

Fotocopie dei trasparenti:

ANALISI MODALE SPERIMENTALE

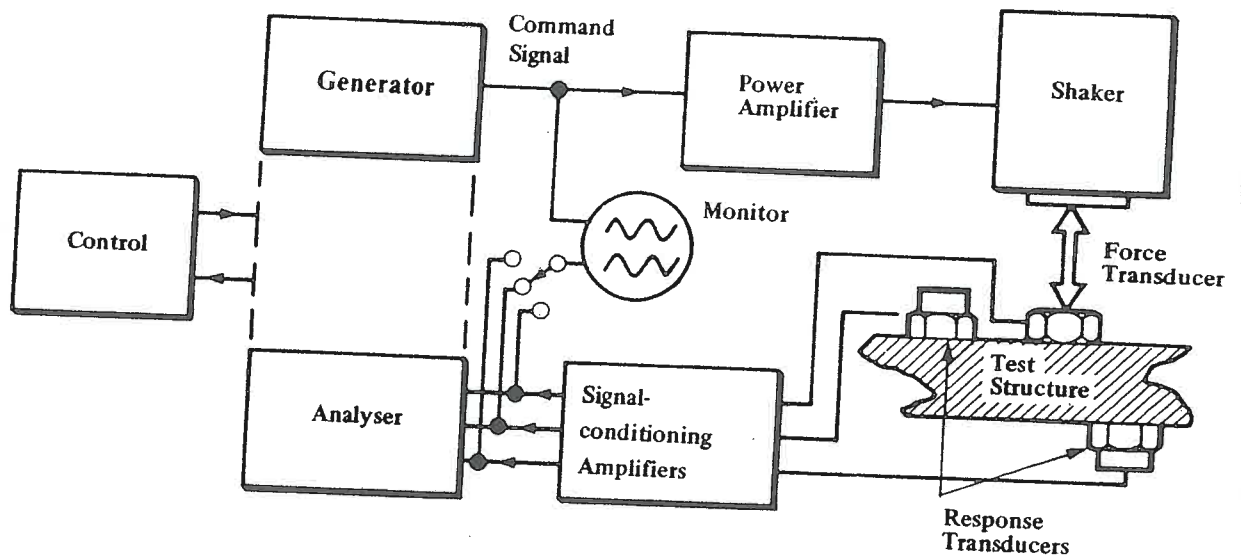
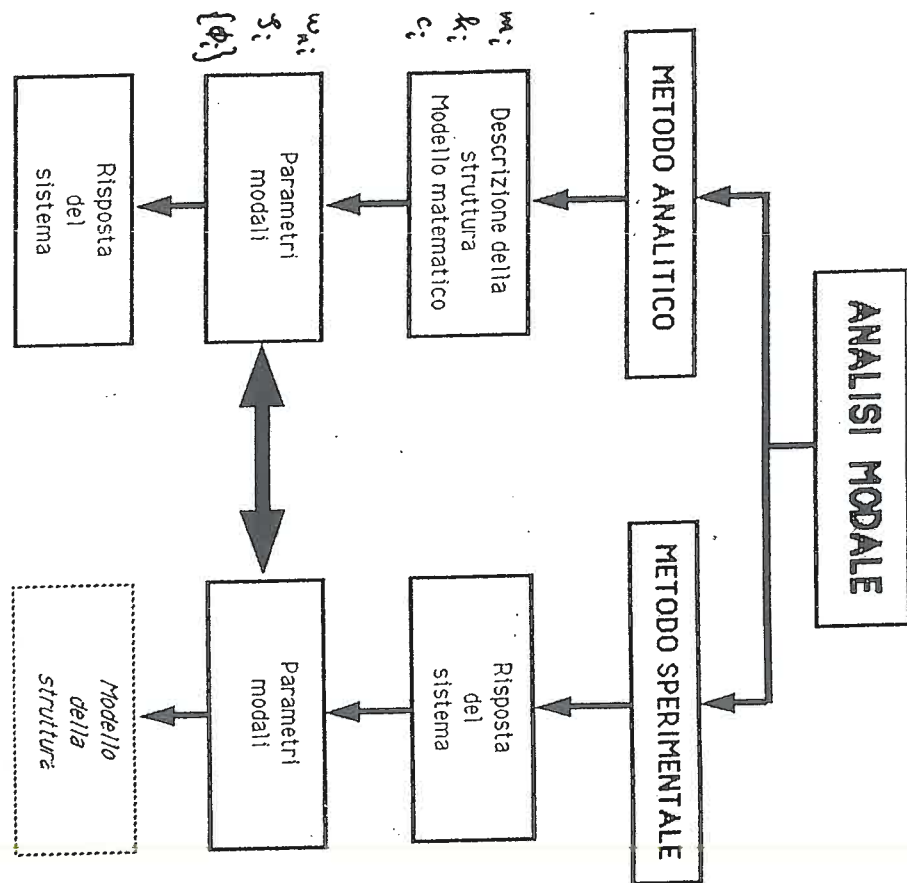


Fig 3.1 General Layout of Mobility Measurement System

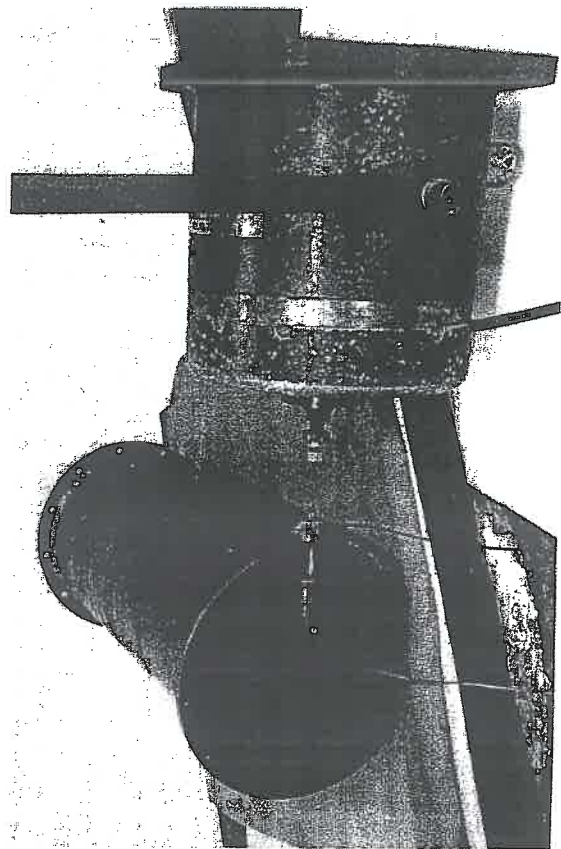
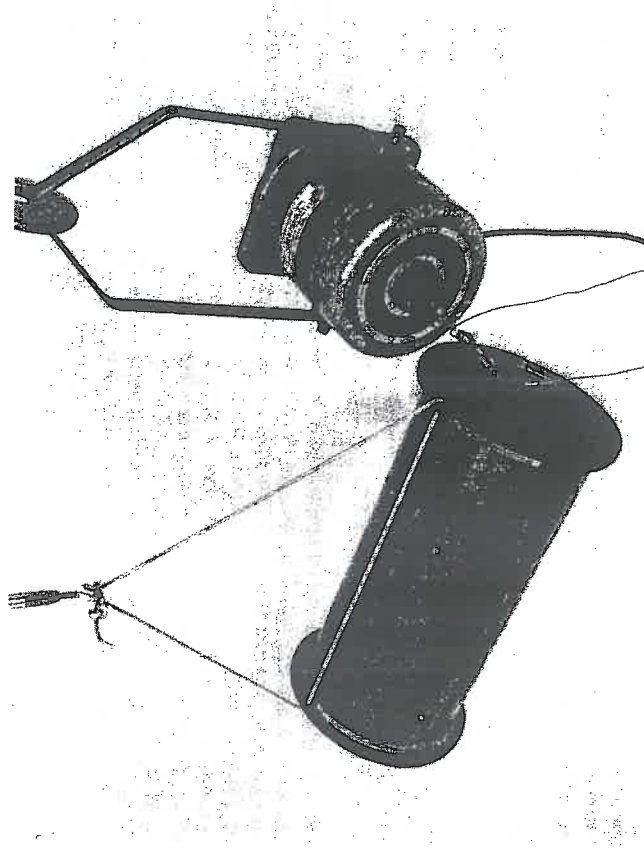


