2.13 INFLUENCE OF STRAIN RATE ON YIELD STRENGTH

It is well known that the mechanical properties of sheet steels are affected by strain rate. The dynamic yield strength is used in Section 3.3.4 for predicting dent resistance, and is also necessary for crash energy management calculations.

Five selected sheet steels (25AK, 35XF, 50SK, 50XF and 100XF) were tested under tension and compression at various strain rates from 0.0001 to 1.0 per second in a research program conducted at the University of Missouri-Rolla sponsored by the American Iron and Steel Institute (References 1,2,3,4,5). Complete engineering stress-strain curves are shown in Figure 2.13-1 for a gradual yielding steel with a nominal yield strength of 35 ksi tested in longitudinal tension at strain rates of 0.0001, 0.01 and 1.0 in./in./sec.

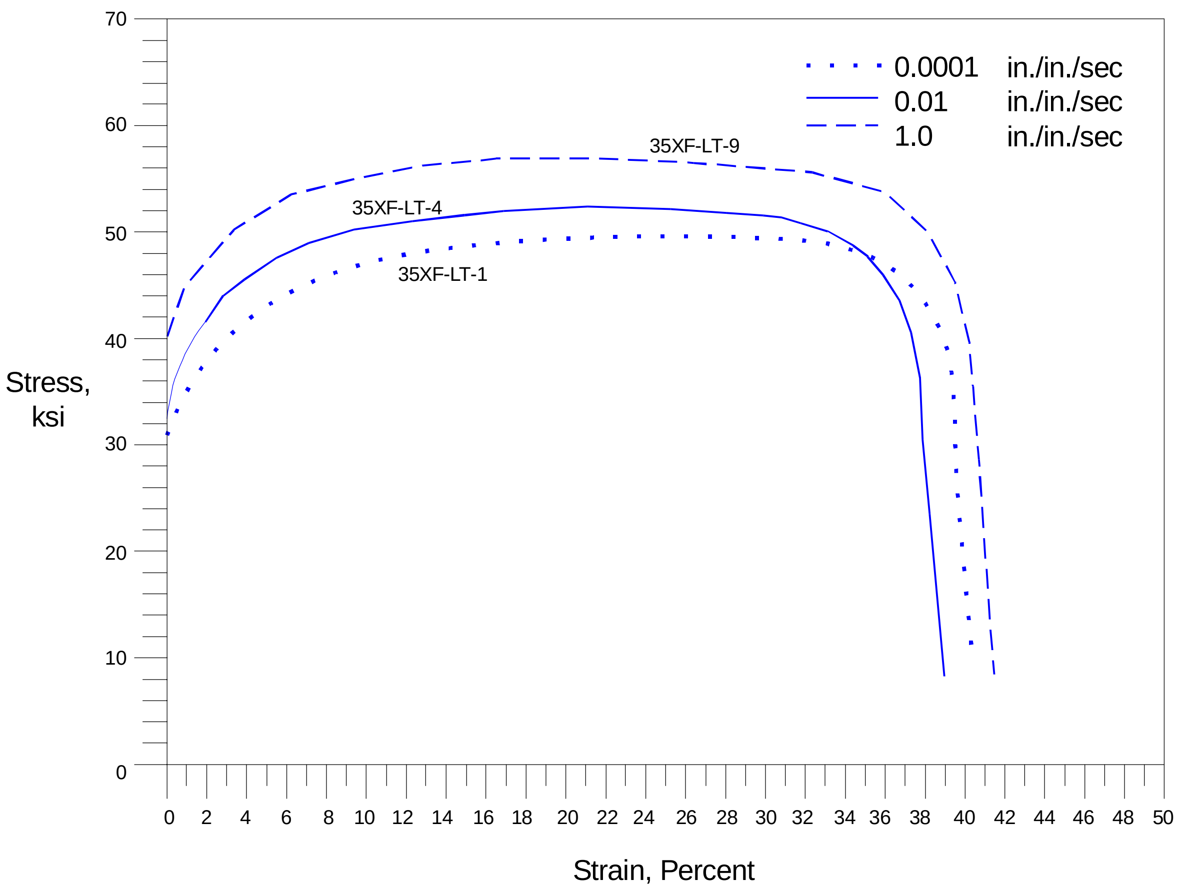

Figure 2.13-1 Tensile stress-strain curves for 35XF-LT steel under different strain rates, virgin materials

Figure 2.13-2 shows tensile stress-strain curves for a steel with a yield plateau and nominal yield strength of 50 ksi. Many other stress-strain curves are given in the reports cited. Based on 250 coupon tests and some extrapolation, the following generalized equations were developed to predict the tensile and compressive yield strengths for strain rates ranging from 0.0001 to 100 per second.

