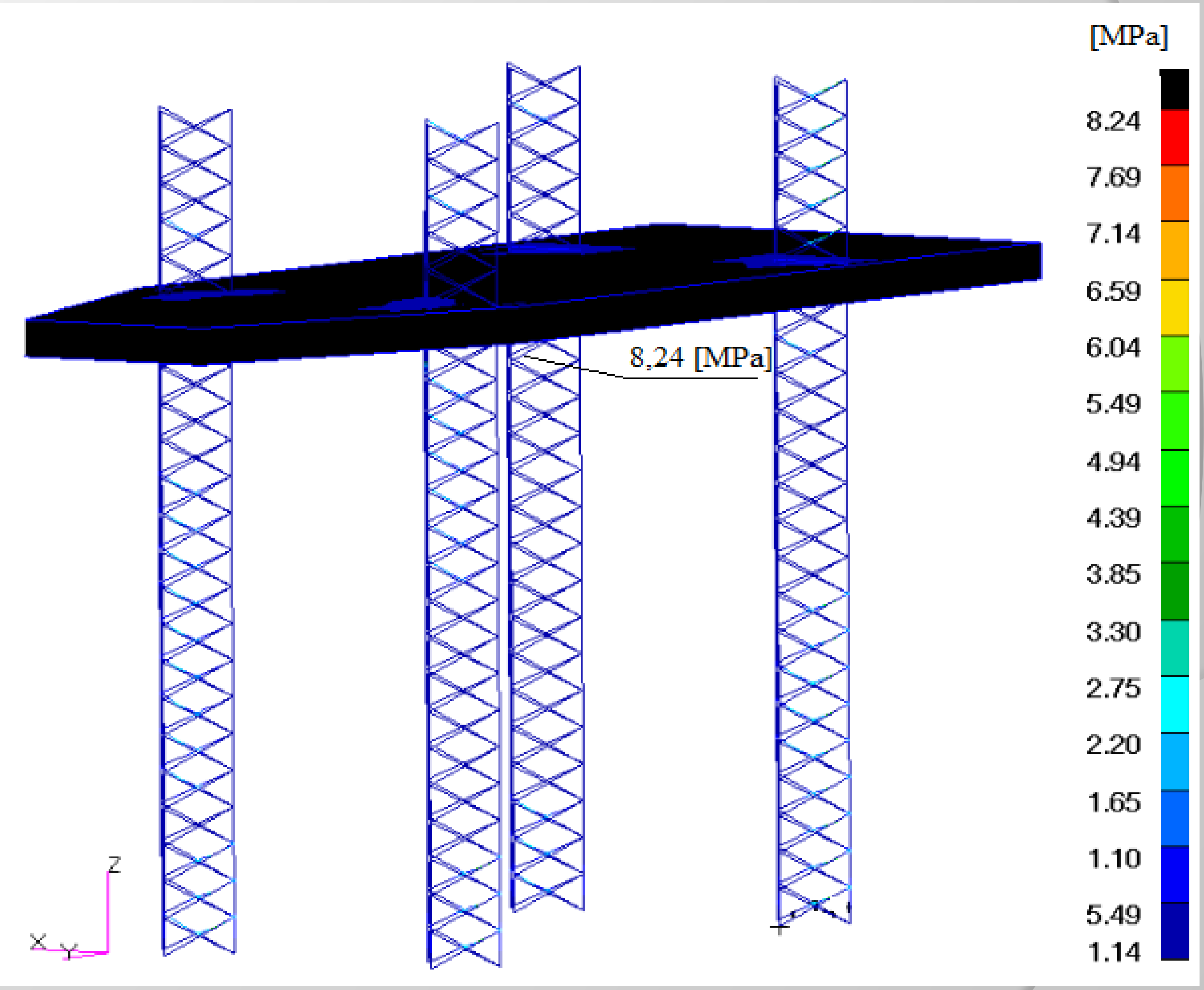


Analiza naprężeń ściskających

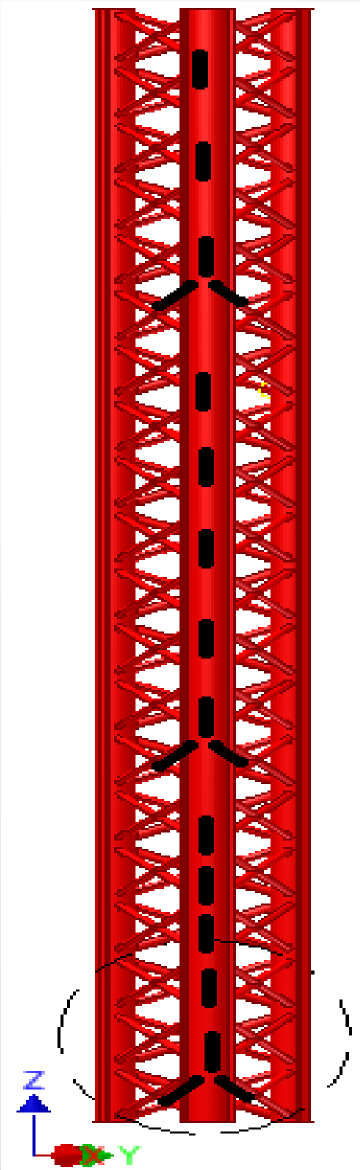


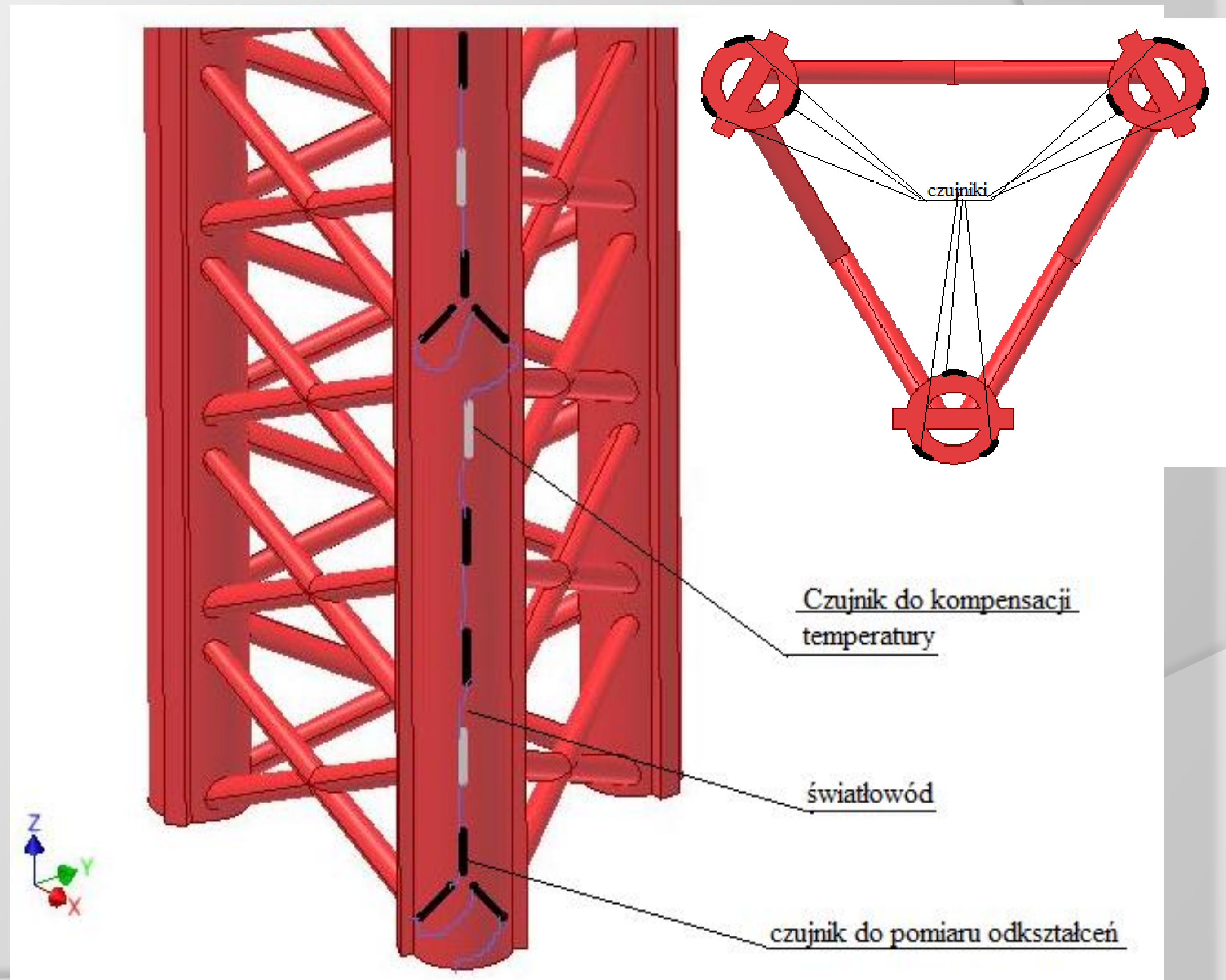


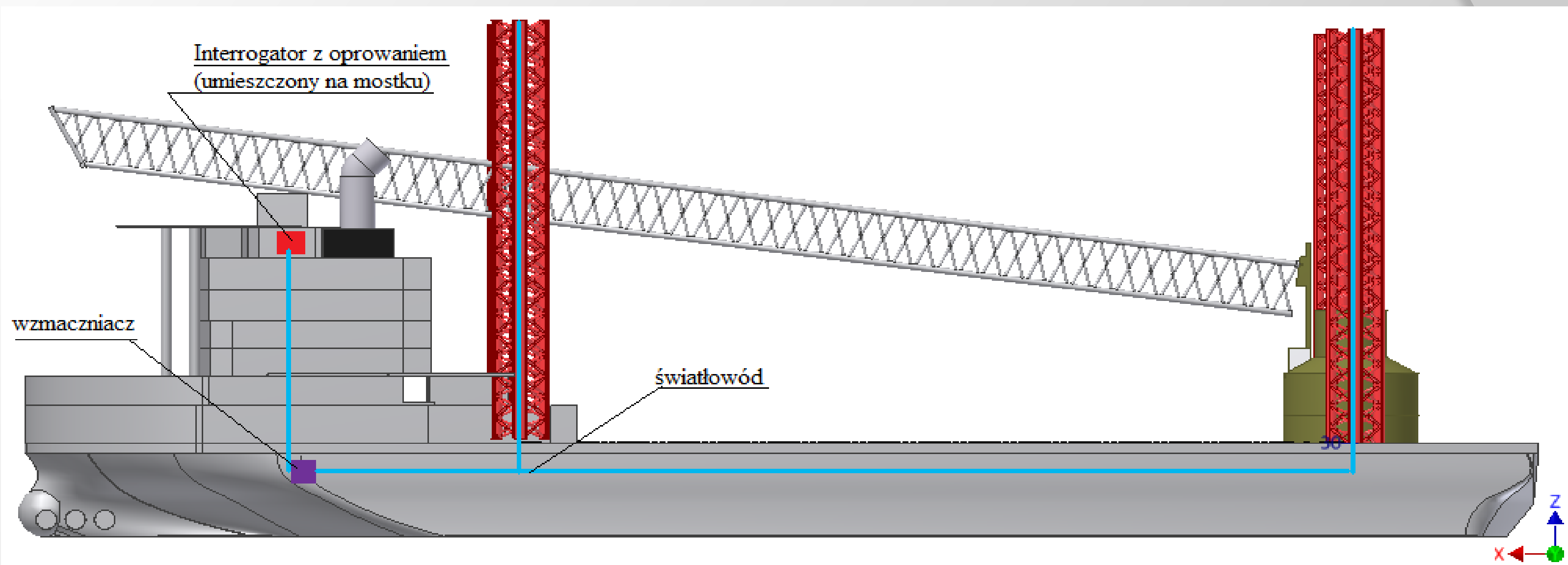
Analiza naprężeń zginających w wyniku oddziaływania siły wzdłuż osi x

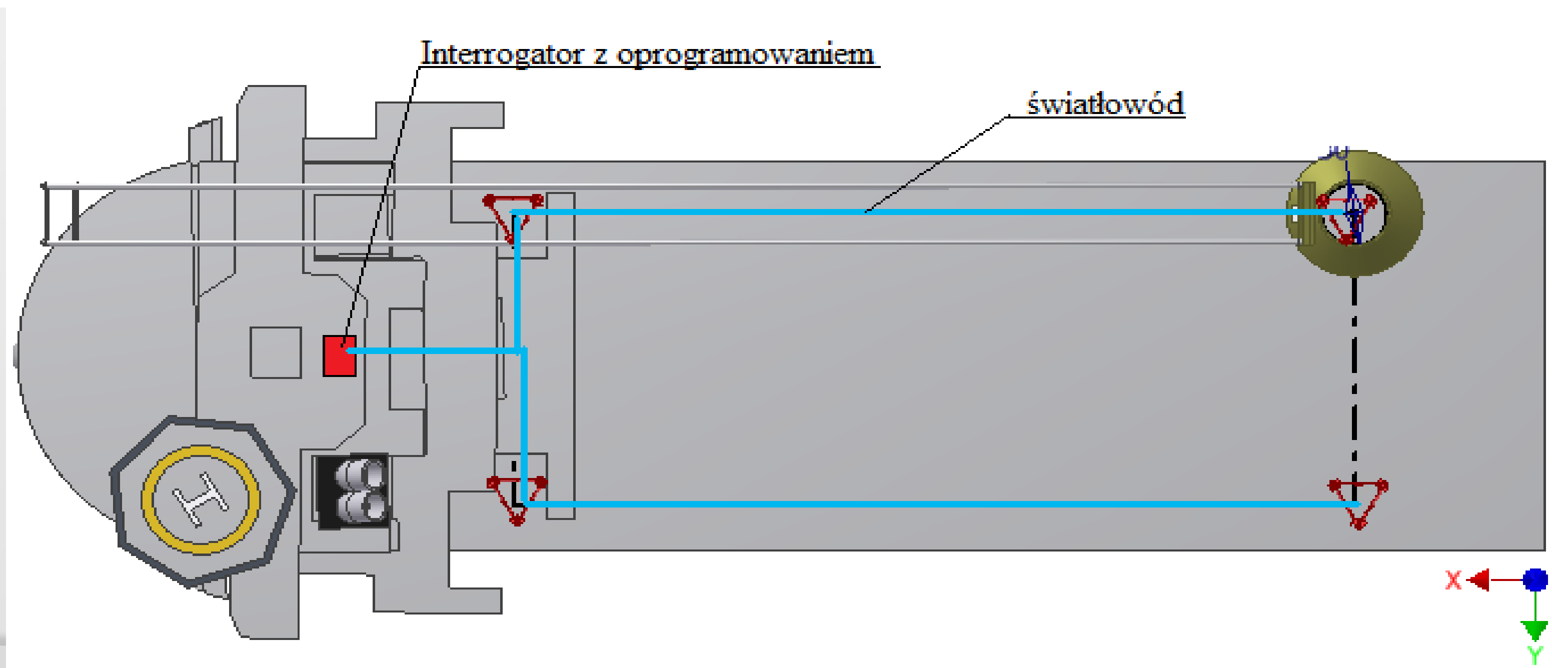


Dobór sposobu i projekt monitoringu



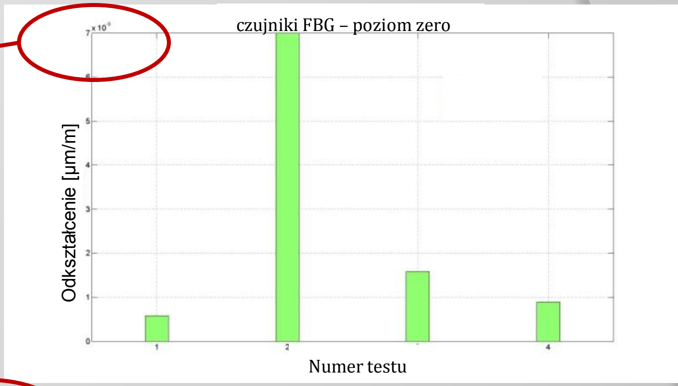



Interrogator z oprowaniem
(umieszczony na mostku)
wzmaczniacz
światłowód
Z
X


Interrogator z oprogramowaniem
światłowód
X
Y

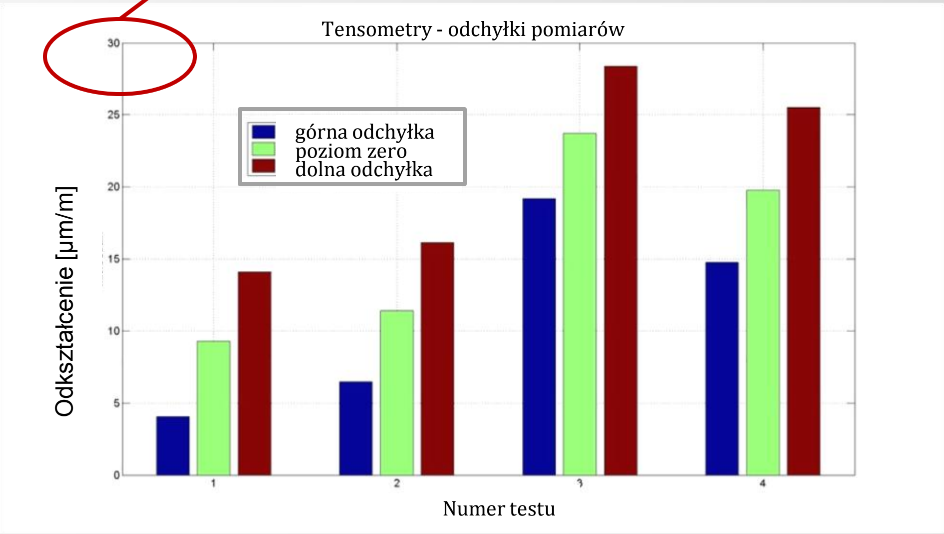
Płynięcie poziomu zerowego
Porównanie techniki tensometrycznej z światłowodową

