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Director of Research

PLASTICITY COMPUTATION IN HYDROCODES COMPARED WITH ANALYTICAL THEORY

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Associated analytical plasticity theory is reviewed and compared with the approach to plasticity used in hydrocodes such as Autodyn and Dyna. In general, the two methods are seen to be quite different, but for certain special cases they agree. It is shown that analytical Prandtl–Reuss plasticity is equivalent to the plasticity model in Autodyn if a Mises strength model is combined with a linear equation of state, while the Autodyn Mohr–Coulomb strength model is very different from the analytical Mohr–Coulomb plasticity model.

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PLASTICITY COMPUTATION IN HYDROCODES COMPARED WITH ANALYTICAL THEORY

1 INTRODUCTION

Plasticity is an important subject in penetration mechanics as well as other areas. There is, however, a great deal of confusion about how plasticity theory actually works, and especially on the relation between analytical plasticity theory and the methods for calculating plasticity in hydrocodes. To the best of our knowledge this has not been properly described in the literature.

In this document we make an attempt to clear up the confusion surrounding plasticity. We have tried to keep the report self–contained, but readers who would like a more comprehensive introduction to analytical plasticity are referred to Teland (1). Our notation is the same as in (1), i.e. with the pressure being negative under compression.

2 ANALYTICAL PLASTICITY

As is well known, we have the following constitutive equations in the elastic regime:

$$p = 3K\epsilon \tag{2.1}$$

$$s_{ij} = 2Ge_{ij} \tag{2.2}$$

These equations will not be discussed any further.

In the plastic regime, however, things are more complicated. There are different ways of representing plasticity, but here we will only look at socalled incremental theories. These theories all make use of a yield condition which is a rule for determining when plasticity occurs, and they have constitutive laws (flow rules) which determine how plastic flow takes place.

In general a yield condition is given on the following form:

$$f(\sigma_{ij}, \dot{\epsilon}_{ij}, T, ...) = k \tag{2.3}$$

We see that there is a loading function f, depending on various physical variables, which has to reach a specific limit k for plastic flow to set in. Equation (2.3) has an interesting geometrical interpretation as a yield surface in stress space. For a material to remain plastic, it follows that $df = 0$, i.e. the material remains on the yield surface and the points outside the surface can not be reached.

From (1) we know that there are two types of constitutive plastic laws, associated and non–associated flow rules. When an associated flow rule is used, the complete material behaviour is derived from the loading function f. However, in non–associated flow, the load-

ing function is only used to determine whether the material is elastic or plastic and the plastic constitutive laws are independent of it.

An associated flow rule is given on the following form:

$$d\epsilon_{ij}^{p} = f_{ij} d\lambda \tag{2.4}$$

where $f_{ij} = \dfrac{\partial f}{\partial \sigma_{ij}}$. Equation (2.4) can be geometrically interpreted as saying that the plastic strain increments are perpendicular to the yield surface, although they are not in the same space.

2.1 Prandtl–Reuss analytical plasticity theory

We will now look closely at one particular analytical plasticity theory, namely Prandtl–Reuss, which is based on associated flow. In this theory the yield condition is given by:

$$f = \sqrt{\frac{1}{2} s_{ij} s_{ij}} = k = \frac{Y}{\sqrt{3}} \tag{2.5}$$

where the constant k defining the yield surface is related to the yield limit Y in uniaxial stress as given above. As long as $f < k$, the material behaves elastically, but when Equation (2.5) is satisfied, the material starts behaving plastically.

During plasticity, the total strain tensor ϵ_{ij} is divided into an elastic and a plastic part. The problem now is to calculate the stress increments $d\sigma_{ij}$ as a function of the total strain increments $d\epsilon_{ij}^{p}$. This is done in the following way:

$$dp = 3K d\epsilon^{e} = 3K(d\epsilon - d\epsilon^{p}) \tag{2.6}$$

$$ds_{ij} = 2G de_{ij}^{e} = 2G\left(de_{ij} - de_{ij}^{p}\right) \tag{2.7}$$

If the total strain increments are known, we only need to calculate the plastic strain increments $d\epsilon_{ij}^{p}$. Using the associated flow rule of Equation (2.4), we have the condition of the plastic strain increments being perpendicular to the yield surface:

$$d\epsilon_{ij}^{p} = f_{ij} d\lambda = \frac{s_{ij}}{2k} d\lambda \tag{2.8}$$

Examining the diagonal components of Equation (2.8), we find:

$$d\epsilon_{ii}^{p} = 3 d\epsilon^{p} = f_{ii} d\lambda = \frac{s_{ii}}{2k} d\lambda = 0 \tag{2.9}$$