Fig 3.2b Examples of Freely-Supported Structures

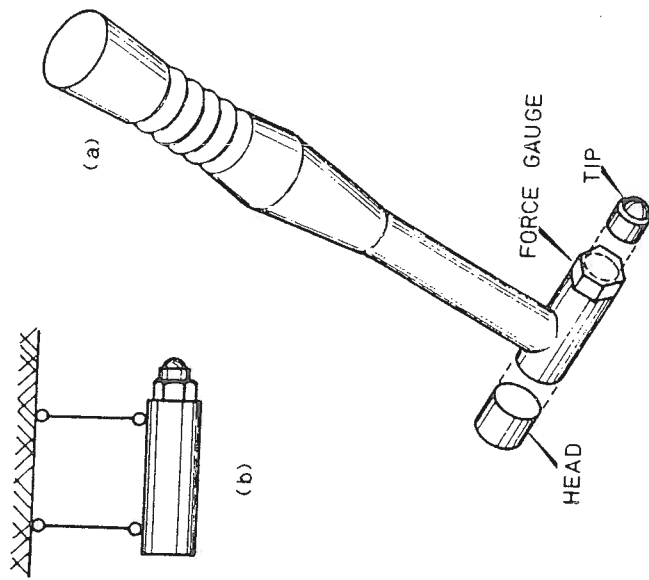


Fig 3.7 Impactor and Hammer Details

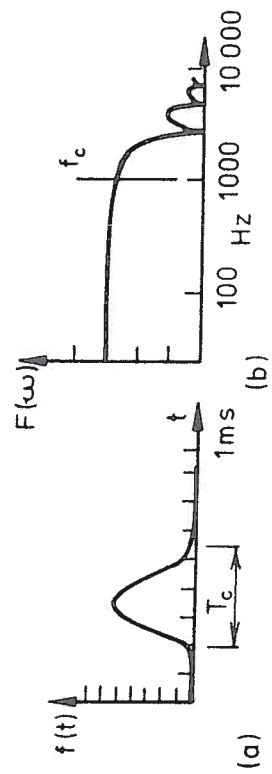
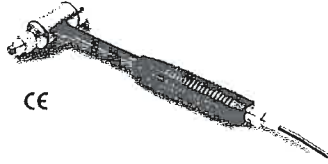


Fig 3.8 Typical Impact Force Pulse and Spectrum
(a) Time History
(b) Frequency Spectrum

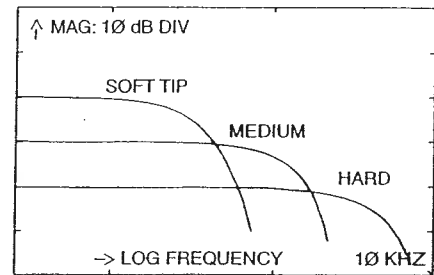
Modally Tuned ICP® Impact Hammers

Model 086C05 - tests medium to heavy structures such as machine tools, light trucks, at low to medium frequencies.

- 5 kHz frequency range
- 5000 lb amplitude range
- 1 mV/lb sensitivity
- 1 lb hammer mass
- 1 inch head diameter



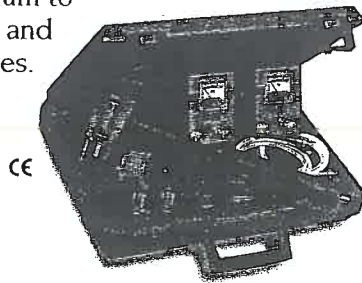
CE



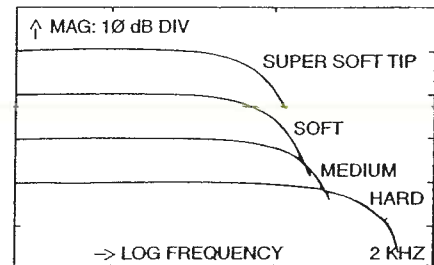
Model 086C05
(shown with cable attached)

Model 086C20 - small sledge, tests medium to heavy structures such as tool foundations and storage tanks at low to medium frequencies.

- 1 kHz frequency range
- 5000 lb amplitude range
- 1 mV/lb sensitivity
- 3 lb hammer mass
- 2 inch head diameter



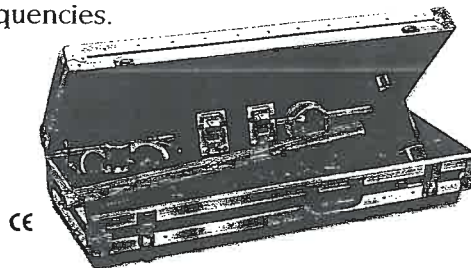
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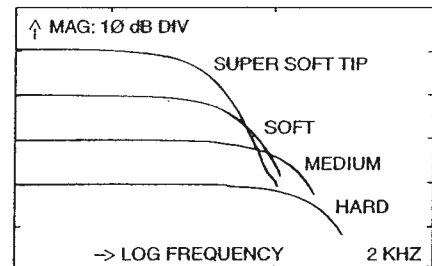
Model 086C20
(shown in Model GK291D20 kit)

Model 086C50 - large sledge, tests very heavy structures such as buildings, locomotives, ships, and foundations at low to very low frequencies.