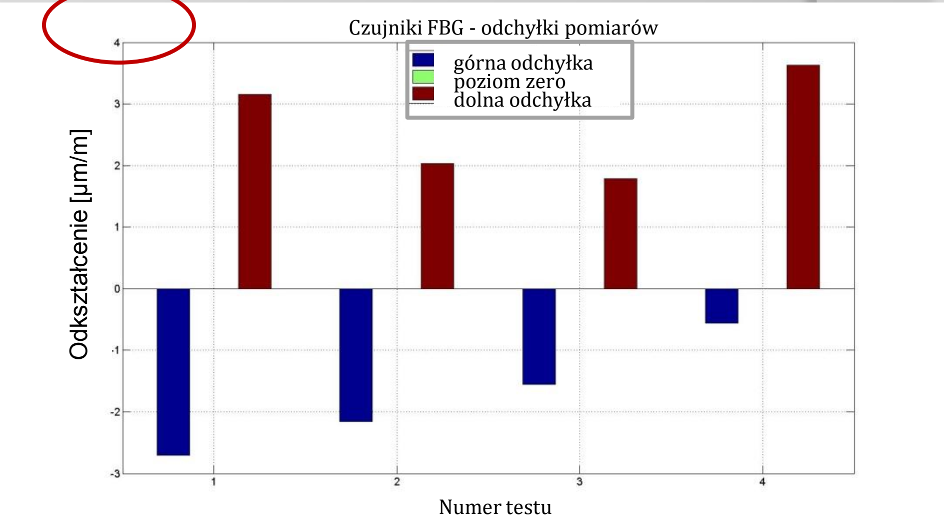
7E-8 $\mu m/m$



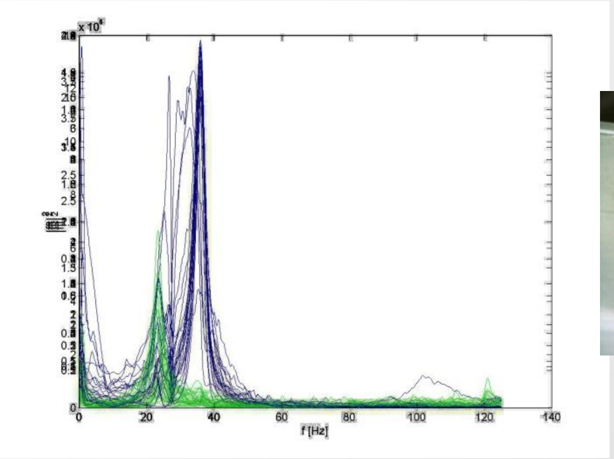
30$\mu m/m$

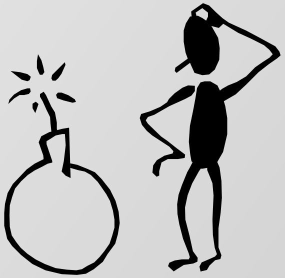
4$\mu m/m$

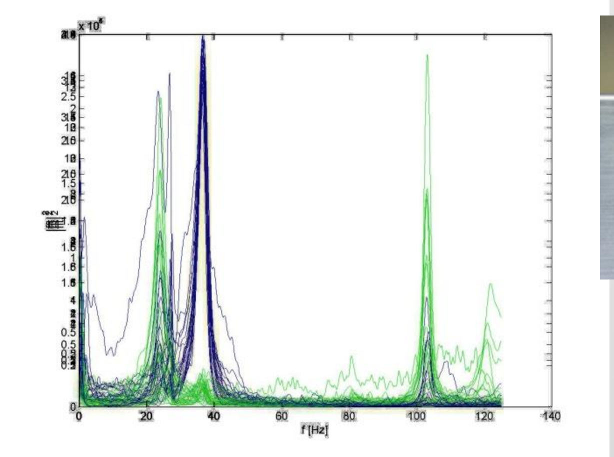


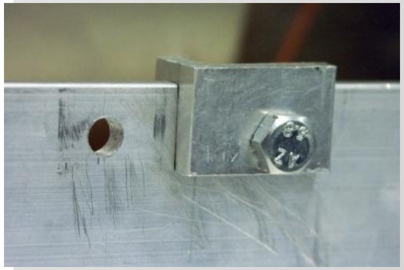


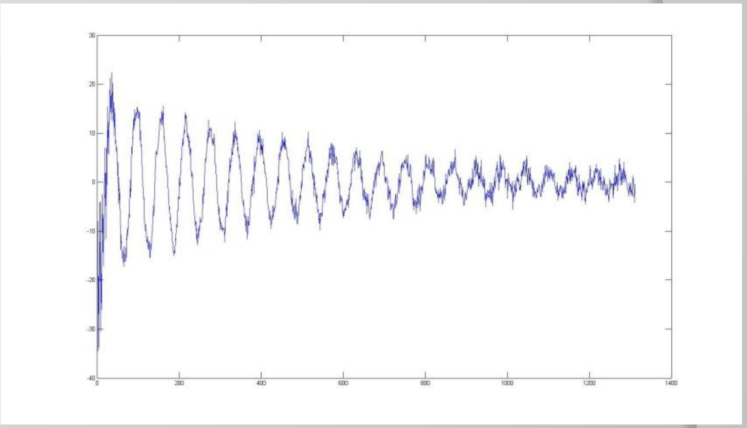
Badania dynamiczne

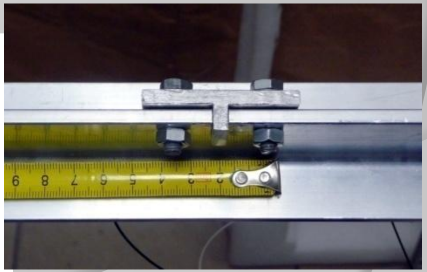


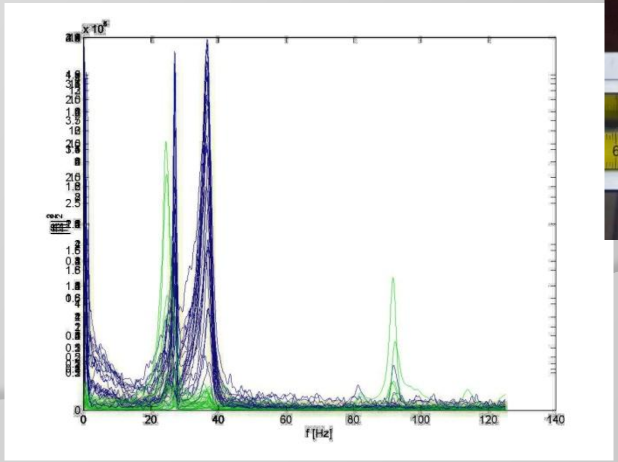




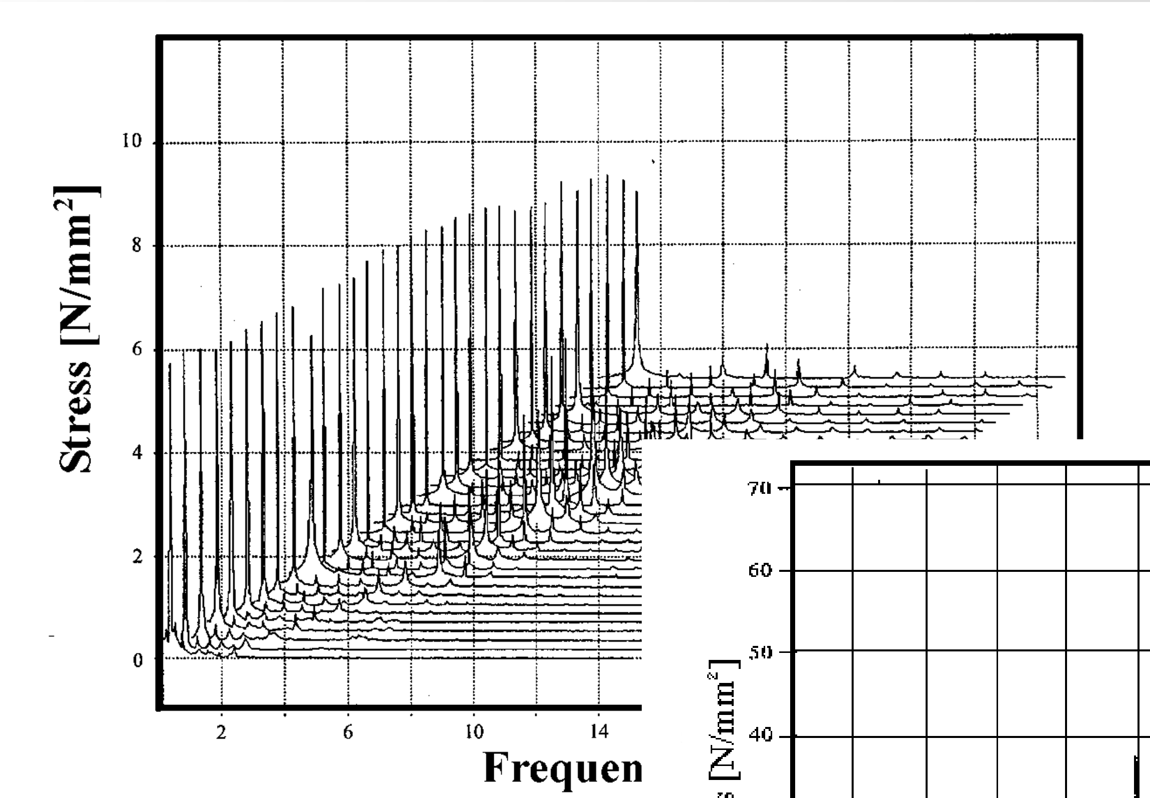


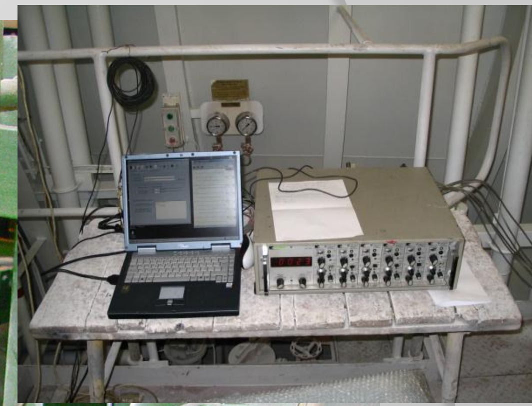


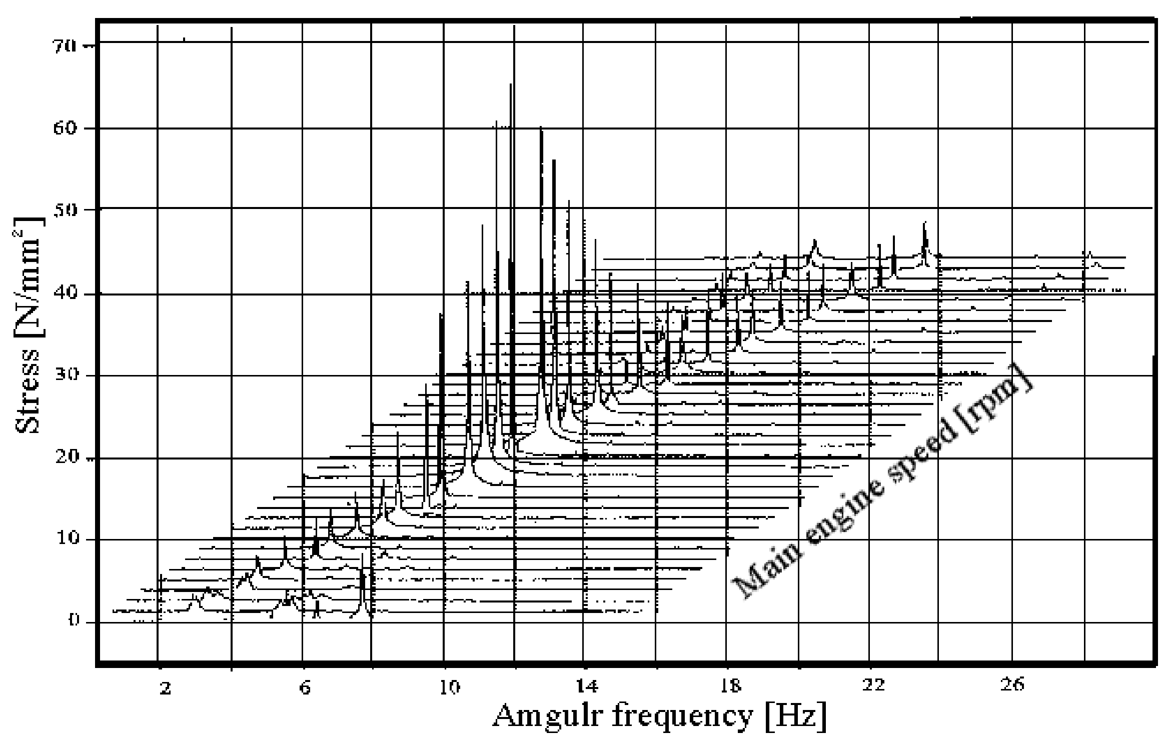




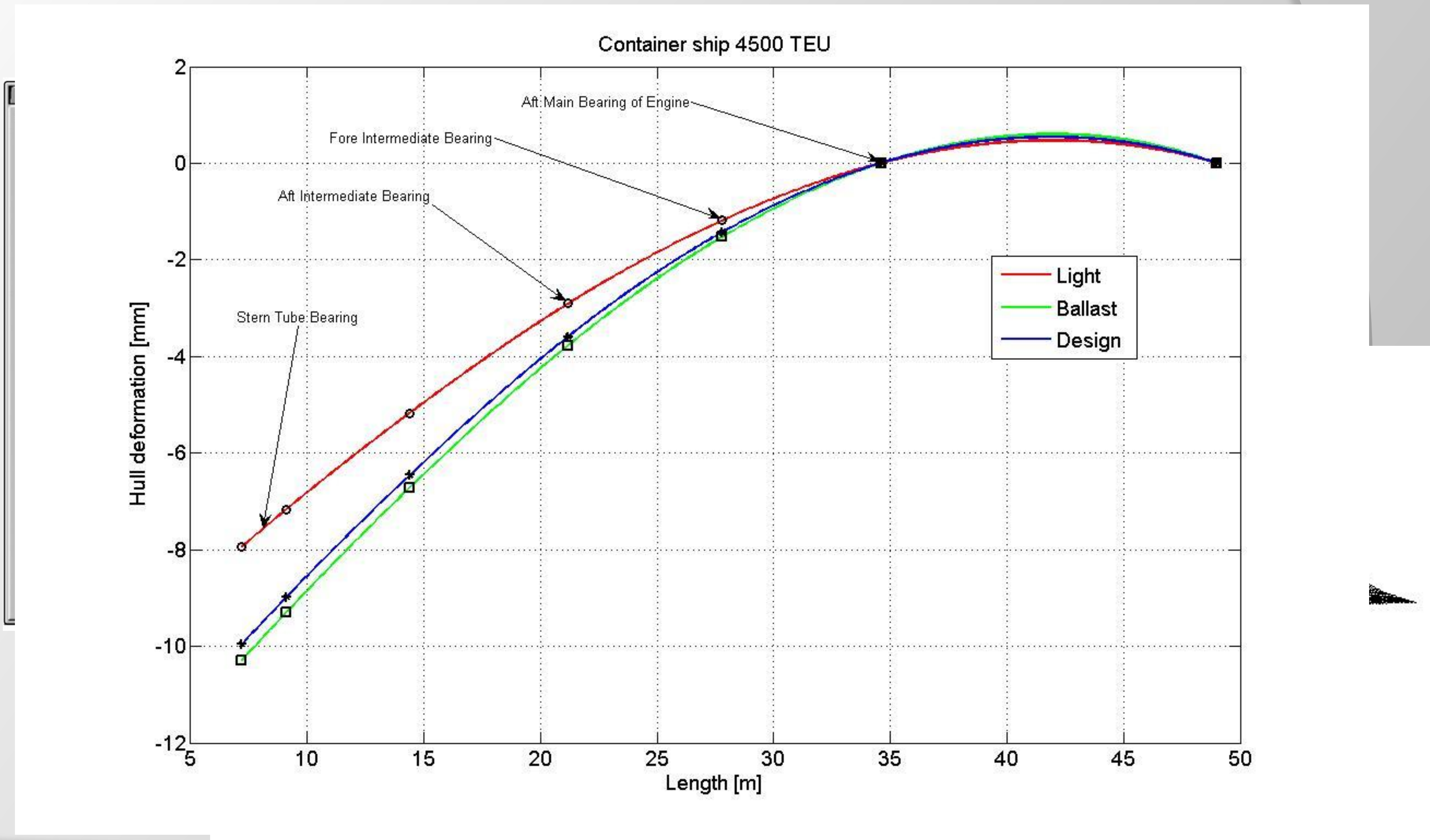
Drgania giętne i skrętne



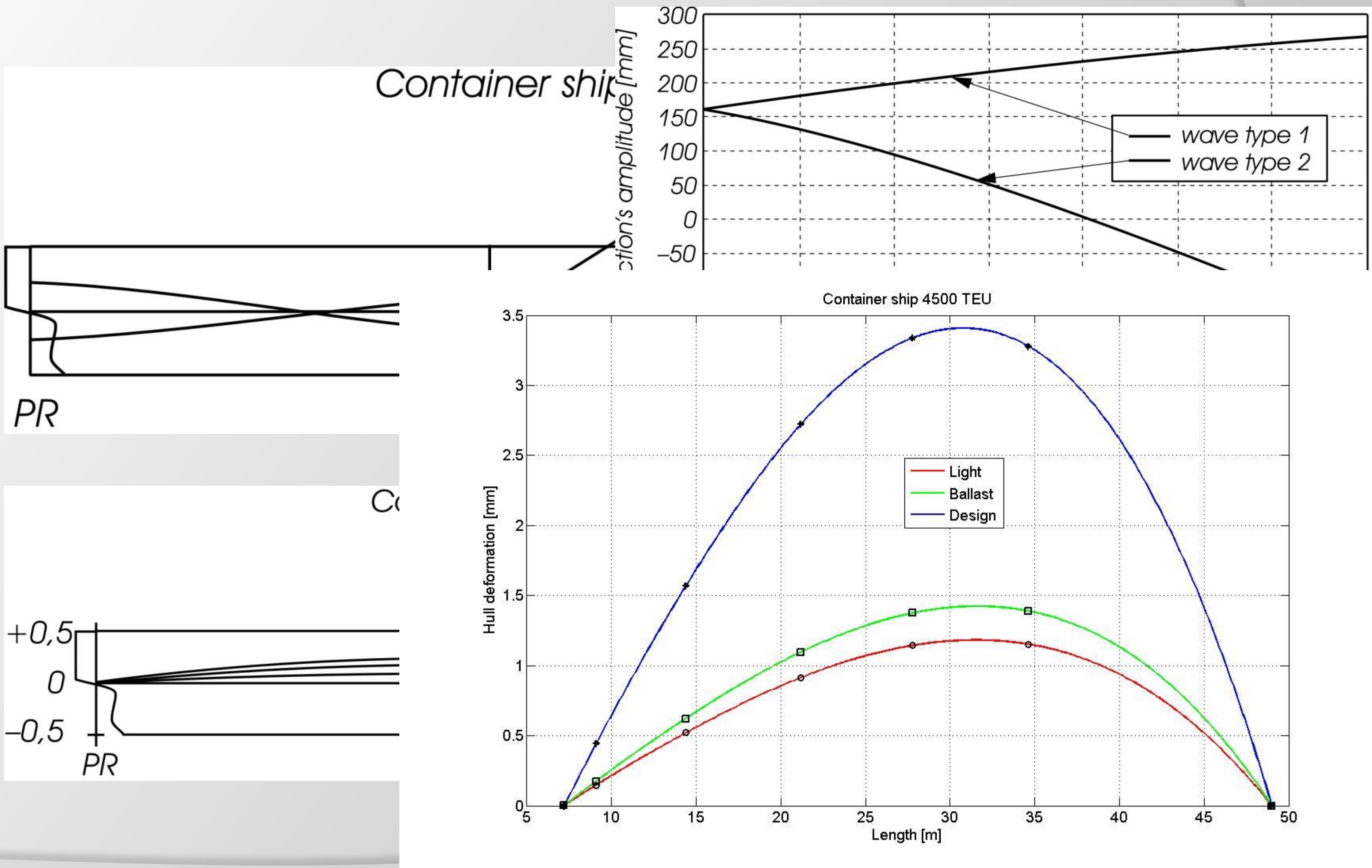




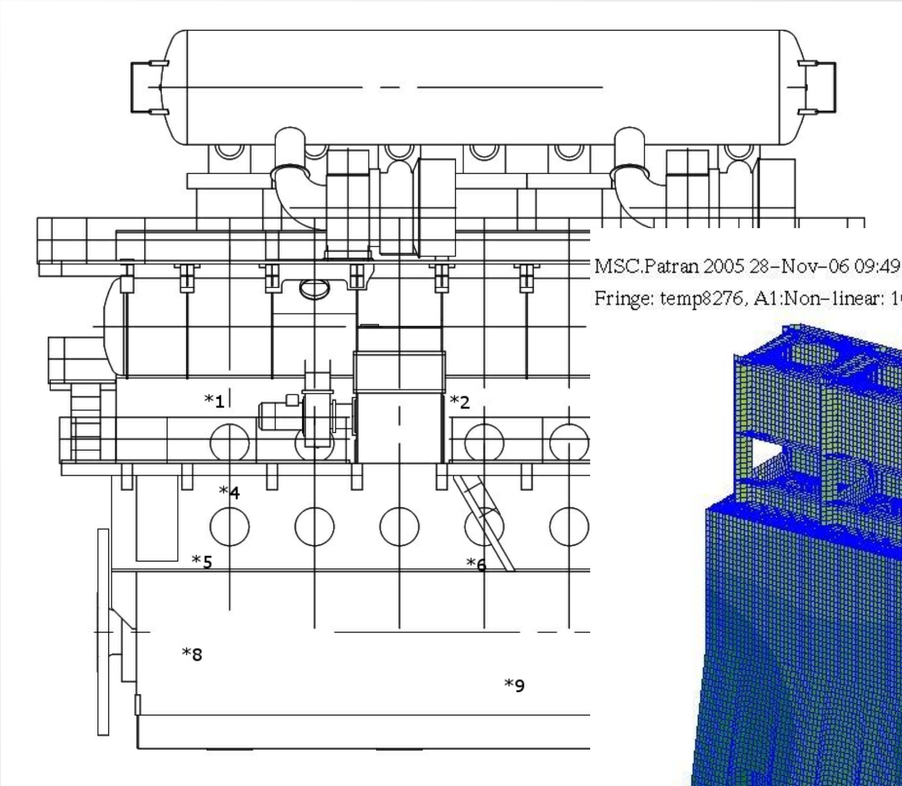
Globalne deformacje kadłuba statku w różnych stanach załadowania