Thus, there is no plastic volume change, so all volume change is purely elastic, $d\epsilon = d\epsilon^{e}$. Equation (2.6) thus becomes:

$$dp = 3K d\epsilon \tag{2.10}$$

Using this information, the equation for the deviatoric plastic strain components may now be written as:

$$de^p_{ij} = d\epsilon^p_{ij} - \delta_{ij} d\epsilon^p = d\epsilon^p_{ij} = f_{ij} d\lambda = \frac{s_{ij}}{2k} d\lambda \tag{2.11}$$

On comparing with Equation (2.9), it becomes clear that things are more complicated for the deviatoric components.

Equation (2.11) gives us the direction of the deviatoric strain increments, but not the magnitude. Therefore we also need to calculate the parameter $d\lambda$. A first try may be to multiply Equation (2.11) by s_{ij} and sum, which gives us:

$$d\lambda = \frac{s_{ij} de^p_{ij}}{k} \tag{2.12}$$

However, the problem with this equation is that it depends on the plastic strain increments de^p_{ij}, which is exactly what we are trying to calculate!

Instead, we use the condition that the stress state remains on the yield surface, i.e. $df = 0$. From this it is possible to derive a general expression for $d\lambda$, see Equation (5.14) in Teland (1). In the Prandtl–Reuss case, this condition simplifies to the following expression:

$$d\lambda = \frac{s_{ij} d\epsilon_{ij}}{k} = \frac{s_{ij} de_{ij}}{k} \tag{2.13}$$

which is almost the same as Equation (2.12), except that the total strain increments de_{ij} (which are assumed to be known) are involved, instead of only the plastic part de^p_{ij}. Inserting into Equation (2.7) then gives us the final expression for the stress increments as a function of the current stresses and total strain increments:

$$ds_{ij} = 2G\left(de_{ij} - s_{ij} \frac{s_{pq} de_{pq}}{2k^2} \right) \tag{2.14}$$

Further, on comparing Equations (2.12) and (2.13) we find that:

$$s_{ij} de_{ij} = s_{ij} de^p_{ij} \tag{2.15}$$

which says that the total deviatoric work is equal to the plastic deviatoric work. Thus, no elastic deviatoric work is performed during plastic loading.

Finally, we briefly mention that the difference between Prandtl–Reuss plasticity and the simpler Mises plasticity theory is that Equation (2.10) is replaced by $d\epsilon = 0$. Thus, there is not even elastic volume change in Mises theory, whereas in Prandtl–Reuss elastic volume change was possible, but not plastic. It also follows that Mises theory is a non–associated plasticity theory, since the constitutive equations are not derived directly from the yield surface.

3 PLASTICITY IN HYDROCODES

Now, let us see how plasticity is handled in hydrocodes like Autodyn (2) and Dyna.

In hydrocodes, all physical quantities must be discretised in both time and space. For example, the stress deviation at some point after timestep *n* is denoted by s_{ij}^n. Given the stresses at the timestep *n*, the problem is to calculate them at the next timestep *n+1*.

3.1 Elastic regime

In the elastic regime, material behaviour is governed by Equations (2.1)–(2.2), and these are discretised in the following way:

$$p^{n+1} = p^n + 3K\Delta\epsilon^{n+1/2} \tag{3.1}$$

$$s_{ij}^{n+1} = s_{ij}^n + 2G\Delta e_{ij}^{n+1/2} \tag{3.2}$$

After the stresses have been calculated, the conservation equations are used to calculate $\epsilon_{ij}^{n+3/2}$ as a function of σ_{ij}^{n+1}. Then the cycle repeats as the new stresses at the next timestep are calculated from the constitutive equations (3.1)–(3.2) and so on. (In reality there are a lot more steps involved in a cycle, but this will be ignored as it is not relevant to our discussion.) To achieve a simpler notation we also drop the superscripts on the discretised strains from now on.

3.2 Plastic regime

We shall now look more closely at how plasticity is handled in Autodyn. In analytical theory, we only needed to supply the loading function *f*, while in Autodyn both a yield condition (referred to as "strength model" in Autodyn's terminology) and an equation of state (EOS), which defines volumetric plastic behaviour, is required.