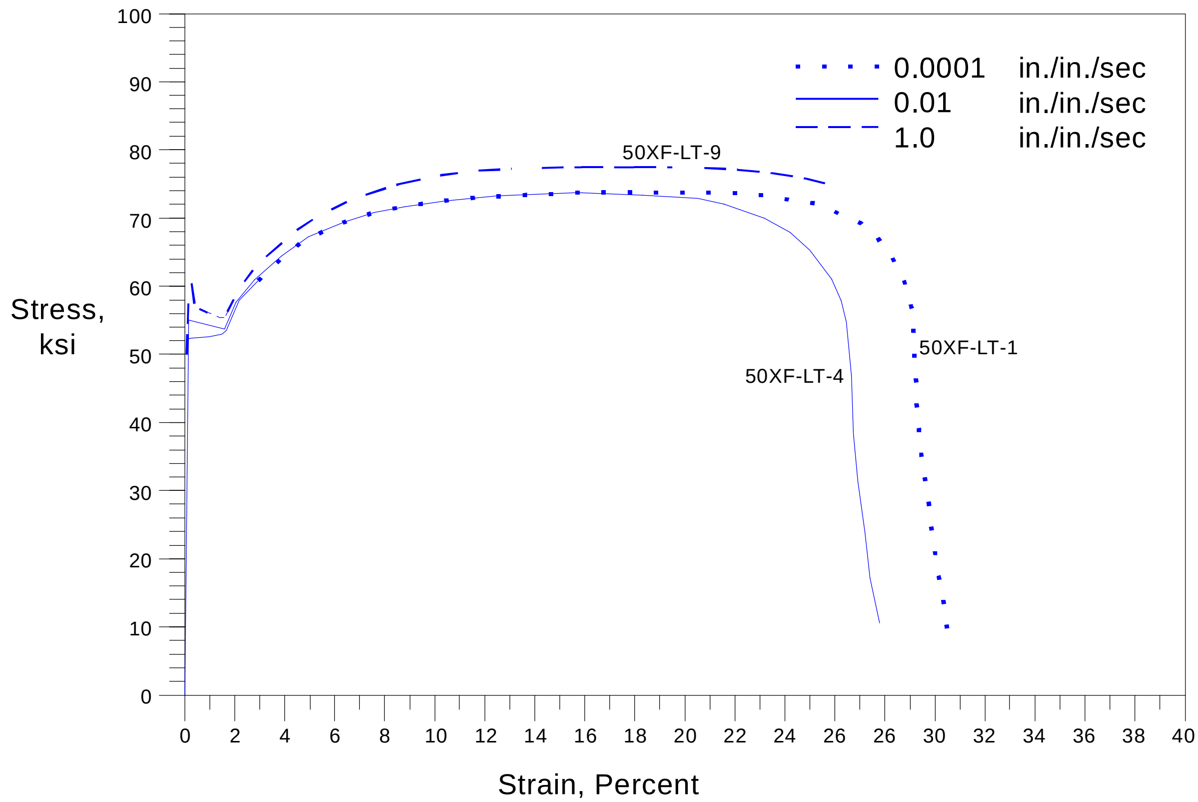

Figure 2.13-2 Tensile stress-strain curves for 50XF-LT steel under different strain rates, virgin materials

$$\left(F_y\right)_{pred} = \left(A\,e^{\left(B/F_y\right)} + 1\right)\left(F_y\right)_s$$ **Equation 2.13-1**

where

$$A = a_1 + b_1 \log(\dot{\varepsilon}) + c_1 \log(\dot{\varepsilon})^2$$ **Equation 2.13-2**

$$B = a_2 + b_2 \log(\dot{\varepsilon}) + c_2 \log(\dot{\varepsilon})^2$$ **Equation 2.13-3**

for tensile yield stress:

$a_{1t} = 0.023$ $a_{2t} = 77.7$
$b_{1t} = 0.009$ $b_{2t} = 0.069$
$c_{1t} = 0.001$ $c_{2t} = -0.595$

for compressive yield stress:

$a_{1c} = 0.033$ $a_{2c} = 64.9$
$b_{1c} = 0.004$ $b_{2c} = 11.1$
$c_{1c} = 0.000$ $c_{2c} = -1.87$

where $\left(F_y\right)_{pred}$ = predicted dynamic yield strength
$(F_y)_s$ = static yield strength
$\dot{\varepsilon}$ = strain rate

Figure 2.13-3 and Figure 2.13-4 are graphic representations of the previous equations.