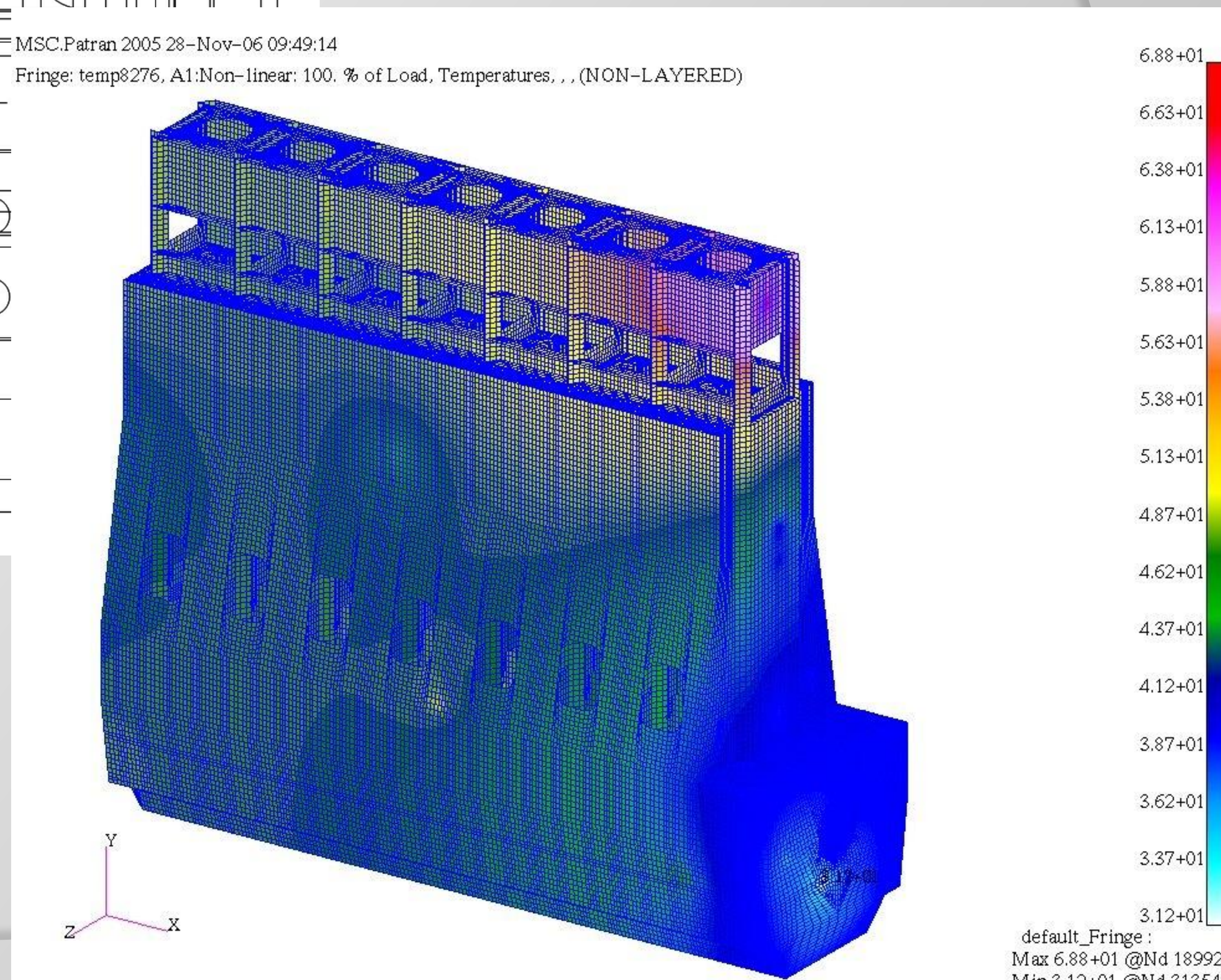


Globalne deformacje kadłuba statku na fali regularnej

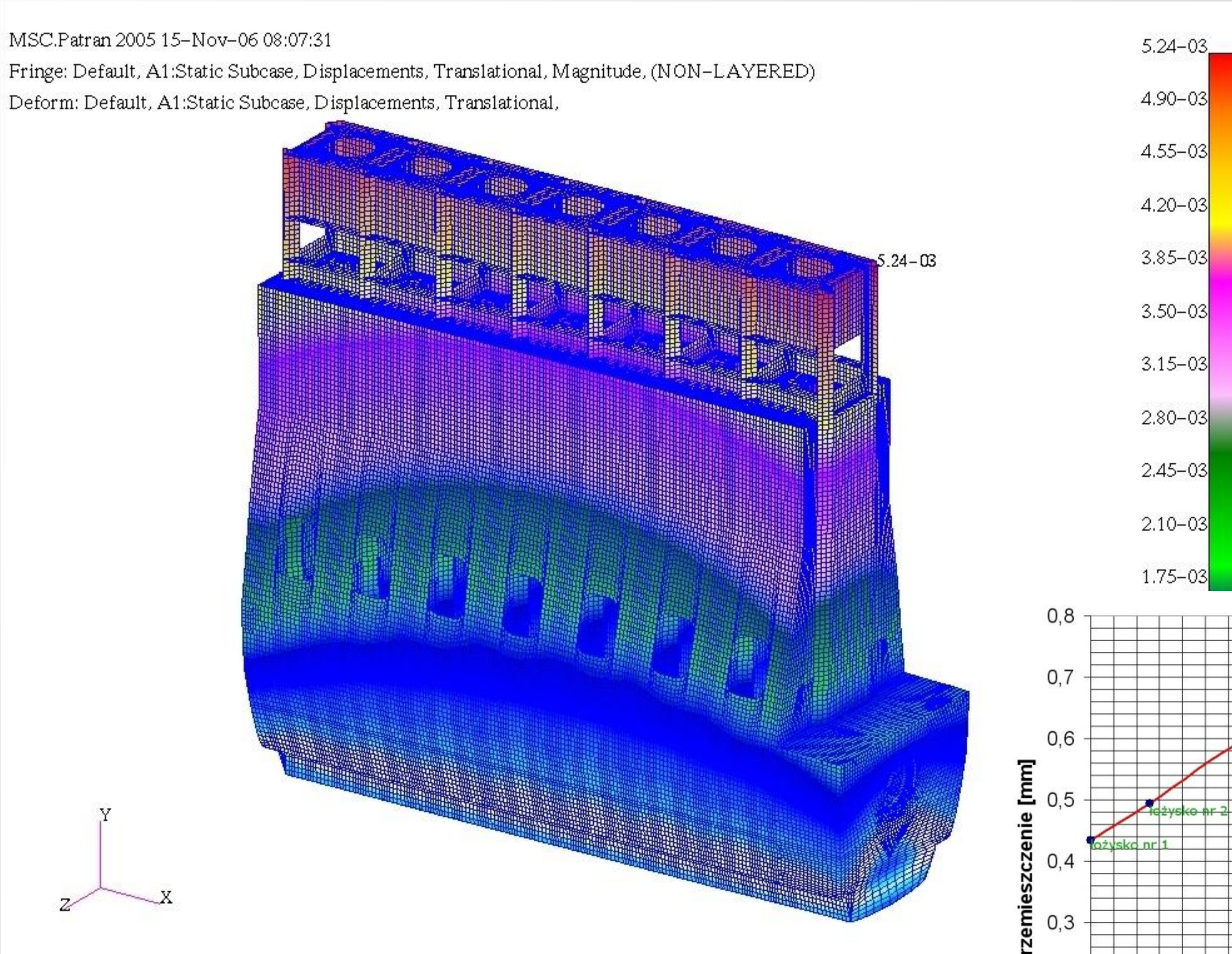


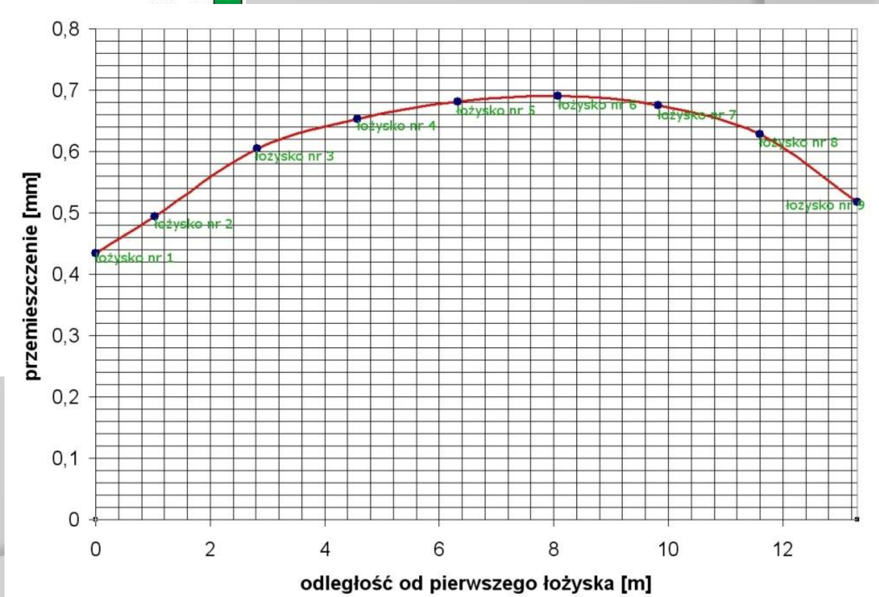
Pomiar rozkładu temperatur korpusu silnika





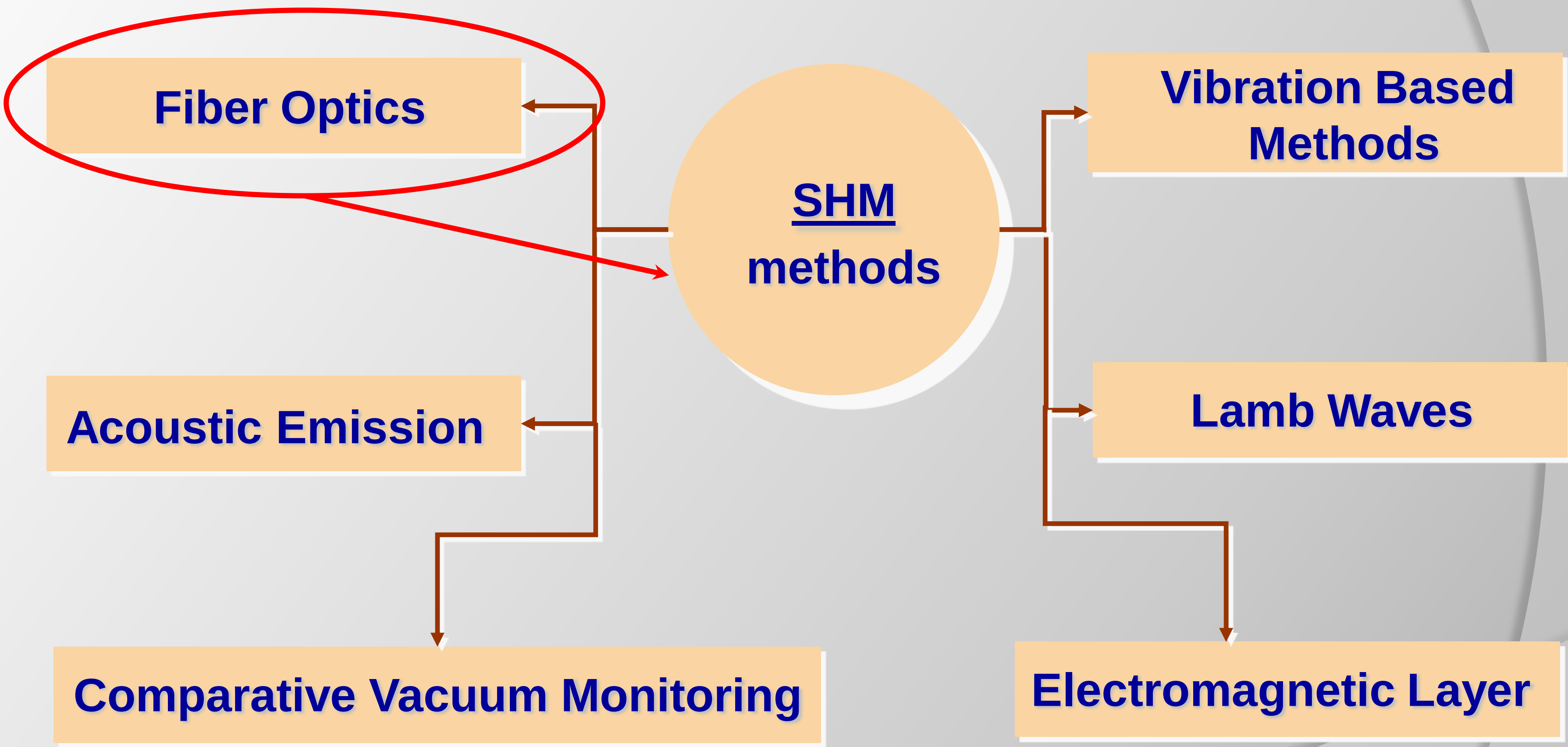
Termiczna deformacja korpusu silnika





SHM Methods

There is a need for SHM methods capable of comprehensive, real-time condition monitoring



Sailing ships hazards

Pogoria

a

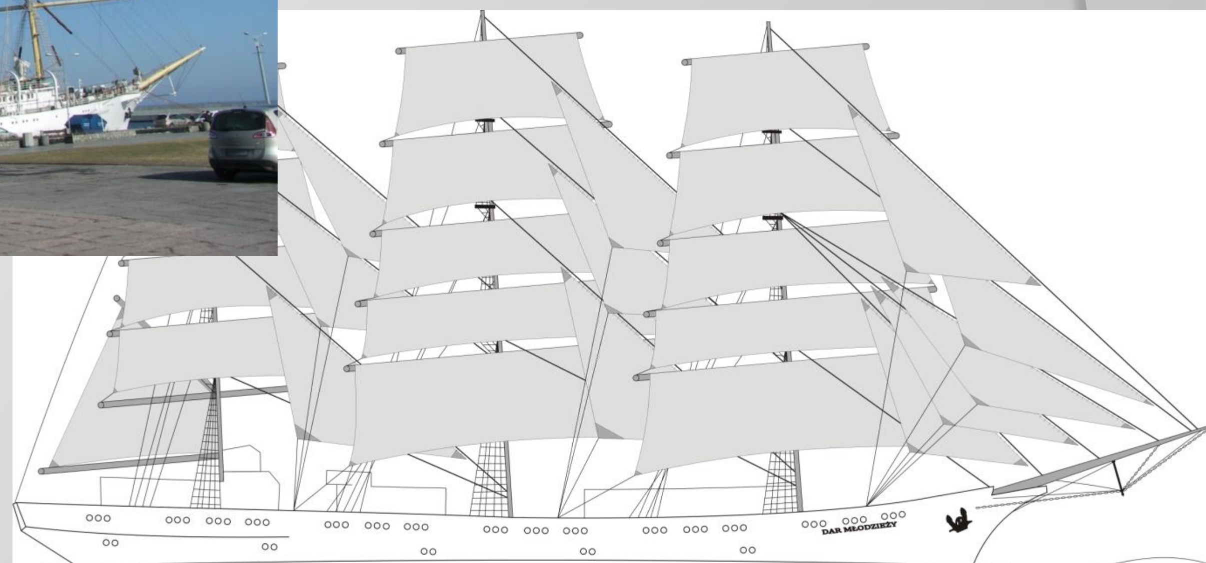
a_1

b

Fryderyk Chopin

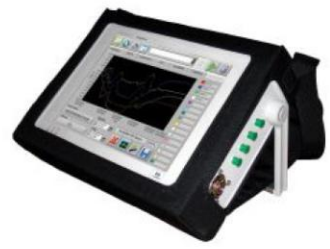
b_1

Investigated frigate: Dar Młodzieży

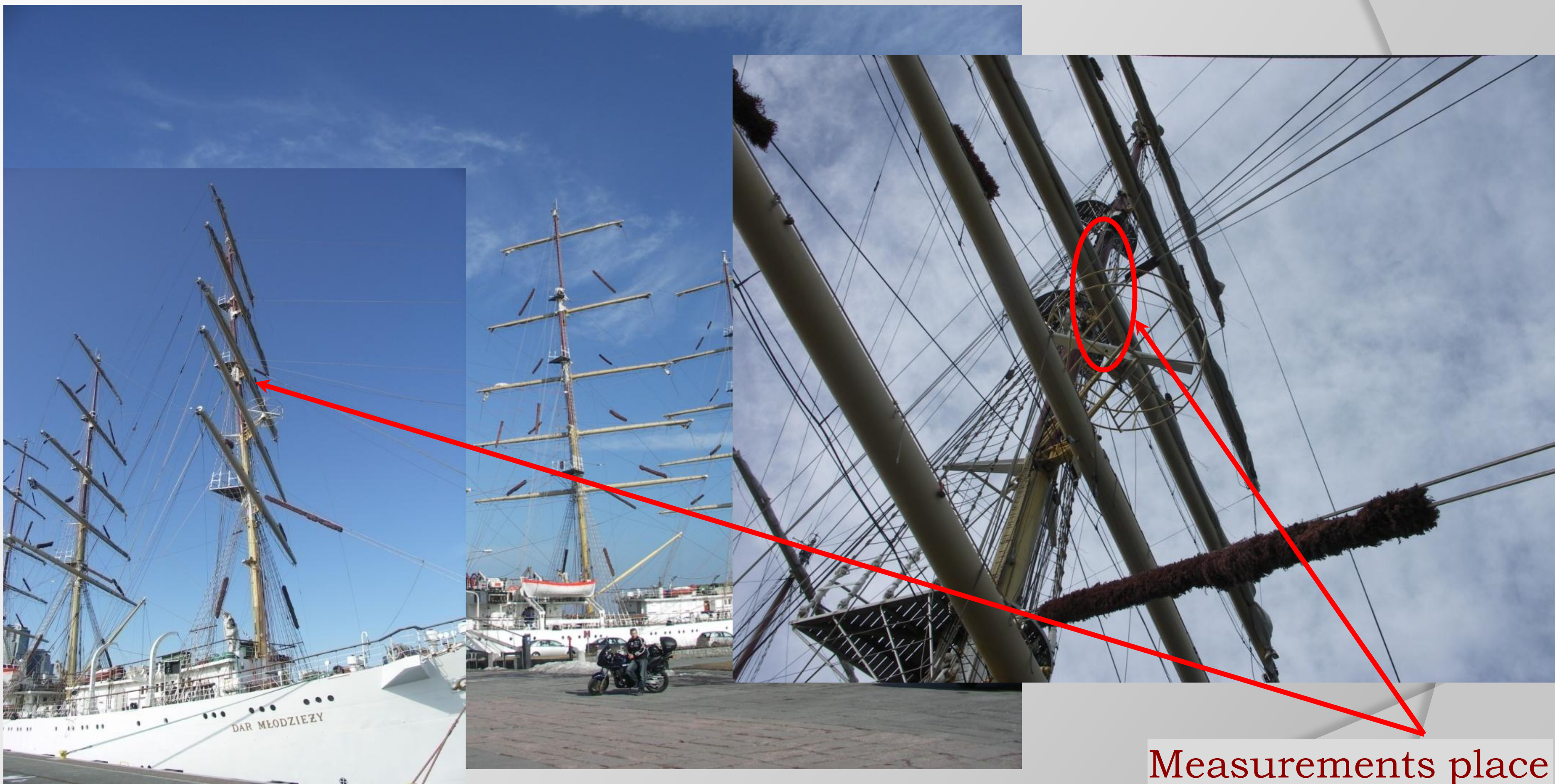


Laboratory equipment

Institute of Fluid Flow Machinery PAS, Gdansk

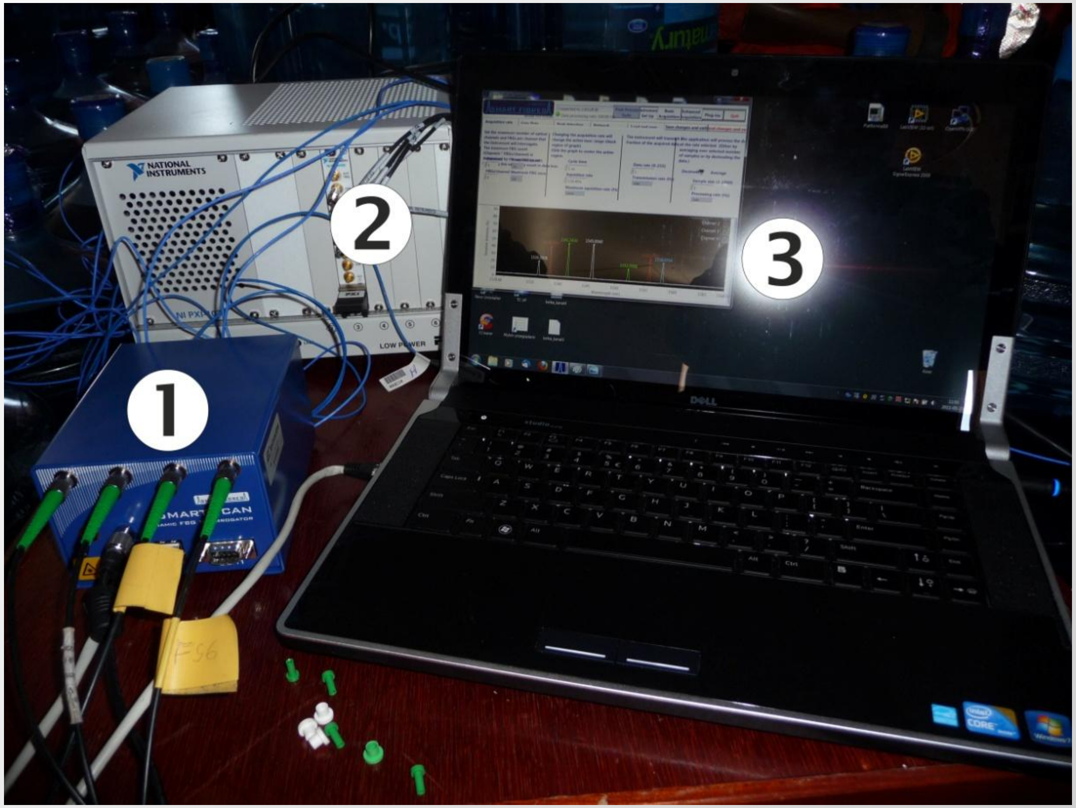
	FS2500 Fiber Sensing	FS4200 Fiber Sensing	si425-500 Micron Optics	SmartScan Smart Fibres
				
operating range [nm]	1530-1570	1510-1590	1520-1570	1528 – 1568
sensor per fibre	max. 4	max. 25	max. 128	max. 16
optical channels	1	4	4	4
scan frequency [Hz]	2 000	1	250	25 000
dimensions [mm]	175x105x60	360x275x100	134x432x451	140x110x70
weight [kg]	1.5	7.3	15.5	0.9