- 500 Hz frequency range
- 5000 lb amplitude range
- 1 mV/lb sensitivity
- 12 lb hammer mass
- 3 inch head diameter



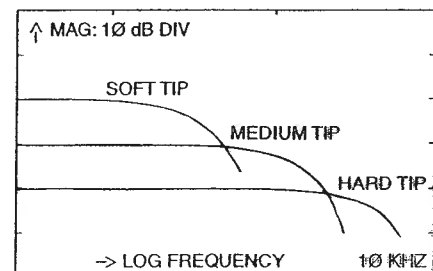
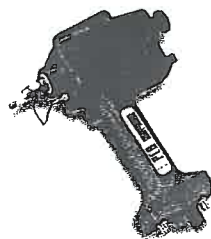
CE



Model 086C50
(shown in Model GK291D50 kit)

Model 086C09 - electric solenoid actuated, for general purpose use, when controlled, repeatable impulse force is required such as with production testing.

- 8 kHz frequency range
- 1000 lb amplitude range
- 10 mV/lb sensitivity
- 0.6 inch head diameter
- local and remote trigger



Model 086C09

Vibration Test Equipment

Mini-Shaker

type 4810

FEATURES:

- Force rating 10 Newton (2,25 lbf) Sine Peak
- Frequency range DC to 18 kHz
- First axial resonance above 18 kHz
- Max. bare table acceleration 550 ms^{-2} (56 g)
- Rugged construction

USES:

- Calibration of accelerometers
- Vibration testing of small objects
- Educational demonstrations
- Mechanical impedance measurements

The Mini-Shaker Type 4810 is a small machine for the dynamic excitation of lighter objects, it is manufactured from quality materials to a high degree of precision and has proved to be a reliable and versatile tool in dynamic testing.

Type 4810 is well suited as the motive force generator in mechanical impedance measurements where only smaller forces are required. It can also be used in the calibration of vibration transducers, both to determine their sensitivity by comparison with a standard accelerometer, and to determine their frequency response up to 18 kHz.

The Mini-Shaker is of the electrodynamic type with a permanent field magnet. A coil, which is an integral part of the table structure, is flexibly suspended in one plane in the field of the permanent magnet. An alternating current signal, provided by an external oscillator is passed through the coil to produce a vibratory motion at the table. A sectional drawing illustrating the method of construction is shown in Fig. 1.

The suspension system consists of radial flexure springs which restrict the moving element to almost perfectly rectilinear motion. Laminated flexure springs provide a high degree of damping to minimize distortion due to flexure resonances. The frequency response curves shown in Fig. 2 show the highly damped flexure resonance around 50 to 60 Hz.

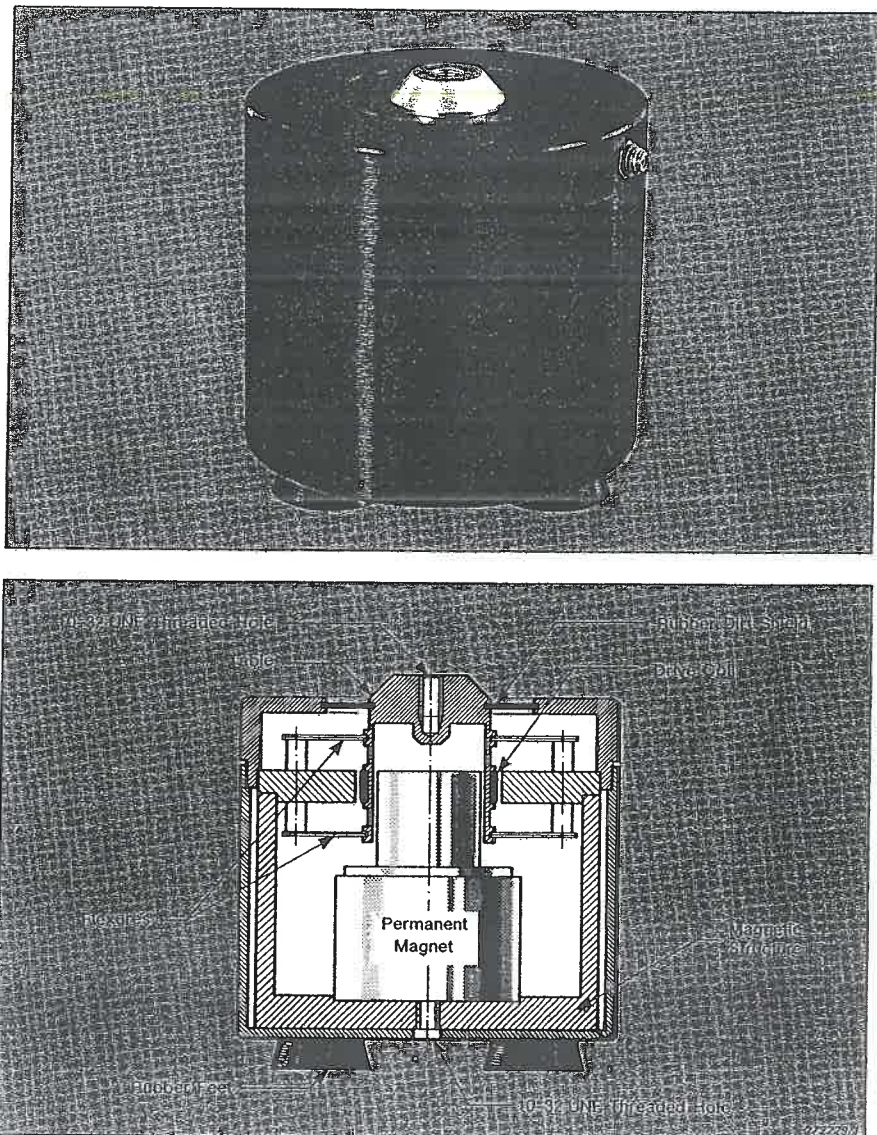


Fig. 1. Sectional drawing of the Mini-Shaker Type 4810

The object to be vibrated is attached to the table by means of a 10 - 32 UNF screw; the thread size commonly used for mounting accelerometers. Performance limits which are defined by the maximum displacement (6 mm), maximum force (10 N or 7 N depending on frequency), and the first axial resonance of the moving element (above 18 kHz), are graphically shown in Fig.3.

Within these limits, the attainable acceleration can be determined by the expression.

$$a = \frac{F}{W}$$

where a = acceleration in ms^{-2}
 $(1 \text{ ms}^{-2} = 0,102 \text{ g})$
 F = shaker rated force in Newtons
 W = exciter moving element weight + test object weight in kg

Examples of maximum test object weight for accelerations of 20 g and 5 g are drawn in on the curve.

In order to attain full rated output force from the 4810 it should be driven by Power Amplifier Type 2706. This is a power amplifier specially designed to drive small vibration exciters and has a current limiter to prevent overdriving the 4810.

