Open Journal of Molecular and Integrative Physiology, 2017, 7, 53-56
http://www.scirp.org/journal/ojmip
ISSN Online: 2162-2167
ISSN Print: 2162-2159

Rotational Flows, Thermodynamics, Angle Vibration and Action of Whirly Flows on Fishes

Lena J.-T. Strömberg

Department of Solid Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
Email: lena_str@hotmail.com

How to cite this paper: Strömberg, L.J.-T. (2017) Rotational Flows, Thermodynamics, Angle Vibration and Action of Whirly Flows on Fishes. *Open Journal of Molecular and Integrative Physiology*, 7, 53-56.
https://doi.org/10.4236/ojmip.2017.74005

Received: August 13, 2017
Accepted: October 17, 2017
Published: October 20, 2017

Abstract

A continuum thermodynamic model for how whirls can transform into thermal energy-forms determined by a functional relation for temperature is derived. This is used to describe how fishes maintain circulation in the vascular system, at very low temperatures.

Keywords

Entropy, Temperature, Thermodynamics, Angular Velocity, Vorticity, Eddy, Harmonic Oscillator, Angle Vibration, Temperature Distribution, Spatial Cylindrical Coordinates, $\varphi(t)$

1. Introduction

Theories for interactions of different types of energy, e.g. kinetic, mechanical and thermal are of importance in many fields. It invokes also transformations between them, dissipation and creation of sublevels and super levels. Here, we will scrutinize the ramifications of thermodynamics and continuum mechanics for a viscous incompressible fluid.

2. Balance Equation for Entropy

For a fluid with viscosity, continuum mechanics with thermodynamics and additional assumptions of heat capacity and heat flux gives an equation for the rate of entropy, reading

$$\rho\theta d_t\eta = s - \kappa\Delta\theta + \lambda\left(trL\right)^2 + 2\mu trL^2 \quad (1)$$

where, with usual notations; ρ, η, s, θ, trL, $\left(\lambda\left(trL\right)^2 + 2\mu trL^2\right)$ is the density, entropy, heat radiation, temperature, trace of velocity gradient and internal friction in the viscous motion, and d_t denotes entire time derivative. Here, we consider a flow consisting of whirls such that $L = \mathrm{skew}(L) = w_x$, where x is the cross product. From thermodynamics, entropy is energy conjugated to temperature, and there are different types of energies, c.f. [1]. The energies are potential functions in so called Legendre transformations, to change between (independent) variables. The conjugated variables for mechanical energy are p/ρ and ρ, but these will not be used in the present analysis.

Entropic Forces in Elasticity and Continuum Mechanics

An example of an entropic system in material science is a study of biological tissues with some elasticity, and motion also governed by a statistic random distribution dependent on temperature, c.f. [2].

It appears that in harmonisation between continuum mechanical formulation and classical statistical mechanics, the molecule mass enters in the statistics caloric equation of state. An exact evaluation gives that $p = (k/m_w)\rho\theta$, where k is Boltzman's constant and m_w is the molecule-weight. If altering the example in [2] into continuum mechanics, then k should be replaced with k/m_w. Since these systems often are used with self-calibration, the exact expressions do not show, but instead changes and ratios. First, we shall adopt the framework in [2] to rotations instead of displacements. Hereby, interpreting w^2 as weighted from a statistical temperature distribution, we obtain that w^2 is proportional to $\theta k/m_w$. Then, with notations of the balance Equation (1), we identify left side with this such that $\rho d_t\eta = k/m_w$.

3. Solutions in Terms of Independent Variables on a Manifold

To connect w^2 with kinematics and geometry, alternate frames could be chosen:

With discrete memory as implied from Tti in anco, the acceleration may be from a previous state. This gives change of direction, such that the angular acceleration is the square of angular velocity.

No heat or terms with temp balanced:

$$\rho\theta d_t\eta = 2\mu w^2 \tag{2}$$

$d_t\eta$ proportional to temperature gives a "symmetry" such that vorticity w is proportional to temperature.