An important difference between Autodyn and analytical theory lies in the use of the loading function *f*. In associated analytical theory, everything was derived from *f*, but in non–associated Autodyn plasticity, the only purpose of *f* is to determine whether the material is elastic or plastic. Further, *f* is always the same and can not be changed by the user:

$$f = \sqrt{J_2} = \sqrt{\frac{1}{2}s_{ij}s_{ij}} \tag{3.3}$$

It should be noted that in Autodyn, the von Mises stress $\sigma_{VM} = \sqrt{3}f$ is used instead of *f* itself. The advantage with this definition is that when determining plastic yielding in Prandtl–Reuss theory, σ_{VM} can be compared directly with the uniaxial stress limit *Y*, unlike *f* which has to be compared with the more mysterious quantity $k = Y/\sqrt{3}$. Either choice has no practical consequences, as is easily seen.

In analytical plasticity, different yield conditions can be obtained by choosing different loading functions *f*. As mentioned above, in Autodyn *f* is always the same, but different yield conditions can, however, be implemented by changing *k*, which might then become a function of other physical quantities like pressure, strain rate, temperature etc. It is then clear that exactly the same yield conditions can be used both in Autodyn and analytical theory. The defining equation, of course, expresses the same yield condition, regardless of whether some terms initially are put on the right or left hand side.

Further, we recall that in analytical plasticity, both the deviatoric stress increments ds_{ij} and pressure increments *dp* during plasticity are derived from the loading function *f* (See Equations (2.6)–(2.8)). In Autodyn, we shall see that these quantities are derived independently of each other through "scaling" procedures that initially seem to have little in common with Equations (2.6)–(2.8).

Since volumetric and deviatoric plasticity are calculated independently in Autodyn, we may have plastic volume change while the stress deviators still follow the elastic laws and vice versa. The user also has greater freedom in implementing material behaviour and approximating experimental results. If Autodyn had been based on associated flow, the volumetric plastic behaviour of the EOS would have had to be derived directly from the yield surface, making it difficult to implement special types of EOS, for instance the porous EOS which is frequently used in concrete modelling. The problem is that there would probably have been a conflict between a user input experimental EOS and an EOS derived from the input yield surface.

We shall now closely examine the connection between the methods used in analytical plasticity and in Autodyn.

3.2.1 Deviatoric components

We start by looking at how the deviatoric stress increments are calculated.

During a simulation, at every timestep Autodyn checks whether yielding has occurred anywhere in the material, i.e. it performs the following check:

$$\text{Is } f > k \text{, i.e. is } \sqrt{\frac{1}{2} s_{ij}^{n+1} s_{ij}^{n+1}} > k = \frac{Y}{\sqrt{3}} \ ?$$

If the above inequality is not satisfied, everything is alright and the elastic equations are used for the next time step as well. (It is not necessary to assume that *k* (or *Y)* is constant. The procedure is the same regardless of whether it is a constant or a function of pressure, strain rates, temperature etc.)

If yes, yielding has occurred and the trial stress state lies above the yield surface. The material has then turned plastic, and the plastic constitutive laws have to be applied instead of the elastic laws. In Autodyn this is achieved by scaling down all stresses in the following way:

$$s_{ij}^{n+1} \rightarrow \frac{s_{ij}^{n+1}}{\sqrt{s_{pq}^{n+1} s_{pq}^{n+1}}} \sqrt{2}\, k \tag{3.4}$$

We see that Equation (3.4) amounts to first dividing the proposed stress deviation tensor by its length to obtain a unit tensor with the same direction, and then multiplying it by the factor $\sqrt{2}\, k$ to make sure it lies exactly on the yield surface.

Now the calculation goes on as if nothing had happened. No additional constitute laws are introduced. This rescaling of the stresses is the only difference between the elastic and plastic regime.

It was obvious that Equations (3.1)–(3.2) were the discretized versions of (2.1) and (2.2). By letting $\Delta t \rightarrow 0$, they are easily seen to be equivalent. It is, however, not equally obvious that the rescaling of the stresses in Equation (3.4) is equivalent to the Prandtl–Reuss plasticity equation.

Recall that in Prandtl–Reuss plasticity, the stress increments were calculated according to the following differential equation:

$$ds_{ij} = 2G\left(de_{ij} - s_{ij} \frac{s_{pq} de_{pq}}{2k^2} \right) \tag{3.5}$$

Is Equation (3.5) really equivalent with Equation (3.4) for small timesteps? They sure look very different.

