Oloid and Inversion

A geometrical and physical excursion

1. Cubes and Inversion

In 1929, the engineer and inventor Paul Schatz discovered a new geometric body and a yet unknown type of movement: he dissected a cube in a certain way into three parts, examined the mobility of the middle part of the body (blue-red in Fig. 1) and observed the shape of the movement. In the following, this is explained step by step:

- Divide a cube into 3 special parts. The middle part (blue-red in Fig. 1) is the so-called "dice belt", a 6-membered ring of uniform, pairwise mirror-symmetric tetrahedrons.
- The remaining two parts (orange-red in Fig. 1) are called "bar bodies" and are identical to each other.
- All three partial bodies have the same volume.
- Take the dice belt, hold it so that you can infiltrate it infinitely into yourself and discover the inversion movement.

Fig. 1: The 3 equal parts of a cube, divided into a cube belt (blue-red) and two bar bodies (orange-red), which are removed for the continuation of the train of thought. Illustration from http://www.kuboid.ch

2. Inversion and Oloid

- During a complete inversion of the cube belt, an Oloid is drawn in space from each of the four cube diagonals. The length of the diagonal is always preserved.
- By holding one of the six tetrahedral of the cube belt and observing the path of its opposite diagonal (white line in Fig. 2), the surface covered by it is an Oloid.
- An Oloid can also be used as a wrapping form of two congruent, perpendicular circles where the circumference of one circle passes through the center of the other circle (see Fig. 2)

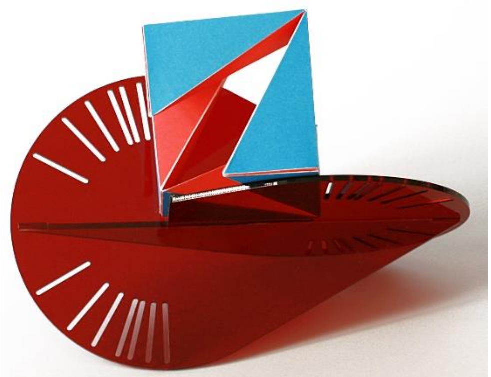

Fig. 2: Visualization of the shape formation of the OLOID during the inversion of the cube belt. Abbildung von http://www.kuboid.ch

- How to find the OLOID shape by the inversion of the cube: https://youtu.be/uBGGIDZIMBI

3. Mathematical facts

- The surface of a ball with radius **r** and the surface of the Oloid with the same radius **r** (three times in the Oloid, see Fig. 3) are identical to each other: **A = 4πr²**.
- The volume of a sphere is **V = (4/3) πr³**. This results, mathematically, in the highest possible surface-to-volume ratio: **A/V = 3/r**.
- The volume of an Oloid cannot be calculated exactly but approximated with **V = 3.0524*r³**. This results in approximately the ratio **A/V = 4/3 π/r.**

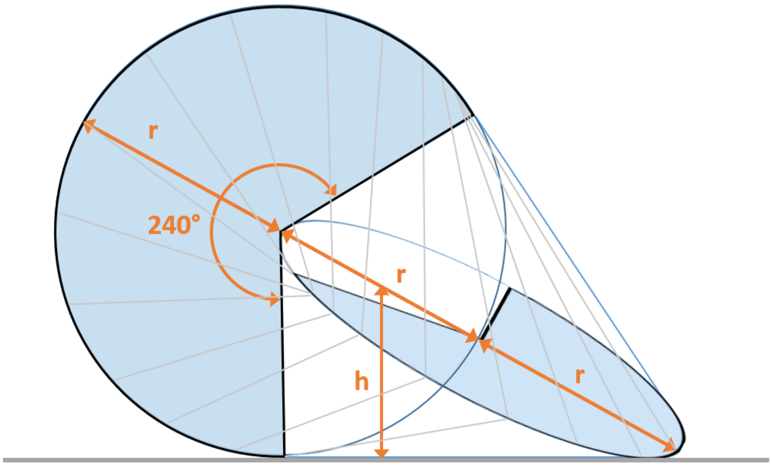

Fig. 3: Mathematical description of the OLOID.

