NASA/TM—2003-212472

The Effect of Tungsten and Niobium on the Stress Relaxation Rates of Disk Alloy CH98

John Gayda
Glenn Research Center, Cleveland, Ohio

August 2003

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at 301–621–0134

- Telephone the NASA Access Help Desk at 301–621–0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076

NASA/TM—2003-212472

The Effect of Tungsten and Niobium on the Stress Relaxation Rates of Disk Alloy CH98

John Gayda
Glenn Research Center, Cleveland, Ohio

National Aeronautics and
Space Administration

Glenn Research Center

August 2003

Document History

This research was oringinally published internally as AST029 in October 1998.

Note that at the time of research, the NASA Lewis Research Center
was undergoing a name change to the
NASA John H. Glenn Research Center at Lewis Field.
Both names may appear in this report.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at http://gltrs.grc.nasa.gov

THE EFFECT OF TUNGSTEN AND NIOBIUM ADDITIONS ON THE STRESS RELAXATION RATES OF DISK ALLOY CH98

John Gayda
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

INTRODUCTION

Gas turbine engines for future subsonic transports will probably have higher pressure ratios which will require nickel-base superalloy disks with 1300°F to 1400°F temperature capability. Several advanced disk alloys are being developed to fill this need. One of these, CH98, is a promising candidate for gas turbine engines and is being studied in NASA's AST Program. For large disks, residual stresses generated during quenching from solution heat treatment are often reduced by a stabilization heat treatment, in which the disk is heated to 1500°F to 1600°F for several hours followed by a static air cool. The reduction in residual stress levels lessens distortion during machining of disks. However, previous work on CH98 has indicated that stabilization treatments decrease creep capability (Ref. 1). Additions of the refractory elements tungsten and niobium improve tensile and creep properties after stabilization, while maintaining good crack growth resistance at elevated temperatures (Ref. 2). As the additions of refractory elements increase creep capability, they might also effect stress relaxation rates and therefore the reduction in residual stress levels obtained for a given stabilization treatment. To answer this question, the stress relaxation rates of CH98 with and without tungsten and niobium additions are compared in this paper for temperatures and times generally employed in stabilization treatments on modern disk alloys.

MATERIAL & TEST PROCEDURES

CH98 is a nickel-base superalloy with a gamma prime content of about 60%. The compositions of experimental heats of CH98 and CH98 with tungsten and niobium additions, hereafter CH98+WNb, are shown in Table 1. As previously stated, this level of alloying addition for these two elements significantly improves creep and tensile capability. Both alloys were produced from argon atomized powder which was compacted at 2000°F followed by extrusion at 2000°F with an 8:1 reduction ratio. Specimen blanks were cut from the extrusions (longitudinal orientation) and HIPed at 2225°F/30KSI/3HR to achieve an ASTM 6-8 grain size without introducing excessive porosity. These blanks were then solution heat treated at 2200°F/1HR and air cooled producing an initial cooling rate of 200°F/MIN. Test specimens, with a cylindrical gage section, were machined from the as-solutioned blanks using a low stress grinding operation per the configuration shown in Figure 1.

Stress relaxation tests were run on the test specimens at 1400, 1500, 1550, and 1600°F using a 20KIP MTS servohydraulic test system equipped with an electric furnace and an axial extensometer. In order to achieve thermal equilibrium, each specimen was held at test temperature for 30 minutes (zero load) prior to the onset of testing. At this point, the

test rig was switched to strain control and the specimen was strained to 1% at 0.2%/SEC and held at this level while a strip chart recorder tracked the load response. An X-Y recorder was also employed to track the initial stress-strain response on loading.

