PROBLEMS OF MECHANIZATION FROM THE ASPECT OF ENVIRONMENTAL PROTECTION AND MATERIAL SCIENCE

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Abstract

Vibration and noise are insidious, continuously acting factors impairing humanity in an increasing rate and in a still rather unknown way. The dangers of this cannot be estimated adequately. Though our knowledge concerning the structure of the atomic nucleus and the secrets of the Universe is increasing, the correlations between the sources of vibration and noise from the aspect of the practical structure of materials are still less known and could not be summarized systematically. The possibility of the limitation of vibration and noise within adequate boundaries is depending upon the knowledge and recognition of this system. The boundaries of the investigation of this system had been recognized by the author concerning the solid materials and he is ready to present them in the form of a textbook containing the common characteristics of all solid materials (plastics, metallic and non-metallic inorganic materials). This paper outlines these problems briefly.

Problems of vibration and noise

Robert Koch said at the end of the last century: "after hundred years we'll have more trouble with the noise than with the illnesses." This was a heretical idea at the time of the devastation of the ten thousands of people by epidemics. And really, nowadays we can localize a number of infections and viruses, but have no universal "serum" against the noise, or noise damages.

It is true, that the dangerous and the injurious noise is a by-product of the scientific and technical development of our century. The noise damage had been already recognized by the ancient Greeks — they were fighting against it too — but the real big problem appeared as a consequence of the extensive mechanization. The comprehensive application of the various internal-combustion engines, the traffic and the differently driven machines are so much focal points of noise damages.

The noise was accepted as one of the biggest dangers of mankind in the United Nation's report published in 1980 about the protection of the human environment. Today the noise of large cities is four times bigger than in 1956 and thirty-two times bigger than in 1932 according to the estimation of the U.N.

Nowadays more and more machines are working and moving around us acting as vibration and sound sources. The human physique and nervous systems are shattered by these by-products of civilization; the noise and vibration damages.

An important task of the protection of the human environment is to recognize and to set limits to the noise and vibration damages preventing the damages of the human body.

The definition of noise is rather difficult. From the physical point of view any aperiodic vibrations of large amplitude can be defined as noise. According to this the vibrations belonging to the infrasonic and the ultrasonic sounds or the radio- and the microwaves can be considered too as noise, the damaging influences of which are less known. The fading of noise accompanying the sound effects is considerably subjective. Somebody being lost in his mental work can feel the most beautiful music like a noise, but just then we don't feel the cry of our children as a noise. The aircraft designer takes delight in listening to the smooth drone of the self-devised engine, but the people living in the houses surrounding the landing path suffer from the noise.

Propagation speed of the mechanical waves depends on the temperature, density and the elastic modulus; so the propagation speed of an acoustic wave is 1497 m/s in water at 24 °C, and 1530–1600 m/s in tissues.

Problems of the qualification of solid materials

On considering the microstructure of solid materials the qualification of materials cannot, at present, be more than a comparison of real microstructures with each other. A given material can be qualified on the basis of properties which change at a particular sensitivity from the interactions of the fundamental building elements of the microstructure up to the macroscopic appearance and which characterize the material statistically. Properties of this type are, for example, the thermal and the electric conductivity, the dielectric behaviour, the magnetic permeability and the elasticity. For ideal structures these properties can be described by the same mathematical method.

One of the most important properties of solid materials is the elasticity. The very extensive literature concerning elasticity can be classified into two fields.

If the regularities of the crystalline structure are taken into account, they present generated relationships which enable the description and definition of the elastic properties of all ideal solid materials whose regularities of structure are identical. Furthermore if these fundamental relationships are used for our start, an attempt can be made to obtain an increasingly more accurate approximation of the elastic deformations and stresses of the materials and for the interpretation coherent with the more accurate material structure of the material constants present in the relationships.

The literature deals with various methods of measurement developed to determine the material constants present in the mathematical expressions of these properties. The obtained results, besides elucidating the relationships of the various properties with each other, promote the mathematical description of the values and changes of the material constants to be expected under various conditions — sometimes only in an approximative way. Thus, for example, they comprise the recognition and approximative formulation of temperature, pressure, variations in composition, regularities in structure and the trends due to deviations from these properties. Investigations of this type are carried out on model substances of a well established structure such as single crystals of high purity.

