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# Tensile Strength of Light Metallic Materials for SST Structures at Elevated Temperatures and After Thermal Aging

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**Key Words:** Light metallic materials, Supersonic transport, Tensile strength, Elevated temperature, Thermal aging.

## 1. Introduction

The Concorde, a supersonic transport developed by the collaboration of France and the United Kingdom, commenced commercial flight in January, 1976, and has continued in service for approximately 20 years. Various kinds of sciences and technologies surrounding aircraft and aircraft industries have made great progress since the development of this aircraft. Moreover, the demand for aerial-transport has become much greater than in the days of the Concorde development. Furthermore, since the Concorde is expected to be retired from commercial flight in approximately ten years, world-wide interest in developing a Concorde successor has grown.

To participate in the future international development of the next generation supersonic transport (SST), aeronautical industries in our country, with the Society of Japanese Aerospace Companies (SJAC) and the Japan Aircraft Corporation (JADC) as leading organizations, are undertaking various kinds of surveys and investigations. In such an environment this study is performed jointly with the National Aerospace Laboratory, Kawasaki Heavy Industries, Fuji Heavy Industries, and Mitsubishi Heavy Industries.

SST's are subjected to high temperatures over a long period of time through aerodynamic heating. Accordingly, it is a fundamental problem to evaluate the effect of thermal aging on the strength of SST structural materials. On this account, candidate materials should be actually exposed to long-term high temperatures and the loss of strength should be investigated.

This study investigates the strength of six kinds of candidate metallic materials for SST structures at room and elevated temperatures before and after thermal aging. The results obtained are presented and discussed. Moreover, the possibility of accelerated environmental-simulation tests to evaluate the effect of thermal aging in a shorter time is discussed. There are no published research reports which systematically clarify the strength deterioration of the relatively new light metallic materials and thermal aging conditions tested in this paper.

## 2. Materials and Test Procedure

### 2.1 Materials

The materials tested are the following six kinds of light metallic materials.

(1) 2618-T61 aluminum alloy: an aluminum alloy for high temperature use, identical to RR.58 or AU2GN used in the Concorde and called a Concorde material CM.001[1], is the base line material of this study.

(2) 2519-T87 aluminum alloy.
(3) 2124MMC-T4: a particulate metal matrix composite material, $S_iC$ particle reinforcement (17% wt.).
(4) 6013-T6 aluminum alloy.
(5) 7150-T77 aluminum alloy.
(6) AL-905XL: an ODS (Oxide-Dispersed Strengthening) alloy produced by a mechanical alloying method. An aluminum base material including $M_g$ and $L_i$, aimed at increasing rigidity and strength and lowering density.

**2.2 Test Procedure**

*2.2.1 Aging Temperatures and Time, and Test Temperatures for Static Strength*

120°C and 180°C were selected as the aging temperatures. This range roughly corresponds to that of Mach number 2.2-2.5. Two thermal aging times were selected, 5,000 and 10,000 hours. Room temperature (RT: 23°C), 120°C, and 180°C were selected as the temperatures used for tensile tests before and after thermal aging.

*2.2.2 Test approach*

Specimen configuration follows the JIS-13B form. Thermal aging was conducted by exposing test pieces in two air circulating ovens maintaining temperatures of 120 °C and 180 °C. Several times during aging these ovens experienced power suspensions. However, the effect of these breakdowns was ignored in this study. The number of test results are normally five in each case, though there are a few cases consisting of four test results for reasons of test pieces or tests.

**3. Test Results and Discussion**

Figure 1 indicates the relationship between tensile strength (average value) and test temperature as a parameter of thermal aging condition. This figure was transformed into the relationship between tensile strength and aging time and shown in Fig. 2.

Contents deduced from these figures and their evaluation are as follows:

(1) The tendencies of strength change indicated in 2618-T61, 2519-T87, and 6013-T6 are similar. In other words, there is practically no strength degradation with 120°C aging, though a trivial degradation for 2519-T87 is found. With 180°C aging, tensile strength deteriorated enormously in the first 5,000 hours and dropped slightly during the interval of 5,000 to 10,000 hours. The strength drop is almost saturated in the first 5,000 hours. Furthermore, the tensile strengths of 2618-T61 and 2519-T87 are close to each other. The tensile strength of 6013-T6 is comparatively lower than these values. If the three materials are arranged in favorable order, this order is 2618-T61, 2519-T87, and 6013-T6.

(2) The tendency of strength deterioration in 2124MMC-T4 is similar to that of 7150-T77. Their strength at room temperature is high and shows a relatively large drop at elevated temperature. The strength reduction through thermal aging also appeared even at 120°C. With 180°C aging the strength reduction nearly saturates in 5,000 hours.

(3) In case of AL-905XL, though the strength at room temperature is very high, it becomes lower at the higher level of test temperature. The effect of 120°C aging on the strength is very small. After

180°C aging the strength at room temperature deteriorates slightly; however, the strength reduction is very small at 180°C. Generally the aging effect on the tensile strength of this material is very small.