RESULTS & DISCUSSION

Before presenting the stress relaxation results, a short summary of tensile and creep data for CH98 is warranted. Previous testing has shown tensile and creep properties of stabilized and aged CH98 is improved by the additions of tungsten and niobium (Ref. 2). At 1300°F, the yield strength and ultimate strength increase by about 10KSI without adversely affecting ductility as seen in Table 2. The time to 0.2% creep at 1300°F/90KSI, an important design consideration for disk operation, is reproduced in Figure 2. A significant difference in creep resistance is evident, with CH98+WNb showing about 400 hours to 0.2% creep compared to about 100 hours for CH98. The enhanced creep resistance of CH98 with tungsten and niobium additions for stabilized material is especially significant provided the level of stress relief is equivalent to that for CH98. The relative merit of a given stabilization treatment can be assessed by comparing the stress relaxation behavior of the two alloys.

As previously stated, relaxation specimens were first strained to 1%. This produced about 0.5% plastic strain in all tests. The initial stress-strain response of both alloys at 1400°F is presented in Figure 3. The higher strength level produced by tungsten and niobium additions is clearly evident. A comparison of each alloy's relaxation rate, at various temperatures, is shown in Figure 4. Examination of the data shows the relaxation rates of CH98 with and without tungsten and niobium additions are essentially equivalent. Further, it would appear that temperatures between 1500°F and 1600°F provided significant stress relief in both alloys. As a 1550°F/2HR stabilization heat treatment was employed on material used to generate mechanical property data in Ref. 2, duplicate stress relaxation runs were performed on both alloys at 1550°F. The relaxation data, shown in Figure 5, gives some feel for variability between runs and suggests that peak residual stress levels would be no greater than 50 or 60 KSI after stabilization, even for disks given a severe quench after solutioning. Increasing stabilization time beyond two hours and/or increasing stabilization temperature yields additional stress relief, but this benefit must be weighed against losses in tensile strength and creep resistance (Ref. 1).

CONCLUSIONS

Additions of tungsten and niobium increase the tensile strength and creep resistance of disk alloy CH98 and do not appear to alter the stress relaxation behavior after solution heat treatment. This finding suggests that the benefits of these alloying additions are not compromised by changes to residual stress relief provided by stabilization treatments at 1500°F to 1600°F. Further, stabilization heat treatments in this temperature range would appear to significantly decrease the residual stresses produced by quenching and therefore enhance the machinability of disks.

REFERENCES

1. Gayda, J., Gabb, T.P. and Ellis, D.L., The Effect of Stabilization Treatments on DiskAlloy CH98, AST023, NASA Report, March 1998.
2. Gayda, J., The Effect of Tungsten and Niobium Additions on Disk Alloy CH98, AST016, NASA Report, August 1997.

Table 1. Alloy composition in weight percent.

	Co	Cr	Al	Ti	Mo	Ta	W	Nb	C	B	Zr	Ni
CH98	17.9	11.6	3.90	4.00	2.90	2.90	0.00	0.00	.049	.030	.050	BAL
CH98+WNb	18.3	11.3	3.90	3.80	2.90	2.20	2.30	1.00	.050	.030	.045	BAL

Table 2. Alloy tensile properties at 1300°F.

