NordFoU: External Influences on Spray Patterns (EPAS)

Report 18: Motion of thawer on a spreader disk

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Abstract

The present report describes preliminary investigation on the parameters affecting on the thawer distribution performance of salt spreader to identify the study subjects important for further development of the spreader test method.

Motion of thawer, i.e. salt and/or water, fed on a spinning disk with 3 blades was studied theoretically and experimentally. High speed movie showed to be a useful tool to obtain an overview of the thawer motion on the disk. The experimental setup developed to measure flying speed of the thawer in the air has functioned acceptable; but further refinement of the method is desired.

The transport capacity of blades and the thawer motion along blades are the basic spreader characteristics determining the thawer distribution performance of the salt spreaders.

Discussion on the study subjects important for the further development of the spreader test method was made and the following subjects were suggested:

- A method to determine the transport capacity of blades is needed to be developed.
- A method to maintain the set feeding rate under the performance test is needed to be developed.
- A method to distinguish the amounts of thawer discharged from the blade tip and from the disk outer edge is needed to be developed.
- A method to maintain the set thawer distribution on disk at the feeding point under the performance test is needed to be developed.
- A study exploring the effects of the friction and vibration of spinning disk on motion of different thawing materials is desired.
- A method to detect the vibration levels of spinning disk under the performance test is desired.
- Further study on the thawer motion along the different types of blades with different arrangements is desired to ensure the appropriate test method for a wide range of spreader type.

Key words: Material motion on a spinning disk, performance test of spreading disk, observation of a high speed moving object, highspeed camera,

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Definition of the terms used in this report

- **Thawer**: Thawing material, i.e. salt, pre-wetted salt and brine (coloured water and whole milk in this study)
- **Feeding point**: The position on the disk, where the salt delivered by the feeder.
- **Feeding rate**: Amount of thawer fed onto the spreading disk per time unit
- **Takeoff velocity**: Velocity of the thawer at the time leaving from the spreader disk (Suffix: \textbf{FfRad} for the rotating coordinate system \textit{xy} and \textbf{Tf} for the stationary \textit{XY} coordinate system, ref. section 2.1)
- **Takeoff angle**: Angle of the takeoff velocity vector to radial direction
- **Spreading angle**: Angle between start and end angle of the spreading, ref. figure 1.
- **Spreading uniformity**: Quantitative distribution of the thawer throughout the Spreading angle

\[
\text{Spreading angle} = 220^\circ - 90^\circ = 130^\circ
\]

![Figure 1: Spreading angle is the angle between start and end angle.](image)

1. **Introduction**

The aim of thawer spreading is to ensure the winter traffic safety under the current weather conditions. The salt spreader to be used for the purpose is required to provide a homogeneous or set thawer distribution within the set spreading angle and dosage. This is also to minimize the amount of thawing material, limit the undesired environmental impact and reduce the cost.

Since the distribution performance is the most important quality feature of a spreading machine, manufacturers and users have created their own test procedures separately from each other in order to obtain information about the distribution quality. This has resulted in a variety of different test methods across Europe. Later on, European experts - manufacturers and users - started at CEN to work out a common test procedure for verifying the distribution quality of spreading machines in a European Standard. (EUtined, 2013).

The Engineering Center Bygholm (ECB), Denmark, has in cooperation with the manufacturers of spreading machines associated in EUtined Municipal Equipment, developed an agreed static test method for verifying the accuracy of set spreading dosage of thawing material brought out with a spreader in a defined time period. Conversely, a common dynamic test for verifying the distribution quality during driving and as close as possible to real operating conditions is not established due to the different kinds of thawing materials used throughout Europe and the lack of experience in determining the exact quantity of thawing material spread on the road.
Further development work is required to establish a standard method making spreading quality estimations comparable and permitting repeatable and reliable test independent from road and weather conditions.