- On a slightly inclined level, an Oloid starts to roll very quickly.
  This can be explained by the straight-line contact of the curved surface area with the ground, whereby the Oloid requires only a very small amount of energy to be set in motion. This already low energy is e.g. even lower for a ball, which is lying on the ground at just one point. The very low static friction is an indicator of an energy-efficient movement. With its single surface and two circular-arc edges, the Oloid is one of the few geometric bodies that touch the ground with its entire surface as it rolls off.
  https://www.youtube.com/watch?v=GM3_JuFgJ2E
- Another example is the Sphericon, which also has only one continuous surface. In contrast to the Oloid, the Sphericon appears compressed because the radius does not occur 3 times in the body and two double cones, which are rotated against each other by 90°, can describe the body. The surface of a Sphericon is calculated to be **A = 2*√2*πr²** and the volume to **V = 2/3*πr³** results in a **√2** larger ratio of **A/V= 3*√2/r** in contrast to the sphere.
- Therefore, the ball has the best surface to volume ratio and the Oloid has a slightly better ratio than the Sphericon.
- However, all three bodies have in common that the centre of gravity corresponds to the centre of the body.

4. Movement

- In physics, translation and rotation are the two standard recognized forms of motion. The course of movement of the cube belt described in the previous section follows a three-dimensional, lying in space '8' and thus opens up a third form of movement that is novel in physics: the **INVERSION**.

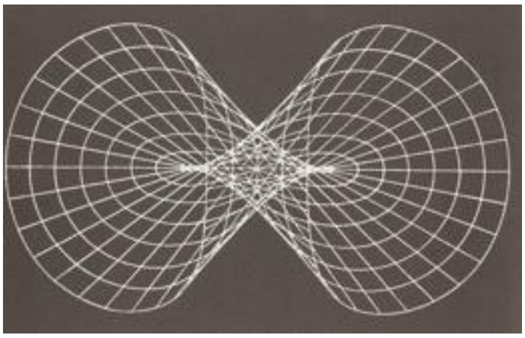

Fig. 4: Visualisation of the inversion movement in space.

- In order to cause an OLOID by a motor to approximate its own rolling motion in a fixed location, the Oloid has to be mounted accordingly with two forks perpendicular to each other (at the level of the two circle centres in the Oloid scaffold) on two oppositely rotating shafts be (see section 6).
  The use of an oval gear mechanism in the gearbox of the engine simultaneously allows different mirror-symmetric speeds of the two shafts. Further details on the mechanical drive can be found in section 6 and on the Internet:
  https://www.youtube.com/watch?v=r-lNe9AUwOg
  https://www.youtube.com/watch?v=ssFZRQuJXJk

5. Unrolling behaviour of the Oloid compared to different bodies

In this section, four geometric bodies are investigated for their rolling behaviour:
A sphere, an Oloid, a cube and a cylinder are compared in terms of volume, surface and rolling surface. Here, the radius or the edge length are fixed, in the case of the cylinder accordingly the height. The representation of the Sphericons was omitted because it was already shown in Section 3 that the Sphericon is located between the sphere and an Oloid.
The radius of the sphere, cylinder and Oloid are randomized to 2 without specifying the units. The edge length (cylinder height) is set to 4, so that the projection surfaces of Oloid, cube and cylinder are the same size. This is demonstrated in the following figure.