	0.2% YIELD	ULTIMATE	ELONGATION	RED. OF AREA
CH98	123KSI	162KSI	27%	32%
CH98+WNb	136KSI	174KSI	32%	33%

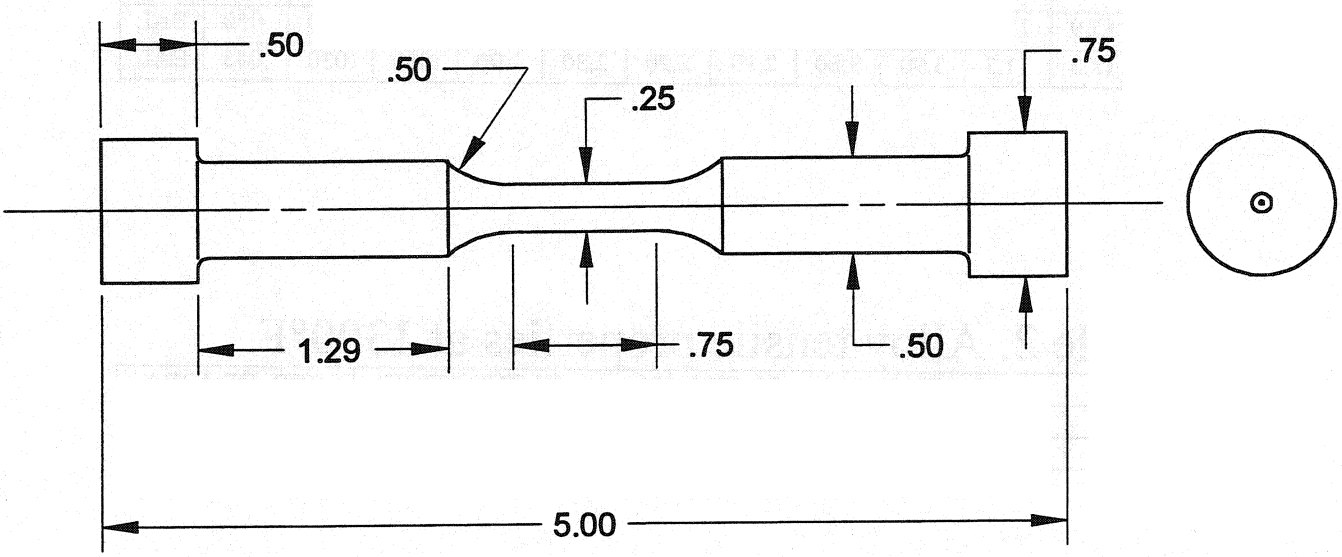

Figure 1. Design of test specimen. All dimensions in inches.