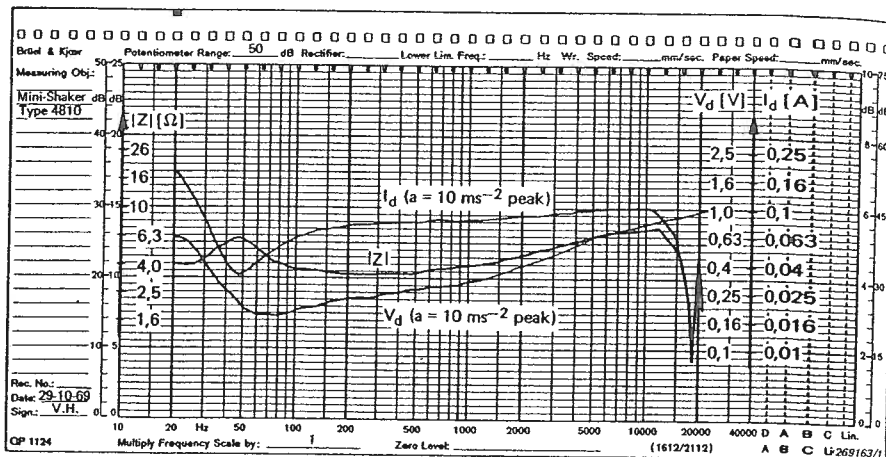


Fig. 2. Frequency response of the 4810 for Impedance (z), current (I) and voltage (V)

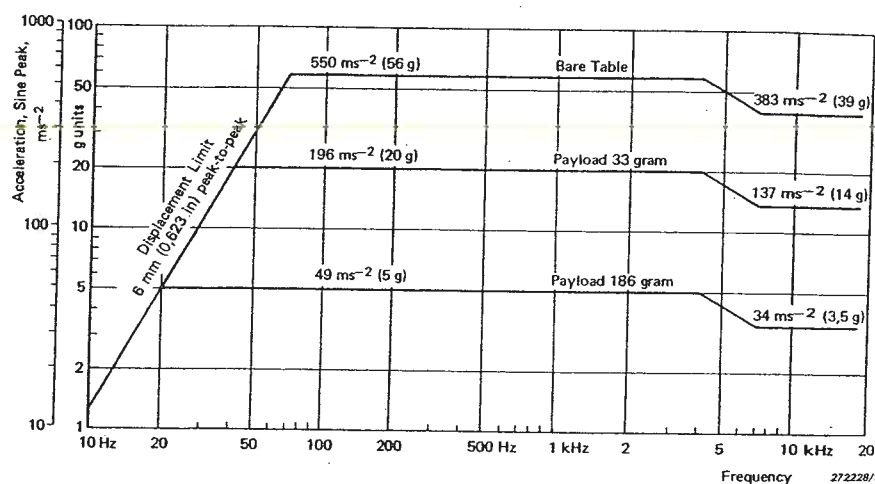


Fig. 3. Sine performance curves for the 4810

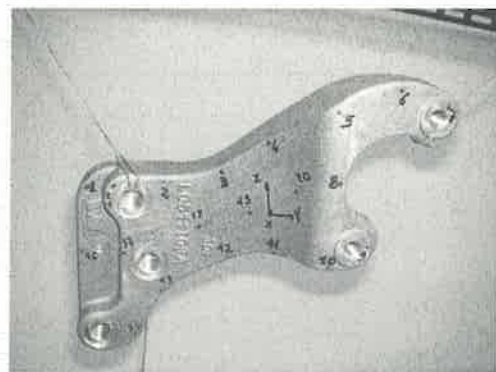
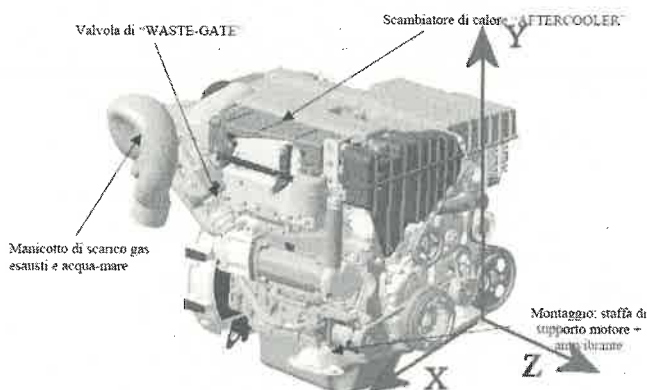
Specifications 4810

FREQUENCY RANGE 0,63 to 13,2 Hz	DYNAMIC WEIGHT OF THE MOVING SYSTEM 1,1 kg	FIGURE Fig. 2, 3
FIRST MAJOR ARMATURE RESONANCE Above 18 kHz	MAGNETIC FIELD Permanent magnet	DIMENSIONS D: 60 mm (2 3/8 in) H: 100 mm (3 9/16 in)
FORCE/INPUT PEAK 1 - NEWTON (0,2248 lbf) 0,63 to 0,2 kHz 2 - NEWTON (0,4496 lbf) 0,25 Hz to 10 kHz	MAXIMUM INPUT CURRENT 0,2 A RMS	ACCESSORIES INCLUDED Cable (10' connector) 10' Vm Shaker to Power Amplifier 2 Power Amplifier 2706 Instruction Manual
MAX. BARE TABLE ACCELERATION (25 A 10 Hz) 550 ms⁻² (56 g) 0,63 to 2 kHz 383 ms⁻² (39 g) 2 kHz to 10 kHz (1 ms⁻² = 0,102 g)	COIL IMPEDANCE 85 A at 500 Hz	ACCESSORIES AVAILABLE 10' Amps (10' cable) 10' Vm 10' Amps (10' cable) 10' Vm 10' Amps (10' cable) 10' Vm Shaker Manual
MAX. DISPLACEMENT (PEAK-TO-PEAK) 6 mm (0,236 in)	CONNECTION Microsocket UNF 10 - 32	
DYNAMIC FLEXURE STIFFNESS 2 New/cm (1,1 lbf/in)	TABLE SIZE 100 mm (4 in) diameter	
	FASTENING THREAD UNF 10 - 32	