(4) The difference in strength after thermal aging of 5,000 and 10,000 hours is small for all six materials. The materials of which aging effect is large at 120°C or 180°C show the aging effect even after 5000 hours and this effect is confirmed by the test results at room temperature after thermal aging.

(5) If the most relevant material is selected for use at less than 120°C, 2618-T61 or the Concorde material CM.001 is still the best among the six materials tested in this study.

(6) Judging from the test results for 2124MMC-T4 and 7150-T77, it is apparently impossible to predict the residual strength after thermal aging only through tensile tests at elevated temperatures without any thermal aging.

(7) Figure 2 indicates that the difference between the strengths at room temperature and aging temperature is very close in every aging case. This is shown by the difference between a broken line and a solid line in this figure. However, with AL-905XL and 7150-T77 the difference between the strengths of non-aged materials at room temperature and 180°C is slightly larger than the value estimated by this principle.

(8) From the results described above, if it can be assumed that the aging effect at 120°C or 180°C on tensile strength almost saturates between 5,000 and 10,000 hours, the strength after any aging longer than 10,000 hours will be at least higher than that predicted by a linear extension line passing through two values of strength at 5,000 and 10,000 hours. This fact provides a possibility of developing a method for accelerated environmental-simulation tests. However, for 2124MMC-T4 and 7150-T77 at 120°C aging it is difficult to consider that the strength reaches saturation by 10,000 hours. Actual aging time of up to about 20,000 hours is thought necessary, which is as long as that for the Concorde material CM.001[1)]

## 4. Concluding Remarks

(1) For application to the SST structures, no other material is found to be superior to the base line material 2618-T61, which is identical to the Concorde material CM.001.
(2) On the basis of the test results of tensile strength vs. aging time, there is a possibility of developing a method for accelerated environmental-simulation tests.

**Reference**

1) N.F. Harpur. "Structural Development of the Concorde," Aircraft Engineering, March 1968, pp. 18-30.