However, we see that Equation (3.4) can take the following form:

$$s_{ij}^{n+1} = \left[\frac{s_{ij}^{n} + 2G\Delta e_{ij}}{\sqrt{\left(s_{ij}^{n} + 2G\Delta e_{ij} \right)^2}} \right] \sqrt{2}\, k \tag{3.6}$$

Using that $s_{ij}^{n} s_{ij}^{n} = 2k^2$ and Taylor–expanding the denominator, we obtain to first order:

$$s_{ij}^{n+1} = s_{ij}^{n} + 2G\Delta e_{ij} - \frac{2G}{k^2} s_{ij}^{n} s_{pq}^{n} \Delta e_{pq} \tag{3.7}$$

On defining $\Delta s_{ij} = s_{ij}^{n+1} - s_{ij}^{n}$, we obtain:

$$\Delta s_{ij} = 2G\left(\Delta e_{ij} - s_{ij}^{n} \frac{s_{pq}^{n} \Delta e_{pq}}{2k^2} \right) \tag{3.8}$$

which is the same as Equation (3.5) for small time steps.

Thus, we see that the scaling of the stresses in Equation (3.4) produces the same deviatoric stress increments as analytical Prandtl–Reuss theory, at least for small strain increments.

However, it is quite interesting to note that we have derived Equation (3.8) without making any reference to plastic strain at all. Remember that in Prandtl–Reuss theory, Equation (3.5) was derived through an expression for the plastic part of the strain increments, but here we have used a different approach.

To calculate how much of the strain increments are indeed plastic, we need to find a computation technique that is equivalent to applying Equations (2.8) and (2.13). Autodyn uses the following method of first applying Hooke's law to find the elastic strain increments, and then subtracting this part from the total strain increments to find the plastic part of the strain:

$$\Delta e_{ij}^{p} = \Delta e_{ij} - \Delta e_{ij}^{e} = \Delta e_{ij} - \frac{\Delta s_{ij}}{2G} \tag{3.9}$$

Assuming small time steps, we can insert Equation (3.8), and easily find:

$$\Delta e_{ij}^{p} = s_{ij}^{n} \frac{s_{pq}^{n} \Delta e_{pq}}{2k^2} \tag{3.10}$$

which is equivalent to Equations (2.8) and (2.13).

Notice, however, that Equations (2.8) and (2.13) were derived on the assumption that k was constant, which has not been assumed here.

3.2.2 Volumetric components

In analytical theory, both the deviatoric and the volumetric components of the stress tensor were derived from the same expression (see Equations (2.8)–(2.10)). However, the method of Equation (3.4) used in hydrocodes only provides results for the deviatoric components. To determine dp and $d\epsilon^{p}$ as well, an additional method is required.

Autodyn allows the user to define a plastic constitutive relation $p = p(\epsilon)$ (actually the user defines $p = p(\rho)$, but remember that $\epsilon = \frac{1}{3}\left(\frac{\rho}{\rho_0} - 1\right)$.)., also known as an equation of state (EOS). What happens is that, in each cycle n, Autodyn calculates the pressure p^{n+1} according to the elastic equation (3.1). It then performs the following check to see whether the volumetric plastic limit has been reached:

Is $p^{n+1} > p(\epsilon^{n+1/2})$?

If the above inequality is not satisfied, everything is alright and the elastic equations are used for the next time step as well.

If yes, the volumetric plastic limit has been reached and volumetric yielding has occurred. The pressure is then simply scaled down to the EOS in the following way:

$$p^{n+1} = p\left(\epsilon^{n+1/2}\right) \tag{3.11}$$

To calculate the volumetric plastic strain increment, we can use the same trick as for the deviatoric strains by subtracting the elastic component from the total incremented strain:

$$\Delta\epsilon^p = \Delta\epsilon - \Delta\epsilon^e = \Delta\epsilon - \frac{\Delta p}{3K} \tag{3.12}$$

4 COMPARISON

Finally, let us compare the analytical plasticity models with some of the plasticity models implemented in Autodyn.

4.1 Mises strength model

We have already shown that by using the Mises strength model in Autodyn (constant yield limit), we obtain the analytical Prandtl–Reuss equations for the deviatoric stress components. If we combine this strength model with a linear equation of state (EOS), it follows easily from Equation (3.12) that $\Delta\epsilon^p = 0$, in agreement with Equation (2.9).

Thus the Mises strength model combined with a linear EOS is equivalent to the analytical Prandtl–Reuss model. As we see, it is not equivalent to the analytical Mises model in which we also have $\Delta\epsilon^e = 0$.

4.2 Mohr–Coulomb strength model

Autodyn also allows the user to define a pressure–dependent piecewise linear yield surface *k(p)*, which there is called a Mohr–Coulomb strength model.