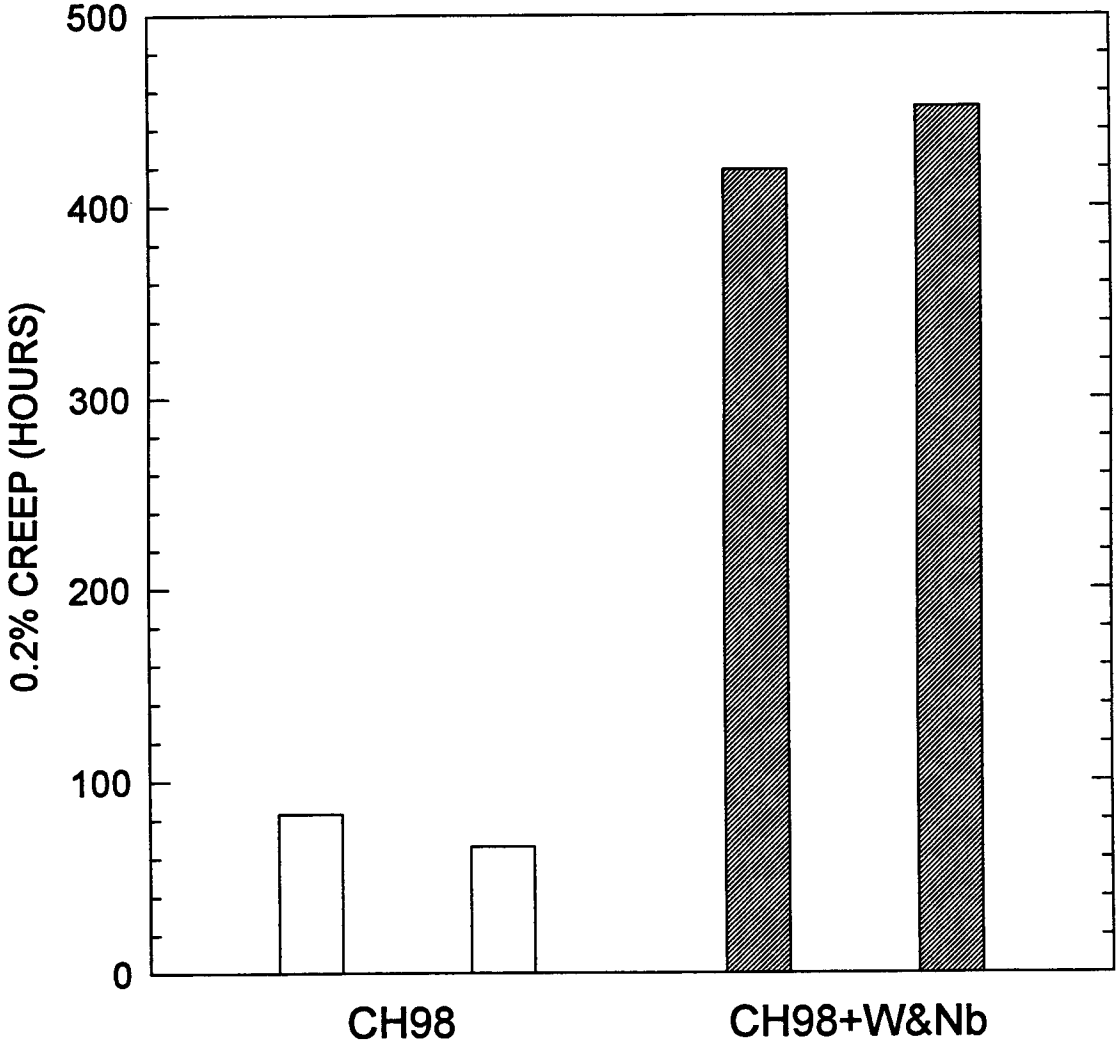

Figure 2. Comparison of 1300F/90KSI creep data for stabilized and aged CH98 with and without tungsten and niobium.

