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Measuring of Vibration Velocity in Layered Composites

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ABSTRACT

The paper presents the results of measuring the vibration velocity, describes the experiment conditions and equipment and discusses the obtained results. Vibration velocity, natural frequency and damping are quantities that we used to evaluate the dynamic response of layered laminates made of carbon and glass fiber twill fabrics.
Keywords: Wave, Impact, Propagation, Material, Layer, Damping.

I. INTRODUCTION

Dynamic response of material is important in many applications, mainly in the most demanding problems such as aerospace but also in special applications in mechanical or civil engineering industry. Dynamic response of material is in form of mechanical waves (vibrations) that propagate in continuum. Vibration is the oscillation of elastic body or environment where individual particles make mechanical oscillation.

The studies try to find the effective methods of damping the response of system on impulse load. We focused on material damping by measuring the vibration velocity and the lowering the values in time. The researched material is layered laminate. The speed of impulse load is important to classify the load as impact load or shock load. In generally, while the velocity of the impact load is about 10-50 m/s, the problems of shock are of several hundred m/s [1]. However, for polymers, as the shock load is recognized the load of velocity 1-10 m/s [2]. Impulse load is characterized by sudden change in the size of the applied force [3]. The impulse wave propagates in material. In microscale, the part of wave spreading in the body hits the area with higher or lower wave velocity; there is refraction or reflection of the wave part. The overall result can be the deflection of kinetic energy spreading. The wave damping and their dispersion in composites is interesting field of study.

Wave propagates in continuum. It represents the spreading of deformation of elastic body, change of temperature, pressure, density, etc. The waves spread the energy in space. The velocity of waves spreading is denoted *c*. In generally, the basic types of waves are:

- Longitudinal wave (of tension or compression type) is the fastest one in bodies. The oscillation (moving of medium particles) is in direction of the propagating wave. They are also named as primary waves and their velocity can be calculated according to:

$$c_L = \sqrt{\frac{E}{\rho}} \tag{1}$$

  where E is Young's modulus of elasticity and ρ is material density.
- Transversal wave (of shear type), the secondary wave; the oscillation is in perpendicular direction to the propagating wave motion. The velocity is:

$$c_T = \sqrt{\frac{G}{\rho}} \tag{2}$$

where G is shear modulus of elasticity.

II. METHODS AND MATERIAL

The measurement was performed on six flat laminate samples, size 115x115, each of which is composed of three layers of carbon or glass fiber twill fabrics in matrix. The orientation of individual layers is different (Table I) to be able to analyse the influence of that orientation. The brief characteristics of the used composite materials are in Table II.

TABLE I
SAMPLES STRUCTURE DESCRIPTION

Sample	Layer	Fabric orientation
1 (4)	1	##
	2	##
	3	##
2 (5)	1	XX
	2	XX
	3	XX
3 (6)	1	##
	2	XX
	3	##
##	fiber orientation parallel to the edges of the sample	
XX	the fiber orientation diagonal (45°) to the edges of the sample	

TABLE III
SAMPLES MATERIALS

C200	Carbon fabric 200g/m^2, twill 2/2	
IG280	Glass fabric 280g/m^2, twill 2/2	
LR285	Epoxy resin: EPIKOTE^{TM} Resin MGS® LR 285	**Ratio** 100:40
LH286	Fixative: EPIKURE^{TM} Couring Agent MGS® LH286	

Fig. 1 shows the sample fixation and the point and orientation of dynamic force load. The photo of jaw clamping of sample during measuring is in Fig. 3b. Moreover, the laser beam point on the sample is visible on the sample.

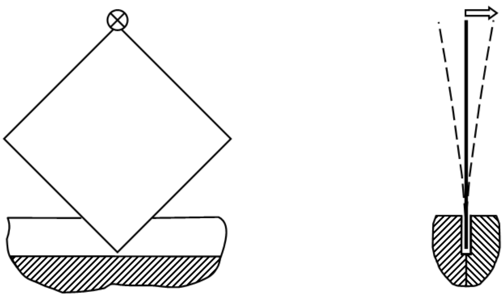

Figure 1. Sample fixation and dynamic load

Fig. 2 illustrates the measurement schema. The measuring equipment is Polytec IVS 400 (Fig. 3a). The main advantage is contactless and wear-free measurement what eliminates the influence of environmental conditions regardless some servo-mechanisms or noise protection to perform the measuring. Polytech is precise and reliable vibrometer based on a phenomenon of Doppler Shift in laser beam to measure e.g. the vibration velocity, amplitude of a moving object. The light beam is reflected by motion of surface and thus the frequency of light is shifted proportionally to its velocity. The light frequency shift is transferred into voltage signal that is subsequently processed. The laser-Doppler vibrometry is significant by the independence of measured data on reflected light intensity. Hence, the laser vibrometer is suitable for surfaces of low reflectivity. More in [4].