During the last 6 years, about 70 salt spreaders from 3 different manufactures have been tested at ECB. Some manufactures have also used the ECB test facility in connection with development of new salt spreaders. We often experienced fluctuating test results, which are more than one can expect or explain. This indicates presence of uncontrollable or unknown fluctuating parameters influencing the test results. We found that the size distribution of the salt particles varies from lot to lot even they are delivered from the same supplier. Furthermore, the size distribution changes in the tank as the tank emptied for salt (Strøm, 2012). Smaller particles, i.e. less than 2 mm, thrown into the air stop shortly after due to the air resistance. Then, they either fall down to the road or submit to the airborne transportation following the turbulent airflow and the wind (Takai, 2012). As the volume and thereby the weight of the salt particles is proportional to the cube of the size, varying size distribution may have crucial effect on the distribution quality.

A software named 3S (Salt Spreading Simulation) is developed by ECB (Takai et al., 2015, Strøm et al., 2016). Simulation analyses using 3S on the effect of different parameters showed that the spreading angle and the spreading uniformity have significant effect on the distribution quality. These parameters are influenced by design of the spreader and the spreader settings including the feeding point, the feeding rate and the disk spinning speed as well as their combination. This may cause fluctuation of the distribution quality and the test results. Further study on the thawer motion on a spreader disk is desired to understand the importance of the different parameters, which are and should be included in the test procedure.

The study described in this report is aimed at exploring the parameters affecting on the distribution performance and identifying the study subjects important for further development of the spreader test method.

2. Method and materials

2.1. Theoretical model for thawer motion on a spreader disk

The thawer fed on the spreader disk moves from the feeding point to the blade tip or to the outer edge of the disk. Then, it flies into the air with a velocity and an angle depending on the spinning speed and design of the disk. The forces acting on the thawer on the rotating disk are a centrifugal force, a Coriolis force and a friction force. The two former forces are inertial forces (fictitious forces) that make it possible to apply Newton’s laws to explain the motion of an object in a rotating reference frame (here a coordinate system, rotating with the disk). The following theoretical models are not taking account of friction force.

Figure 2 illustrates a spreader disk that spins clockwise with an angular velocity of \( \omega [\text{rad/s}] \) \( (\omega = 2\pi \cdot \text{rpm}/60) \). The following description assumes that we as observers rotate along with the disk, i.e. the disk appears to stand still, while the surroundings seem to rotate counterclockwise.

An \( xy \) coordinate system fixed to the disk surface is introduced (origin at the disk center; \( x \)-axis along spreader blade of interest; see fig. 2). Although the \( xy \) coordinate system is rotating clockwise along with the disk (as opposed to the stationary \( XY \) coordinate system of the surroundings, the world), we as observers will see it as being stationary.

We assume that an object is dropped on the disk at the feeding point, which is located at a distance of \( r \) from the disk center. In the \( xy \) system the initial velocity vector of the object will be perpendicular to the radial direction and of magnitude

\[
\mathbf{v} = \omega \mathbf{r}
\]  

(EUnited, 2013).
According to classical analytical mechanics (Fowles, 1977) the centrifugal force, $F_{cn}$, and the Coriolis force, $F_{Cr}$, will be of magnitudes:

\begin{align}
F_{cn} &= m\omega^2 r \\
F_{Cr} &= 2m\omega v
\end{align}

Where $m$ is the mass of the object. The centrifugal force is directed radially towards the disk edge, while the Coriolis force is perpendicular to the velocity vector (to the left, i.e. pointing towards the disk center in this case).