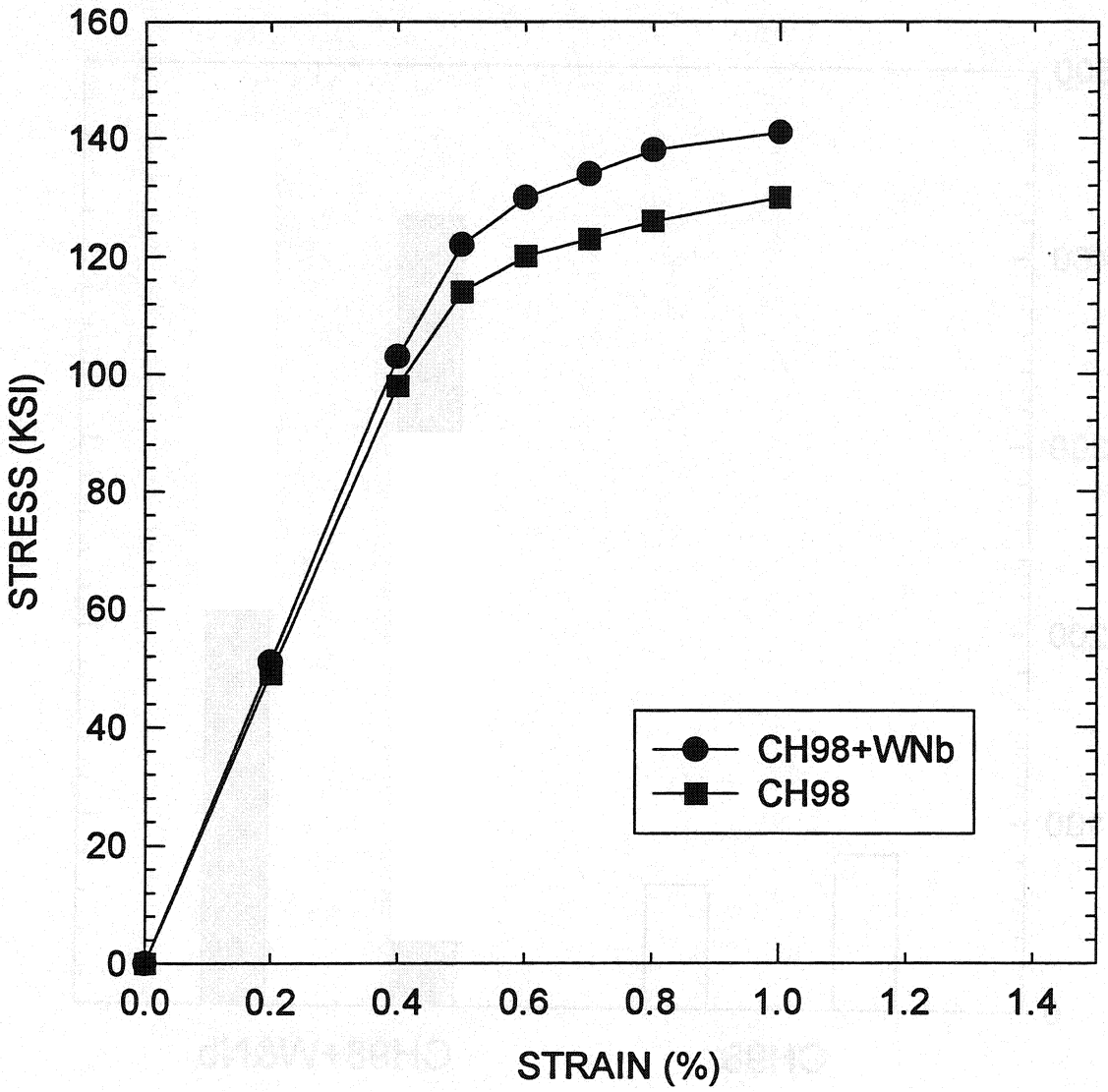

Figure 3. Inital stress-strain response at 1400F.

