HAND ARM VIBRATION

International conference

6-9 JUNE 2023

Espace Prouvé,
Nancy, France

Nonlinearity of Power Absorption Curve and Hand-Arm System Physiology

Enrico Marchetti, Luigi Fattorini, Marco Tarabini, Raoul Di Giovanni, Massimo Cavacece and Angelo Tirabasso

Introduction

- many authors have assessed the Hand-Arm power absorption nonlinearity in different conditions of grip, push force and posture;
- while studying models of the HAS, this nonlinearity is usually disregarded;
- this lack of linearity suggests the action of a physiological active mechanism which may be connected with the insurgence of vibration pathology;
- anyway, the lack of inclusion of muscular synchronization does not affect the model's effectiveness;
- This speach is written to point out this fact as well as the need to better understand nonlinearity in power absorption, taking its many features into account.

Hand–Arm System Vibration Biodynamics

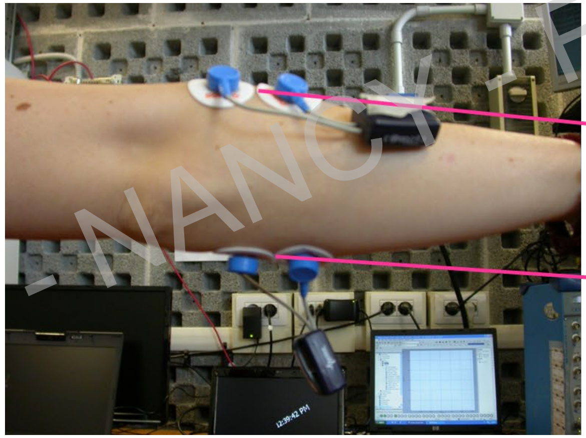
- The first biodynamical study of HAS was dated in 1972 with the work of Reynolds. After that Reynolds, Radwin et al., in 1987, studied the interaction of grip force and frequency of mechanical vibrations, finding an influence of the frequency stimulus on grip force.
- In 1994, Burstrom and Lundstrom pointed out that the main experimental conditions influencing measurements were the vibration direction, the grip force, the vibration level, the hand–arm posture and the constitution of hand and arm.
- Threafter Martin and Park, in 1997, highlighted the mechanism of Tonic Vibration Reflex (TVR) and proposed an electromyographical measurement standard for assessing the TVR influence in the normalized synchronization index SYNC, both within vibration frequency and far from it.
- More recently, other works considered the relation between TVR, grip force and fatigue.

Hand–Arm System Vibration Biodynamics

- The presence of an external, mechanical, and rhythmic stimulus induces a coherent activation of muscular fibers (e.g., motor unit synchronization) which may impair the physiological muscular activation pattern while performing the motor task (grip and push force).

Hand–Arm System Vibration Biodynamics

- The assessment of SYNC is done by surface electromyography (sEMG) .
- Muscular activity is assessed by sEMG of extensor carpi radialis longus (ECRL) muscles (preliminar data processing).