![Diagram](image)

**Figure 2:** Illustration of the inertial forces acting on an object in motion on a rotating spreader disk.

Combining Equations (1) and (3) we find that $F_{Cr} = 2m\omega^2 r$, and consequently the net force is of magnitude $F_{Cr} - F_{cn} = m\omega^2 r$ and directed towards the disk center. According to classical mechanics this is exact centripetal force that will make the object follow a uniform circular motion. When the object reaches the $x$ axis it will hit the blade. Provided that the collision with the blade is inelastic the velocity of the object will immediately drop to zero, and consequently the Coriolis force also vanishes. This means that the only force acting on the object at that point is the centrifugal force ($F_{cn} = m\omega^2 r$) resulting in an acceleration along the blade towards the disk edge. However, as soon as a velocity in the $x$-direction is achieved, a Coriolis force perpendicular to the velocity vector will occur (to the left). A normal force, $F_n$, of the same magnitude in the opposite direction will balance the Coriolis force, and thus the net force, $F_{\text{net}}$, during the motion along the blade is equal to the centrifugal force, which is a function of the $x$-position:

$$F_{\text{net}} = F_{cn} = m\omega^2 x$$

Combining this with Newton’s second law, $F_{\text{net}} = mx''$ (second derivative of $x$ is acceleration), we get the following differential equation:

$$mx'' = m\omega^2 x$$

or

$$x'' = \omega^2 x$$

with initial conditions $x(0) = r$ and $x'(0) = 0$ (assuming that the object starts its journey along the blade at time $t = 0$). Given these initial conditions the solution to the linear differential equation (4) is:

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\[ x(t) = r \cosh(\omega t) \]

The velocity, \( v \), as function of time can be obtained by differentiation of this expression:

\[ v(t) = \omega r \sinh(\omega t) \]  

(5)

Assuming that the distance from the disk center to blade tip is \( R \), the time, \( t_{TF} \), when the object leaves the blade can be calculated by solving the equation \( x(t_{TF}) = R \). This results in:

\[ t_{TF} = \frac{1}{\omega} \cosh^{-1} \left( \frac{R}{r} \right) \]  

(6)

Applying this result in Equation (5) the radial velocity of the object at takeoff time can be calculated:

\[ v_{TFRad} = v(t_{TF}) = \omega \sqrt{R^2 - r^2} \]

This is the takeoff velocity in the \( xy \) coordinate system. To calculate the takeoff velocity in the world (stationary) coordinate system we must include the transversal contribution from the rotation. As the circumferential velocity at radius \( R \) is \( v_{TFCir} = \omega R \), the takeoff velocity, \( v_{TF} \), in the real-world coordinate system can be calculated as:

\[ v_{TF} = \sqrt{v_{TFRad}^2 + v_{TFCir}^2} = \omega \sqrt{2R^2 - r^2} \]  

(7)

The takeoff angle, \( \theta_{TF} \), can be calculated as:

\[ \theta_{TF} = \tan^{-1} \left( \frac{v_{TFCir}}{v_{TFRad}} \right) = \tan^{-1} \left( \frac{R}{\sqrt{R^2 - r^2}} \right) \]  

(8)

2.2. Experimental setup:

2.2.1. Experimental setup for the observation of thawer motion on a spinning disk:

The experimental study has initiated with observation of thawer motion by high speed movie playback to obtain an overview of the motion. Three different spreader disks were used: one with 3 flat blades (flat-blade disk), one with 1 flat blade + 2 Bredal blade (mixed-blade disk) and Bredal disk, which was provided by a company Bredal a/s, Vejle, Denmark.

Flat-blade disk had a 0.7 m diameter disk, on which 3 flat blades were mounted on radial direction and perpendicular to the disk surface. The height of the blade was 0.05 m and spinning radius was 0.4 m. Mixed-blade disk had a 0.5 m diameter disk, on which 1 flat bade and 2 Bredal blades were mounted. Their spinning radius was 0.32 m. Bredal disk had 0.5 m diameter disk, on which 3 Bredal blades were mounted, figure 3. Bredal blade is a factory designed blade with a blade height of 0.065 m and a spinning radius of 0.32 m. The blade had a U-shaped cross section. The width of the U-shape bottom expands toward the tip so that the thawer flow gets an inclination of about 10°. The disks were mounted on an electric motor with a frequency controller, which enabled to control spinning speed.