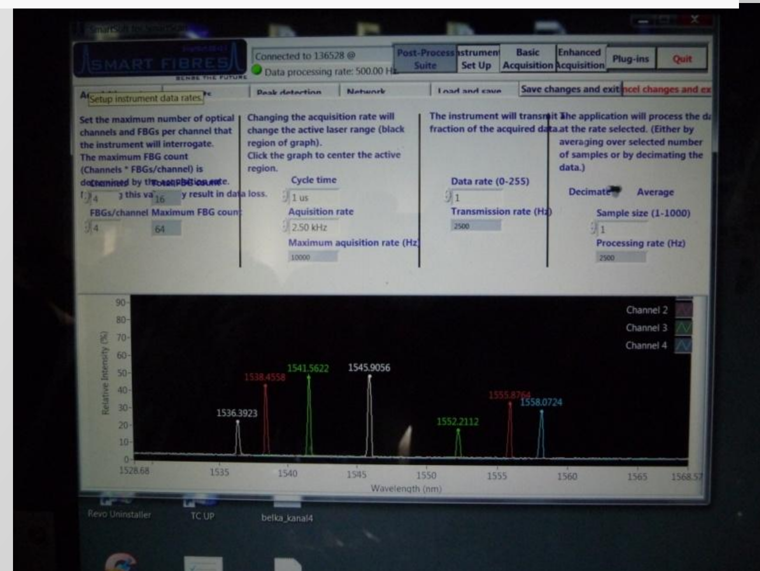
Experimental investigations of the foremast



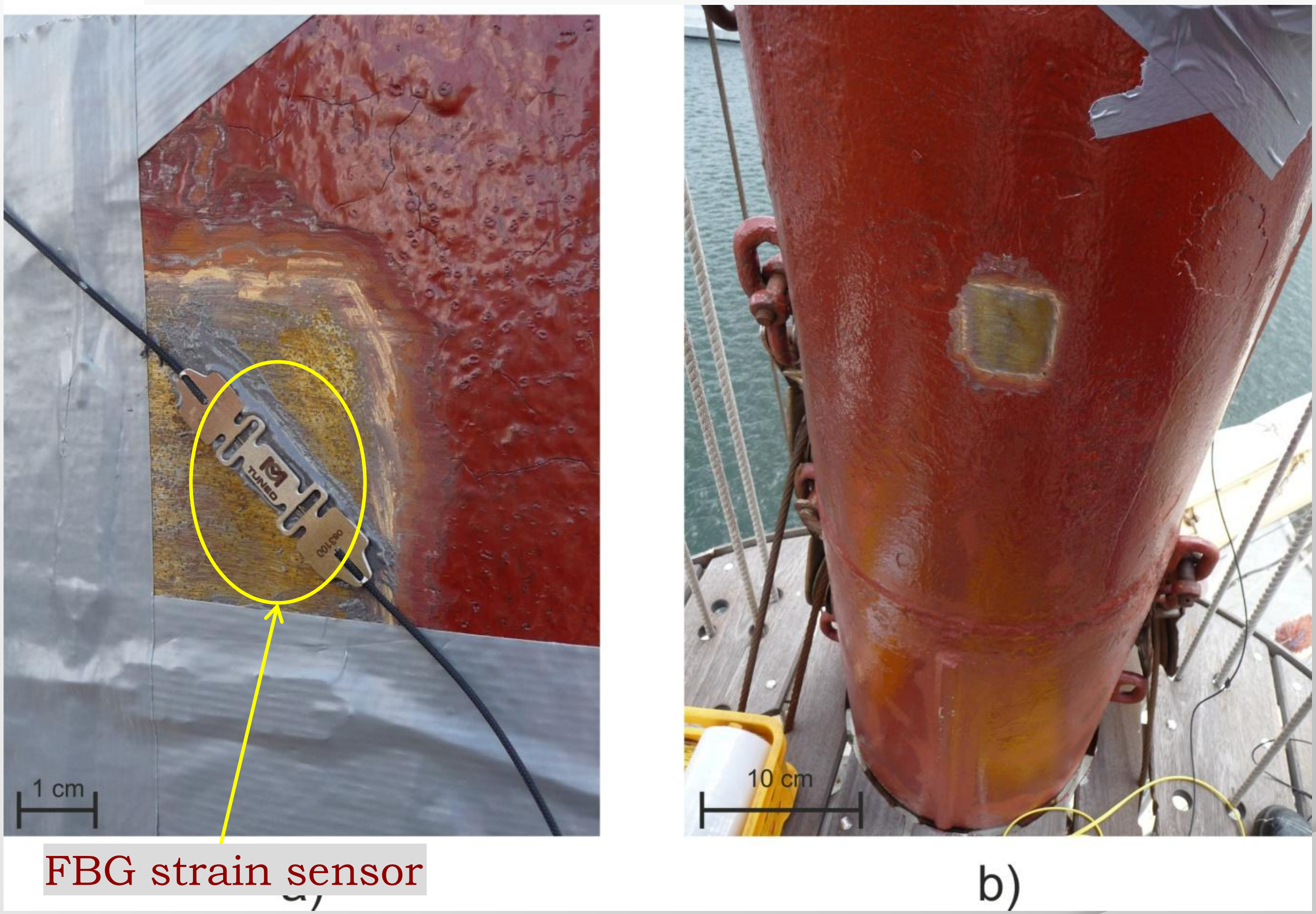
Experimental investigations: three stays from foremast to bowsprit

