AD-761 455

PROBLEM OF CALCULATING BOLTED JOINTS UNDER STRESS RELAXATION AND CREEP CONDITIONS DURING VIBRATIONS

D. Ya. Bragin, et al

Foreign Technology Division
Wright-Patterson Air Force Base, Ohio

7 May 1973

AD 761455

FTD-HT-23-0276-73

FOREIGN TECHNOLOGY DIVISION

PROBLEM OF CALCULATING BOLTED JOINTS UNDER STRESS RELAXATION AND CREEP CONDITIONS DURING VIBRATIONS

by

D. Ya. Bragin, I. N. Shkanov, G. V. Vasil'yev

13

FTD-HT- 23-0276-73

EDITED TRANSLATION

FTD-HT-23-0276-73

PROBLEM OF CALCULATING BOLTED JOINTS UNDER STRESS RELAXATION AND CREEP CONDITIONS DURING VIBRATIONS

By: D. Ya. Bragin, I. M. Shkanov, G. V. Vasil'yev

English pages: 8

Source: Kazan. Aviatsionnyy Institut. Trudy, No. 136, 1971, pp. 34-41.

Country of origin: USSR

Translated by: TSgt Victor Mesenzeff

Requester: FTD/PDTA

Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

A i

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

PROBLEM OF CALCULATING BOLTED JOINTS UNDER STRESS RELAXATION AND CREEP CONDITIONS DURING VIBRATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Translation

5. AUTHOR(S) (First name, middle initial, last name)

D. Ya. Bragin, I. N. Shkanov, G. V. Vasil'yev

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1971	8	7

8a. CONTRACT OR GRANT NO. b. PROJECT NO AP5A c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-0276-73 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

20

DD FORM 1 NOV 65 1473

9

UNCLASSIFIED
Security Classification

All figures, graphs, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}
rot	curl
lg	log

PROBLEM OF CALCULATING BOLTED JOINTS UNDER STRESS RELAXATION AND CREEP CONDITIONS DURING VIBRATIONS

D. Ya. Bragin, I. N. Shkanov, and
G. V. Vasil'yev

The existing methods for calculating tight bolted joints for stress relaxation are based on equations corresponding to a particular theory of creep which gives the most accurate quantitative description of the creep and stress relaxation of fastening materials in the examined specific conditions. Thus, for example, I. A. Birger [1] uses the flow theory developed by L. M. Kachanov for calculating bolted joints; other authors use the theories of Yu. N. Rabotnov and N. M. Belyayev. However, the calculation relationships for describing the creep and stress relaxation, obtained on the basis of these theories, are in good agreement with the experimental data only for the pure metals and alloys structurally stable at increased temperatures and are less suitable for describing these processes in the heat resistant aging alloys based on nickel, working under conditions of vibrations, especially in the temperature range of their aging intensified by vibrations and progressive with a decrease in the specific volume of the material. In our opinion the following equation of stress relaxation proposed by B. M. Rovinskiy [2, 3, 4] is more suitable for these purposes:

$$\sigma_\tau = \sigma_0 \exp[-k_1\tau]^p, \qquad (1)$$

which generalizes the known Maxwell equation when

$$\mu = \frac{E}{pk_1^p\tau^{p-1}}; \qquad (2)$$

although this expresses a more complex dependence of the material's viscosity factor μ as compared with Maxwell equation, but it describes the stress relaxation process more accurately for the heat resistant alloys tested by us, used for manufacturing fastening parts.

In equations (1) and (2), σ_0 and σ_τ are the primary stress and stress at the moment of time τ, respecively; p is the material's index of relaxational pliability; k_1^p is the coefficient characterizing the stress decrease in the initial period; E is the modulus of longitudinal elasticity of the material. Using the values of coefficients k_1^p and p it is possible to make a practical calculation both for the stress relaxation as well as for creep. The method for determining the coefficients taking into account the peculiarities of stress relaxation in heat resistant alloys under conditions of vibrations is described in work [5].

The condition of tightness for a bolted joint will be satisfied up to a certain time by the constancy in the dimensions of the flange and bolt (in the case of the absolutely rigid flanges when the tightness of the junction under the effect of the applied load is broken due to the relaxation of stresses in the bolt) or (in the case of pliable flanges) by the change in the dimensions within the limits corresponding to a tight union when as a result of the bolt creep under the effect of the applied load and increased temperature there will occur a "straightening" of the compressed flanges. In this case, even though the creep of the flanges and the bolt will be different, the total relative elongation (elastic and plastic) should be identical. Then from the condition of strain compatibility of the bolt and flanges we can write the condition which satisfies their tight mutual union:

$$\frac{1}{E_б}\frac{d\sigma_б}{d\tau} + \frac{\sigma_б}{\mu_б} + \frac{1}{E_\varphi}\frac{d\sigma_\varphi}{d\tau} + \frac{\sigma_\varphi}{\mu_\varphi} = 0 \qquad (3)$$

