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CREATION OF DAMPING CARBON AND ALLOY STEEL

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ABSTRACT

As the object of the study, carbon and alloy steel were selected for the parts with a high hardness and superior wear resistance at small deformation. Alloys with high damping properties were smelted and their acoustic and damping characteristics were studied. Based on the analysis of installations for the study of acoustic (sound level, sound pressure level) properties of the alloys, the device for the study of acoustic properties of the plate samples was selected.

Key words: Alloy steels, Alloys, Damping properties, Acoustic characteristics, Plate samples.

INTRODUCTION

Mechanical noise of transport equipment is created as a result of friction, collision of parts and assemblies. During the design of transport equipment, designers and engineers pay attention to the strength characteristics of parts and assemblies. While doing this, the radiated noise and vibration are completely ignored which may detrimentally have an impact on the body of the maintenance personnel. Known methods to reduce the noise (sound absorption, sound insulation, the use of personal protective equipment, etc.) are not effective for the transport equipment due to cluttering of the working transport, increasing fire danger, dust, masking of warning signals.

One of the effective methods of noise reduction is its attenuation in the source (replacement of impact processes by unstressed ones, change of gear pairs to V-belt, the use of non-metals, damping alloys).

Schetky and Perkins[1] have studied the damping properties of metals and alloys. They identified the malleable magnesium as the most damping metal (specific damping capacity - 49%), followed by the alloy inkramut and sonoston - 40%, Nitinol - 40% saylentelloy - 40%,

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high-carbon cast iron - 19%, nickel (net) - 18%, technically pure iron - 16%, martensitic stainless steel - 8%, gray cast iron - 6%, mild steel - 4%, ferritic stainless steel - 3%, malleable cast iron with spheroidal graphite - 2%, medium carbon steel - 1%, acoustic stainless steel - 1%, aluminum - 0.3%, nickel-based alloys - 0.2%, titanium alloys - 0.2%, brass, bronze - 0.2%.

The possibilities of using inter-granular corrosion in a process of cracking from heating and plastic processing of sheet materials with pre-applied grooves on its surface in order to increase the damping properties were also studied[2]. The originality of this method is obvious. However, technological complexity of this treatment regimen should be noted. One way to reduce the noise at the source is the use of composite materials. In the studies[3,4] bimetallic materials such as St.45 - MT copper, steel X18H10T - AMGC alloy, steel X18H10T - M1 copper, steel 08X18H10T - steel 08X18H10T, obtained by hot rolling, explosion welding were proposed to deal with industrial noise. It should be noted that these bimetal materials are expensive materials, both as used steel grades and as manufacturing technology, compared with the conventional sheet structural steel.

Using the damping properties of structural steel and alloys in the noise control method is the most promising solution to reduce noise and vibration in the workplace.

As a study object in this paper, carbon and alloy steel for the parts with high hardness and high wear resistance at low deformation were selected. Carbon steel 40, 45, and similar steel with high content of manganese 40G, 45G, 50G are used for making a wide variety of machine parts (half-line of cars and trucks, distribution rollers, crankshafts, connecting rods, axles, universal joint shafts, brake levers, friction wheels, gears, spline shafts and gear shafts, anchor bolts). In cold condition and after tempering - bolts, nuts and studs are of high strength. Steels have higher elastic properties. Thus, depending on the operating conditions of parts, various kinds of heat treatment are used: normalization, improvement, hardening with low tempering, HFC hardening.

Manganese steels (40G, 45G, 50G) have greater hardness penetration, however, manganese enhances the tendency to grain growth, so they are sensitive to heat and may have reduced toughness, especially at low temperatures. Most commonly, these steel are used for products bearing the greatest impact loads.

These parts are subjected to vibration and shock impacts and as consequence, an intense noise is generated. Damping properties of these steels absent in reference books. Therefore, it has been tasked to evaluate the damping (logarithmic decrement, internal friction, the relative scattering) and acoustic (sound levels, sound pressure levels), physical and mechanical (tensile strength, elongation after fracture, relative narrowing, density, electrical resistivity) characteristics of the used steel grades and to develop new high damping steel. One of the study, objectives is to prevent the reduction of the strength properties of alloys developed. Furthermore, the alloys were smelted with high damping properties, and their acoustic and damping characteristics were studied (Table 1). The content of alloying elements in steel was determined by studying the diagrams Fe-C, Fe-Cr, Fe-Mn, Fe-Si, Fe-Ni. Chromium, silicon, manganese and nickel are among the most commonly used special alloying elements. Additives of alloying elements changed within the following range: 0.8-0.9% chromium, manganese from 0.7% to 0.9%, silicon from 0.2% to 1.9%, nickel from 0.4 to 0.8%. Selection of chromium, manganese, silicon and nickel as alloying elements is explained as follows. Chromium helps to ensure a high and uniform hardness of steels. Steels alloyed with chromium have higher hardness penetration. It dissolves in the ferrite and cementite and has a beneficial effect on the mechanical properties of the steel, which explains its widespread use in construction steels. Manganese increases the strength of steel in the hot rolled product, and reduces the brittleness of steel. Manganese is often used as a substitute for nickel, it significantly increases the yield strength of steel. 2-4% manganese additives affect the damping properties of the alloys. Silicon is a chemical element, which is ever-present in steels, while it has a significant impact on the composition and the nature of non-metallic inclusions. Silicon is the most effective graphitizer in steel, and the presence of graphite increases the tendency of steels to irreversible dissipation of fluctuations energy.

