Coarse- and fine-grained 2024 and 7075 alloy sheets were tensile tested at strain rates ranging from $10^{-3}$ to $10^2$/s. Ultimate tensile strengths decreased up to $10^{-1}$/s and increased at higher strain rates. Total elongations at failure showed the same behavior with uniform and localized components showing similar dependencies on strain rate. The initial ductility decrease at low strain rates is attributed to thermal gradients associated with a transition from isothermal to adiabatic conditions. At strain rates above $10^{-1}$/s, ductility increases as strain rate hardening effects become dominant. Although the fine-grained materials had higher elongations than their coarse-grained counterparts, both variants responded similarly to changes in strain rate. The only difference was a tendency for off-center failures in coarse-grained specimens tested at the slower strain rates.

Studies on other materials, however, have shown a decrease in elongation with increasing strain rate (Ref 5-7), whereby plastic adiabaticity results in thermal gradients, in which strain and strain-rate hardening compete with thermal softening. These thermal effects appear particularly operative in the postuniform deformation regime (Ref 7-8), i.e., the stabilizing influence of rate sensitivity is mitigated by temperature gradients in the diffuse neck region. Finally, at strain rates above about $10^3$/s, inertial factors become significant (Ref 9-11), which generally have a strong positive effect on ductility. Within a certain range of “dynamic” strain rates ($10^1$ to $10^2$/s), a ductility minimum may be expected (Ref 10).

Although the tensile properties of a number of aluminum alloys have been examined as a function of strain rate (Ref 2-4, 9), no studies have been conducted on aircraft AA2024 and AA7075 sheet products, which are commonly formed in the annealed (O temper) condition and subsequently heat treated to the T4 and T6 tempers. We present here such data for these materials over the nominal strain rate range of $10^{-3}$ to $10^3$/s. Since the alloys are supplied in relatively coarse-grained (batch annealed) and fine-grained (continuously annealed) structures, both conditions were evaluated.

2. Experimental

Tensile specimens with a 50-mm gage length and a 12.5-mm width (ASTM E8) were machined in the transverse direction from 1.6-mm-thick production sheets of the nominal compositions shown in Table 1. A Universal Instron (Instron Corporatron, Canton, MA) testing machine was used for tests at cross head speeds of 2.5,
25, 250, and 500 mm/min (initial strain rates of $8.33 \times 10^{-4}$, $8.33 \times 10^{-3}$, $8.33 \times 10^{-2}$, an $1.67 \times 10^{-1}$/s). Digital data acquisition was achieved using Instron DSA Series IX software (Instron Corporation Canton, MA). Displacements and elongations were obtained from an extensometer attached to the specimens. "Machine" elongations were also checked against manual measurements on the broken specimens. MTS Systems Corporation (Eden Prairie, MN) servohydraulic machines were used for the higher strain rate tests. At a ram speed of 6850 mm/min (2.25/s), a standard ??? (MTS) load cell and hydraulic grips were used, with light oscillograph recordings of analog load-displacement outputs. Tests at the highest strain rate (85/s) utilized special low-mass grips and a slack drawbar to minimize harmonic effects. The data were captured with a Nicolette digital storage scope (company). Displacements were obtained with internal linear variable differential transducers (LVDTs) on the MTS machines, but elongations were measured manually on the broken specimens. For another measure of ductility, reductions of area were determined 12.5 mm from the fractures. Similarly $R$ values (ratio of thickness to width strains) were measured at this location. All tests were conducted in still air at ambient temperature (21 to 24 °C).

3. Results

True stress-true strain curves covering the complete range of strain rates are shown in Fig. 1. There appeared to be little effect of strain rate on the stress-strain behavior in the low stress region. Ultimate stresses and elongations at maximum load and at failure, however, did depend on strain rate. Figure 2 shows that the ultimate strength decreased up to about 0.1/s and then increased at higher strain rates, with no apparent influence of grain structure in either alloy. Yield strengths (0.2% proof stress) showed the reverse trend, increasing 15 to 20% up to 0.2/s. We were unable to make accurate assessments of yield strength at the higher strain rates because of noise in the data acquisition systems. As would be expected from the similarity of the stress-strain curves, work hardening rates were not significantly affected by strain rate over the $10^{-3}$ to $10^{-1}$/s range. For 2024, average $n$ values were 0.207 (fine grain) and 0.204 (coarse grain); the corresponding values for 7075 were 0.176 and 0.164.

The effect of strain rate on total elongation is shown in Fig. 3. As with ultimate strength, elongation decreased up to about 0.2/s and then increased fairly dramatically. Note that these ductility variations are not related to differences in data retrieval systems. Elongations at the two highest strain rates were measured manually, and values at the low strain rates were checked identically. Elongations in fine-grained 2024 alloy were consistently higher than those in the coarse-grained materials, which was expected (Ref 12). The fine-grained version of 7075 was also more ductile at the higher strain rates. On a nor-