AIN SHAMS UNIVERSITY

Faculty of Engineering

AN INVESTIGATION INTO THE EFFECT OF ALTERNATING & MEAN STRESS ON THE DAMPING PROPERTIES OF MATERIALS

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By

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ABSTRACT

This work is a study for the effect of both alternating and mean stress on the damping capacity of materials.

The theoretical investigation is based on the idea of Granto & Lücke (2,8) for damping due to dislocation movement that are pinned at minor and major pinning points. The viscous drag for the dislocation movement has been neglected.

The tests have been carried out by the vibrophore which is a fatigue testing machine that both alternating and mean stress can be applied to the test piece, also the run-out (decay) diagrams can be recorded photographicaly after the required number of stress cycles have been applied to the test piece.

The experimental investigation has been carried out on specimens made of copper. All results were taken after the specimens were subjected to the same number of stress cycles (600,000 cycle); to execlude the effect of stress history. The specimens have been annealyed after machining to execlude cold-work effects and to ascertain the same dislocation density for all test pieces.

The damping "Δ_p" was found theoretically to increase as the alternating stress "f_o" increases according to the following relation;

$$\Delta_p = C_1 / f_o \cdot e^{-C_2 / f_o}$$

Where C_1, & C_2 are constants.

This theoretical relation between the damping and the alternating stress has been verified experimentally. The experimental res - ults were in agreement with the theoretical results up to a total stress of about (480 - 580) Kg / Cm^2 .

Theoretically, the damping " Δ_p " increases as the mean stress " f_m " increases, according to the following relation :

$$\delta(\Delta_p) / \Delta_p = C_1 . \; e^{-C_2 / f_m} .$$

Where : $\delta(\Delta_p)$ is the increase in damping decrement.

Δ_p is the damping at zero mean stress.

C_1 & C_2 are constants .

but experimentally, this increase was observed to be only up to a mean stress of about 160 Kg / Cm^2 and then damping decreases again. The increase in damping was found to be due to the increase in dislocation density, while the decrease of damping is due to dislocation interaction .

Some of the physical properties of the test material used which can not be measured easly by experiment; e.g, dislocation density , major length, minor length; has been estimated from the results and curves obtained from the internal friction tests.

SYMBOLS

L_N ... Network length (major length) .

L_c ... Length of segment as determined by impurities (minor length) .

C ... Line tension of dislocation line .

B ... Viscous damping force per unit length and velocity .

A ... Mass per unit length .

F ... Applied shearing force per unit length .

F_c ... Amplitude of the applied force .

W ... Angular frequency of the applied force. (Rad/ Sec.).

t ... Time .

σ ... Applied alternating shear stress.

σ_o ... Amplitude of the alternating shear stress.

a ... Burger's vector . / Atomic spacing .

y Dislocation displacement .

W_n Natural angular frequency for transverse vibration of the dislocation line . (Rad./Sec.)

l ... Dislocation length .

$\bar{Y}$ ... Average displacement of ... dislocation line .

ϵ ... Strain .

$\epsilon_{dis.}$ ... Dislocation strain .

Λ ... Total dislocation length per unit volume , (Dislocation density) .

$N(l)\,d(l)$. Number of loops which have length between l&l+dl

δ ... Delta function .

$\mathcal{L}$ ... Breakaway length .

Γ ... Breakaway stress .

$\Delta W'$ ... Damping energy dissipated during one stress cycle .

W' ... Potential energy at the beginning of the stress cycle .

Δ ... Damping decrement .

Δ_0 ... Damping decrement for the testing machine (vibrophore) and the compensation test piece .

Δ_{P}	...	[illegible]
$\delta\Delta$	...	Variation in damping [illegible] .
f	...	Axial external alternating stress .
f_{o}	...	Amplitude of the axial external alternating stress.
e	...	Axial strain .
P	...	Axial external alternating force .
P_{m}	...	Axial external mean force .
f_{m}	...	Axial external mean stress.
T	...	Orientation factor .
E	...	Modulus of elasticity .
G	...	Modulus of rigidity .
f'_{m}	...	Maximum binding force which a pinning point can held a dislocation line .
z'	...	Distance between the impurity atom and the dislocation axis .
ϵ'	...	Miss fit paramter .
r'	...	Raduis of solute atom .