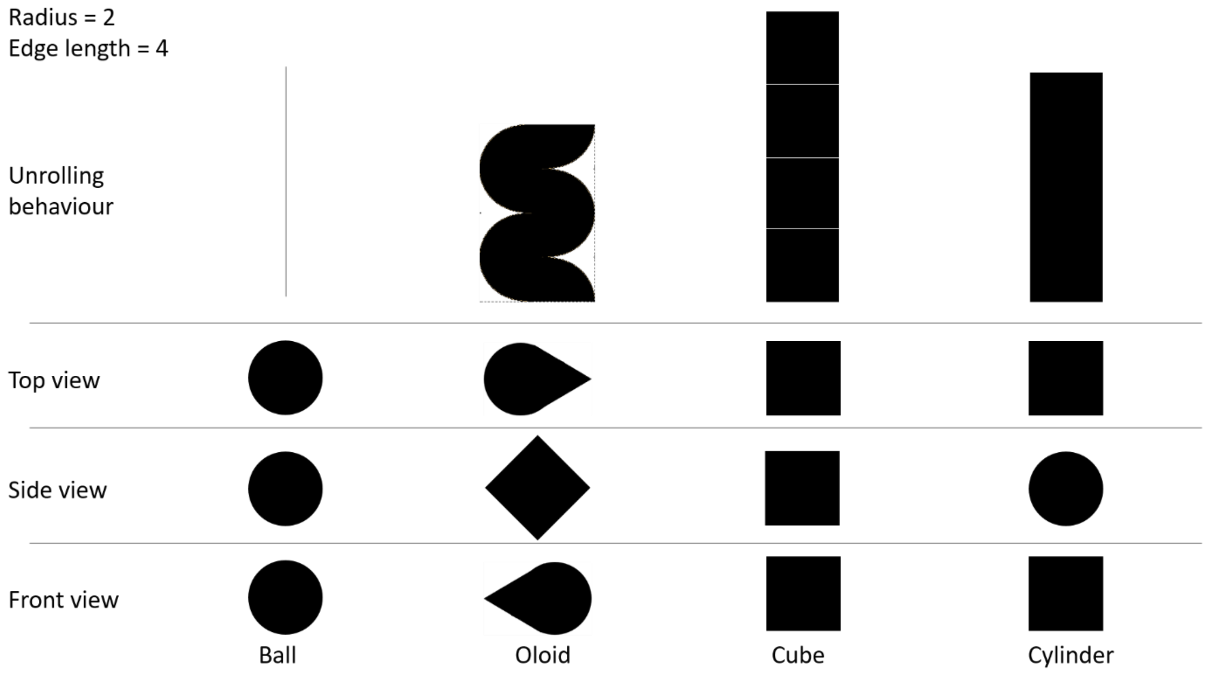

Fig. 5: Comparison of the rolling behaviour as well as top, side and front view of ball, Oloid, cube and cylinder.

The unrolling behaviour is analysed for a full revolution, where the cylinder is unrolled along its circumference. See top row of Fig. 5. It is a little difficult to compare the one-dimensional unrolling of the ball against the other unrolling patterns, as they are two-dimensional. Nevertheless, the coefficient demonstrates the very good ratio of surface to unrolling surface of the Oloid.

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The following table summarises the body volume, surface, unrolling surface, and its coefficient (ratio surface/unrolling surface). For all parameters are SI units given.

Parameter	Ball	OLOID	Cube	Cylinder
Radius r [m]	2.00	2.00		2.00
Edge length a [m]			4.00	
Height h [m]				4.00
Volume [m³]	33.51	24.40	64.00	50.27
Surface [m²]	50.27	50.27	96.00	75.40
Unrolling surface [m²]		50.27	64.00	50.27
Circumference [m]	12.57			
Surface / Unrolling surface []*	**4.00**	**1.00**	**1.50**	**1.50**

* Dimensionless except for the ball, where the coefficient Surface / Circumference [1/m] is given.

It can be clearly seen that the OLOID unrolls with its entire surface, hence the coefficient 1. For the cube and cylinder, it is clear that there are always surfaces, which are not involved in unrolling, hence the coefficients 1.5. The coefficient for the ball has to be treated with caution, as the circumference and a true surface are used for calculation.

6. OLOID in Water

This is how it looks if all of the above is brought together in our OLOID systems:

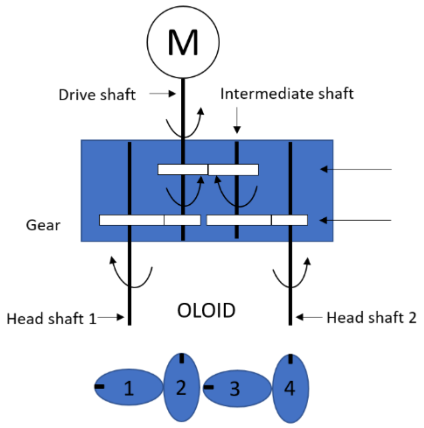
https://www.youtube.com/watch?v=tpNiGhmHCG4

