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FACULTY OF MANUFACTURING TECHNOLOGIES WITH
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STRENGHT AND DYNAMIC
CHARACTERISTICS OF
STRUCTURAL UNITS IN
MANUFACTURING ENGINEERING

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Abstract

The present monograph deals with research and optimization of strength and dynamic characteristics in manufacturing engineering. The introduction of the work describes findings about the importance of the given subject. Furthermore, it analyses the current status of the addressed issues at home and abroad. The publication is divided into two basic parts, namely the theoretical and the practical part. The theoretical part provides a detailed description of theoretical assumptions on solutions in the field of research and it also describes optimization of structural units in manufacturing engineering; while the practical part analyses strength and dynamic characteristics of the selected structural unit which is the drive of a manufacturing machine for bulk materials packaging. The practical part is also devoted to the experimental measurements of vibrations, ultrasound and sound on the given drive. The conclusion of the work presents the obtained results with new findings.

Key words

strength characteristics, dynamic characteristics, impacts in manufacturing engineering

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List of Symbols and Abbreviations

$I_j^{(i)}$	body's reduced moment of inertia $I_j^{(k)}$ on i -element	$(kg.m^2)$
$I_j^{(k)}$	body j moment of inertia on k -element	$(kg.m^2)$
ω_i	i (main) element angular velocity of structural unit	$(rad.s^{-1})$
ω_k	k -element angular velocity	$(rad.s^{-1})$
$k_j^{(i)}$	reduced stiffness $k_j^{(k)}$ on i element	$(N.m^{-1})$
$k_j^{(k)}$	stiffness of j part of k -element	$(N.m^{-1})$
$M_j^{(i)}$	reduced moment $M_j^{(k)}$ on i -element	$(N.m)$
$M_j^{(k)}$	moment applied on body j on k -element	$(N.m)$
M_{dyn}	reduced dynamic moment of system	$(N.m)$
M_d	driving torque reduced to main element of structural unit	$(N.m)$
M_z	machine load moment reduced to main element of structural unit	$(N.m)$
ω	angular velocity	$(rad.s^{-1})$
σ_h	high-stress amplitude	(MPa)
σ_d	low-stress amplitude	(MPa)
σ_m	medium-stress amplitude	(MPa)
σ_a	stress amplitude	(MPa)
T	oscillation period	(s)
f	frequency	(Hz)
x	mutual approximation of bodies	(m)
x_+	relative velocity of bodies right after impact	$(m.s^{-1})$
x_-	relative velocity before impact	$(m.s^{-1})$
a	radius of circular faying surface	(m)
r_1, r_2	radii of osculating spheres	(m)

E_1, E_2	moduli of elasticity in tension	(Pa)
m	mass	(kg)
τ	impact time	(s)
x_{max}	maximum approximation of bodies	(m)
\dot{x}_-	relative velocity right before impact	(m.s ⁻¹)
I	impulse of impact forces	(N.s)
F_{ed}	impact forces	(N)
$(\dot{x}_t)_{red}$	relative velocity of bodies right before impact	(m.s ⁻¹)
k	stiffness	(N.m ⁻¹)
$dF_r(\xi)$	retraction force	(N)
ξ	deviation corresponding to extension or spring shortening	(m)
φ_k	phase angle of harmonic function k	(rad)
f_k	harmonic frequency	(Hz)
f_1	fundamental frequency	(Hz)
ω_k	angular frequency of harmonic function k	(s ⁻¹)
F	amplitude of applied harmonic force	(N)
f_r	resonant frequency	(Hz)
f_0	dependence for oscillation frequencies of system	(Hz)
A	amplitude	(m)
C	wave propagation velocity	(m.s ⁻²)
σ_m, τ_m	middle (static) element of oscillating stress	(MPa)
σ_a, τ_a	amplitude of alternating stress element	(MPa)
R	impact coefficient	
$f(t)$	continuous periodic function with T period which characterizes time course of oscillation	
μ_1, μ_2	Poisson's numbers of colliding bodies' material	

ϑ_1, ϑ_2 intersection constants

$q(t)$ modal coordinates

$H(f)$ frequency transmission

$x(t)$ any function

A_k amplitude of harmonic function k

ul dimensionless unit (generated by Inventor software)

FFT Fast Fourier Transform

FEM Finite Element Method

Introduction

Manufacturing engineering is a field that is functionally and parametrically broad in its extent. For this reason, it is necessary to structure manufacturing engineering on the principles of trade union profiling in the field of mechanical engineering, agriculture, wood manufacturing and processing, food industry, utilities industry etc. The term manufacturing engineering does not only include manufacturing machines that implement manufacturing technologies, but the given field also includes a variety of machinery that simultaneously participate in the given process. This peripheral equipment of manufacturing engineering also embraces other technical components that control, monitor, evaluate the given process in order to achieve a system optimization. It is important to note that it would be difficult to find a product which would not use at least one of the parts of manufacturing engineering systems during its manufacture or disposal.

A machine has always been, is and will be the technical progress. The basis of every economy is the progressiveness of manufacturing engineering since it manufactures components for all industries. Technical requirements in manufacturing engineering are constantly leading to an increase of the technical level of manufacturing equipment. Profound knowledge of scientific fields precedes a successful fulfilment of the technical requirements. Structural units of manufacturing machines are complex mechanisms that must work reliably and safely with an emphasis on their important function. These units create new objectives for their research and optimization.

There are industrial sectors in which a person can encounter manufacturing machines and equipment, and there are impacts occurring during their operation. These impacts have, on one hand, their significance, e.g., work of hammers, mechanical hammers, vibrating conveyors etc.; and on the other hand, there are impacts that occur during operation which are undesired accompanying phenomenon. They increase noise, deterioration and stress of structural units which can result in an incorrect operation of manufacturing engineering components. These are mostly gears, rotors, cam mechanisms and other structural units in which excessive oscillation occurs. Design parameters of the given units should be determined in a way that eliminates an occurrence of sustained motion with an intensive impact. Manufacturing operation influences force effect which results in various changes, e.g., change of velocity, amplitudes, frequencies etc. These changes have a direct impact on reliability of structural units. Calculations are based on theoretical assumptions which are often not the same as operating conditions, such as extremely low or high temperatures, corrosion and others. Therefore, it is necessary to consider not a perfect structural unit with perfect properties. This fact is related to the current tests of

structural units which are performed under conditions similar to the operating ones, e.g., under cyclic force, combined loading etc. Time characteristics have a significant effect on strength of structural units.

The present publication is divided into several parts based on motivation and analysis of strength and dynamic characteristics of structural units in manufacturing engineering. The beginning of the publication is devoted to the motivation and aims of the work, as well as to the brief summary of the given field and it continues with the theoretical essentials for research and optimization of strength and dynamic characteristics in manufacturing engineering. Another part of the publication is the practical part that is devoted to strength analysis, dynamic analysis together with modal analysis, and to experimental measurement of the screw conveyor drive. Subsequently, the work continues with optimization of the defective unit and the results that compare the calculated and the measured values with the new findings in the given field.