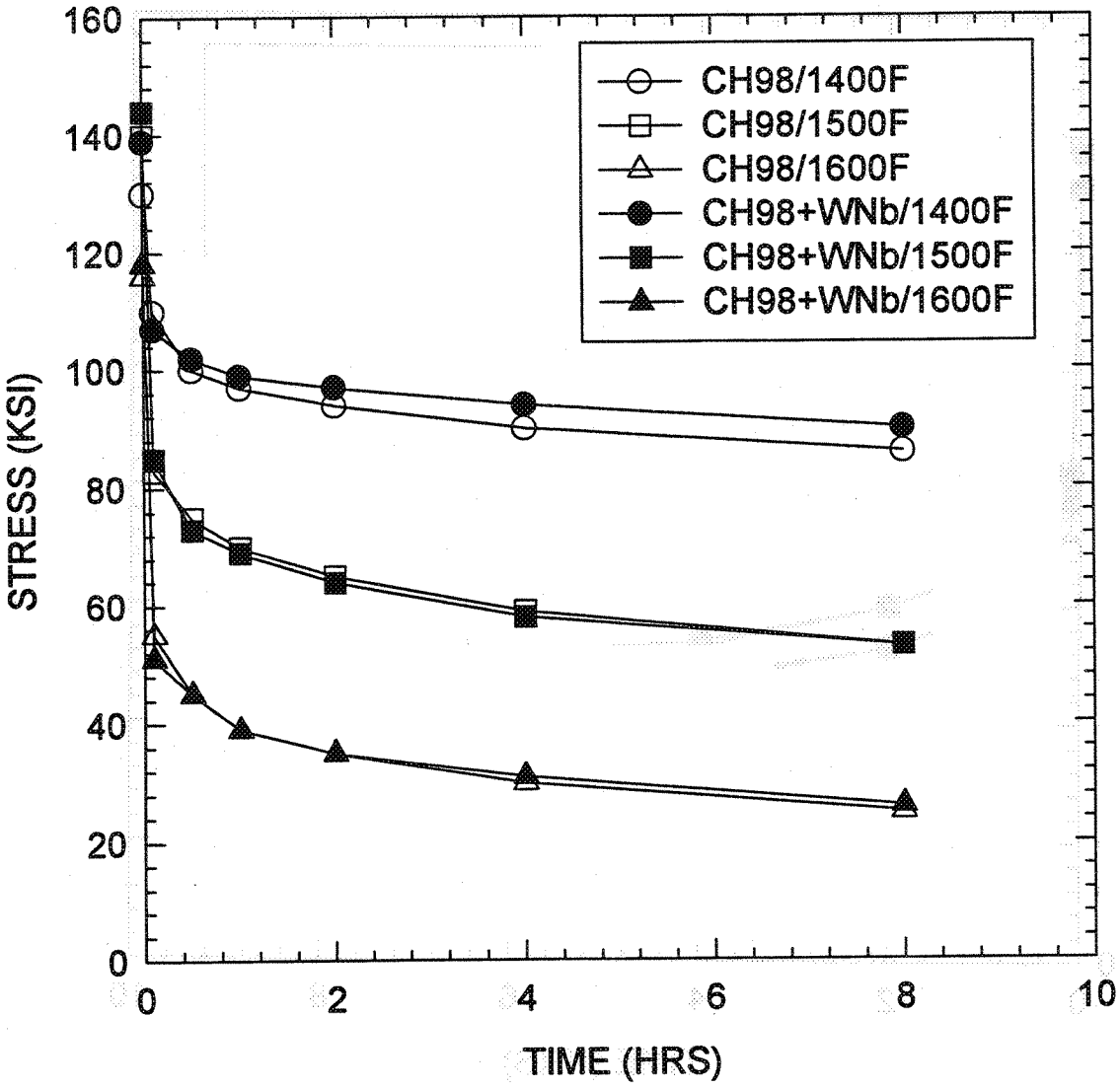

Figure 4. Stress relaxation data as a function of temperature.