Analisi Modale sperimentale: un esempio reale

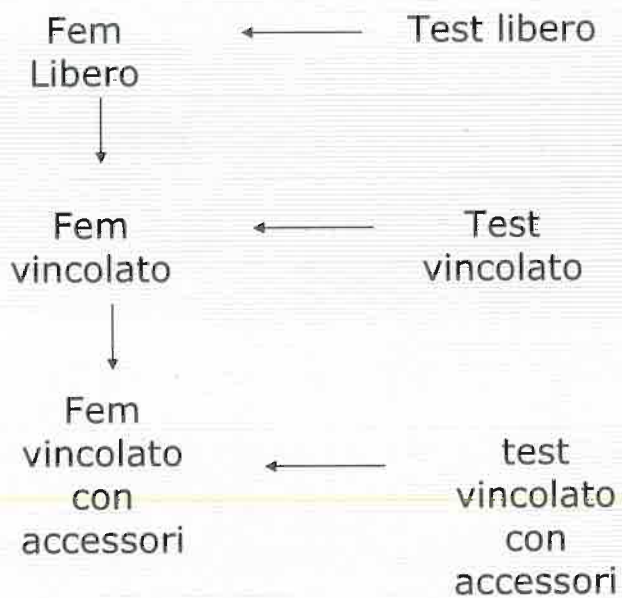
E. Mucchi

Componente in esame

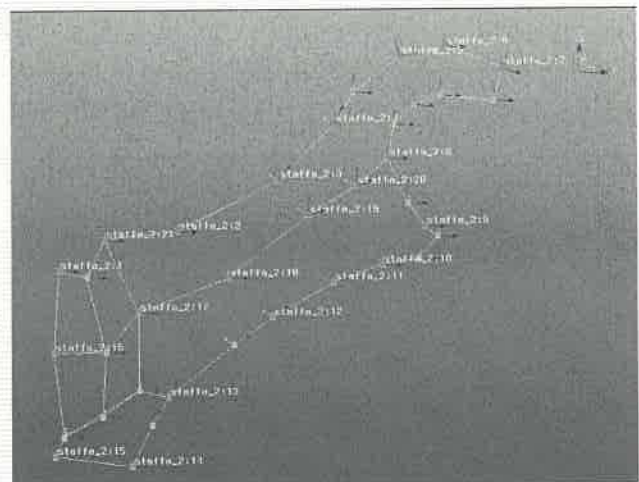
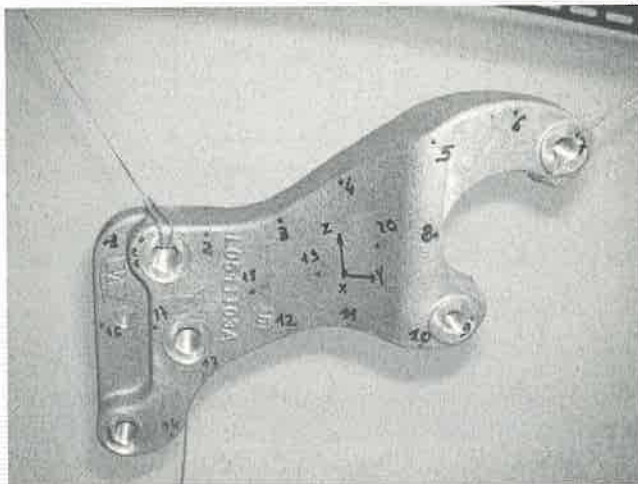


Obiettivo: valutare le frequenze naturali di una staffa accessori e validare un modello FE