It greatly increases the yield strength, reduces the viscosity and increases the threshold of cold brittleness if over 1%. Usually, manganese and silicon are introduced into the steel for deoxidation. Selection of nickel as an alloying element is due to the fact that this element is also widely used in high-damping alloys. Addition of nickel to other metals substantially alters their properties and creates opportunities for a wide range of different very valuable materials. By strongly reinforcing the ferrite, nickel does not reduce its viscosity and decreases the threshold of brittleness, whereas the other elements, if does not reduce the viscosity (Cr), then very slightly strengthen the ferrite, or by intensively reinforcing the ferrite, reduces quickly its viscosity (Mn, Si). Also in small percentage such alloying elements as titanium, aluminum and bismuth were added. Additives of alloying elements were changing in the following ranges: titanium 0.03%, aluminum 0.02%, titanium 0.01%.

EXPERIMENTAL

Smelting was produced in the laboratory of casting of the professorate "Machine tools, materials science and engineering production technology" (SMiTMP) of KazNTU named after K. I. Satpayev. Experimental alloys were smelted in a crucible induction furnace of 12 Kg with basic lining. The starting material was Armco iron. Alloying was produced by 99.5% metallic manganese, 99.98% fired nickel, 98.0% metal powder titanium, 99.97% granulated aluminum, 93.0% metallic bismuth. Carbonaceous additive was a synthetic iron with a carbon content of 3.9%. Steel was cast in metal mold with dimensions of 210 x 115 x 115 mm.

Casting, forging, machining were performed using the same equipment, to eliminate the influence of the processing technology on the studied characteristics.

After casting and cooling, the ingots were forged at a temperature of 1100-1150^{o}C.

Samples for the study of acoustic and physical-mechanical properties were forged from excised bands. Surface roughness after machining corresponded to class 5. Forged samples have undergone milling, planing, cutting, grinding. Deviations of the defined dimensions (50 x 50 x 5 mm) did not exceed 0.2 mm. Acoustic (sound level, sound pressure levels) and vibration properties (acceleration level and the level of vibration velocity) were determined after forging, then these same samples were subjected to annealing, normalization. Mode of annealing - heating to Ac_3 + 50^{o}C, holding for 0.5 hr, cooled in the furnace. Normalization was carried out by the regime: heating to Ac_3 + 50^{o}C, holding for 0.5 hrs, air cooling. Heating and holding at normalization and annealing was carried out in quartz ampoules under vacuum with discharge of 10^{-3} atm.

Table 1: Chemical composition and mechanical properties of the studied carbon and alloy steels[5]

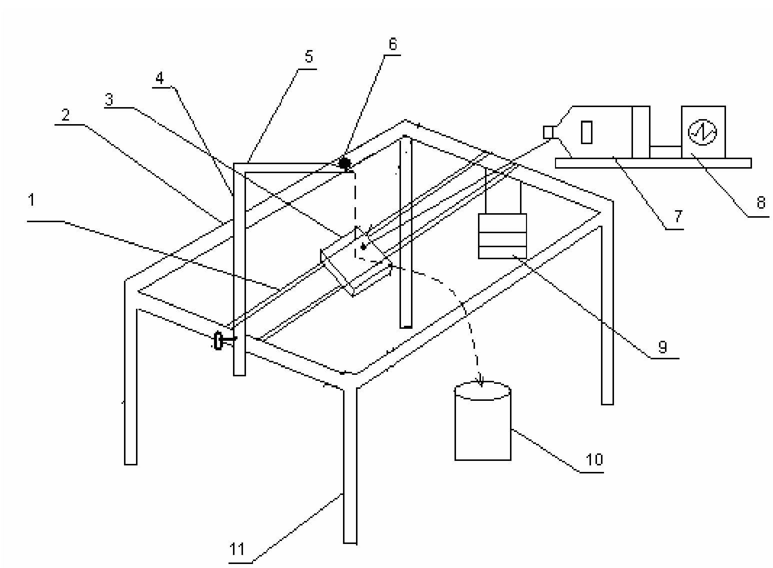
Steel grade	Chemical composition, % weight						Mechanical properties				
	C	Si	Mn	Cr	Ni	Other elements	$\sigma_в$, MPa	δ_5, %	ψ, %	k_{cv}, J/sm^2	$\sigma_т$, MPa
40	0.37-0.45		0.50-0.80	0.25	≤ 0.3		700	18	45	60	340
45	0.42-0.50		0.50-0.80	0.25	≤ 0.3	S ≤ 0.035	660	14	40	50	380
40G	0.37-0.45	0.17-0.37	0.70-1.00		≤ 0.3	P ≤ 0.035	800	17	45	60	360
45G	0.42-0.50		0.60-1.00	0.30	≤ 0.3	Cu ≤ 0.30	900	15	40	50	380
50G	0.48-0.56		0.70-1.00		≤ 0.3		750	15	40	50	380