High-speed camera A:

A highspeed video camera AOS S-PRI 2124, AOS Technonlogies AG, Switzerland, was used. Motions of the dry salt and the coloured water on the disk were filmed with a frame rate of 500 and 1000 frames per second (fps). The movie films were taken outside to ensure the strong light source, i.e. sun. This caused a problem with shadows, which sometime disturbed image analysis.
2.2.2. Experimental setup for measurement of thawer motion:

Figure 4 shows the experimental setup. Its main components are:

**Highspeed camera B:**
A highspeed movie camera type Exilim EX-FH20, Casio, Japan, was used. It was adjusted to take 420 fps with a resolution of 224 × 168 pixels. The camera was mounted horizontally on an instrument holder with a traverse device.

**Thawer feeding arrangement:**
The thawer feeding arrangement was consisted of a plastic container. The container with a desired amount of thawer was hold horizontally by a clasp until the spreader disk reached to the desired spinning speed. Then, the container was released so that it turned over and fed the contents onto the desired feeding point on the disk.
Spreader disk with frequency controller:
The disk was placed horizontally. The spinning speed of the disk was controlled by frequency controller and three speed levels were used, i.e. 149, 235.5 and 296.5 rpm. A photoelectric tachometer was used to measure disk spinning speeds.

Table with radial and angular rule lines:
A black coloured table was placed horizontally under the spreader disk. The distance between the disk surface and the table was 0.04 m. The major angular rule lines were drawn every 30 degrees with minor 10 degrees marks between them. The major radial rule lines (circles) were drawn with radiuses of 0.35, 0.45, 0.55, 0.65 with 0.05 m marks between them

2.3. Procedure for flying velocity determination by observing the highspeed movie
Examine the movie to find a particle (or a small lump) of thawer, which can be distinguished so that its flying trajectory can be observed, figure 5. By using the information about the relative positions of the camera, the disk and the table, calculate the positions of the particle and the distance between the positions at the start and at the end of the observation (Figure 6). Count the number of frames between the start and the end position. And, convert it to the time by multiplying 1/420 s. Then calculate flying velocity.

A small salt lump can be seen in the red circle. It can be followed in the highspeed movie so that its flying trajectory can be observed to determine the flying distance and flying velocity.

Figure 5: An example: A small salt lump was distinguished in the red circle (Camera B 420 fps)

Figure 6: Explanatory drawing for determination of flying velocity based on the highspeed movie observation.
2.4. Coloured salt and water

The thawers, i.e. salt, pre-wetted salt and water, used in the experiment were coloured to obtain clear contrast to the background in the movies and photos. Natural fruit extracts with different colours from Dr. Oetker Danmark AS, Denmark were used for the purpose. Whole cow milk (3.5 % fat) was used instead of white coloured water.

3. Results and discussion

3.1. Observations of the thawer motion on the spreader disk

As soon as the thawer falls onto a spinning spreader disk, it gets into motion and friction force, centrifugal force and Coriolis force acts on it. Sum of these three forces determine the thawer motion on the disk. It moves radial direction toward the outer disk edge and tangentially against the spinning direction, i.e. obliquely toward the outer disk edge. If the thawer reaches the blade, it changes to move along the blade toward its tip. Then, it flies into the air with the velocity and the direction determined as the sum of radial and tangential velocity vectors, provided the blade is mounted on the radial direction. If the thawer reaches the outer disk edge it flies into the air with the velocity and the angle determined as the sum of radial and tangential velocity vectors at the time of leaving from the disk edge.

The situation shown in Figure 7 is slightly different from the above description. Specifically, three portions of coloured salt (6 g.) were placed in 3 different places on the flat-blade disk. All portions were placed ca. 20 cm from the centre. Then the motor was started. The picture shows the situation at ca. 0.34 seconds after the start. The salt placed near one of the blades moved along the blade, ref A in the figure. The portions placed away from the blades reached the disk outer edge with a radius of 0.35m, ref. B and C in the figure. The spinning radius of the disk is smaller than that of the blade. Consequently, the velocity of the salt flies from the disk edge will be lower than the velocity of the salt flies from the blade tip, of which radius is 0.4m.