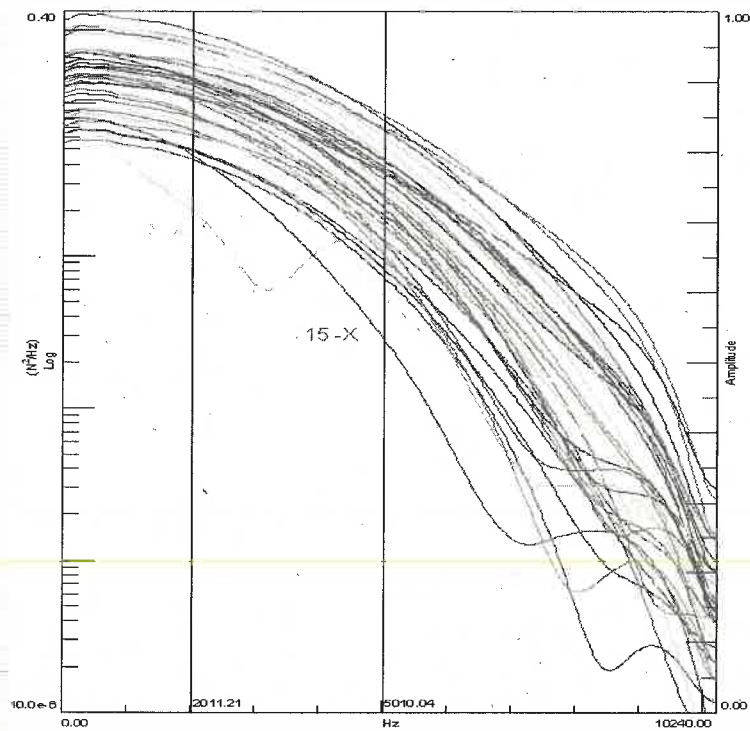
Per ottenere un modello affidabile



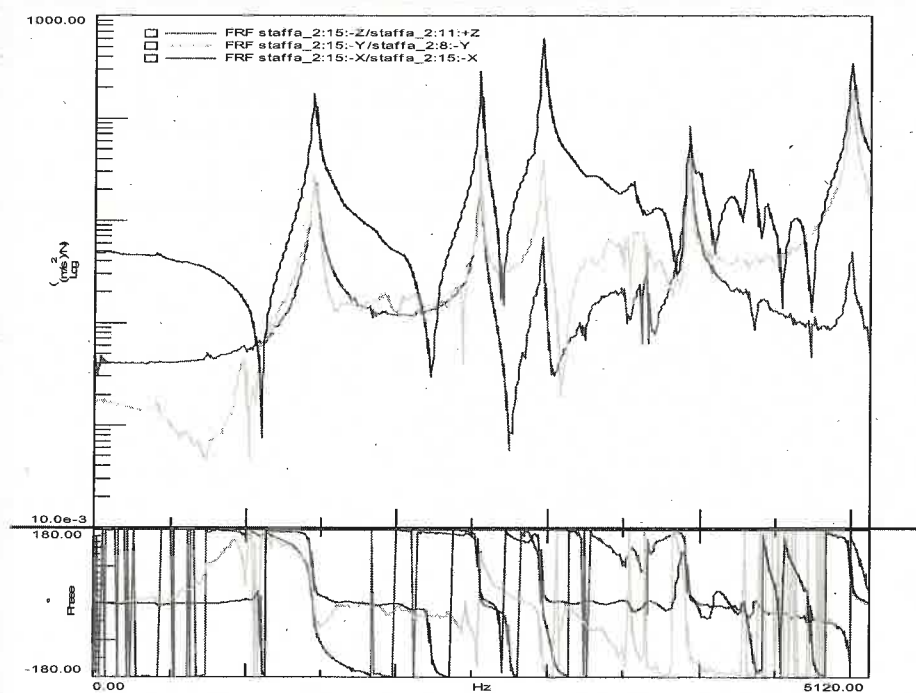
Analisi modale libera



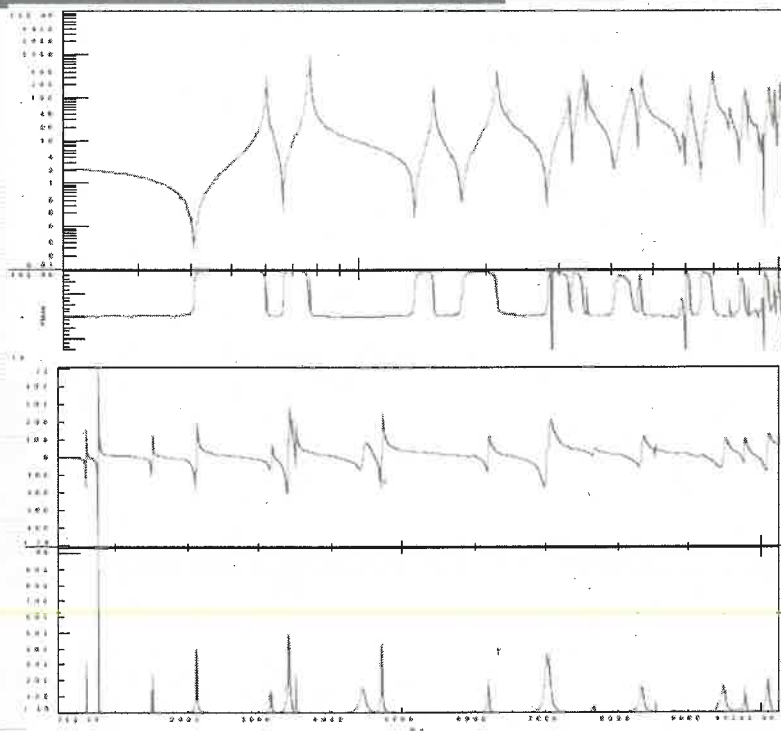
Spettri delle martellate



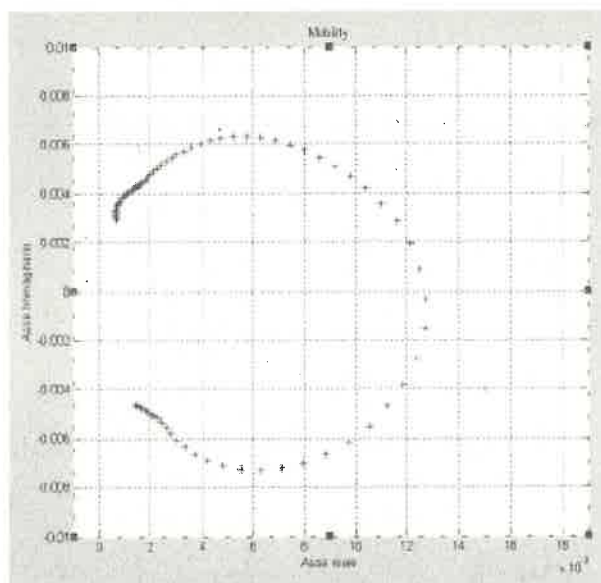
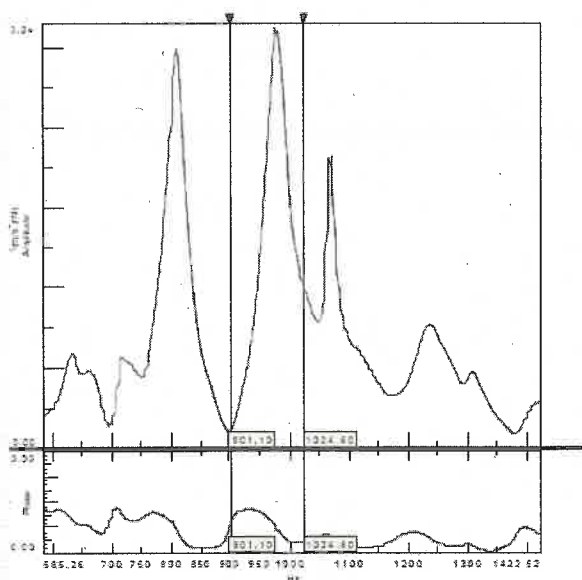
FRF puntuali



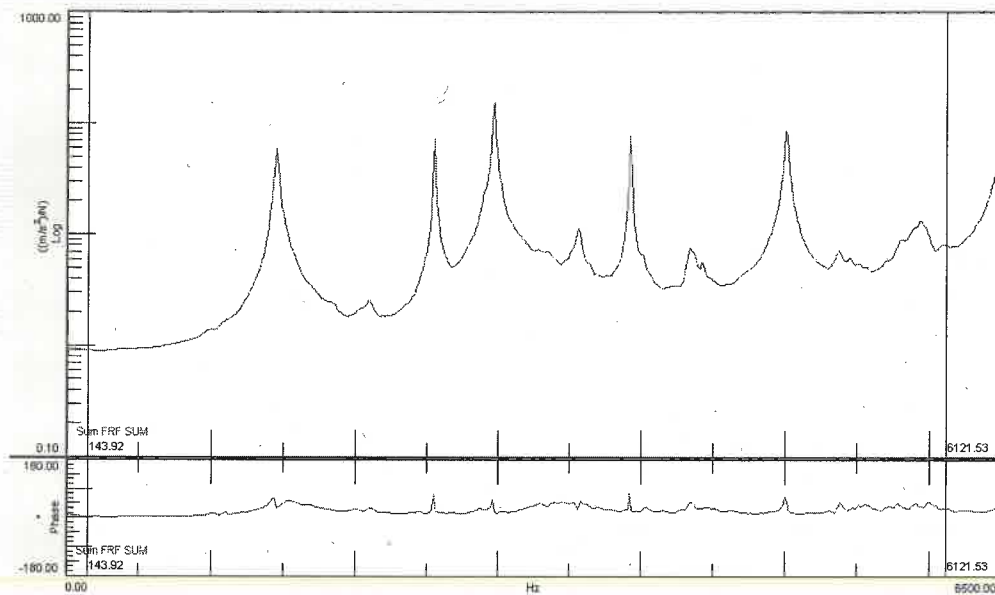
FRF ampiezza/fase e reale/immaginario



Nyquist

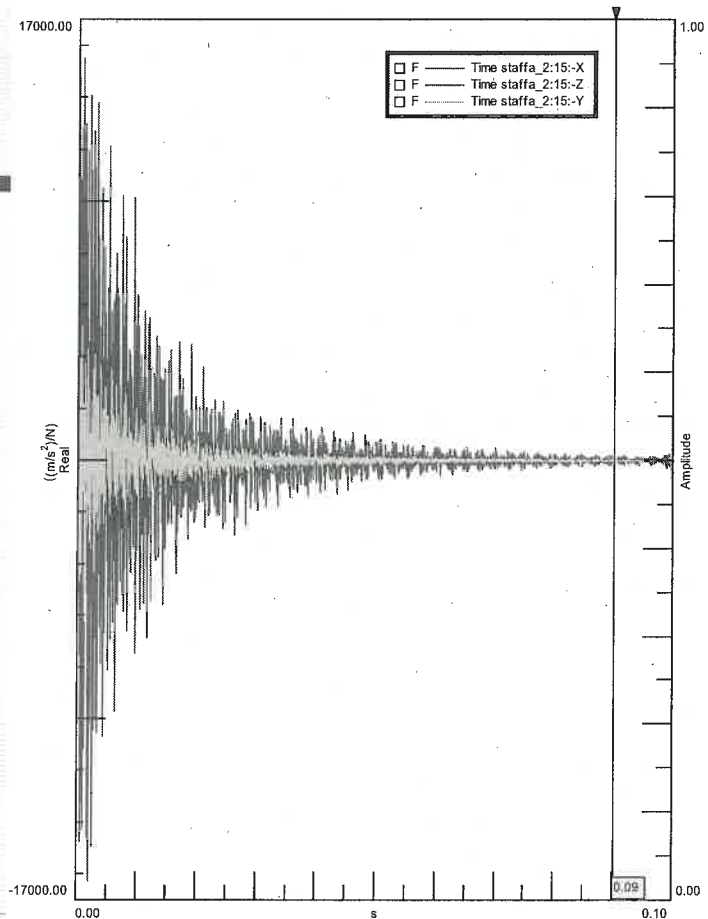


FRF somma: perchè utile?