Cont…

Steel grade	Chemical composition, % weight						Mechanical properties				
	C	Si	Mn	Cr	Ni	Other elements	$\sigma_в$, MPa	δ_5 %	ψ %	k_{cv}, J/sm^2	$\sigma_т$, MPa
M-1	0.39	1.7	0.8	0.85	0.45	S = 0.035 P = 0.035	580	13	45	55	330
M-2	0.41	0.35	0.85	0.78	0.51	Cu = 0.35	600	11	40	50	350
M-3	0.45	0.41	0.75	0.79	0.62	Al = 0.02 Bi = 0.01	608	14	35	45	370
M-4	0.47	0.33	0.81	0.81	0.81	Ti = 0.03	620	15	42	63	350

Note -$\sigma_в$ – tensile strength, MPa; δ_5 – relative elongation after fracture on the samples of five-time length, %; ψ - relative contraction after fracture, %; k_{cv} – impact strength, J/sm^2; $\sigma_т$ – limit of stretching strain, MPa.

Based on the analysis of installations for the study of acoustic (sound level, sound pressure level) properties of the alloys, the device for the study of acoustic properties of the plate samples was selected (Fig. 1).



1-Nylon thread; 2-Frame; 3-Plate sample; 4-Frame leg; 5-Inclined plane; 6-Ball-striker; 7-Sound level meter "Octave 101A"; 8-PCS-500; 9-Cargo; 10-Balls receiver; 11-Frame leg.

Fig. 1: Installation for a comprehensive study of acoustic and vibration properties of steel plate samples

The device operates as follows –

Ball (striker) is installed on an inclined plane. In the measurements the ball-striker slides down from the inclined plane and falls free into the geometric center of the plate sample. After the collision the ball-striker reaches the balls receiver. The noise from the collision of the ball-striker and the sample is recorded by sound level meter "Octave-101A". Tension of the plate sample vibrating in the threads tension is always constant, since the load controls this tension. Drop height of the ball can be changed using the mounting screws of striker rack. The whole mounting system of the sample and the ball-striker is mounted on the frame, which is using the racks is located at a certain height above the floor.

During measurements there were used steel (SH-15) balls-strikers of the following diameters: 13.2 mm; 16.0 mm and 18.3 mm (weight of balls-strikers is respectively: 11 g; 16 g; and 18 g). Analysis of the literature shows that for experimental works the selection of the ball as a striker for the measurement of sound radiation is the most effective, because the ball is hollow and in the collision it provides even distribution of the wave on the surface of the studied sample.

Plate-like shape of the sample allows with a sufficient degree of accuracy to evaluate the conditions of formation of the sound field in the excitation of acoustic vibrations in the structure. The width and length of the plate-sample should be at least 5 times bigger than its thickness. The investigated plate with dimensions of 50 x 50 x 5 mm meets these requirements.

Sound pressure levels were investigated in octave frequency bands in the range of 125-8000 Hz and under the scale of "A". Air temperature and humidity in the laboratory were maintained constant. Acoustic measurements were calculated as the average of five measurements.

The weight of the ball, the density of the sample, the distance from the collision point to the sample, the sample thickness are interrelated under[6]:

$$m < 4.6 \cdot \rho \cdot l \cdot h^2 \qquad \dots(1)$$

where m- weight of the plate sample, g; c- density of the material of plate sample, g/cm^3; l- distance from the collision point to the nearest edge of the plate- sample, cm; h- thickness of the plate- sample, sm.

The width and length of the plate-sample should be at least 5 times bigger than its thickness. The investigated plate with dimensions of 50 x 50 x 5 mm meets these requirements.