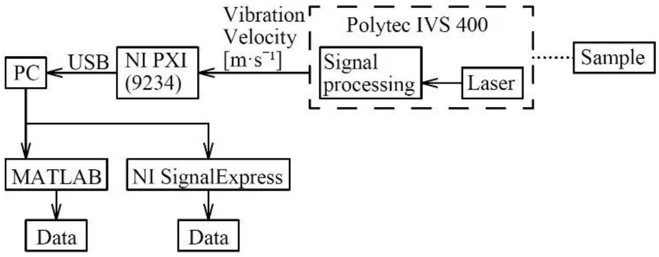

Figure 2. Schema of measuring

Figure 3. Laser vibrometer Polytec (a), jaw clamping of sample (b)

III. RESULTS AND DISCUSSION

We obtained the velocity amplitude depending on time for each sample. The time course of vibration velocity of one sample is in Fig. 4. The crossing of wave through the individual layers is obvious. L1, L2 and L3 denote the laminate layers. The time of crossing individual layers is different for different laminate arrangement.

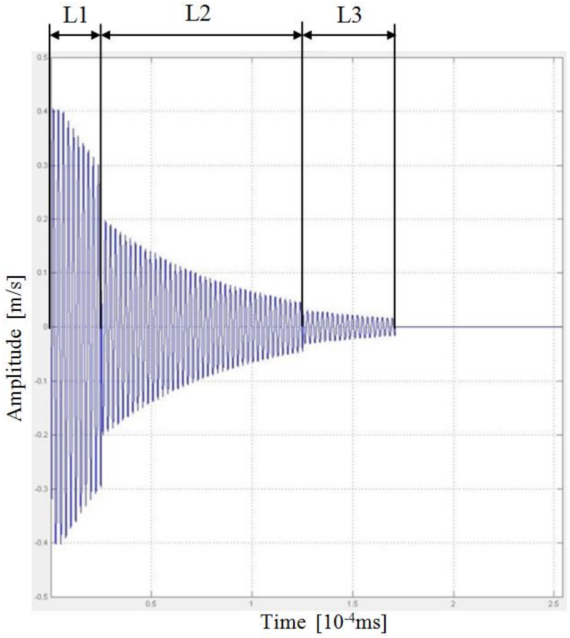

Figure 4. Vibration velocity (carbon laminate ## ## ##)

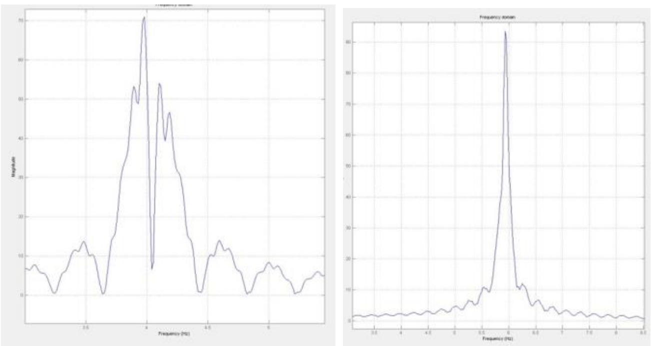

Figure 5. Natural frequency

Fig. 5 shows natural frequency of heterogeneous (left) and homogeneous material (right). Natural frequency of homogeneous material is characterized by one sharp peak comparing to several peaks of composite material. Such material is appropriate for dynamic performance.

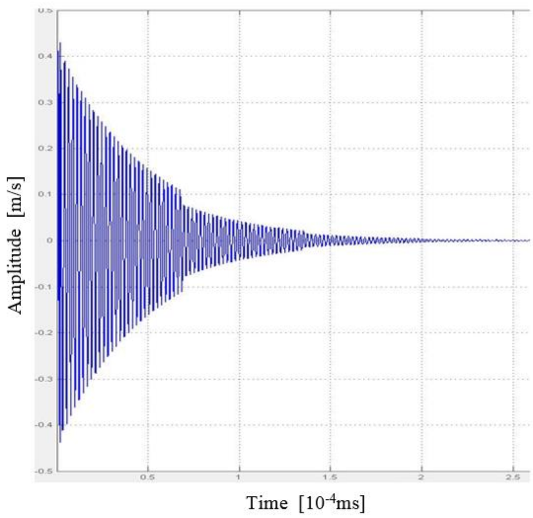

Figure 6. Vibration velocity (glass laminate ## XX ##)

Fig. 6 presents vibration velocity of glass laminate. Analysing Figs. 4 and 6, we can compare the wave crossing time in individual layers and the damping time in whole laminate. Damping time is shorter for carbon laminate.

The fibers in material caused the reflexion and interaction of waves and thus the initiate impulse wave is damped and diffused. The Figs. 4 and 6 present the material damping. Each material involves imperfections despite the fact that we suppose it homogeneous. In ideal homogeneous material the wave propagates without any micro-barriers in whole volume and wave is reflected at the body boundaries. The inclusions – particles, fibers - that are of significantly different material properties give rise to reflexion, refraction and interaction of the propagating waves.

IV.CONCLUSION

The understanding of dynamic behaviour regarding the internal composite material structure in detail is important for improving and utilization of its dynamic properties. The layered composites are used in aerospace industry and we presented their very good damping properties that are supported by individual layers. The material and layer orientation have the significant influence on dynamic response.

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