IFFT delle FRF

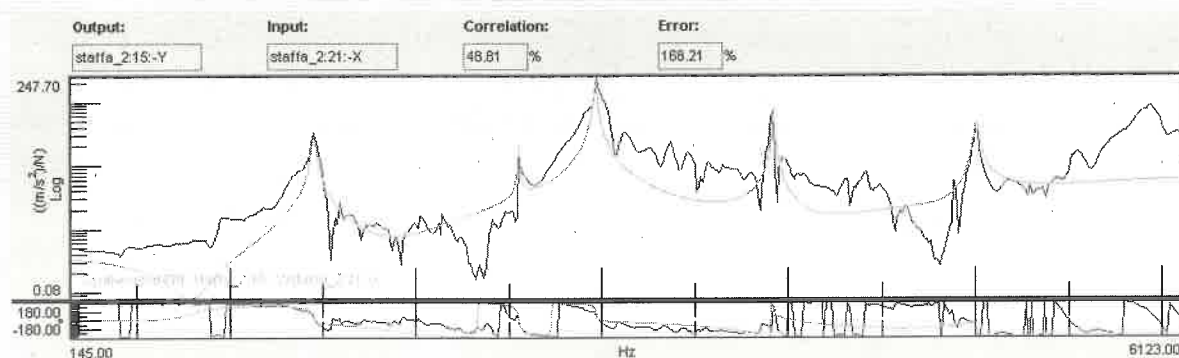
Sistema
smorzato



Frequenze naturali

F _n	Smorz modali
1452,082	0,47
2550,992	0,09
2964,984	0,12
3920,696	0,10
5003,263	0,18

FRF misurate (curva rossa) vs. sintetizzate (curva verde)



FEM-TEST (free-free)

Tipo modello	1 ^a fn [Hz]	2 ^a fn [Hz]	3 ^a fn [Hz]
Staffa FEM libera	1461	2560	3015
Staffa sperimentale libera	1451	2550	2965
Errore percentuale	0.41%	0.31%	1.65%

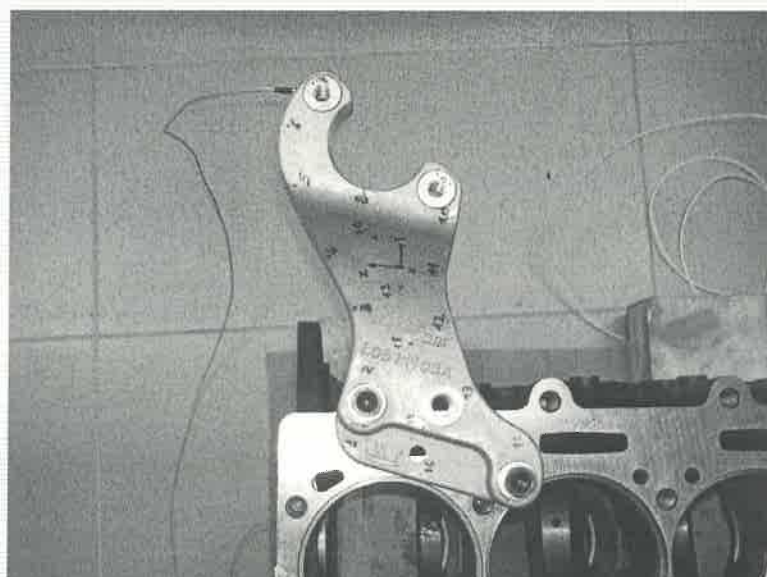
Tabella 1 – Confronto delle frequenze naturali fra la staffa AM libera FEM e sperimentali



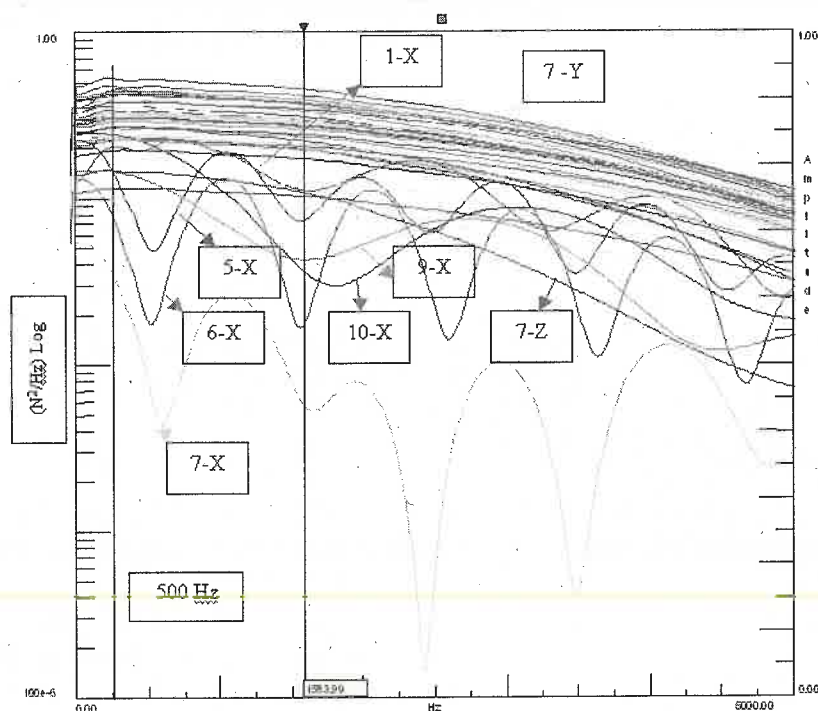
Tipostaffa	#nodi	#elementi	Tipo-elemento	Modulo-Young [MPa]	Densità [Kg/m³]
Staffa-Acqua-Mare	20994	12908	Tetragonale 10-nodi	70000	2700

Tabella 26: caratteristiche dei modelli FEM

Analisi modale vincolata



Spettro delle martellate



Tipo modello	1 ^a fn [Hz]	2 ^a fn [Hz]
Staffa FEM vincolata	580	1299
Staffa sperimentale vincolata	507	1257
Errore percentuale	14%	3.3%