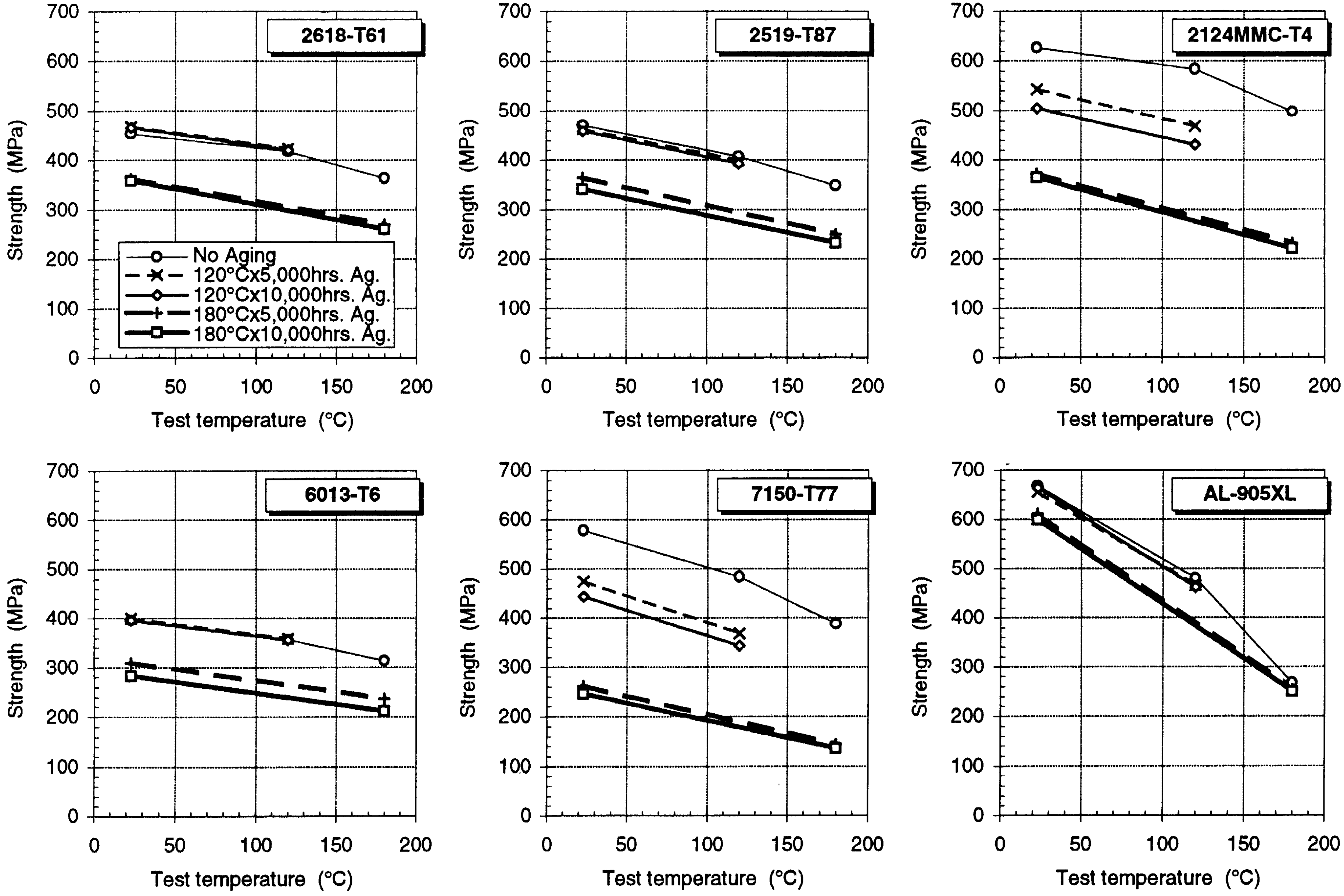


Figure 1 Averaged Tensile Strength versus Test Temperature for Six Kinds of Metallic Materials

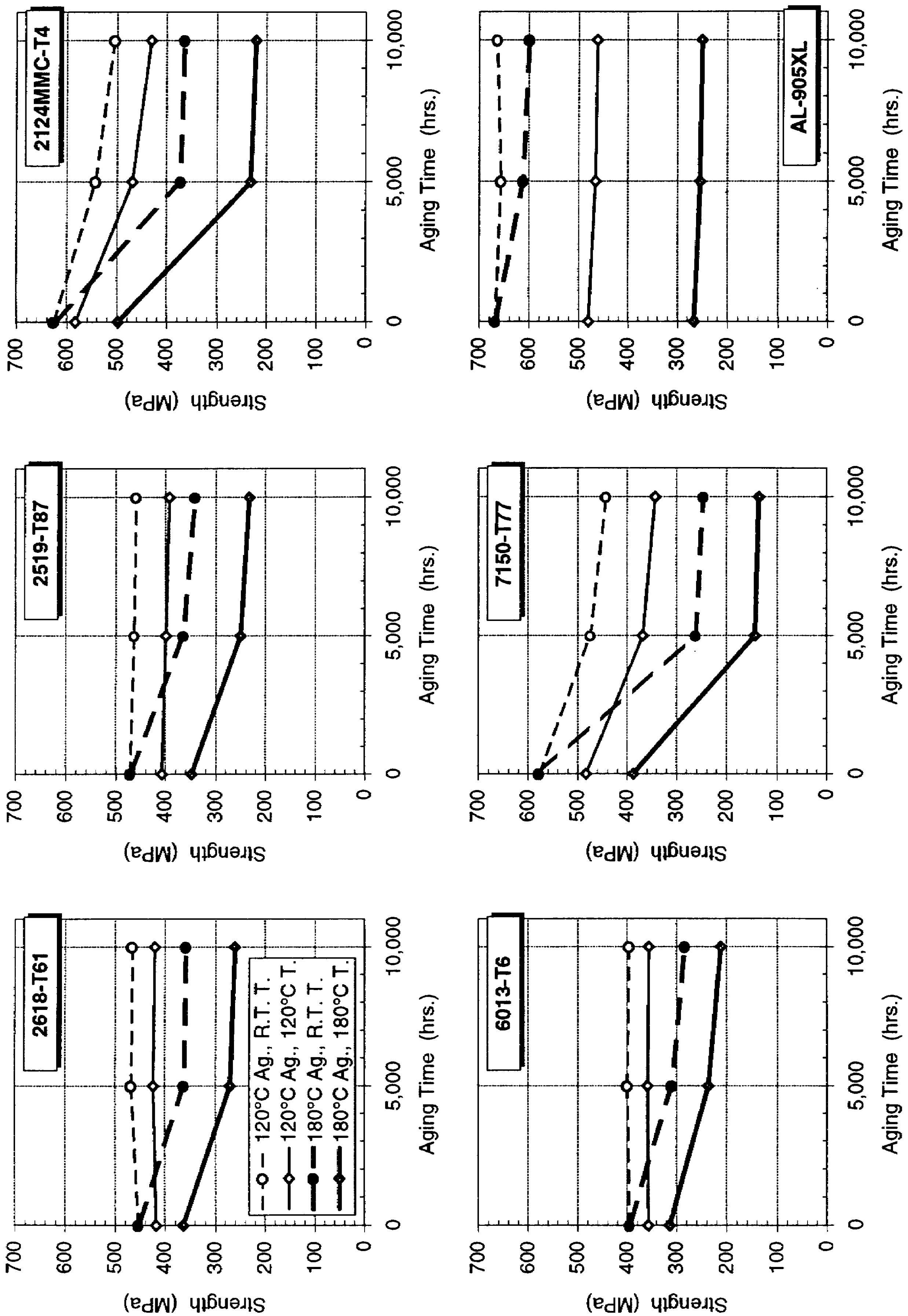


Figure 2 Averaged Tensile Strength versus Thermal-aging Time for Six Kinds of Metallic Materials