Experimental investigations: equipment

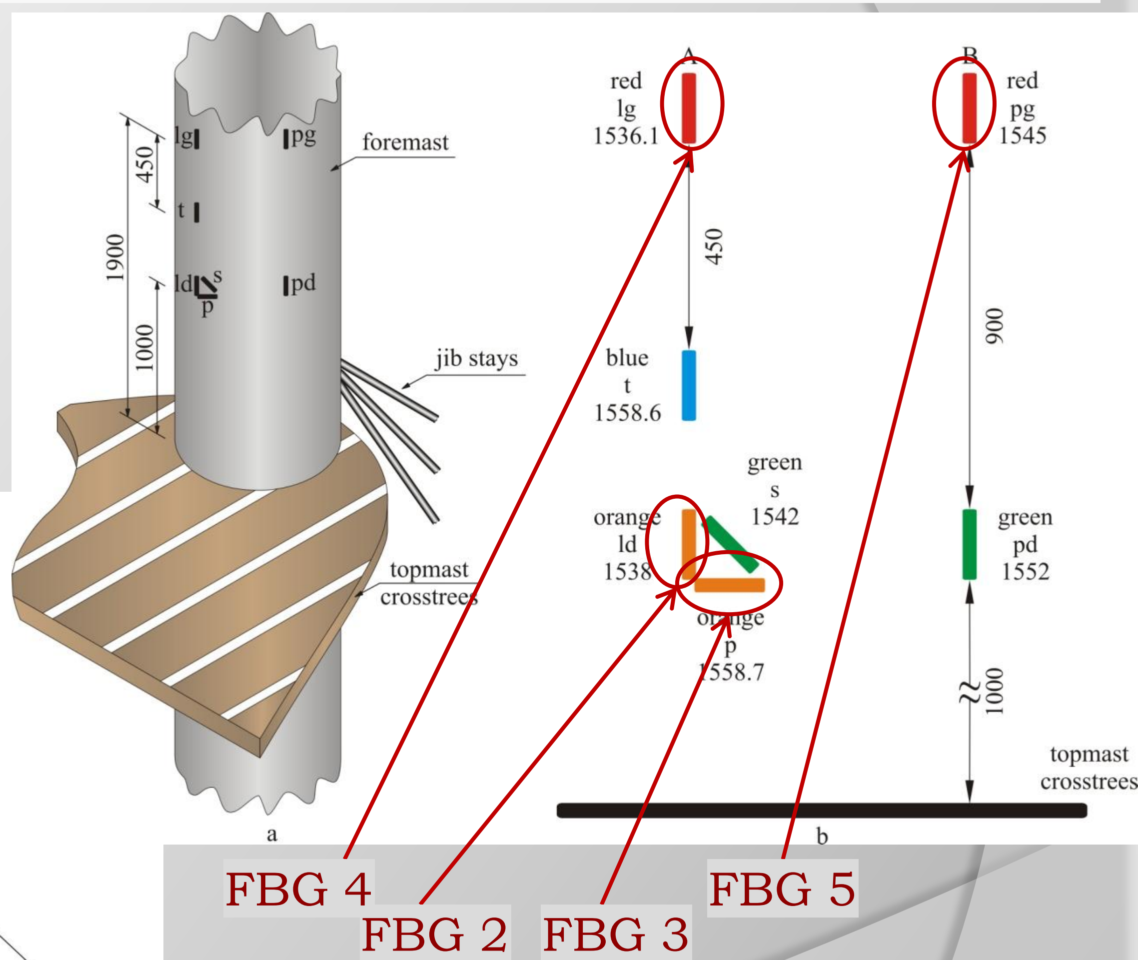


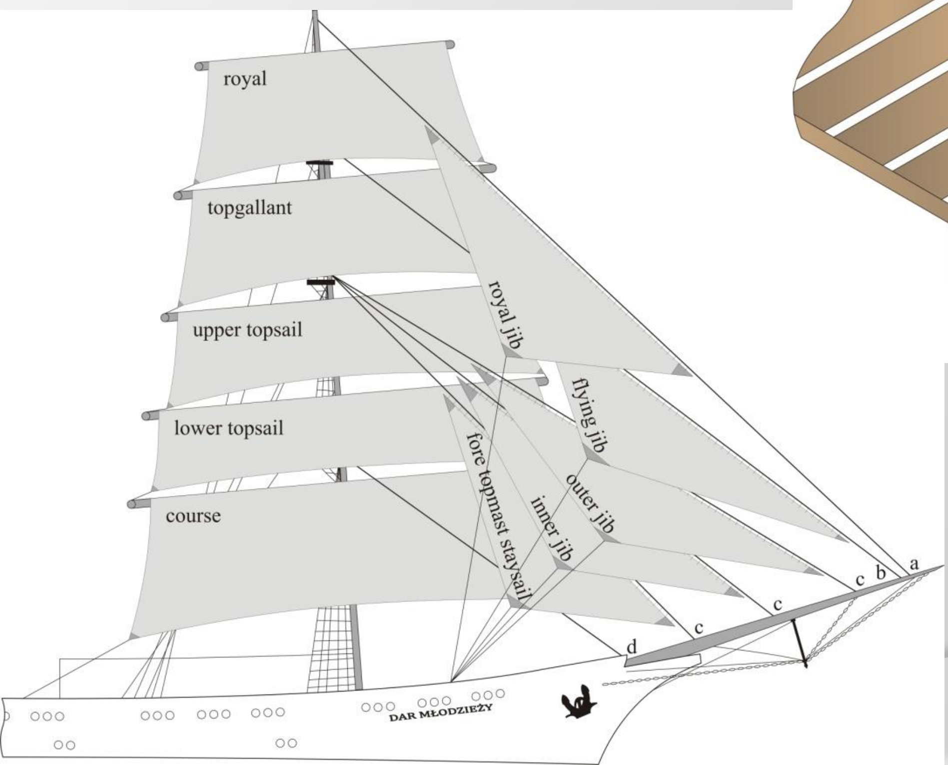


Experimental investigations:
FBG sensor on the foremast

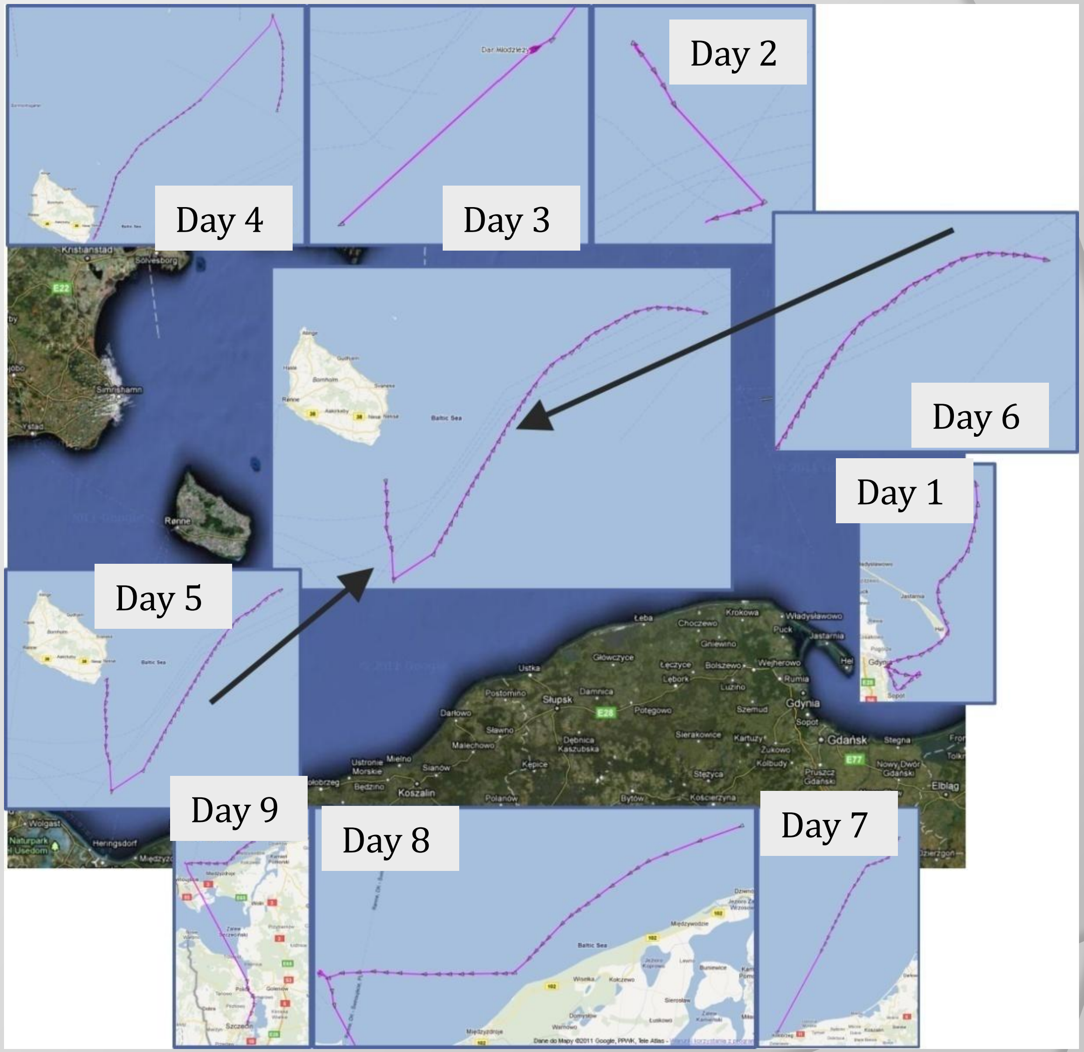


Experimental investigations: FBG sensors location

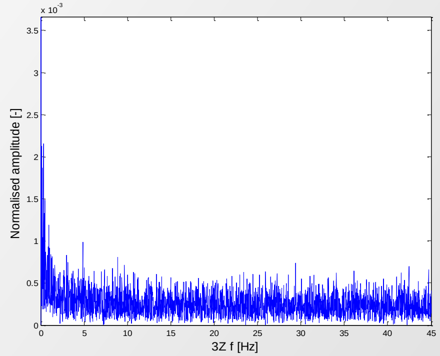




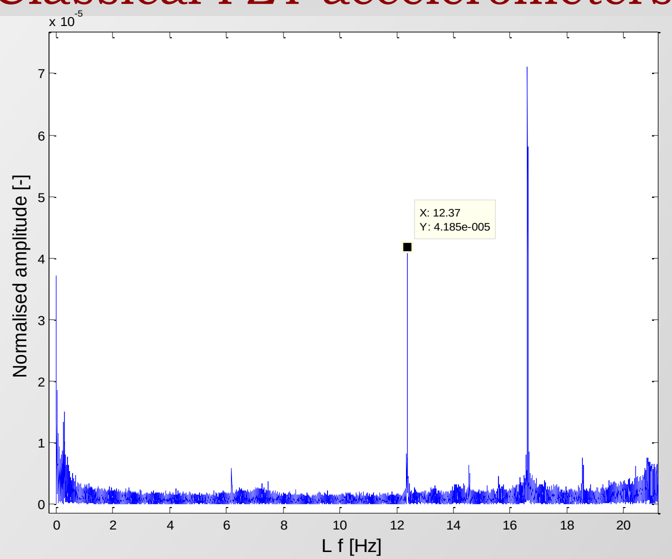
Route of the Dar Młodzieży



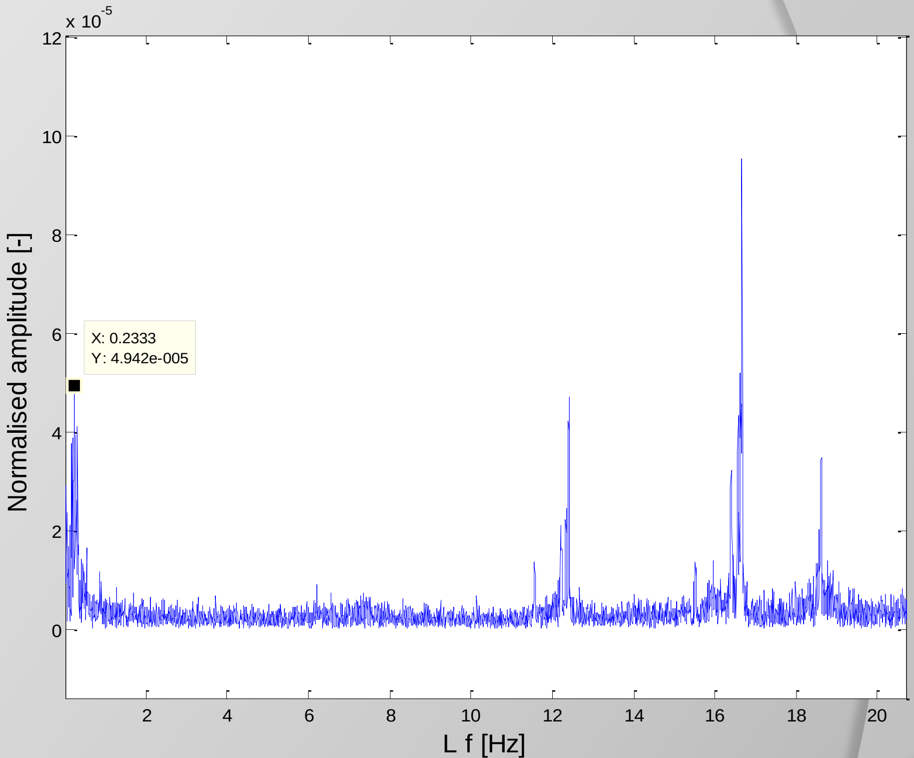
Hull vibrations and displacements



Classical PZT accelerometers

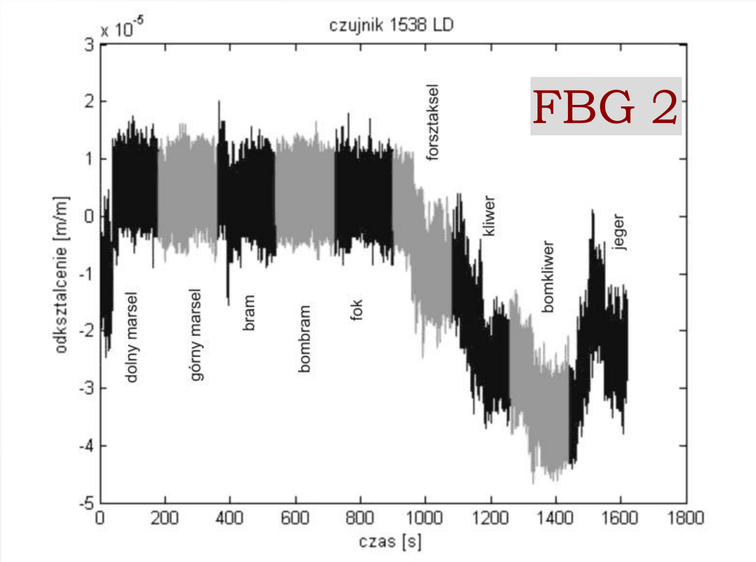


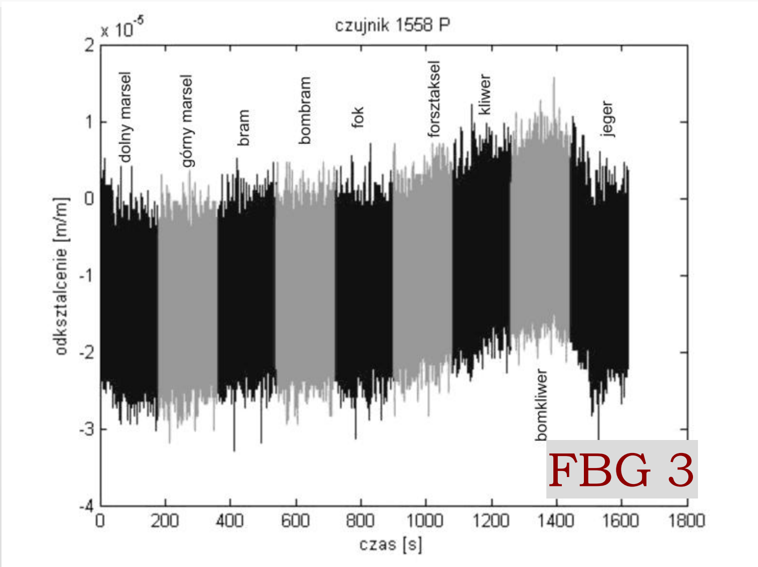