Sound pressure levels were investigated in octave frequency bands in the range of 1000-16000 Hz. The sound level – under the scale of "A".

Sound Generator SG-10 was used to calibrate the measurements produced by the sound. Amendment on the change of the sound signal from the atmospheric pressure was carried out using the piston-phone of PF-101 brand. Temperature and air humidity in the laboratory were constantly maintained. Acoustic measurements were calculated as the average of five measurements.

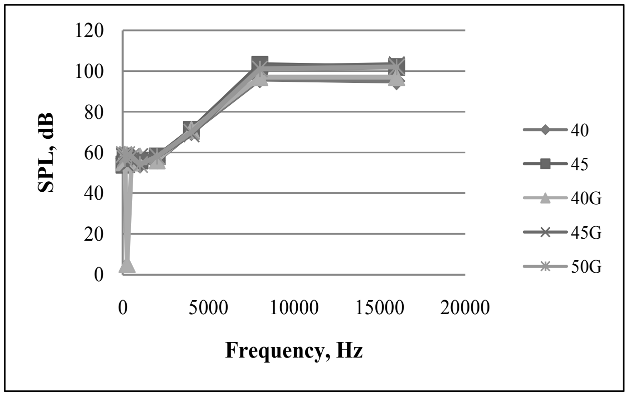
Mathematical treatment of the results of the experiment and the determination of confidence intervals in accordance with the method were carried out[7]. Configuration of the measurement channel was carried out by checking the sound pressure levels of the reference sample before the start of work.

RESULTS AND DISCUSSION

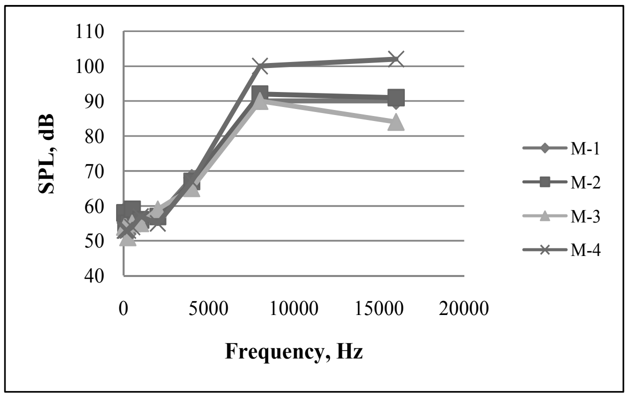
Mean values of sound levels (L_A) and the sound pressure levels (SPL) of the investigated steels after forging are shown in Table 2 and Fig. 2.

Table 2: Average values of sound levels and sound pressure levels of investigated steels after forging

Steel grade	Sound pressure level, dB in octave bands with center frequencies (Hz)									Sound level (dBA)
	63	125	250	500	1000	2000	4000	8000	16000	
40	57	53	56	54	54	56	70	96	95	98
45	54	58	56	55	56	58	71	103	102	103
40G	55	59	5	55	58	56	71	97	97	98
45G	58	58	54	56	58	58	69	102	103	105
50G	59	57	59	58	54	58	70	101	102	104
M-1	58	59	52	56	55	57	68	90	90	92
M-2	58	55	55	59	56	57	67	92	91	93
M-3	54	54	51	55	55	59	65	90	84	93
M-4	53	53	53	54	57	55	67	100	102	102



(a)



(b)

Fig. 2: The sound levels and sound pressure levels of the studied steels after forging

The results of experimental studies are found as: analysis of the acoustic properties of the steels showed that the SPL of the investigated materials varies from 52 to 112 dB in the frequency range 63-16000 Hz. SPL peaks are at the frequency of 8000 Hz and 16000 Hz. Sound levels of steels vary in the range of 91-104 dBA. The maximum frequencies are recorded at frequencies of 63 Hz - in steels M-2 and 40 (59dB); 125 Hz - in steel 50G (58dB); 250 Hz – 50G (58dB); 500 Hz – M-2 (58dB); 1000Hz – 45G and M-3 (59dB); 2000 Hz – 45 and 50G (59dB); 4000 Hz – 50G (71dB); 8000 Hz – 45, 45G, and M-4 (109dB); 16000 Hz – 50G (112dB).

CONCLUSION

Among the standard steels with a reduced sound emission are characterized the steels 40 (97 dBA) and 40G (99dBA). The steels 45 and 45G (104dBA); 50G (103dBA) are characterized by elevated L_A.

Among the developed steels the reduced sound radiation is attributable to steels M-1 (92dBA); M-2 (92dBA); M-3 (93dBA). Steel M-4 is characterized by elevated levels of sound (102dBA). Reduced sound radiation is explained by the increased dislocation density after forging and the damping effect of chromium.

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