In analytical theory, however, an associated Mohr–Coulomb plasticity model is derived from the following loading function:

$$f = \beta p + \frac{1}{2}\max\left(|\sigma_1 - \sigma_2|, |\sigma_1 - \sigma_3|, |\sigma_2 - \sigma_3|\right) \tag{4.1}$$

Are these two plasticity models equivalent?

We shall see that the Autodyn model differs from analytical theory in several ways. First, the yield condition is not even the same, as the corresponding Autodyn yield surface is on the form $\sqrt{J_2} = k(p)$, since $\sqrt{J_2}$ is used as a loading function instead of the maximum shear strength. We notice, however, that $\sqrt{J_2}$ is the same as the maximum shear strength for situations in which two of the principal stresses are identical, i.e. all axis symmetric problems.

Anyway, the analytical plasticity model which uses $\sqrt{J_2}$ instead of maximum shear strength to define the yield surface, is referred to as Drucker–Prager in the literature (3)–(4). Thus, we should really compare analytical Drucker–Prager plasticity with Autodyn's Mohr–Coulomb model.

In analytical Drucker–Prager plasticity, we have $f = \sqrt{J_2} + \beta p$, and thus if we define *Y(p)* linearly ($k(p) = k_0 - \beta p$) in Autodyn, the two yield surfaces should be identical. (There is some potensial for confusion here, as in Autodyn the pressure p is defined as positive in compression, whereas here it is negative.)

Using the analytical flow rule $d\epsilon^p_{ij} = f_{ij} d\lambda$ and the requirement that stresses remain on the yield surface, $df = 0$, we find the follow plasticity equations for a Drucker–Prager material:

$$de^p_{ij} = \left[\frac{s_{ij}}{2\sqrt{J_2}}\right] d\lambda \tag{4.2}$$

$$d\epsilon^p = \frac{\beta}{3} d\lambda \tag{4.3}$$

$$d\lambda = \frac{G/\sqrt{J_2}\, s_{mn} de_{mn} + K\beta d\epsilon/3}{G + K\beta^2} \tag{4.4}$$

This gives the following equation for the stress increments:

$$ds_{ij} = 2G\left[de_{ij} - \frac{s_{ij}}{2\sqrt{J_2}}\left[\frac{G/\sqrt{J_2}\, s_{mn} de_{mn} + K\beta d\epsilon/3}{G + K\beta^2}\right]\right] \tag{4.5}$$

However, on using the “scaling–down” approach of Autodyn, we obtain the following expression for the stress increments:

$$\Delta s_{ij} = 2G\left(\Delta e_{ij} - s^n_{ij}\frac{s^n_{pq}\Delta e_{pq}}{2k^2}\right) \tag{4.6}$$

which is clearly not equivalent to Equation (4.5).

Further, the analytical Drucker–Prager model gives the following pressure increments:

$$dp = 3K\left[d\epsilon - \frac{\beta}{3}\left[\frac{G/\sqrt{J_2}\, s_{mn} de_{mn} + K\beta d\epsilon/3}{G + K\beta^2}\right]\right] \tag{4.7}$$

In Autodyn the EOS has to be defined independently as $p(\epsilon)$, but we notice that since according to Equation (4.7) the analytical pressure increments depend on the plastic deviatoric work performed $s_{mn} de_{mn}$ and thus on the loading path, it will generally be impossible to define an EOS on the form $p(\epsilon)$ which is the same as Equation (4.7).

Thus, the Mohr–Coulomb strength model in Autodyn and the linear analytical Drucker–Prager plasticity model are quite different, even though they define the same yield surface. This is because the analytical model is based on associated flow, while the Autodyn model is non–associated.

5 SUMMARY

We have seen that under certain circumstances the analytical plasticity models are equivalent to the plasticity models implemented in Autodyn, but this does not hold in the general case.

Especially, it has been shown that by using the Mises strength model and a linear equation of state in Autodyn, one obtains analytical Prandtl–Reuss plasticity theory. Further, we saw that the Mohr–Coulomb strength model in Autodyn bears little resemblance to the analytical Mohr–Coulom plasticity model.

However, this is not necessarily a problem, as long as one is aware that the same name is often used for different models. Real plasticity is a quite complicated process, and it is not obvious how to model it correctly.

References

(1) Teland J A, A Review of Analytical Penetration Mechanics, FFI/RAPPORT–99/01264

(2) AUTODYN Theory Manual, Century Dynamics

(3) Chen W F, Plasticity in Reinforced Concrete, McGraw Hill, 1982

(4) Nordal S, Soil Modeling – A Continuum Mechanics based Approach to Elasto–Plasticity for Soils, 1999

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