Sejsmic PZT accelerometers: equipment vibrations

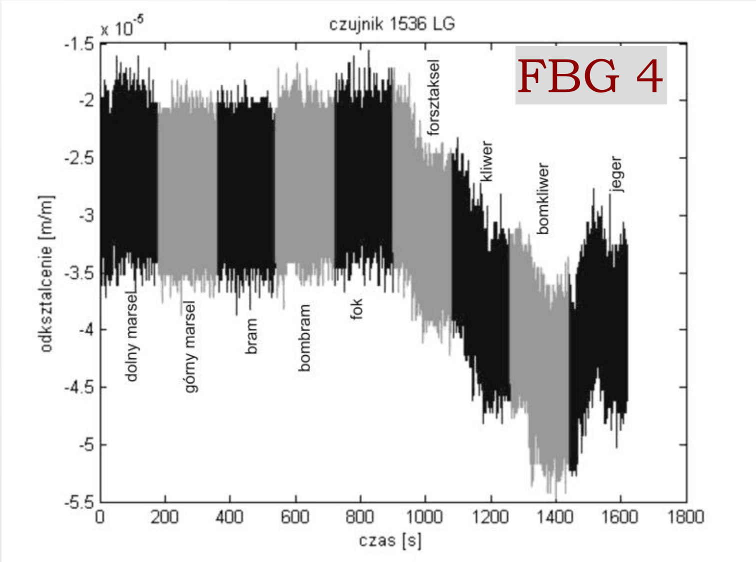


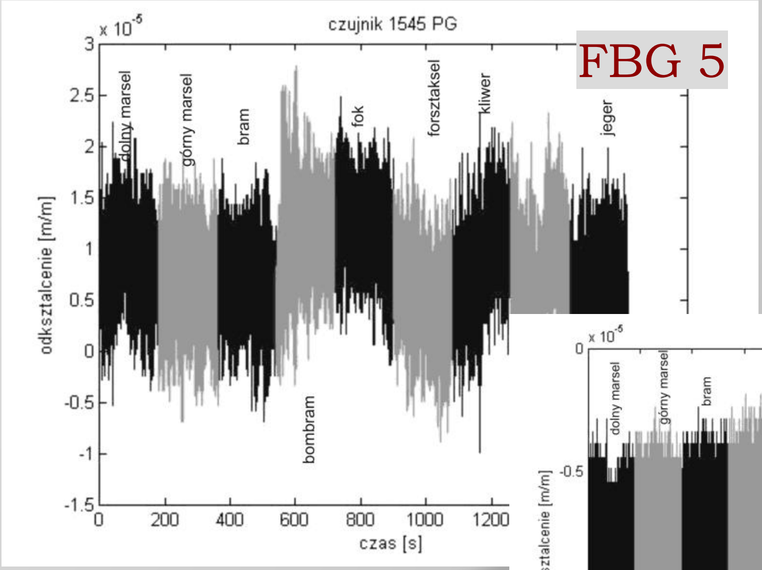
Sejsmic PZT accelerometers: ship rocking

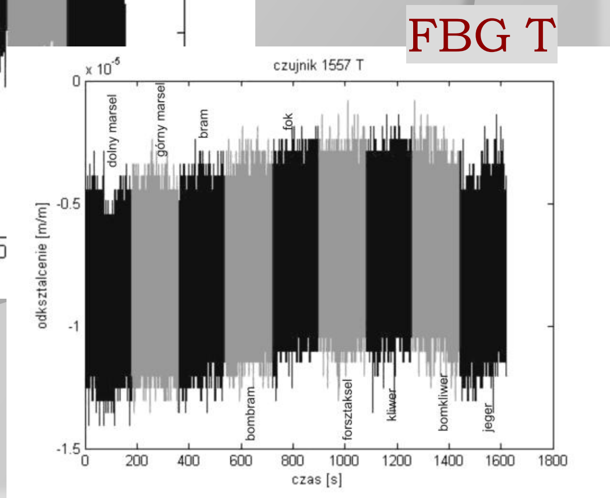
FBG sensors data – sails settings



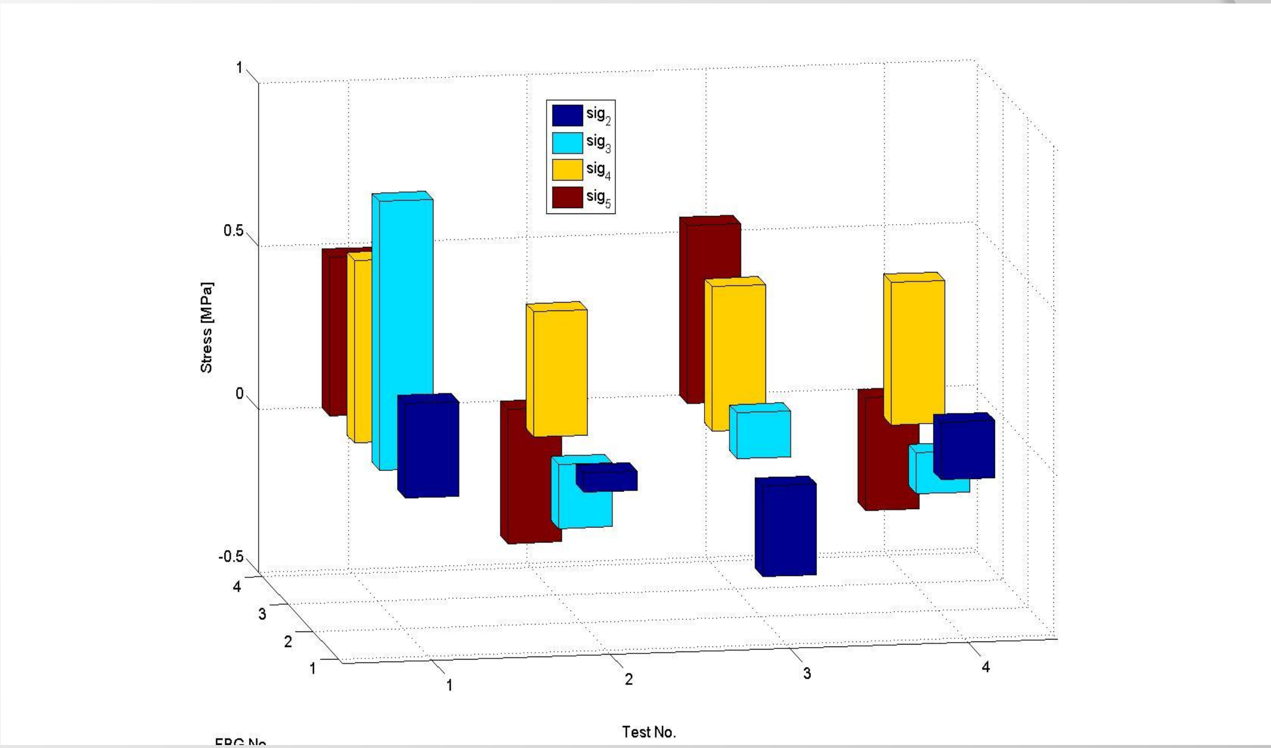






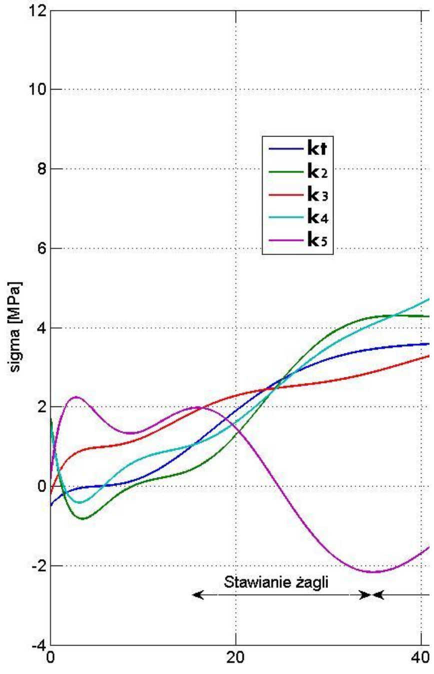


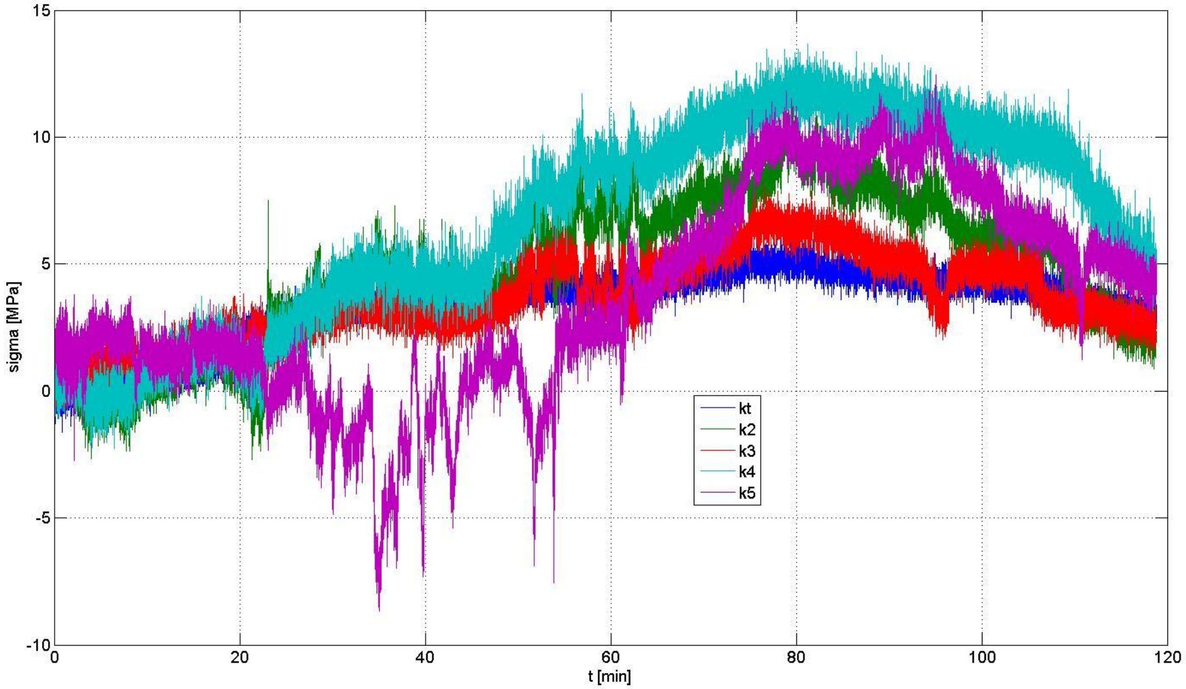
Zero deviation in the port



- four day measurements in different time of day
- temperature compensation
- fluctuations source: mostly, changes of rigging temperature