![Diagram of three positions](image)

A) Salt was located near the blade and 20 cm from the center.
B) Salt was located 90° away from the blades and 20 cm from the center.
C) Salt was located 60° away from the blades and 20 cm from the center.

Estimated rotation speed at 0.34 s. after the switch-on to start the disk: 167 rpm

Figure 7: Three portions of coloured salt (6 g each, coulored black) were placed in 3 different positions on the flat-blade disk. Then, the motor was started. The picture shows the situation at 0.34 seconds. (Cameraa A, 1000 fps)

If there is no friction, the object (salt and/or water) dropped on a spinning disk will follow a uniform circular motion, ref. section 2.1. But, as seen in the figures 8, 10, 11 and 12 the water moved obliquely toward the outer disk edge. This is due to the friction. This has significant influence on the spreader performance.

Figure 8 shows the traces of coloured water fed on the flat-blade disk (153 rpm). It indicates that a considerable portion of water was discharged from the outer disk edge. It also shows that the water was not fed continuously, i.e. no water was fed just behind the blade. This is due to “shadow effect” of the blade. The water falls
continuously on the disk and forms a continuous water flow between the feeder and the disk surface until a blade cut through the flow. Then the lowest part of the flow falls in front of the blade. Consequently, a greater portion of the water is collected here. In turn, no water just behind the blade because it takes some times to fall the distance equal to the blade height.

Figure 8 and 9 show other phenomenon indicating the transport capacity of the blade. The feeding rate for the situation shown in Figure 8 was low. The water did not flow over the upper edge of the blade. Conversely, a part of the water flowed over the upper edge and turned into water droplets flying in the air when the feeding rate was too high, figure 9. The maximum transport capacity of the spreader disk must be somewhere between these two situations. Figure 9 shows another interesting phenomenon. A portion of water moved toward the centre, i.e. against centrifugal force. This is probably due to the high feeding rate. It can be too high so that the water cannot move fast enough to give the place for the water falling continuously. The falling water pushes the water on the disk to the all directions.

Figure 10 shows the moment just after the start of feeding. Feeding rate was low. This is probably the reason why the movement of the water fell on the disk can be observed clearly. Water falling on the disk spread in all directions and created a circle around the feeding point. A portion of water moved together with the disk resulting in a tapering end.

Figure 11 shows the situation just before the blade cuts the lowest part of the water flow. The shape of the water trace seen in the figure can probably be considered as the basic shape of the thawer fed on a spinning disk with a low feeding rate.

Figure 12 shows the situation 0.13 s. after the situation shown in Figure 11. The traces of the water motion show that the water moved irregularly. This indicates vibration of the spinning disk and not-perfect flat surface, i.e. the friction with disk surface varies place to place. Nevertheless, the traces tell interesting phenomenon. The water fed in start, i.e. away from the blade, seems to be discharged over the outer disk edge. The water fed a little later, i.e. fed apart from the blade, seems to reach the blade tip before the water fed latest, i.e. fed in close proximity to the blade, figure 12.

The traces of the water motion show that some of the water did not reach the blade before it reached the outer disk edge.

No water was fed just behind the blade due to the “shadow effect” of the blade, i.e. the lowest part of the water flow from the feeder was captured by the blade.