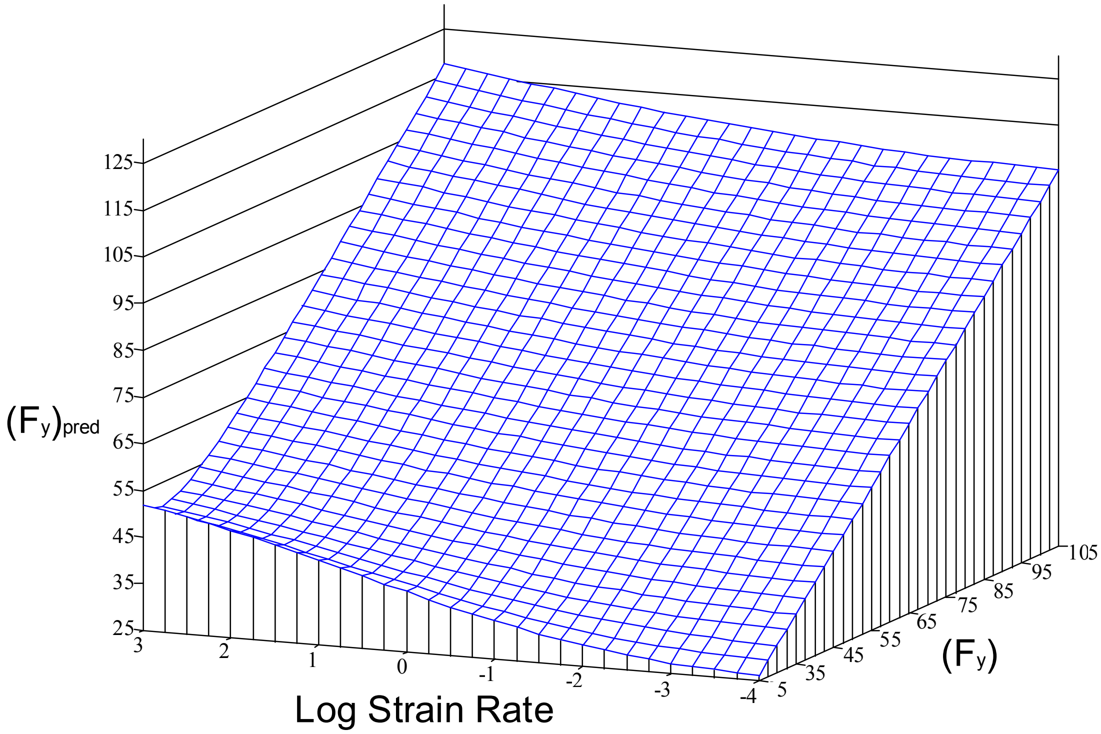

Figure 2.13-3 Generalized prediction of dynamic tensile yield stress

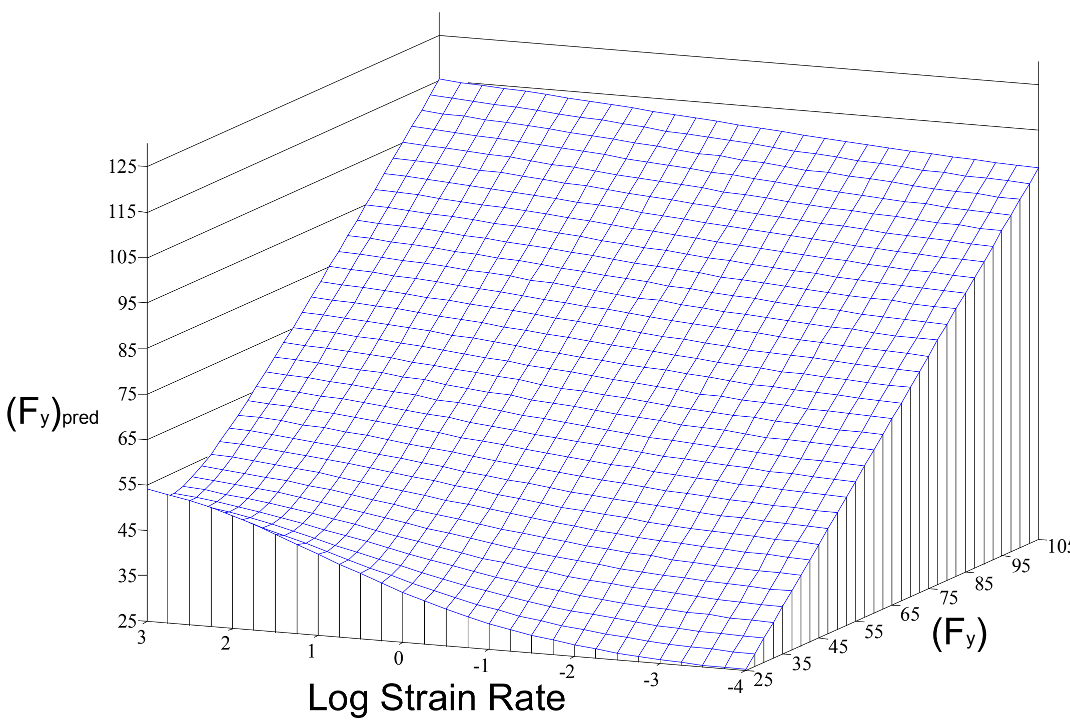

Figure 2.13-4 Generalized prediction of dynamic compressive yield stress

More recently, the Auto/Steel Partnership sponsored a strain rate characterization project at Los Alamos National Laboratory using strain rates up to 65000/second and obtaining the true stress-strain curves. Example of such curves for a DQSK and an HSLA material are shown Figure 2.13-5. Many other curves are given in Reference 6.

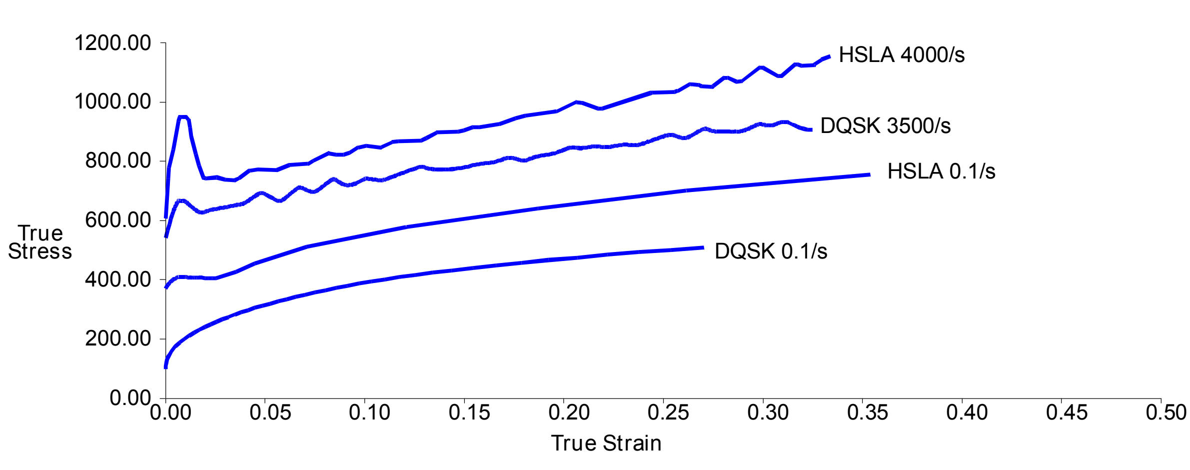

Figure 2.13-5 True Stress/Strain Curves for 0.05%C Mild Steel and 50 ksi HSLA Steel at 25°C

REFERENCES FOR SECTION 2.13

1. Kassar, M. and Yu, W.W., Design of Automotive Structural Components Using High Strength Sheet Steels: Effect of Strain Rate on Material Properties of Sheet Steels and Structural Strengths of Cold-Formed Steel Members, Fourteenth Progress Report, Civil Engineering Study 90-2, University of Missouri-Rolla, May 1990.

2. Kassar, M. and Yu, W.W., Effect of Strain Rate on Material Properties of Sheet Steels, ASCE, Journal of Structural Engineering, Vol. 118, No. 11, November, 1992.

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4. Pan, C.L., and Yu, W.W., Influence of Strain Rate on the Structural Strength of Cold-Formed Steel Automotive Components, Proceedings of Automotive Body Materials, International Body Engineering Conference, (M.Nassim Uddin, Ed.), September, 1993.

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6. Cady, C.M., Chen, S. R., Gray III, G.T., Lopez, M.F., Carpenter II, R.W., and Korzekwa, D., Dynamic Material Testing and Constitutive Modeling of Structural Sheet Steel for Automotive Applications, Final Progress Report, Los Alamos National Laboratory, August 1996.