r	...	Radius of solvent atom .
ν	...	Boisson's ratio .
D	...	Average grain diamter .
n	...	Number of dislocations .
N_s	...	Number of dislocations crossing unit area.
N_v	...	Total length of dislocation lines in unit volume of the solid .
N'_v	...	Total length of dislocation lines per source .
V	...	Grain volume .
$\Delta\Lambda$	...	Variation in dislocation density..
Λ_i	...	Initial dislocation density .
Λ_t	...	Total dislocation density .
ν	...	Ratio between major and minor loop length .
q	...	Ratio between the breakaway length and the minor length .
		Ratio between the breakaway stress and the applied alternating shear stress.

q_m ... Ratio between the breakaway stress and the applied mean shear stress.

Z ... Number of vibration cycles under the tangent to the envelope of the decay curve .

INTRODUCTION & HISTORICAL REVIEW

The Internal friction (damping capacity) of metals is quite sensetive to plastic deformation. The effects are very complex and depend on variables such as the amount of plastic strain, the purity of the metal, the frequency of vibration, ... etc.

It is important to state that the plastic deformation mentioned here is in a range of stress within the elastic limit.

On the submicroscopic scale, dislocation movement is responsible for most of the plastic deformations. The theory due to Koehler(1) and Cranto & lucke(2) assumes that internal friction is due to a stress strain hysteresis arising from the irreversibility of dislocation lines breaking away from pinning impurity atoms (or point defect in general) .

Dislocation is the defect responsible for the phenomenon of slip, by which most metals deform platically. The concept of dislocation was first intorduced to explain the discrepency between the observed and theoretical shear strength of metals.

It is well known that the stress which will cause passage of a dislocation through a crystal lattice is far less than the theoretical shear stress(3) (that required to move one plane of atoms over another in a perfect lattice). In general a small force, the Pierls-Nabarro force in needed to drive a dislocation through a lattice .

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Recently, considerable attention has been given to the problem of constructing a dislocation theory capable of quantitively explaining the part of the internal friction in metals as first suggested by T.A.Read (4) (1944) is the result of the motion of dislocations. Theories and experiments have been developed along two main lines, namely, the study of the influence of impurities and of cold working. Theories have been based upon the ideas, presented by J.S. Koehler (I) and A.S. Nowick (5).

Koehler (I) (1952) develops the analogy between the vibration under an alternating stress of a dislocation line segment pinned down by impurity particles and the problem of the forced damped vibration of a string. He solved the differential equation by an approximate method . According to Koehler's theory the energy loss in internal damping depends on the frequency, but according to experimental work carried out by A.S. Nowick (5) (1954) strain- amplitude dependant loss is independant of frequency for frequencies in the kilocycle range (i.e. up to $\sim$ 1 MC/ Sec.) .

To account for this limitation of frequency, Nowick has suggested the quantitative theory that the loss mechanism is of a hysteresis type, in which the dislocations are moved from one potential minimum to another .

J. Weertman and E.I Salkovitz (1955) construct specific hysteresis model using the theories of Mott and Nabarro[7] (1946) from which they are able to make semiquantitative calculations of the damping decrement.

Granto & K.Lucke[2,8] (1956) found an exact solution for the damping differential equation for all frequencies in a form in which the dependance of physical quantities on the length of dislocation loops may be analyzed and applied .

In the present work, the effect of the static mean stress as well as that of the alternating stress on the internal friction will be investigated . The solution of the differential equation obtained including the mean stress as a paramter has been get by using to some extent Laplace transformation[9] and theory of complex variables[9] .

As the frequency dependant loss is small in the range of frequency used in normal mechanical engineering applications, the amplitude dependant loss is the only one considered in this work. The range of frequency for all the tests in this work is of order 100-200 c/sec. , while the range of neglection is extending up to about 1 Mc/sec. , (the kilocycle range)[10] . Granto & Lucke[2,8] suggested that in most materials the resonant frequency of the dislocation loops is of the order 500 Mc/Sec. (10) .

As there are no available informations about the effect of the mean stress on the internal friction properties of copper, and as copper is used in several mechanical engineering applications, it has been selected as the test material for the experimental part of this work .