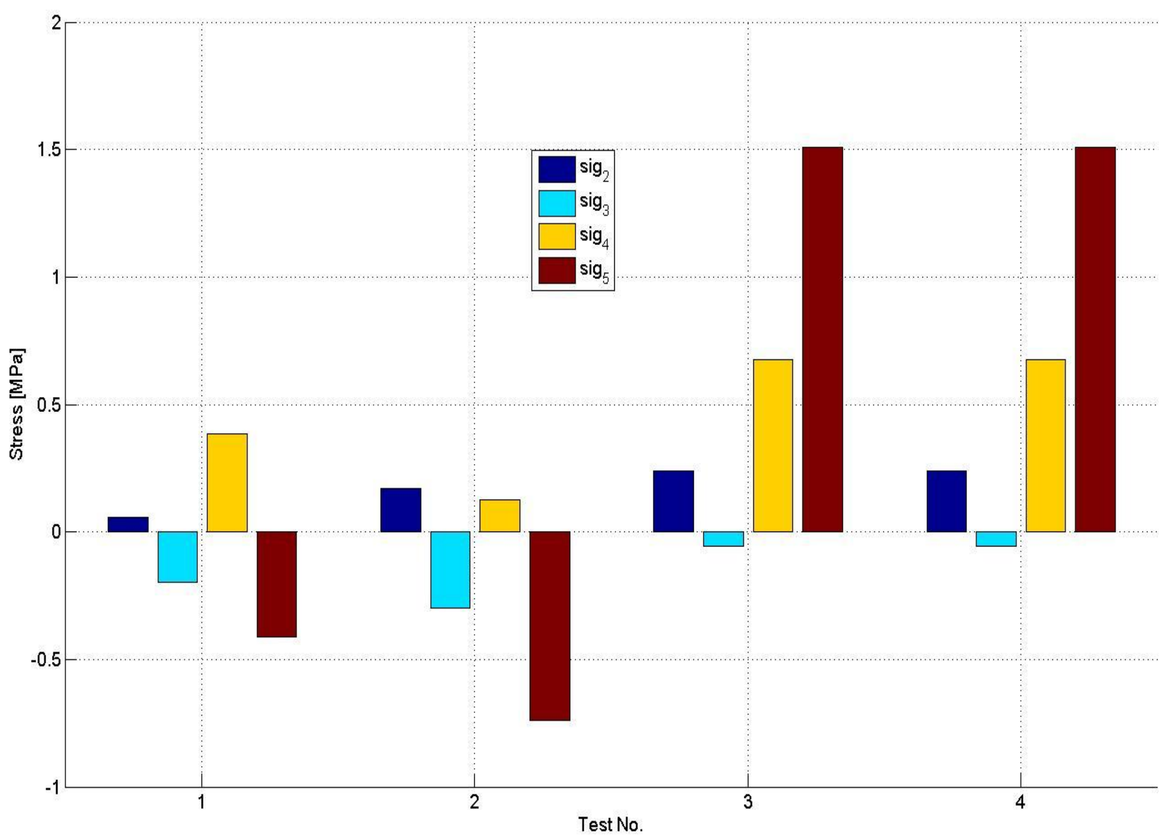
Sails setting – close to Gdynia harbour





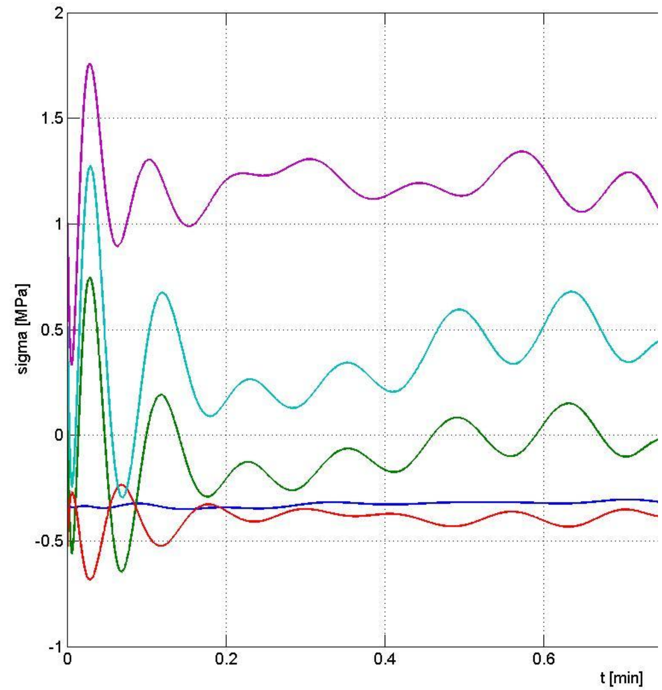
- quasi-static stress changes in the foremast during maneuvers are close to 12 Mpa
- high-frequency stress deviation, (~2 Mpa), -> comes from FBG sensors characteristics
- stress peak (~5 Mpa – FBG No. 5), -> comes from eksploitations: maneuvers, sails setting

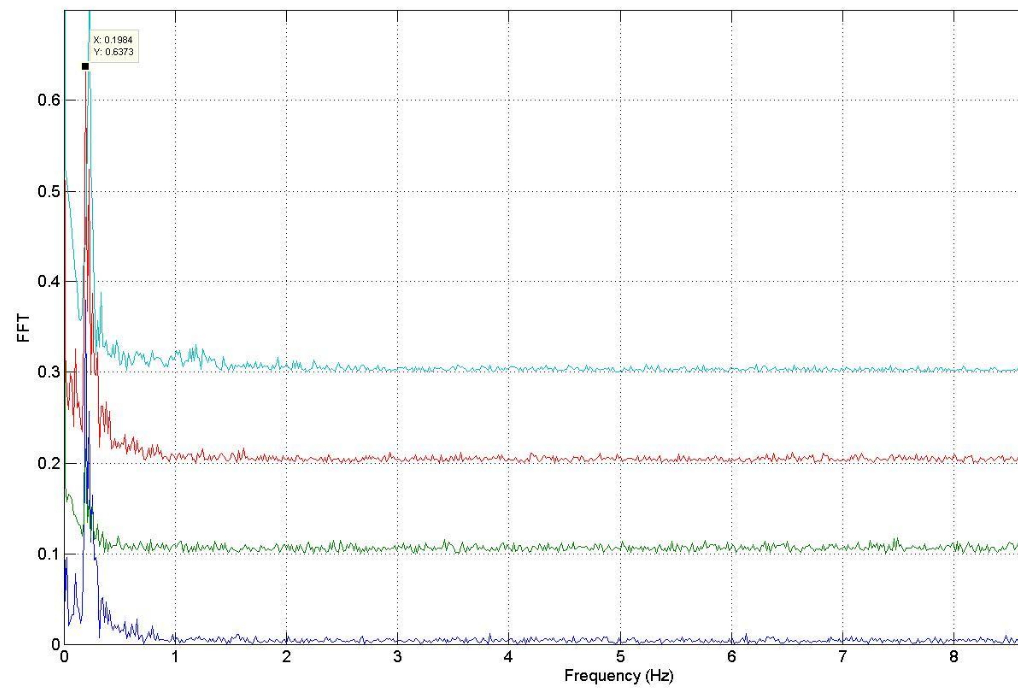
Steady sailing conditions



- Test No.1 without sails; Test No.2 full sails, wind 6 knots
  Test No.3 i 4 sails: course and both topsail, wind 15 knots
- stability and repeatability of SHM system is very good

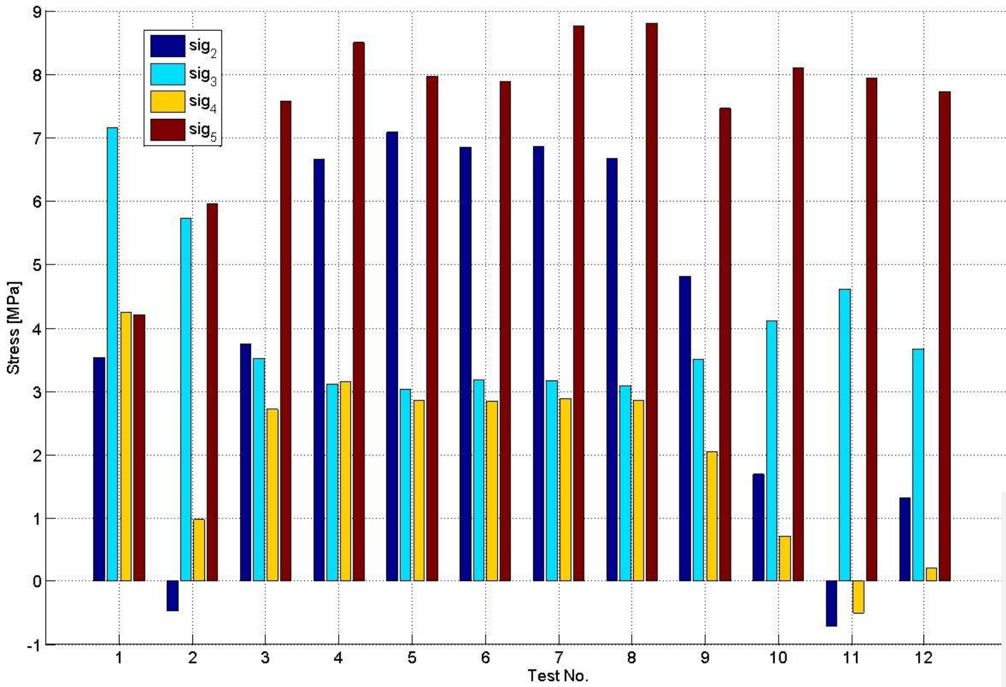
Steady sailing conditions - dynamic

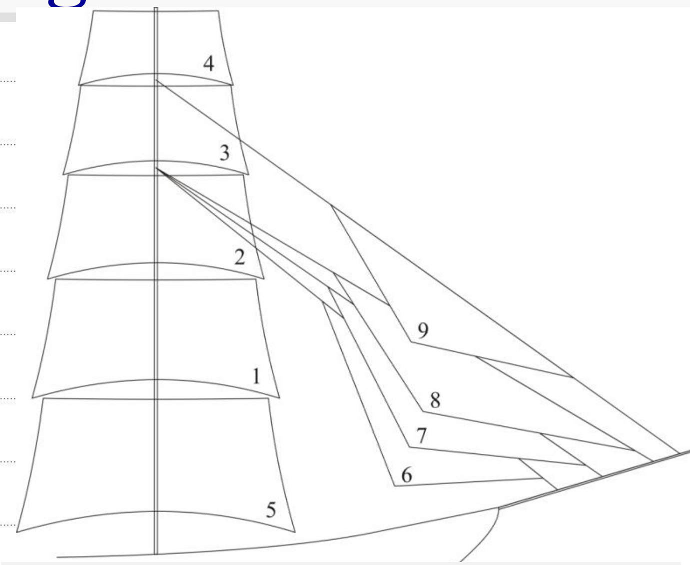




- Excitation oscilations of the foremast; sails: course and both topsail, wind 15 knots
- All FBG sensors shows the same characteristic = ~0.2Hz. Period of change is equal to sea waves period; accelerometers shows the same value
- Taking into account fatigue strength might be important

Sails settings I

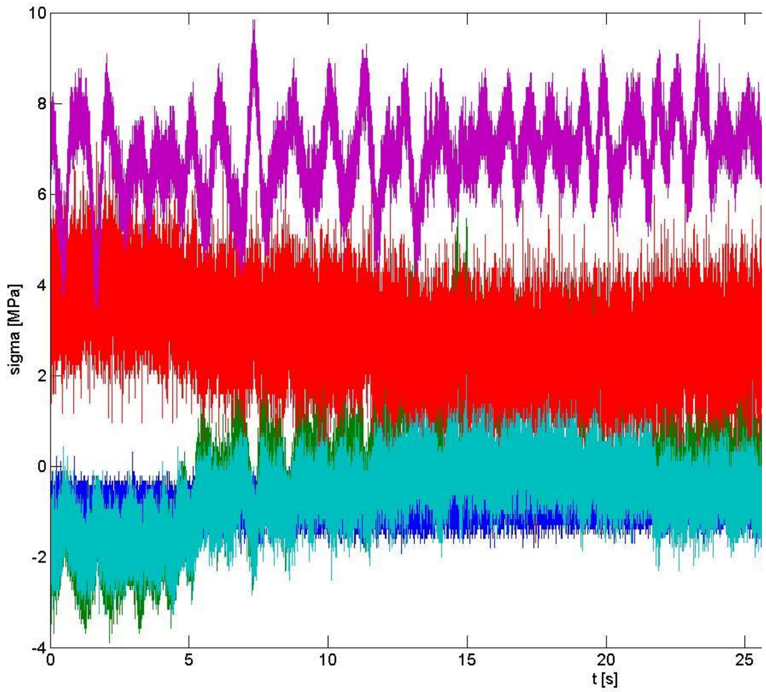


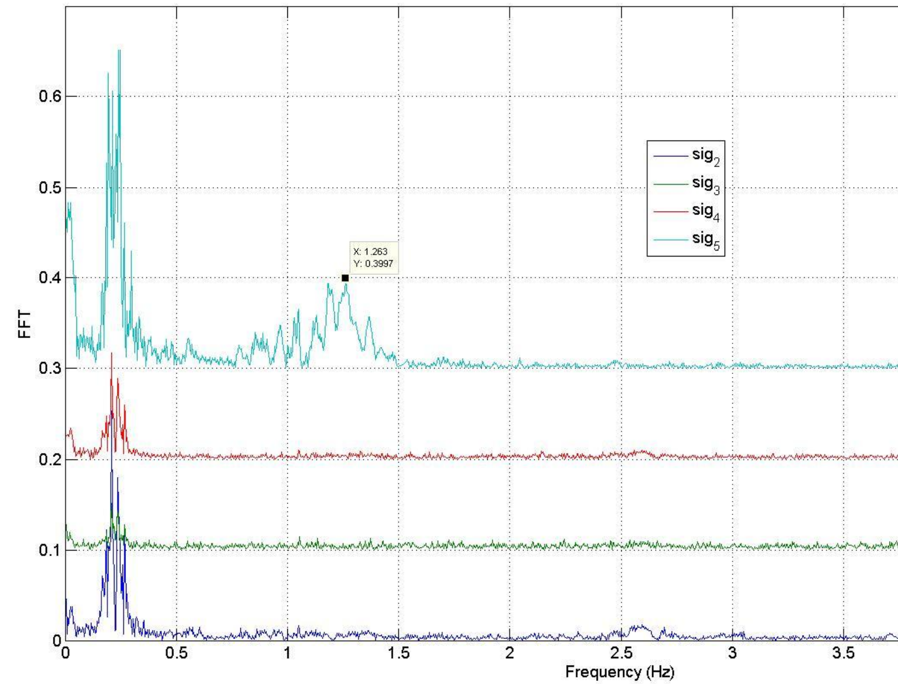


1- Tack by the stern, 2 – jibs removal,
3 – without sails, 4 – lower topsail setting,
5 – upper topsail setting, 6 – topgallant setting,
7 – royal setting, 8 – course setting,
9 – staysail setting, 10 – inner jib setting,
11 – outer jib setting, 12 – flying jib setting