No flow over the upper edge of the blade when the feeding rated is low. (See also figure 9)

Figure 8: The traces of the water movement on the spinning spreader disk (Flat-blade disk, 153 rpm, Camera A, 1000 fps).
Figure 9: Situation with a high feeding rate. (Flat-blade disk, 293 rpm, Camera A, 1000 fps)

Figure 10: The water fallen down on the disk spread in all directions. And, a portion of water moved together with the disk, which resulted in a tapering end. (Flat-blade disk, 150 rpm, Camera A, 1000 fps)
Figure 11: The situation just before the blade cuts the lowest end of the water flow. (Flat-blade disk, 150 rpm, Camera A, 1000 fps)

Figure 12: The situation 0.13 s. after the situation shown in Figure 11. (Flat-blade disk, 150 rpm, Camera A, 1000 fps)

Figure 13 and 14 shows salt motion along the flat blade and the Bredal blade, respectively. The salt cluster collected along the blades tends to be stretched toward the tip because of increasing radial velocity with increasing distance from the disk center. This can clearly be seen with the flat blade, along which the salt cluster can move more freely than the Bredal blade, of which shape seems to reduce this effect. This is probably the reason why the cluster along the flat blade got a tapering end. Whereas, the cluster along the Bredal blade got a spearhead shaped front. These will reflect directly on the Spreading uniformity and thereby thawer distribution quality.
0 sec. Blade has just passed the feeding point.

0.04 sec. Salt was collected by the flat-blade and formed a cluster along the blade.

0.06 sec. The salt cluster was stretched and formed tapering end.

Figure 13: Salt motion along the flat blade. (Mixed-blade disk, 196 rpm, Camera A, 500 fps)

0 sec.: Blade has just passed the feeding point.

0.04 sec.: Salt was collected by the blade and gathered along the Bredal blade

0.08 sec.: The salt cluster got a spearhead shaped front

0.12 sec.: The rest of the salt cluster was roughly the same thickness.

Figure 14: Salt motion along the Bredal blade (Mixed-blade disk, 196 rpm, Camera A, 500 fps)
3.2. Validation of the theoretical model for takeoff velocity and angle

The highspeed movie method used for the validation includes relatively large estimation error due to rough rule lines on the table, unsureness in the measurement of the relative positions of the facility elements, i.e. camera, disk and table. Furthermore, the time step $1/420 = 0.00238$ s is maybe too rough compared with the time of flight, which varied from 0.017 to 0.048 s. Albeit the constraint condition of the experimental measurements, comparing the calculated values with the values obtained experimentally gave indications of the validity of the theoretical method.

Figure 15 shows the flying velocities determined based on the highspeed movie observations (X-axis) and the takeoff velocities calculated by the theoretical model (Y-axis), i.e. equation 7. The theoretical model does not include the friction effect. The thawers used in the experiments were: Dry rock salt, pre-wetted rock salt, red colored water and milk. The theoretical model overestimates increasingly as the flying velocity increases. The deviations at flying velocity levels of 6.5, 10.1 and 11.9 m s$^{-1}$ were 6.2, 7.9 and 15.2%, respectively. This indicates that the friction force acting on the thawer on the disk and in the air increases with increasing velocity. The effect of different thawers on the deviation between the results from the calculation and the experiment was not clear.

Figure 16 shows a photo from the experiment with spreading of milk, which left the trace of the spread milk trajectory on the table. The milk was fed at ca. 10 cm from the disk center and the disk spinning speed was 149 rpm. Takeoff angle was estimated to be about 45°, which agreed well with the theoretical calculation of 46.5°.

![Graph showing flying velocities determined based on highspeed movie observations and the theoretical calculated takeoff velocity without taking account of the friction effect.](New Robert exp Nov2016 Excel)

Figure 15: Flying velocities determined on the basis of the highspeed video observations and the theoretical calculated takeoff velocity without taking account of the friction effect. (Experimental facility, Bredal blade, Camera B, 420 fps, ref figure 4)
3.3. Parameters affecting on the takeoff velocity and angle

The relatively good agreement of the model calculation results with the values obtained experimentally indicates the reliability of the theoretical model to analyse the effects of different parameters on the operational characteristics of a spreader disk.

