ANL-AMMT-002

Report on Capability Expansion towards the Development of an Accelerated Creep Test Scheme at ANL

Nuclear Science and Engineering Division

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ABSTRACT

This report reports the expansion of creep testing capabilities at ANL through the installation of 9 new creep frames in the Nuclear Science and Engineering Division. Data from the commissioning tests is presented.

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1 Introduction

Advanced materials are a key element in the development of advanced nuclear energy systems. The DOE-NE's Advanced Materials and Manufacturing Technologies (AMMT) program aims to accelerate the development, qualification, demonstration and deployment of advanced materials and manufacturing technologies to enable reliable and economical nuclear energy. A current focus of the AMMT program is to establish a rapid qualification framework through Code-qualifying 316H stainless steel produced by laser powder bed fusion (LPBF) for high-temperature reactor structural applications. Creep-rupture data are the key time-dependent property data for inclusion of a new material in the ASME Boiler and Pressure Vessel Code, Section III, Division 5. To support the development of a 100,000-h code case for LPBF 316H SS and evaluation of creep behaviour of new materials, investment has been made to expand the creep testing capability at ANL. This report details the activities related to the purchase, installation and commissioning of the 9 lever arm creep frames in FY23.

2 Purchase and installation

Figure 2.1. ANL's creep testing lab.

The Lab G-169 in Building 212 in ANL is a high-bay area with the infrastructure in place to support 24 creep testers. The room was equipped with 14 Applied Test Systems (ATS) 2320-MM series and 1 ATS 2330-CCM series lever-arm load frames with the ATS WinCCS software in control for performing creep tests per ASTM standard. The frames were labelled from 1 to 15. In this project, we purchased 9 new 2320-MM series testers which were labelled from 16 to 24. The ATS WinCCS software is used to control them. The new systems were calibrated for the load ranges of 200 lbs to 10,000 lbs. All the systems are precision knife-edge lever arm testers with a lever arm ratio of 20:1. All are equipped with 3-zone air furnaces for testing up to 1100°C. Figure 2.1 shows a picture of the creep lab with the 24 frames. The temperature in the system is controlled by the ATS temperature control system which regulates the power applied to the resistive heating elements and maintain the desired temperature (setpoint) as measured by a control thermocouple. Type K thermocouples will be used to measure the specimen temperature.

3 Confirmative testing

After the installation, confirmative tests were performed on the 9 frames. ASTM standard-sized creep specimens were machined from an Alloy 709 plate (heat # 529900, plate # CG05455) in the solution annealed condition. The specimen dimensions are shown in Figure 3.1 (Natesan, et al., ANL-ART-151, 2018).

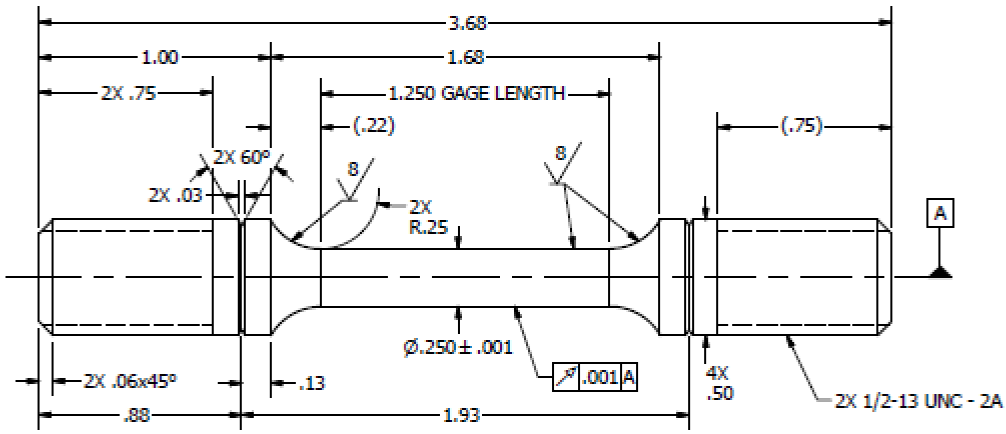

Figure 3.1. Schematic drawing of ASTM standard-sized creep specimens.

The creep tests under this project are conducted according to the ASTM Standard E139-11, "Standard Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests on Metallic Materials." Before test, samples were measured, mounted on individual rigs with LVDTs retrieved to zero position, had thermocouples spot-welded, and loaded to the frames. To initiate a test, the required dead weight was first calculated based on the sample geometry and placed on the pan. Then the furnace was heated up to the set temperature and soaked for one hour. The load was then applied in a step manner and fully loaded in about 2 to 5 minutes. A load cell was placed directly above the dead weight to measure the load applied on the sample at each step.