In this case, for the flange union it is valid to pose the requirements for constant ratio between the stresses in the bolt and flanges, i.e.,

$$\frac{\sigma_б}{\sigma_\varphi} = C_1 \qquad (4)$$

and constant ratio of their coefficients of viscosity

$$\frac{\mu_б}{\mu_\varphi} = C_2 . \qquad (5)$$

Then, after substituting (4) and (5) and also

$$\frac{1}{C_1} = \frac{1}{E_б} + \frac{1}{E_\varphi C_1} \qquad (6)$$

differential equation (3) it will assume the form:

$$\frac{1}{C_1}\cdot\frac{d\sigma_б}{d\tau} + \frac{\sigma_б}{\mu_б}\left(1 + \frac{C_2}{C_1}\right) = 0 . \qquad (7)$$

After integrating equation (7) within the limits from σ_0 to σ and from 0 to τ with the consideration of (2) for the bolt material and designating

$$\frac{1}{E_б}\left(1 + \frac{C_2}{C_1}\right) = C_2 \qquad (8)$$

we obtain the following relationship in the final form

$$\sigma_\tau = \sigma_0 \exp[-C_1 C_2 K_1^p \tau^p]. \qquad (9)$$

The introduced relationship (9) describes the general case of stress relaxation in the bolt taking into account the effect of elasticity and creep of the intermediate parts. For a more accurate calculation the material's viscosity factor of the intermediate parts should be determined by the values of parameters entering expression (2) which were obtained from the experimental curves on stress relaxation or creep during compression. However, due to the fact that there is a total absence of the former and scantiness of the latter in the literature, we can use the data on stress relaxation and creep during extension, which is valid for small deformations which do not exceed 1-2% [6]. The comparison of the curves of creep for alloy EI437B during compression, presented in work [7], with those for this alloy during extension speaks in favor of this assertion. A somewhat smaller deformation of stabilized creep during extension, as compared with the compression applicable to flanges (intermediate parts), yields the coefficient values obtained by formulas (2), (5), and (8) as a safety factor when calculating the end stresses.

Figure 1 shows the experimental curves on stress relaxation of steel EI481 in logarithmic coordinates $\lg L - \lg \tau$ $(L = \ln \frac{\sigma_\tau}{\sigma_0})$ with and without vibrations for three primary stresses. The stress relaxation characteristics found using these curves are tabulated in Table 1, while Fig. 2 shows their dependences on the primary stress. These dependences, with a certain degree of accuracy (however, satisfactory for engineering calculation requirements for threaded connections), are assumed to be linear and are described by empirical formulas which permits one to find coefficients p and K_1^p for any primary stress in the examined period.

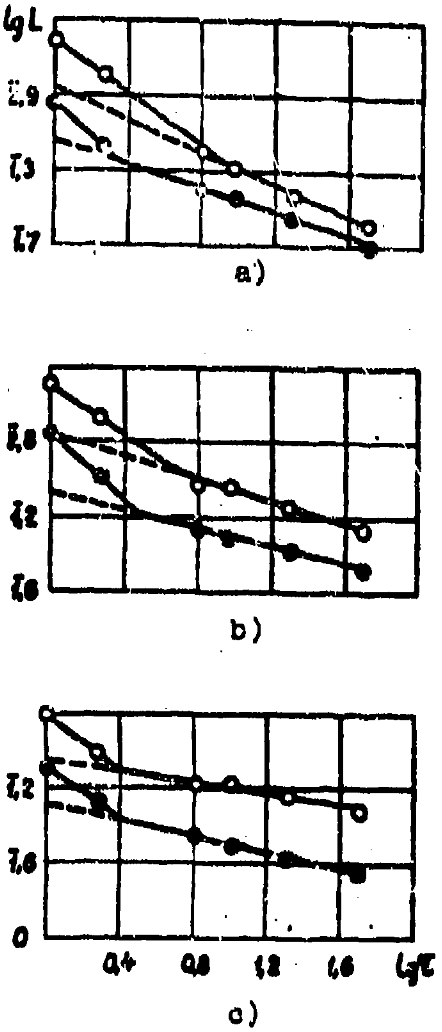

Fig. 1. Stress relaxation curves for steel EI481 with T = 650°C and primary stresses: a) σ_0 = = 30 kgf/mm^2; b) σ_0 = 20 kgf/mm^2; c) σ_0 = 10 kgf/mm^2;

● – ● – with vibrations
o – o – without vibrations

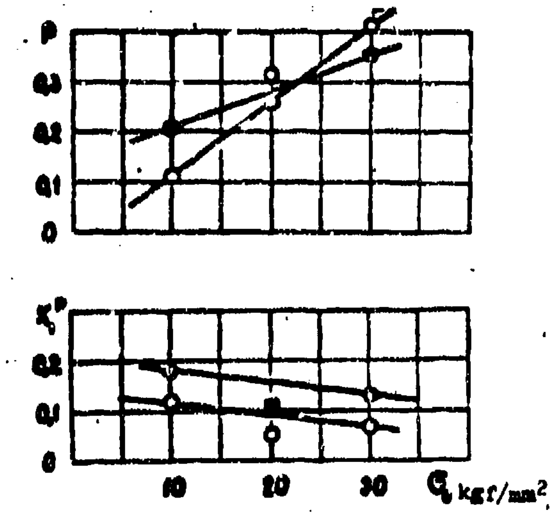

Fig. 2. Stress relaxation characteristics of steel EI481 as a function of the primary stress (T = 650 °C):

● – ● – with vibrations

o – o – without vibrations

Table 1.