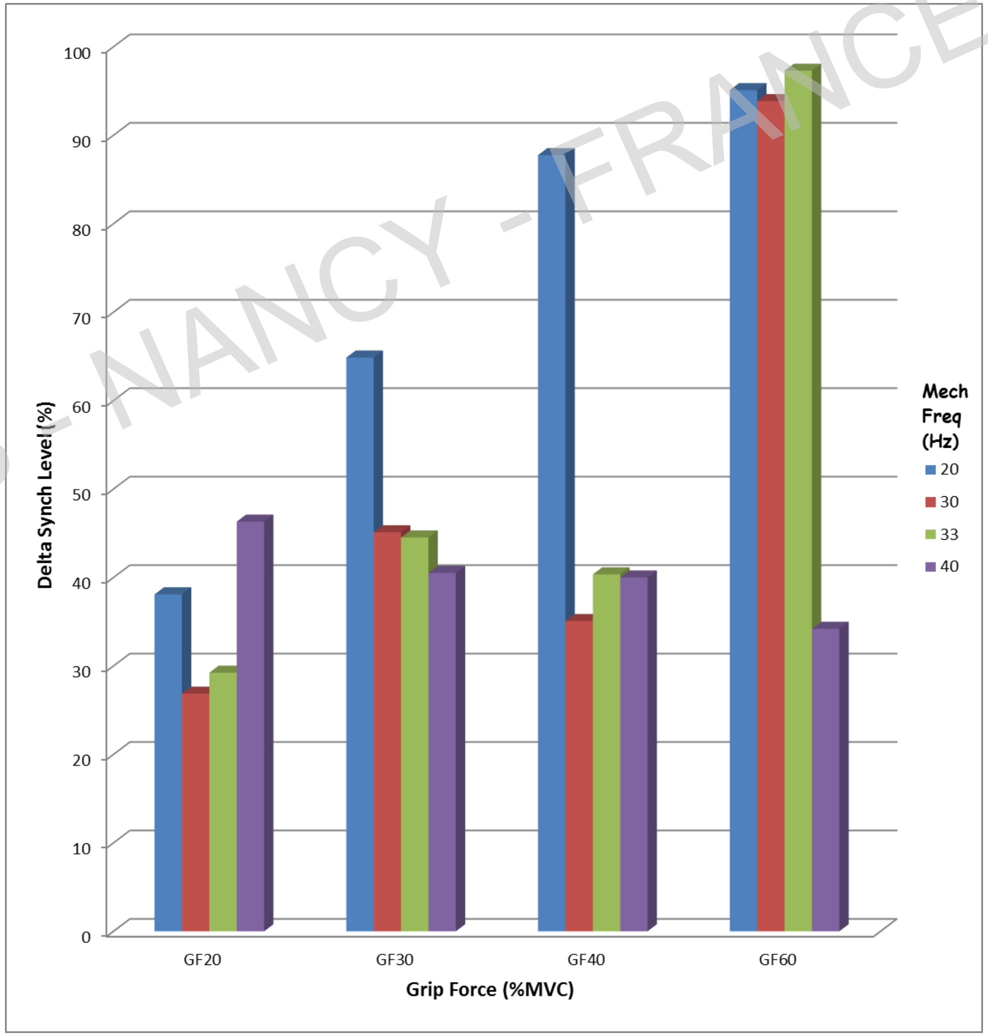
Hand–Arm System Vibration Biodynamics

- In this study, delta SL (ΔSL) was defined as the percentage of the difference from early exposure (average of first 5 seconds) and at the end of the 45 seconds exposure (average of last 5 seconds).