For systems with many (rotational) d.o.f, often harmonic oscillators are assumed as the point of departure. Therefore, only the inertia parts are exported to a multi-dimensional Hamiltonian and the individual potentials, as well as potential energy is invoked in some manner into entire energy, and the kinematic interactions are neglected. This is the foundation of the Schrödinger equation in QM.

Here we will proceed with one d.o.f on the meso-scale provided by continuum mechanics. Formulations in terms of energies depending on θ, η, w and energy conjugate to w, could be done comparison with notations of a manifold, c.f. [1]. Then, either a measure of whirl and temperature as forms without connection to coordinates, or the whirl and temperature expressed in R^3-coordinates, could be used as the independent variable in analysis.

Next, the latter will be considered to see how the fields matter in real space.

Solutions in Terms of Spatial Coordinates in R^3

Since w is connected to angle φ as $w = \varphi_t$, we will consider solutions $\theta = \theta(\varphi)$.

- With $w^2 = \varphi_{tt}$ *i.e.* angular acceleration and θ proportional to angle φ (2) gives hyperbolic solutions as functions of angles.
- When $d_t\eta =$ const there are solutions to (1); $\theta = C\exp(-a\varphi)$ where *r*, φ are cylindrical coordinates, and $(a/r)^2\kappa = \rho d_t\eta - b$, $2\mu w^2 = -s + b\theta$. When $d_t\eta = 0$, the solution parameters *a*, *b* can be expressed in statistical variables; $b = k/m_w$, $(a/r)^2\kappa = -b$.
- Finally, a case with small scale harmonic oscillator solutions will be derived.

With $\Delta\theta$ proportional to θ, *a* solution is $\theta = D\sinh(a\varphi)$ where *D* and *a* are constants with $w^2 = \varphi_{tt}$, insertion in (1) gives; $2\mu\varphi_{tt} = -s + \left(\rho d_t\eta - \kappa(a/r)^2\right)\theta$. Linearised Taylor expansion of θ in gives now a harmonic oscillator for a sub-scale coordinate angle $\varphi(t)$, and thus, the Taylor expanded $\theta(\varphi)$. Hereby, from a spatial representation of temperature as sinus-hyperbolicus (φ), we obtained (on a sub-level) a time dependent harmonic oscillator for a sub-angle, *i.e.* $\varphi = \varphi_0\sin(\Omega_0 t)$, where Ω_0 is constant depending on material parameters, coordinate r and $\rho d_t\eta$.

4. Applications

A plausible application is the vascular system of fishes in the North Sea where it is cold. At the outside boundary of the fish, the flow creates whirl. This could be copied inside, but such a remote connection of shapes is not necessary to invoke in this modeling. It is sufficient to assume that any large scale kinetic energy from outside can be transferred to interior fluid with a density and a vorticity flow.

Another application, where whirls transform into other energy is when fishes move up in a fall, c.f. **Figure 1** and [3]. First, we may consider it as a quantised system with two states, namely down with whirls of energy *V*, and on its way almost up with energy $V\text{-}V_{pot}$. Looking in more details, it appears that the whirls provide an elastic ground to bump from. Then the description will materialize in spatial coordinates, but the input may remain similar with energies. Functional expressions while depending on coordinates in R^3 is explained in [1], as exemplified above.

5. Conclusions

The model shows how whirls can transform into a thermal energy-form determined by a functional relation for temperature. Solutions are evaluated in cylindrical coordinates, such that temperature is a function of angle.

Figure 1. Waterfalls and a whirly waterfall with Salmons swimming/jumping up.

The possibility for fishes of turning a larger scale kinetic energy into heat inside a system is probably the most important application in this respect.

Acknowledgements

To Dr Chaffin and Dr Pudikievicz for providing guidance and references.

References

[1] Starke, R. and Schober, G.A.H. (2016) Ab Initio Materials Physics and Microscopic Electromagnetism of Media. Subsection 4.1. Short Review of Thermodynamics. arXiv:1606.00445v2.

[2] Freund, L.B. (2014) Entropic Forces in the Mechanics of Solids. *Procedia IUTAM*, **10**, 115-124. https://doi.org/10.1016/j.piutam.2014.01.013

[3] https://www.youtube.com/watch?v=iM0mn5unvoM