σ_0, kgf/mm²	With vibrations		Without vibrations	
	p	K_1^p	p	K_1^p
30	0,353	0,192	0,410	0,074
20	0,260	0,112	0,310	0,056
10	0,212	0,156	0,106	0,120

Table 2.

Material	Temperature, in °C	Range of application according to the primary stresses σ_0, kgf/mm²	k_1^p	p
EI481	650	10-30	$-0,0024\ \sigma_0 +0,20^*$ $-0,0025\ \sigma_0 +0,14$	$0,007\ \sigma_0 +0,14^*$ $0,0153\ \sigma_0 -0,06$
	550	10-35	$-0,0128\ \sigma_0 +0,45^*$ $-0,0043\ \sigma_0 +0,17$	$0,0048\ \sigma_0 +0,05^*$ $0,0045\ \sigma_0 +0,05$
EI437B	700	25-45	$0,00035\ \sigma_0 +0,047^*$ $0,00054\ \sigma_0 +0,032$	$0,017\ \sigma_0 -0,36^*$ $0,019\ \sigma_0 -0,46$
EI598	800	10-30	$0,002\ \sigma_0 +0,1^*$ $0,09$	$0,0096\ \sigma_0 -0,1^*$ $0,018\ \sigma_0 -0,19$
	700	20-45	$0,00054\ \sigma_0\ ^*$ $0,00066\ \sigma_0 +0,004$	$0,029\ \sigma_0 -1,11^*$ $0,0036\ \sigma_0 +0,05$

Note: Empirical formulas for k_1^p and p with vibrations are indicated with the asterisk.

Table 2 shows the empirical formulas of the stress relaxation characteristics of certain alloys, used in the manufacture of fastening parts for gas turbine engines, at operating temperatures and stresses. The range of their use according to primary stresses is given for these formulas.

The selection of empircal formulas was accomplished by the graphic method. The difference in the scales of values plotted along the axes of ordinates and abscissae is taken into account in the angular coefficient of these formulas.

The presented formulas reflecting the experimental graphic dependence are obtained on the basis of the tests carried out on stress relaxation for the indicated alloys for a period of 60 - 100 h with and without vibrations; some of them were experimentally checked for the reliability of extrapolation up to 200 h. It turns out that the use of coefficients p and k_1^p found by these formulas yields a totally reliable calculation for 200 h, both in the tests with and without vibrations; the difference between the final stresses calculated by formula (9) for the case of rigid flanges and those obtained by the experiment for 200 h did not exceed 10-15%; moreover, calculation by the formula gave a stress value to within the safety factor. There is basis to assume that extrapolation to even longer time is possible. However, in the majority of cases it is precisely during this period that the first, unstabilized, most intense with respect to the decrease in stress, section is totally completed in the relaxation curve of heat-resistant alloys. With vibrations this section is completed even faster.

Tests on the indicated alloys with vibrations were carried out at frequencies of 310, 470, and 700 Hz and vibration amplitudes from 1 to 1.8 kgf/mm^2. The tests were done on cylindrical samples whose working section was 100 mm long and 10 mm in diameter, both with and without vibrations. The sample blanks were heat processed according to the series production technique.

BIBLIOGRAPHY

1. Б и р г е р И. А. Расчет резьбовых соединений. М., Оборонгиз, 1959.

2. Р о з е н с к и й Б. М. К вопросу о механизме релаксации напряжений в металлах. ИАН СССР, ОТН, 1954, № 2.

3. Р о з е н с к и й Б. М., Л и т ц а у В. Г. Некоторые итоги изучения релаксации напряжений в металлах и сплавах. В сб.: Релаксационные явления в металлах и сплавах. М., Металлургиздат, 1963.

4. В о р о т н и к о в Г. С., Р о з е н с к и й Б. М. Релаксация напряжений, ползучесть и одноосное растяжение; общность и особенности процессов. ЖПМТФ, 1966, № 6.

5. Б р а г и н Д. Я., В а с и л ь е в Г. В. О некоторых особенностях релаксации напряжений в жаропрочных сплавах в условиях вибраций. В сб.: Термопрочность материалов и конструктивных элементов, вып. 5. Киев, "Наукова думка", 1969.

6. С а з о н о в а Н. Д. Испытание жаропрочных материалов на ползучесть и длительную прочность. М., "Машиностроение", 1965.

7. Д у б и н и н В. П., Л у ж а н о в В. К., О с а с ю к В. В. Исследование ползучести сплава ЭИ437Б при сжатии. В сб.: Термопрочность материалов и конструктивных элементов, вып. 4. Киев, "Наукова думка", 1967.

Received
29 April 1971