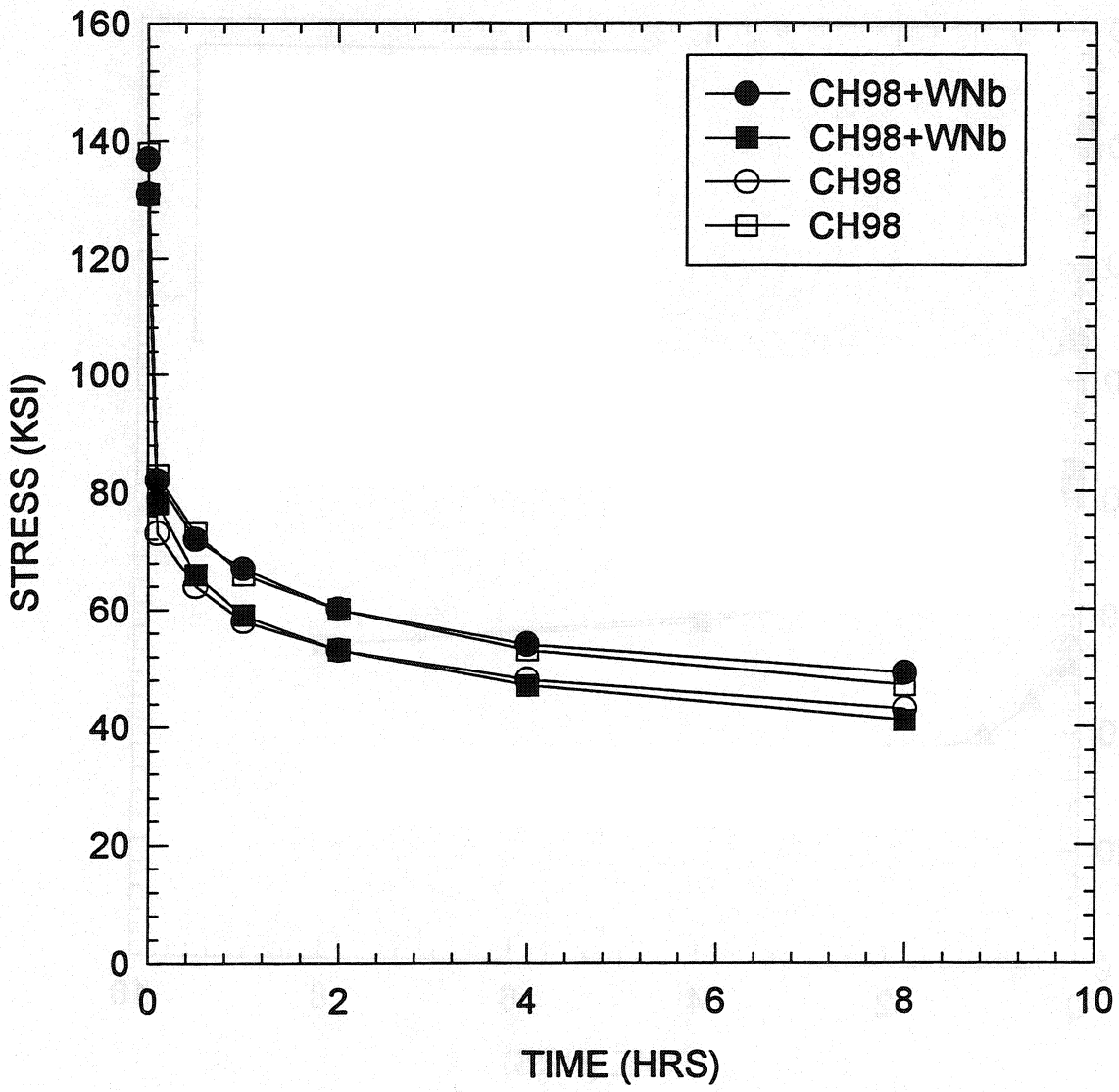

Figure 5. Stress relaxation data at 1550F.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 2003	Technical Memorandum

4. TITLE AND SUBTITLE

The Effect of Tungsten and Niobium on the Stress Relaxation Rates of Disk Alloy CH98

5. FUNDING NUMBERS

WU–538–12–40–00

6. AUTHOR(S)

John Gayda

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–14010

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM—2003-212472

11. SUPPLEMENTARY NOTES

This research was originally published internally as AST029 in October 1998. Responsible person, John Gayda, organization code 5120, 216–433–3273.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category: 26 Distribution: Nonstandard

Available electronically at http://gltrs.grc.nasa.gov

This publication is available from the NASA Center for AeroSpace Information, 301–621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Gas turbine engines for future subsonic transports will probably have higher pressure ratios which will require nickel-base superalloy disks with 1300 to 1400 °F temperature capability. Several advanced disk alloys are being developed to fill this need. One of these, CH98, is a promising candidate for gas turbine engines and is being studied in NASA's Advanced Subsonic Technology (AST) program. For large disks, residual stresses generated during quenching from solution heat treatment are often reduced by a stabilization heat treatment, in which the disk is heated to 1500 to 1600 °F for several hours followed by a static air cool. The reduction in residual stress levels lessens distortion during machining of disks. However, previous work on CH98 has indicated that stabilization treatments decrease creep capability. Additions of the refractory elements tungsten and niobium improve tensile and creep properties after stabilization, while maintaining good crack growth resistance at elevated temperatures. As the additions of refractory elements increase creep capability, they might also effect stress relaxation rates and therefore the reduction in residual stress levels obtained for a given stabilization treatment. To answer this question, the stress relaxation rates of CH98 with and without tungsten and niobium additions are compared in this paper for temperatures and times generally employed in stabilization treatments on modern disk alloys.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Superalloy	14
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	