FEM vincolato rigidamente-TEST

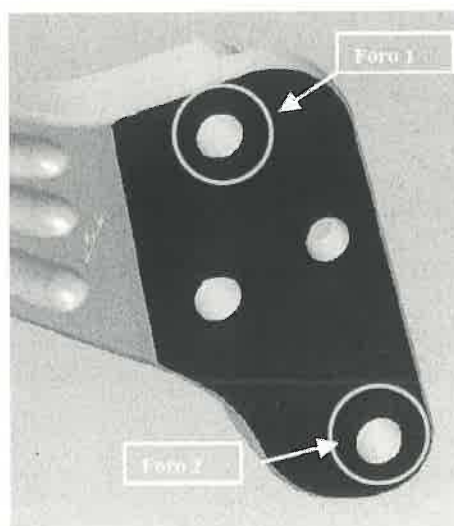
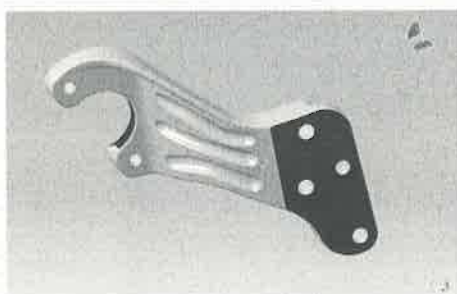
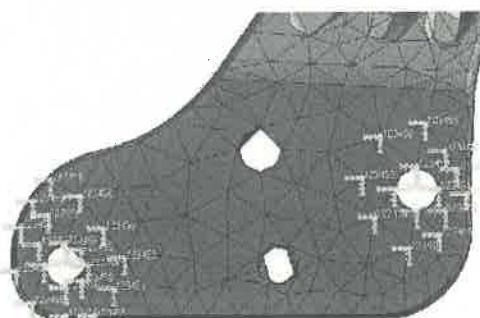


Figura 2 Particolare della Staffa Acqua-Mare

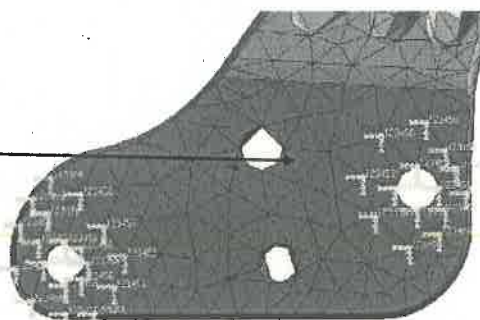


FEM-Test vincoli cedevoli

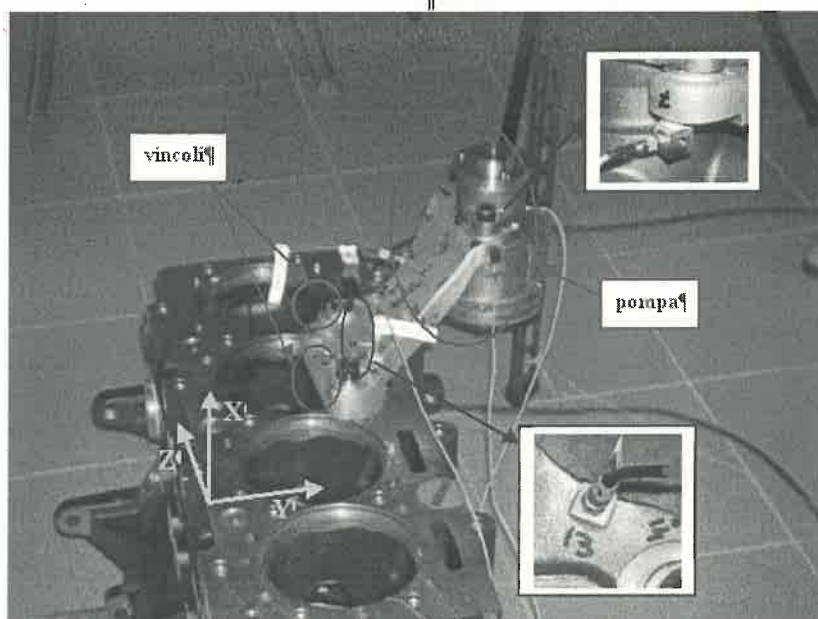
Tipo modello	1 ^a fn [Hz]	2 ^a fn [Hz]
Staffa FEM vincoli cedevoli	499	1226
Staffa sperimentale vincolata	507	1257
Errore percentuale	1.5%	2.4%

- Confronto delle frequenza naturali FEM e sperimentali della staffa AM con vincoli cedevoli

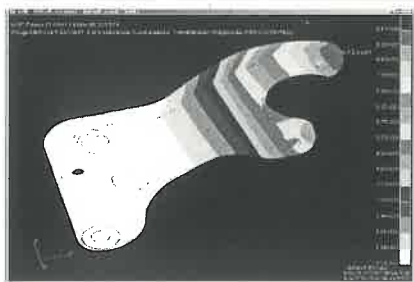
molle



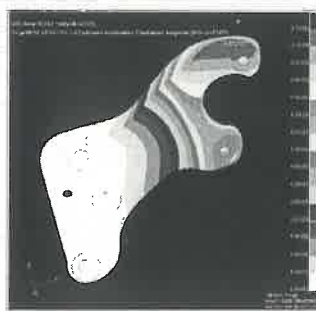
STAFFA VINCOLATA CON ACCESSORI



Analisi forzata



Accel alla
 $F_{n1} = 9g$



Accel alla
 $F_{n2} = 9g$



Accel alla
 $F_{n4} = 14g$

8. Conclusioni e modifiche progettuali suggerite

Le verifiche a fatica e statiche si possono considerare abbondantemente superate.

L'analisi modale e l'analisi forzata mettono in evidenza che il terzo e quarto modo sono i più pericolosi; il terzo modo interessa la torsione ed è eccitato dalle armoniche motore, mentre il quarto modo che interessa la flessione è eccitato da una risonanza del motore.

Alcune modifiche sono pertanto necessarie:

- Vincolare il foro evidenziato in blu in Figura 18 con un bullone al motore. Questa modifica permette di aumentare la quarta frequenza naturale da 619Hz a 734Hz e superare la zona critica di risonanza del motore fra i 600-700Hz.
- Per diminuire le accelerazioni del terzo modo si suggerisce di togliere le linee di scarico della staffa che rendono simile la sezione della staffa ad una sezione a C che male sopporta la torsione evidenziata dal modo in questione.
- Irrigidire la staffa a flessione per diminuire la resistenza a flessione nei modi 1,2,4, come evidenziato in Figura 18 in rosso.

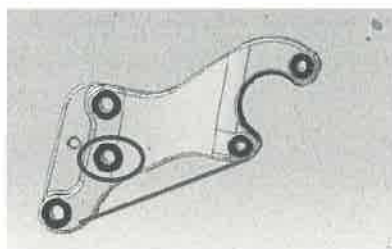


Figura 18: zone in cui apportare le modifiche progettuali