The test condition was 725°C, 140 MPa for all. Figure 3.2 shows a picture of ruptured specimens and Figure 3.3 shows the creep curves. During the initial loading, frames 16, 17, 20, 21, 24 were successfully loaded within hours. Frames 18, 19, 22 and 23 were having furnace or mechanical issues, which were resolved within days. However, the samples in frames 18, 19, 22 and 23 experienced much longer aging at 725°C prior to the loading than those in the other frames, so likely the microstructures of those samples evolved (e.g., extensive precipitation occurred) that resulted in slightly shorter creep rupture lives. The star symbols at the curve ends are the total elongations measured by putting the ruptured pieces back together. The values agree very well with the creep elongations measured by the LVDTs. The galling happened to the top threads in sample A709-455-SA-18 is likely due to insufficient graphite anti-seize spray being applied to the material prior to the sample installation.

The successful completion of the confirmative tests concluded that the 9 new testers were in good working status.

Figure 3.2. A picture of the ruptured specimens from the confirmative tests on the 9 new frames. The labels are the last numbers in the sample ID string.

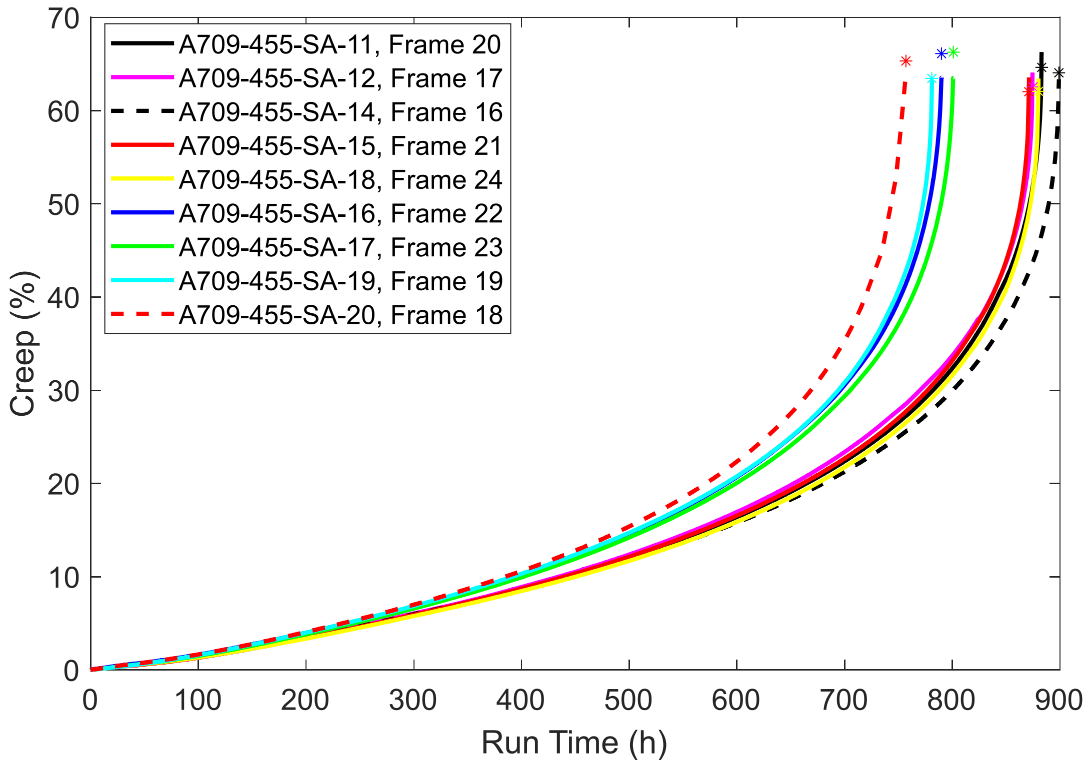

Figure 3.3. Creep rupture curves from the confirmative tests. The star symbols at the curve ends are the total elongations measured by putting the ruptured pieces back together.

4 Conclusions

This report summarizes the activities related to the commissioning of the 9 lever-arm creep frames purchased in FY 23 under the AMMT program. Through confirmative testing, it is demonstrated that all the frames are in good working status.

Acknowledgements

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[1] Natesan, K., X. Zhang, and M. Li, Argonne National Laboratory Report, ANL-ART-151, August 2018.

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