- Test No.12: close hauled, tilt up to 7°; sea 2°B; wind15-20 kt.,
- Transverse stresses (sig5) of the mast are depended on the sailing conditions
- Stresses in the ship P.S. (sig2, sig4) are depended on the number of sails
- Jib settings is a source of offloading of the top part of the foremast

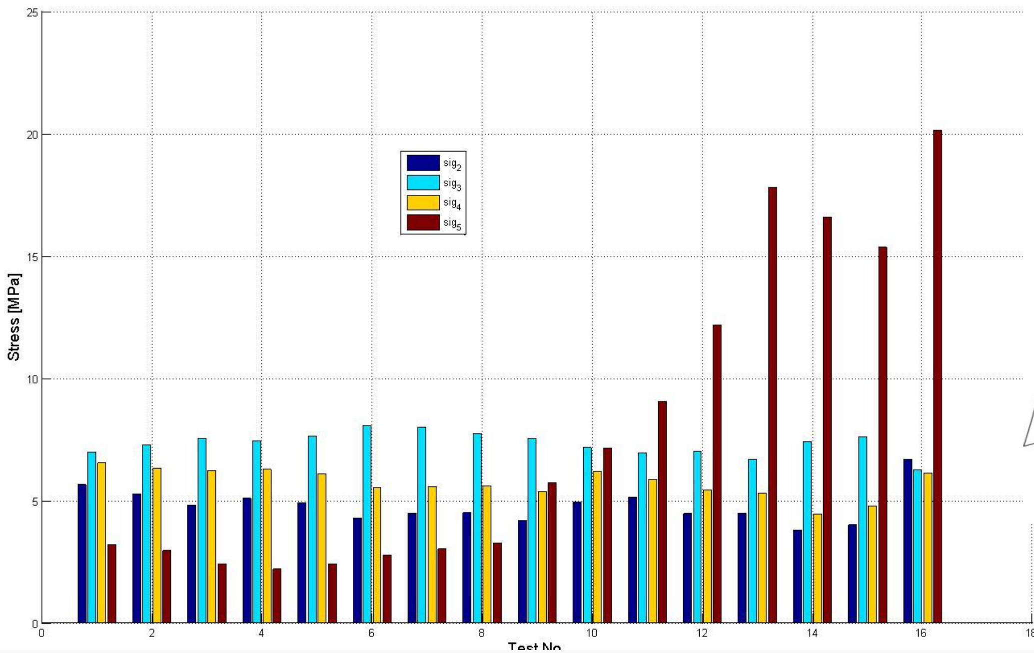
Sails settings I - dynamic





- Test No. 7: full sails of the foremast without jibs and course
- FFT -> waves loading -> T=~6.5sek. + natural vibrations of the foremast -> f=1.26 Hz
- Foremast without jib loading is sensitive on the dynamic excitations
- Foremast loaded by jib sails is more stable, is less sensitive even on wave loadings

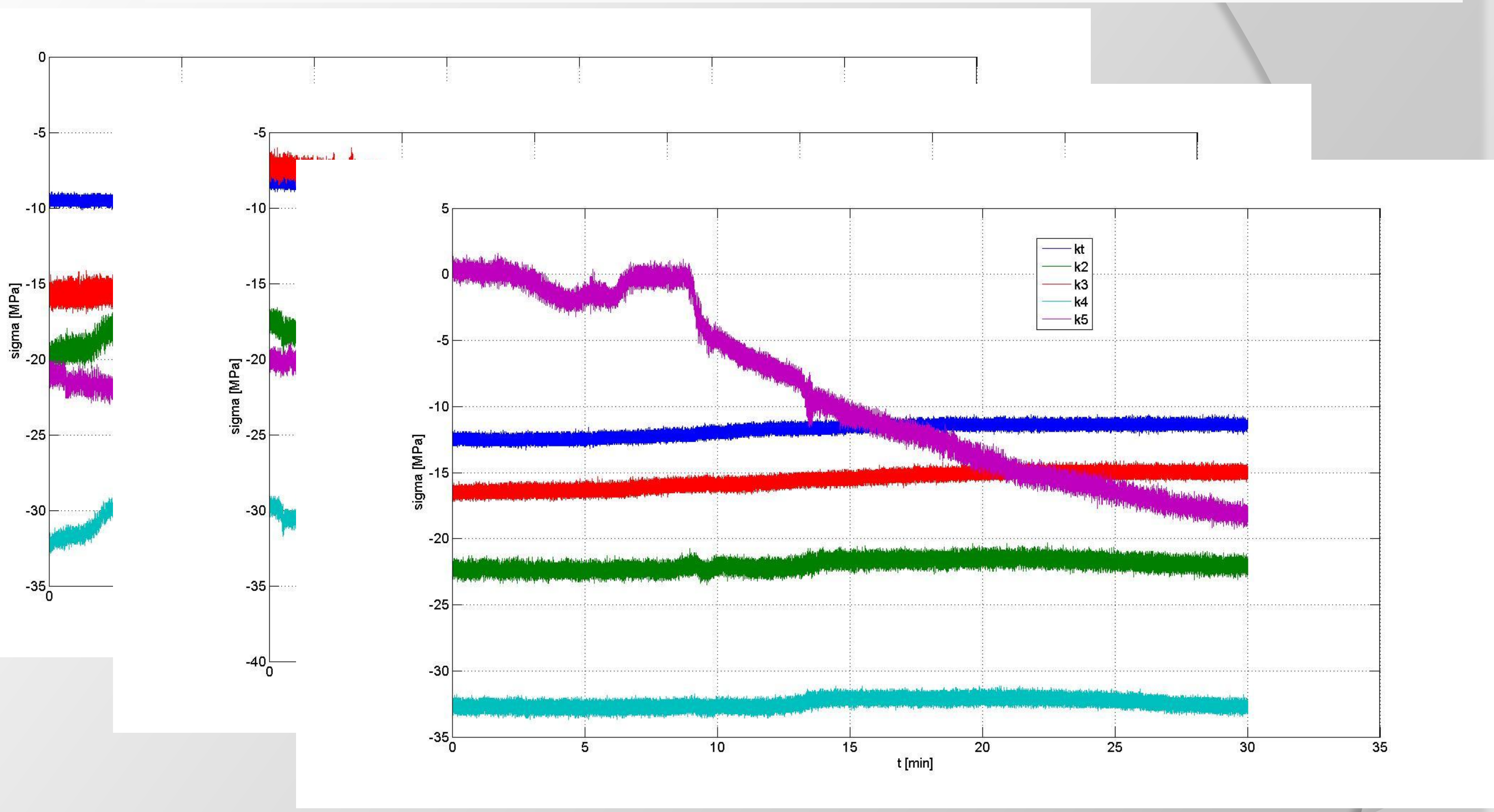
Sails settings II



Test No.1- without sails
Test No.2 – staysail setting
Test No.3 – inner jib setting
Test No.4 – outer jib setting
Test No.5 – flying jib setting
Test No.6 – lower topsail setting
Test No.7 – upper topsail setting
Test No.8 – topgallant setting
Test No.9 – royal setting
Test No.10 – course setting
Test No.11 – royal removal
Test No.12 – course removal
Test No.13 – tack by the stern
Test No.14 – course setting
Test No.15 – sails brace
Test No.16 – steady sailing

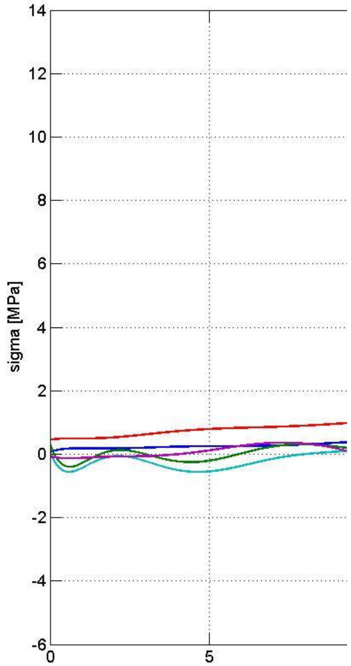
- Test No.16: close reach, speed up to 9 kt.; sea 3°B; wind17 kt.,
- Ship tack or sails brace is source of bigger transvesre stresses then sail settings
- Relative wind changing caused transverse stersses level increasing (2x) with relative small stresses level changing in the ship P.S.
- Isolated course removal (test No.12) is a source of important transverse stersses level increasing
- If the loading of the mast is heavy then vibrations and fatigue stress of the mast is negigible

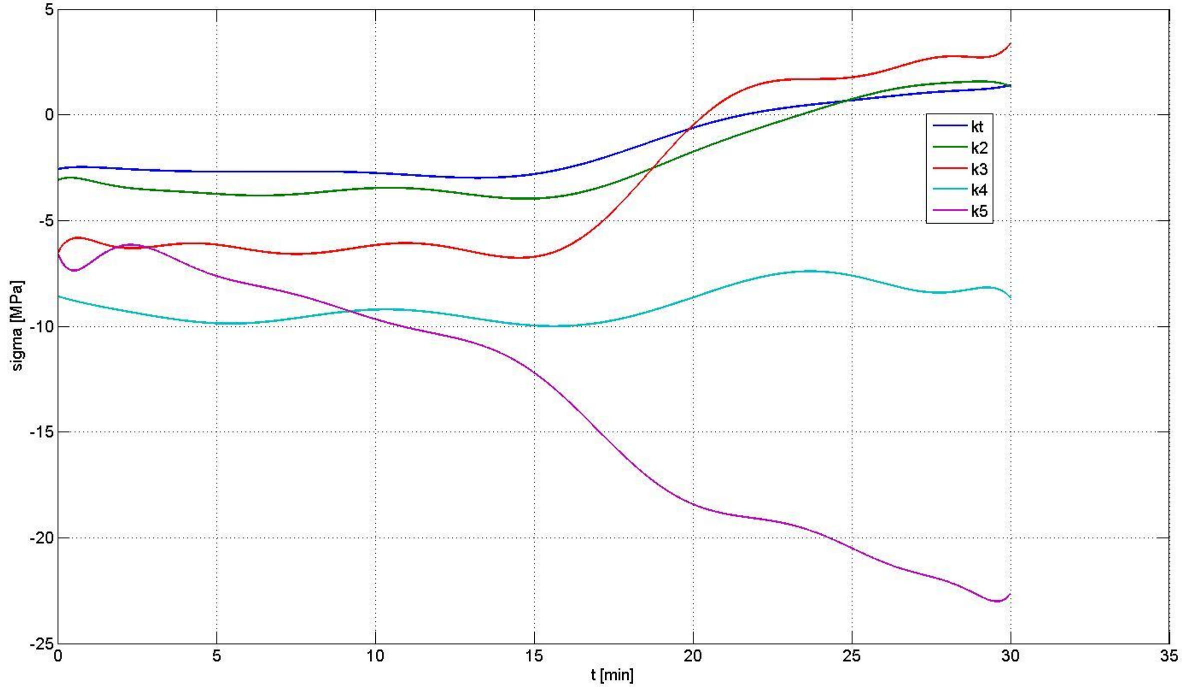
Different eksploitation conditions



- Test No.1: speed 2.8 kt.; sea 2°B; wind 12-17 kt., topsails+jibs, still tack
- Test No.2: speed 9.6 kt.; sea 3°B; wind 18 kt., settings and remouving sails
- Test No.3: speed 3.5-4.8 kt.; sea 2°B; wind 10 kt., adding the sails

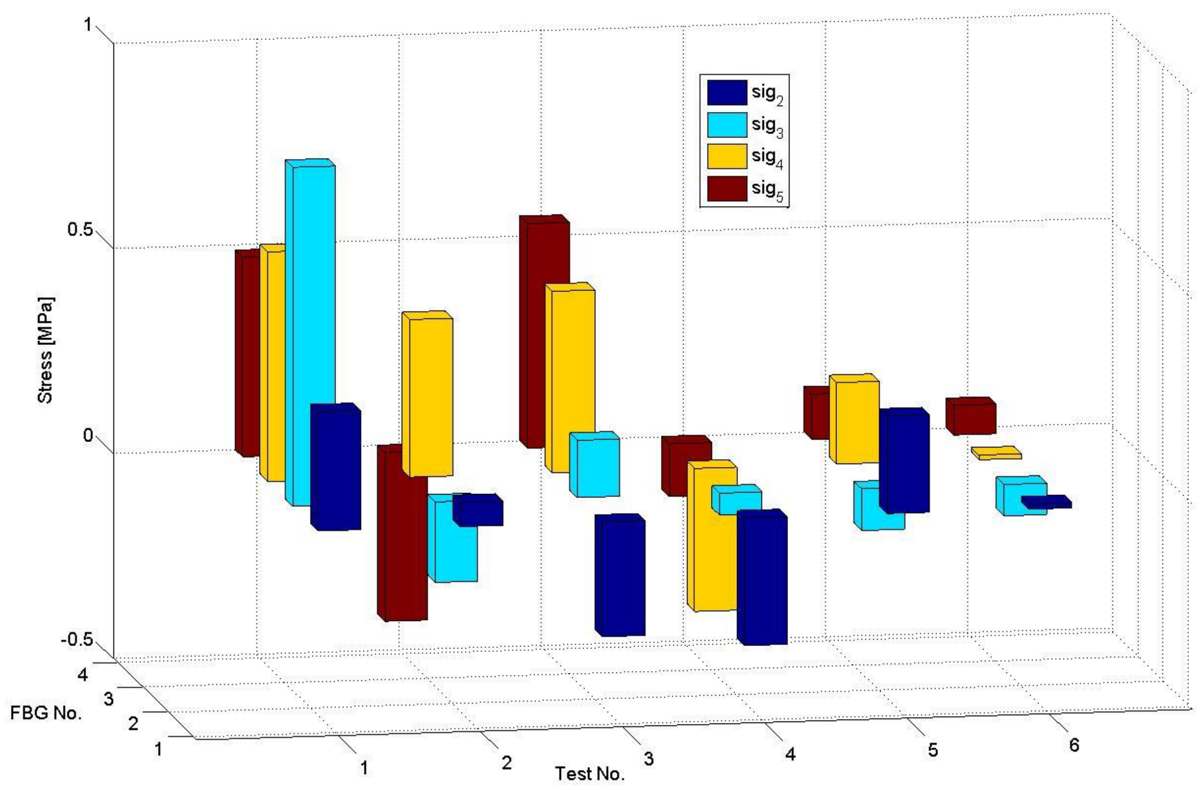
Sails settings and remouving





- Test No.4: 1°B, wind 6kt, speed max 2.6 kt, sails setting from anchor;
  Test No.5: 3-4°B, wind 26kt, sails remouving (from topsails) and anchoring;
- Influence of upper topsail remouving (10 min) for stress level is negigible, all sails remouving (16 min) was a source of stress distribution changing
- Anchoring was performed at 21 min

Stability and reliability of the SHM system



- Stresses reference level („zero") recorded at 25, 29, 31 may, 5 june and 23 september 2011
- Differences are less then 1 MPa -> good result becouse of long time and different environmental and eksploitation conditions


Dziękuję za uwagę!