- When the OLOID body is completely submerged below the surface of the water, the OLOID is a very energy efficient stirrer, producing a pulsed flow while achieving excellent homogenization of the mixed material. This promotes or accelerates i.a. the activation and maintenance of chemical-biological processes in (waste) water treatment (e.g., flocculation & precipitation).
- The inversion movement creates its own flow form in the water, which promotes its self-cleaning ability.
- By partially lifting the OLOID-body out of the water, the OLOID will generate an oxygen input while losing a little bit of the circulation effect (important for horticulture, lakes and fish farming).
- In general, the OLOID is more an agitation system than an aeration system.
- Please observe the following while watching above video:
    - Emission of air bubble vortexes visualise the following:
        - impulse-like current
        - oxygenation
        - opening angle of 30° of the current
    - Self-cleaning effect of the OLOID-body through water/air flow (cavitation)
    - No danger of entwinement on agitator / OLOID-body through complete inversion

7. Mechanics of the OLOID-gear

Different sized OLOIDS are operated at different speeds. However, this does not matter for the principle of operation.

OLOID 200 = 125 rpm	LOID 200 = agitator body length of 195 mm
OLOID 400 = 55 rpm	RPM = revolutions per minute
OLOID 600 = 55 rpm	Engine speed = max. head shaft speed



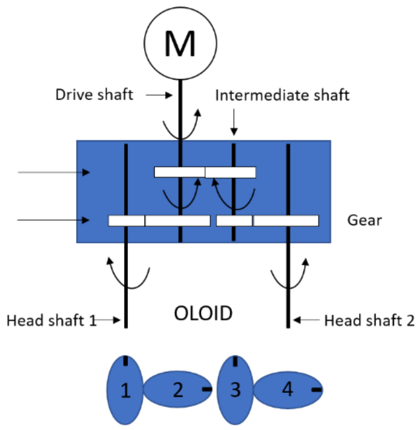
M=Motor

Passing speed on second side =
Level with 2 round gears

Speed ratio to function =
Level with 4 oval gears

Shaft speed changes according to function
(determined by oval gears)

Oval gear position in the 4 positions:
The position of the oval gear changes by 90 degrees per pulse



1 motor revolution provides 1 revolution of the head shafts provides 4 impulse to the OLOID, thereby producing no translation or reduction, but by the pairing of the oval gears, swells the speed of the head waves = **2 pulses left and 2 pulses right**.

The positions of the oval gears result in different speeds of the head shafts at the same times. If the speed of the head shaft 1 is maximum, the speed of the head shaft 2 is at the same time minimal and vice versa. It should be noted that the shaft speed according to engineering language could NEVER be 0, since this is equivalent to a blockage. That is: the shaft speed is almost 0!!!

8. Prospect

- Optimisation of applications through combination with any type of aeration system (surface / pressure aerators).
- Also applicable for viscous fluids and high solids content.
  - In activated sludge in waste water treatment (Link; ARA Gäu)
  - In an application in liquid manure treatment (Link Cattle farm, HU)
  - Or in beer production (see also section 9 Vision)

9. Vision

The OLOID beer. http://oloid-bier.de/

By using an OLOID, the mash can be better mixed during the beer brewing and there are lower shear forces acting on the mash than in conventional mashing processes. This not only shortens the time it takes to lauter but also reduces energy consumption by up to 80%.

Thus, in 2017 we were able to brew the first OLOID beer in cooperation with our cooperation partners.

10. References

- Further information on the mathematics and physics of the OLOID and other geometrical objects that Paul Schatz discovered and described can be found in the following book: http://www.paul-schatz.ch/publikationen/

- Further information on Paul Schatz and his life and work can be found here: http://www.paul-schatz.ch/home/

- Various Oloids and invertible cubes can be ordered through the Kuboid GmbH: http://www.kuboid.ch/

11. Other interesting links to inversion and its application

- First 3D-Windtrubine
  http://vayu.swiss/
- Heliodome as an architecture concept of an energy efficient house
  http://www.heliodome-uk.com/
- FLOYD pendant lights = lights in the form of the Oloid
  http://kuboid.ch/store/en/14-floyd-lampen
- Ship drive by the Paul Schatz Foundation
  https://youtu.be/v381DYll1js
- Rhythmixx – a hand-operated inversion mixer after Paul Schatz
  http://www.kuboid.ch/store/en/15-rhythmixx