In the case of systems of complex structure such as multicomponent systems containing impurities of a property-modifying nature and having different degrees of arrangement (including various degrees of arrangement from the amorphous states to the crystalline arrangement), the measurement and interpretation of the material constants is rather difficult due to the lack of an adequate interpretation of microstructure.

For the time being the qualifications are usually based on a statistical comparison of samples of the material to be investigated, which samples are considered to be optimal.

The determination of the elastic properties of solid materials gives information concerning the forces acting between the atoms or ions present in the solid material, i.e. the nature or the bonds existing in the solid material. Since the mechanical behaviour of the materials is depending upon the elastic properties, their measurement is of prominent importance both from theoretical and from practical aspects. On selecting the appropriate material the knowledge of the mechanical properties is in the majority of cases indispensable. The elastic properties of the material are governing the behavior of the material employed above the stress domain of the material behaving elastically. The behaviour of the material under stress is typical for most solid materials, excepting those which are exceptionally fragile.

Within the domain of elastic behaviour, the proportionality factor correlated with the load and with the stress, the so-called constant or modulus of elasticity is suitable for the characterisation of the complex properties of the material. This value can be determined by measuring the velocity of the sound waves crossing the material. Since the problem of velocity determination cannot be separated from the actual nature of the crystals themselves, very important conclusions can be drawn from the correlations between the elastic properties of the crystals and the velocity of the sound.

Thermosonimetry

In the technique of thermosonimetry (TS) the sounds emitted by a substance are measured as a function of temperature whilst the substance is subjected to a controlled temperature programme. The emitted sounds arise from the thermal stresses which are imposed on the substance by the temperature programme and the induced structural strains may be accommodated or released by a variety of processes depending on the chemical, physical and mechanical properties of the substance. The best known strain release processes, by virtue of the fact that they are more easily detected, are the chemical and physical changes, e.g. chemical decomposition, melting, solid-state transformation.

Mechanical strain release processes involve motions and creations of structural imperfections, e.g. microcracks, dislocations, grain boundaries, and occur in all thermally stressed substances irrespective of whether chemical or physical changes also occur, but because they are considerably less energetic, they are rarely detected with a conventional thermoanalytical equipment. However, the acoustic energy (sound) release which accompanies mechanical strain release processes is readily detected using the TS technique.

In practice the sounds are emitted as mechanical vibrations during and prior to thermal events occurring within the substance and they consist of a rapid cascade of decaying signals each of "ringdown" shape. Conventional TS equipment measures the quantity of sound emitted from a substance by the technique of ring-down counting in which each signal is digitised and is registered as a single count. In the conventional TS curve the total count or the count rate (as counts per second, cps.) is displayed as an ordinate versus temperature as abscissa.

In common with other thermoanalytical curves, TS curves may be used to "characterise" substances. Also, given suitable calibration, TS data may be used qualitatively to assess the "condition" or "integrity" of a substance. For example, assessments or radiation damage, dislocation density and degree of annealment can be accomplished.

For every ring-down signal the initial amplitude, the rate of amplitude decay and the time interval between components (the frequency), each contribute to the magnitude of its count. The TS count is therefore a composite measure having practical convenience but no theoretical significance, and consequently any TS technique based on ring-down counting can never provide truly quantitative assessments. Data relating to the fundamental parameters upon which the "condition" or "integrity" of the substance depend (e.g. numbers of microcracks, their dimensions and energies) are, however, obtainable from measurements of amplitudes, distributions and frequency distributions.*

Composites

If the problem of noise is of a such complex nature, and the situation is essentially not improved but — according to the presented data — is rather worsening, the question emerges whether there is a rational alternative at all? According to the opinion of the author this alternative exists! First of all, a general but concrete model must be chosen for the appropriate studying of both the bright and the bad sides of civilization by scientific methods, with the use of systems analysis procedures.

Though the present paper is discussing — according to its title — the problem of noise from the aspect of material science as a main object — being the base of the modernization of technology — also all the essential data of the complex investigation such as the problems of the operation of motor cars, of the pollution of air and of solids, the decay of forest trees etc. are awaiting means for solving their problems.

