4.2: Cutting Water Saturated Sand

From literature it is known that, during the cutting process, the sand increases in volume. This increase in volume is accredited to dilatancy. Dilatancy is the change of the pore volume as a result of shear in the sand. This increase of the pore volume has to be filled with water. The flowing water experiences a certain resistance, which causes sub-pressures in the pore water in the sand. As a result the grain stresses increase and therefore the required cutting forces. The rate of the increase of the pore volume in the dilatancy zone, the volume strain rate, is proportional to the cutting velocity. If the volume strain rate is high, there is a chance that the pore pressure reaches the saturated water vapor pressure and cavitation occurs. A further increasing volume strain rate will not be able to cause a further decrease of the pore pressure. This also implies that, with a further increasing cutting velocity, the cutting forces cannot increase as a result of the dilatancy properties of the sand. The cutting forces can, however, still increase with an increasing cutting velocity as a result of the inertia forces and the flow resistance.

The cutting process can be subdivided in 5 areas in relation with the cutting forces:

- Very low cutting velocities, a quasi-static cutting process. The cutting forces are determined by gravitation.

- The volume strain rate is high in relation to the permeability of the sand. The volume strain rate is however so small that inertia forces can be neglected. The cutting forces are dominated by the dilatancy properties of the sand.

- A transition region, with local cavitation. With an increasing volume strain rate, the cavitation area will increase so that the cutting forces increase slightly as a result of dilatancy.

- Cavitation occurs almost everywhere around and on the blade. The cutting forces do not increase anymore as a result of the dilatancy properties of the sand.

- Very high cutting velocities. The inertia forces part in the total cutting forces can no longer be neglected but form a
Under normal conditions in dredging, the cutting process in sand will be governed by the effects of dilatation. Gravity, inertia, cohesion and adhesion will not play a role. Internal and external friction are present. Saturated sand cutting is dominated by pore vacuum pressure forces and by the internal and external friction angles. The cutting mechanism is the **Shear Type**. This is covered in Chapter 6: Saturated Sand Cutting.

![The Shear Type](https://eng.libretexts.org/Bookshelves/Civil_Engineering/Book%3A_The_Delft_Sand_Claim_and_Rock_Cutting_Model_(Miede...

**Figure 4-2**: The Shear Type in saturated sand cutting.

The forces $K_1$ and $K_2$ on the blade, chisel or pick point are now:

\[
\begin{align*}
K_1 &= \frac{W_2 \cdot \sin(\delta) + W_1 \cdot \sin(\alpha + \beta + \delta + \varphi) + G \cdot \sin(\alpha + \varphi)}{\sin(\alpha + \beta + \delta + \varphi)} + \frac{-I \cdot \cos(\alpha + \beta + \delta + \varphi)}{\sin(\alpha + \beta + \delta + \varphi)} \\
K_2 &= \frac{W_2 \cdot \sin(\alpha + \beta + \varphi) + W_1 \cdot \sin(\varphi) + G \cdot \sin(\beta + \varphi)}{\sin(\alpha + \beta + \delta + \varphi)} + \frac{I \cdot \cos(\varphi) + C \cdot \cos(\varphi) - A \cdot \cos(\alpha + \beta + \delta + \varphi)}{\sin(\alpha + \beta + \delta + \varphi)}
\end{align*}
\tag{4-7}
\]

The normal forces $N_1$ on the shear plane and $N_2$ on the blade are:

\[
N_1 = K_1 \cdot \cos(\varphi) \quad \text{and} \quad N_2 = K_2 \cdot \cos(\delta)
\tag{4-9}
\]

The horizontal and vertical forces on the blade, chisel or pick point are:

\[
\begin{align*}
F_h &= -W_2 \cdot \sin(\alpha) + K_2 \cdot \sin(\alpha + \delta) + A \cdot \cos(\alpha) \\
F_v &= -W_2 \cdot \cos(\alpha) + K_2 \cdot \cos(\alpha + \delta) - A \cdot \sin(\alpha)
\end{align*}
\tag{4-10, 4-11}
\]
The equilibrium of moments around the blade tip is:

\[
\left(\mathrm{N}_1 - \mathrm{W}_1\right) \cdot \mathrm{R}_1 - \mathrm{G} \cdot \mathrm{R}_3 = \left(\mathrm{N}_2 - \mathrm{W}_2\right) \cdot \mathrm{R}_2 \tag{4-12}
\]

Analyzing these equations results in the following conclusions:

- The pore pressure forces \( \mathbf{W}_1 \) and \( \mathbf{W}_2 \) are limited by the occurrence of cavitation.

- All the terms are positive, resulting in positive forces on the blade and also positive normal forces.

- In the non-cavitating case the pore pressure forces are related to the (mobilized) blade height or the length of the shear plane. In the cavitating case the pore pressure forces are proportional to the (mobilized) blade height or the length of the shear plane. Theoretically the **Curling Type** and the **Tear Type** may occur. This has however never been observed with in dredging normal blade heights and layer thicknesses.

- When the argument of the sine in the denominator gets close to 180 degrees, the forces become very large. If the argument is greater than 180 degrees, the forces would become negative. Since both conditions will not happen in nature, nature will find another cutting mechanism, the wedge mechanism.