$$SYNC_{VF} = \frac{\int_{VF-2}^{VF+2} PDS(f)df}{\int_{0}^{2000} PDS(f)df}$$

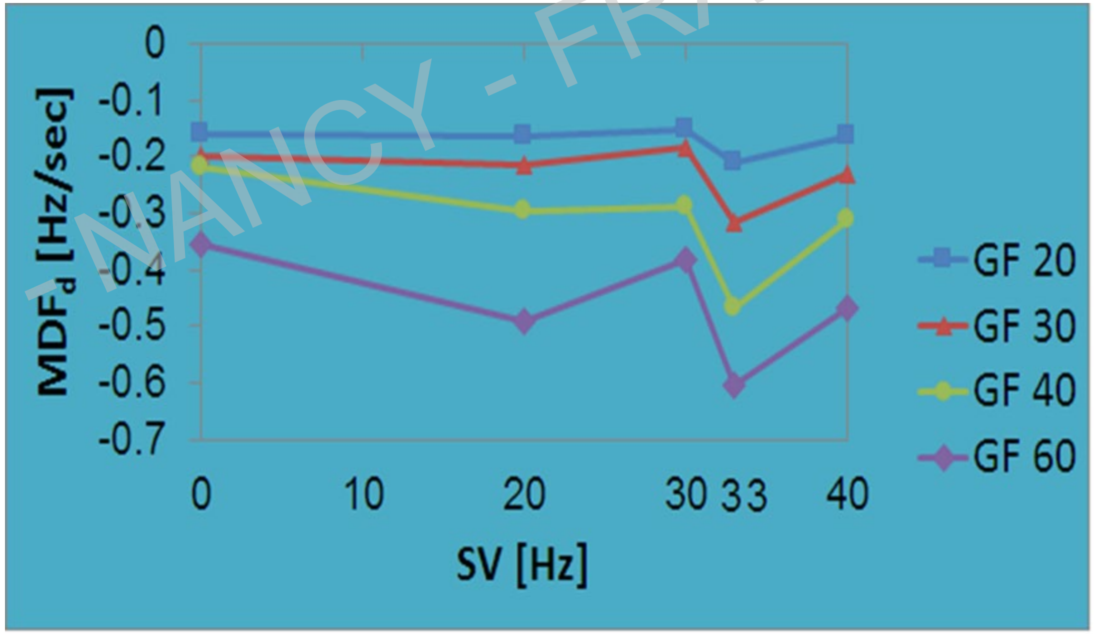
Hand–Arm System Vibration Biodynamics

- It is possible to see that there are some couple of grip-frequency that are more elicited.



Hand–Arm System Vibration Biodynamics

- Median frequency decay (MDFd) has been associated with muscular fatigue.
- The reason must be sought in the muscular response driven by the stretch reflex, i.e., the muscular contraction induced by the variations detected by muscular spindles and the Golgi tendon's receptors.
- This reflex allows the fibers that have a firing frequency near that of the vibrational one to contract more often than the other.
- This implies that there are some fibers that do not have rest, while there are others that not affected by the vibration.
- Neuromuscular systems have to satisfy two motor tasks: grip force production and TVR.
- For this, a capacity reduction to maintain a force level is expected, and this mechanism is the basis of muscle fatigue from a physiological point of view.



Models of HAS

- Models are useful tools for the prediction of the HAS response to vibration exposure;
- Models work efficiently in that sense, even without the implementation of physiological nonlinearity;
- the nonlinearity could help model muscular fatigue in the physiological definition.
- In general, the lack of the fatigue and physiological elements imply that models are representative of the HAS response just for limited exposure times and for forces that are small.

Muscle Fatigue Measurement

- Subjects are required to grip a handle with forces equal to 30% and 60% of MVC.
- Participants were exposed to vibration with a frequency of 30 Hz and amplitudes of 5–7.5 and 10 m/s^2.

Table 1. Time of endurance in minutes of a motor task of 30% of MVC upon varying the handle vibration.

	No Vib	**5 m/s^2**	**7 m/s^2**	**10 m/s^2**
1	4.53	5.10	4.75	5.03
2	5.02	5.04		
3	3.40	2.26		
4	4.35	5.12	4.02	3.55
5	4.48	3.40	3.38	4.70

Muscle Fatigue Measurement

- Present results (summarised in Tables 1 and 2) show a limited influence of vibration on the time for which the subject could endure the motor task.
- Some subjects even improved their endurance under vibration, while some others shortened it.

Table 2. Time of endurance in minutes of a motor task of 60% of MVC upon varying the handle vibration.

	No Vib	5 m/s^2
1	1.28	1.35
2	2.01	1.00
4	0.45	1.14
5	2.40	2.02

Conclusions

- The conclusion is that there are some active mechanisms that intervene in the contraction while exposed to vibrations and that those mechanisms have to be studied in depth before we can obtain complete knowledge of muscular synchronization and fatigue.
- In other works, we encourage a larger collaboration between vibration experts and physiologists to overcome the current lack of specific knowledge on the effect of fatigue on the HAS response.

THANK YOU
FOR YOUR KIND ATTENTION