Now let us discuss why — according to the opinion of the authors — the complex problem of the quality of solid materials is put in the foreground! Namely, the author is convinced that this is the starting point of the scientific approximation, around which the solutions of all the other problems may be coordinated. Though at present the metals are playing a predominant role in the motor car industry, the future appears to be favoured rather by plastics and ceramics. Thus, though use of plastics fortified by glass fibres is rather spreading in motor cars and lorries, the evaluation of ceramics in traditional sense is as follows:

Ceramics to figure in nonmetal car

Many possible future applications of ceramics in motor vehicles have surfaced in news media reports over the past few months. Perhaps the most exciting is a Metalworking News article indicating that the two top Japanese automakers, Toyota and Nissan, as early as the 1900's will offer vehicles with ceramics and plastics replacing metal parts.

The trade magazine quoted former U.S. trade official Harald B. Malmgren as saying that the two firms will use all-ceramics engines, carbon-fibercomposite chassis, and ceramic or plastic body panels. "If you think the pace is not going to be that fast"-Metalworking News reported Malmgren as

* These data were drawn from the works of K. Lønvik (Trondheim University, Norway).

telling a joint session of the Lead Industries Assn., and the International Lead Zinc Research Organization — "I have to warn you that Toyota's track record in meeting its own objectives is almost perfect in the past 20 years."

Malmgren's assertion had "no basis in fact" and was "purely speculation", according to John McDonnell, corporate public relations manager for Nissan U.S.A. Toyota had not commented on Malmgren's statements.

Road Track in its June edition reported that General Motors' Buick Div. "will reportedly have a ceramic turbo charger rotor in two years." However, Ronald L. Kociba, Buick's assistant staff engineer for turbocharger systems, told Ceramic Bulletin that the division more likely would have a ceramic rotor for the 1987 model year.

Kociba said that Buick will probably get ceramic rotors from one of two suppliers, Garrett — which now provides it with metal-alloy rotors — of Warner-Ishi — which, according to the Buick engineer, "is coming on strong". The 3.8–L V–6 will probably be the first candidate.

Other applications Kociba would like to see for ceramics include sheaths for ignition wiring, exhaust-systems parts such as port liners, and turbocharger housings. However he cautioned that these, for now, are "pipe dreams".

Kociba also posed an interesting question, why cannot the catalytic converter, using ceramics, be incorporated in the entire exhaust system rather than being a separate unit, as is the case today?

In a related development, Warner-Ishi has picked a site near Decatur, Ill. for its new turbocharger assembly facility. The plant reportedly will lack a casting shop to fabricate metal rotors; Warner-Ishi officials are confident that ceramic turbo rotors will be feasible by the plant opened in mid-1984. Road Track and Automotive Industries claimed.

Meanwhile, two more ceramic-engine developments from Japan: 1) Autoweek reported that Hitachi is working on a 2-L diesel using Si_3N_4 pistons and cylinders. 2) According to Technology Update, Asahi Glass is looking at a 3.6–L, 75–kW, stationary, Stirlingtype (external combustion) engine using ceramic piston heads and cylinder liners".

The fact that this problem can be solved only starting at the level of material science, is confirmed also by the presented description of thermosonimetry. The efforts of the manufacturers of the turbined aeroplanes and diesel cars include the increase of the efficiency and the decrease of the specific consumption and of the environmental pollution. One of the ways to reach this aim is the rise of the operational temperature which already excludes the use of metals! This is just the way why e.g. also silicon carbide entered into the foreground. The interest of the manufacturers in diesel engines is newer, the study and interest of the manufacturers of diesel engines for ceramics is newer. This was due mainly to the study of the adiabatic motors. The use of ceramic insulating materials makes possible the decrease and abolition, respectively, of the amount of energy absorbed by the cooling system, furthermore also the recovery of the heat in a turbogenerator as a warmer exhaust gas. Obviously, this means at the same time also a change in the conditions of the environmental pollution.

The author has gained his experiences required for the complex study of material sciences and environmental protection by developing at the beginning of the sixties some microstructure systems of ceramics (Al_2O_3, SiC), and by creating in 1973 a method for the investigation of a system for environmental protection. The transfer of these experiences to a metallic and plastics system appears to be suitable for attaining qualitative alterations of the correlations between the structure and properties of composites.

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