Addendum to "A User-Material Subroutine Incorporating Single Crystal Plasticity in theABAQUS Finite Element Program", Huang, Y., Mech Report 178, Division of Engineering and Applied Sciences, Harvard University, 1991.

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November, 1997
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Reason for Modifications

This UMAT has been modified to keep track of the cumulative shear strain in each individual slip system. This information is needed to correct an error in the implementation of the Bassani and Wu hardening law. In order to keep track of the changes in the UMAT, any line of code which has been added or modified is preceded immediately by a line beginning CFIXA and succeeded by a line beginning CFIXB. Any comment line added or modified begins with CFIX.

The hardening law by Bassani and Wu was implemented incorrectly. This law is a function of both hyperbolic secant squared and hyperbolic tangent. However, the arguments of sech and tanh are related to the **total** slip on individual slip systems. Formerly, the UMAT implemented this hardening law by using the **current** slip on each slip system. Therein lay the problem since the UMAT does not restrict the current slip to be a positive value. When a slip with a negative sign was encountered, the term containing tanh led to a negative hardening rate (since tanh is an odd function). Since the sense of the slip is determined by the coordinate system, the results were sensitive to the choice of coordinate system.

The modifications also allow the loading to be non-monotonic. However, it is important to note that, with both the hardening laws implemented in this UMAT, a slip system does not weaken upon a load reversal (i.e. these hardening laws do not model the Bauschinger effect.)

Additional state variables were defined to keep track of the **total** slip on each individual slip system. The total slip is calculated by integrating up the absolute value of slip rates for each individual slip system. These "solution dependent variables" are available for post-processing in ABAQUS Post.

The only required change in the input file is that the parameter associated with the DEPVAR command must be altered. This is discussed in more detail in the following section. What follows is a list of the necessary changes in the manuscript and input file; the changes are italicized.

Modifications to Manuscript and Input File

Section 4.1, Page 12.

The name of the source code which includes the modifications discussed in this addendum is umatcryspl_mod.inp. The file can be obtained by writing to Professor James R. Rice, Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138 (e-mail: rice@esag.harvard.edu).

Section 4.2, Item (2).

(2) Following the card *DEPVAR the user must provide the number of solution dependent state variables. This number equals *ten* times the total number of independent slip systems NSLPTL plus five, i.e. *10**NSLPTL+5. As discussed in Section 2.3, the slip system ($-\mathbf{s}^{*(\alpha)},\mathbf{m}^{*(\alpha)}$) is not considered as independent of ($\mathbf{s}^{*(\alpha)},\mathbf{m}^{*(\alpha)}$) for a cubic crystal. There are *ten* solution dependent state variables in each slip system, namely the current strength $g^{(\alpha)}$, shear strain $\gamma^{(\alpha)}$, resolved shear stress $\tau^{(\alpha)}$, normal to slip plane $\mathbf{m}^{*(\alpha)}$, slip direction $\mathbf{s}^{*(\alpha)}$, *and the total cumulative shear strain* $\gamma tot^{(\alpha)}$ *on each individual slip system*. The total cumulative shear strain γ on all slip systems is also considered as a solution dependent state variable. For an FCC metal crystal the number of solution dependent state variables should be *125* (=*10**12+5).

Appendix B, Paragraph 1.

STATEV(1)	-	STATEV(NSLPTL)	: current strengths $g^{(\alpha)}$
STATEV(NSLPTL+1)	-	STATEV(2*NSLPTL):	shear strains $\gamma^{(\alpha)}$
STATEV(2*NSLPTL+1)	-	STATEV(3*NSLPTL):	resolved shear stresses $\tau^{(\alpha)}$
STATEV(3*NSLPTL+1)	-	STATEV(6*NSLPTL):	slip planes normals $\mathbf{m}^{*(\alpha)}$
STATEV(6*NSLPTL+1)	-	STATEV(9*NSLPTL):	slip directions $\mathbf{s}^{*(\alpha)}$
*STATEV(9*NSLPTL+1)*	-	*STATEV(10*NSLPTL):*	*total cumulative shear strain on each individual slip system* $\gamma_{tot}^{(\alpha)}$
STATEV(*10**NSLPTL+1)			: total cumulative shear γ

Appendix B, Paragraph 3.

SDV13,SDV14,SDV15,SDV16,SDV17,SDV18,SDV19,SDV20
SDV21,SDV22,SDV23,SDV24,SDV*121*

Appendix C, Page 2 of listing of umatcryspl.inp.

*DEPVAR
125

Appendix C, Page 24 of listing of umatcryspl.inp. (The italicized lines replace the non-italicized lines. ABAQUS no longer accepts parameters CYCLE, ROTTOL and PTOL.)

*STEP, INC=500,CYCLE=25,NLGEOM,ROTTOL=0.02
*STATIC, PTOL=0.2

**STEP, INC=500, NLGEOM*
**STATIC*