Theoretically, the takeoff angle is independent of disk rotation speed. While, the takeoff velocity is directly proportional to the disk spinning speed, figure 17.

![Figure 17: Effect of disk spinning speed on the takeoff velocity and angle](image)

Feeding point: 0.1 m from disc center
Blade tip radius: 0.32 m

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Feeding point has crucial influences on the takeoff velocity and angle. The takeoff velocity decreases and the takeoff angle increases as the feeding point moves away from the disk center, figure 18.

![Graph showing the effect of feeding point on takeoff velocity and angle](image)

**Figure 18:** Effect of feeding point on the takeoff velocity and angle

The time needed for the thawer to move from the feeding point to the blade tip will be shorter when the feeding point moves away from the disk center. This means that the angle between the feeding point and the point of spreading start will be reduced, figure 19, which resulting in the shift of Spreading angle against to the disk rotation direction.

![Graph showing the effect of feeding point on the angle between feeding point and spreading start angle](image)

**Figure 19:** Effect of feeding point on the angle between feeding point and spreading-start angle.

### 3.4 Overall discussion

Discussions in this section are intended to identify the study subjects important for further development of the spreader test method to obtain more reliable and reproducible data than today.
Feeding rate and transport capacity of the blade:
Increasing feeding rate to more than the blade can transport, the overloaded thawer moves toward the outer disk edge, from where it will fly into the air with lower velocity than from the blade tip of which spinning radius is larger than the disk. This will result in more thawer will be spread near the salt truck. If feeding rate is increased further, some of the overloaded thawer remains on the disk longer time. This may result in wider spreading angle than intentional angle. If the thawer remains on the disk longer time and flies in the driving direction so that it hits “the salt-guard plate” (ref. figure 3) mounted vertically between the spreader and the back side of the truck, there will be increased thawer distribution along the lane. Excessive feeding rate can result in undesired thawer distribution on the road.

Thus, the maximum transport capacity of the blade is the important factor determining the working range of the salt spreader concerning the spreading pattern, the salt spray rate (g salt per m² road surface) and the driving speed. The observations of the thawer motions along two different type blades, i.e. the flat-blade and the Bredal blade, indicates that the blade design has crucial effect on the thawer motions and thereby the transport capacity of blades and the distribution quality.

- A method to determine the transport capacity of blades is needed to be developed.
- A method to maintain the set feeding rate under the performance test is needed to be developed.
- A method to distinguish the amounts of thawer discharged from the blade tip and from the disk outer edge is needed to be developed.

Feeding point:
The feeding method used in the present study fed the thawer on a relatively small disk area. The actually used spreaders may feed on a larger area. The thawer distribution around the feeding point will reflect on the shape of the thawer cluster along the blades and thereby on the thawer distribution on the road.

- A method to ensure the set thawer distribution on the disk at the feeding point is maintained under the performance test is needed to be developed.

Disk:
Friction and vibration are the important parameters affecting on the motion of thawer on a spinning disk.

- A study exploring the effects of these parameters on motion of different thawing materials, i.e. salt, brine, sand etc., is desired.
- A method to detect the vibration levels of spinning disk under the performance test is desired.

Blade:
The blades used in the present study were mounted on radial direction. The blade design and arrangement applied to the currently used spreaders vary widely.

- Further study on the thawer motion along the different types of blades with different arrangements is desired to ensure the appropriate test method for a wider range of spreader type.

4. Conclusions

Motion of salt and water fed on a spinning disk was studied theoretically and experimentally. The highspeed movie playback showed to be a useful tool to obtain overview of the thawer motion on the disk. The experimental setup developed to measure flying velocity of the thawer in the air functioned acceptable; but further refinement of the method is desired.
The transport capacity of blades and the thawer motion along blades are the basic spreader characteristics determining the thawer distribution performance of the salt spreaders.

The study subjects important for further development of the spreader test method to obtain more reliable and reproducible data than today are suggested.

5. Reference