# PLATYNEREIS DUMERILII CHAETAE: MECHANICAL LOADING ESTIMATION FROM KINEMATICS IN LARVA STAGE

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## 1. Introduction

Bristle worms (Polychaeta) take their name from the bundles of bristles (chaetae) borne by the appendages (parapodia) of their segmented body. Chaetae are extremely well-tailored chitinous extracellular beam-like structures, often combining materials with different density and texture, and exhibiting medullary and cortical channels of different size, stiffening diaphragm, joints, and teeth [1, 2].

On the one hand, the outward appearance of chaetae were extensively investigated by biologists as a means for the species determination [3]. On the other hand, chaetae turn out being an interesting case study for engineers. Indeed, deciphering the engineering principles of nature can improve the design and manufacturing of artificial structures. However, the systematic analysis of chaetae functions is at its very infancy.

### *1.1 Chaetae function and worm behavior*

Our research focuses on *Platynereis dumerilii*, a well-established laboratory reference species of bristle worms [4]. The mixed benthonic-pelagic lifestyle of *Platynereis dumerilii* suggests that chaetae have versatile functions during worm life. Furthermore, from the second to the seventh day of development, *Platynereis dumerilii* larvae have both chaetae bundles and ciliary bands (prototroch and metatroch) both used for swimming, rendering the perception of chaetae function a challenging task.

Qualitative analysis of swimming larvae have highlighted two different swimming strategies: (i) slow crawling-like movements, when larvae swim using chaetae and (ii) fast torpedo-like movements, when larvae swim using cilia. In particular, during torpedo-like swimming, chaetae are tightly attached to the animals bodies (Figure 1, left), while larvae stretch chaetae apart from the body for effective deceleration and swerve actions (Figure 1, right).

**Fig. 1.** P. Dumerilii larvae at the third day of development. Position of the chaetae during torpedo-like swimming (left) and decelerating (right) larvae.

### *1.2 Aims*

According to the considerations introduced in Section 1.1, inertial forces acting on larva body during decelerations are identified as an interesting estimator for the mechanical loads acting on the chaetae, allowing for the definition of a well-set engineering problem. Aiming at estimating the inertial forces, the present contribution discusses the procedure used for the evaluation of the accelerations experienced by *Platynereis dumerilii* larvae in laboratory conditions.

## 2. Materials and methods

Swimming *Platynereis dumerilii* early nectochaete (i.e., the development stage of larvae at 72 hours post fertilization) were filmed. Images were recorded with a frequency of 5 frames per second with a 5x magnification and a resolution of 1920 x 1080 pixels. Frames were processed with the software ImageJ. The positions $\boldsymbol{p}_i = (x_i, y_i)$ of the early nectochaete at time $t_i$ (for $i = 1 \ldots N_f$, being $N_f$ the total number of frames) have been recorded using a semi-automatic tracking procedure.

The instantaneous velocity $\boldsymbol{v}_i$ and acceleration $\boldsymbol{a}_i$ are estimated using finite difference formulas of second order of accuracy, reading

$$\boldsymbol{v}_i = \frac{p_{i+1} - p_{i-1}}{2\Delta t} \qquad (1)$$

$$\boldsymbol{a}_i = \frac{p_{i+1} - 2p_1 + p_{i-1}}{\Delta t^2} \qquad (1)$$

The unit vector tangent to the trajectory is evaluated as $\boldsymbol{t}_i = \boldsymbol{v}_i / |\boldsymbol{v}_i|$ and the tangential component of the acceleration was computed as $a_{t\,i} = \boldsymbol{a}_i \cdot \boldsymbol{t}_i$.

Globally, 5220 velocities and accelerations were recorded and analyzed. Since we are interested in the deceleration mechanism, we limited the statistical analysis to negative tangential accelerations $a^-_{t\,i}$ and we interpolate their absolute value distribution using a lognormal curve.

## 3. Results

Fig. 2 summarize the results obtained from the procedure described in Section 2. The interpolations based on a lognormal curve seems appropriate. Indeed, the obtained results are associated with an extremely low Root Mean Squared Error (RMSE) and a high coefficient of determination.

Maximal deceleration was estimated as the 98th percentile of lognormal curve, resulting equal to 5930 micron/sec$^2$. Knowing the mass of the larva, we estimated the inertial forces acting on the larvae. Finally, we estimated the chaetae maximal stress assuming that all the chaetae contribute equally to the deceleration of the larvae and modeling the chaetae as a cantilever with uniformly distributed load. The resulting maximal stress ranges between 10 and 100 Pa.

The obtained the maximal stresses looks small in comparison with the strength of chitin (ranging from 0.4 to 400 MPa, according to data available in literature [5, 6]). Such a result suggests that the considered loading mechanism is not significant for chaetae in considered stage development and environment conditions.

## 4. Conclusions

The proposed methodology has allowed to analyze fundamental kinematic quantities associated to the swimming of *Platinereis dumerilii* early nechtochaetae. The adopted interpolation has the capability to provide accurate and quantitative information on empirically observed phenomena, allowing for a simple preliminary analysis of the magnitude of loads acting on chaetae.

Future research will include the extension of the proposed analysis to other development stages of *Platinereis dumerilii* and more realistic life conditions, aiming at identifying loads inducing highest stresses.

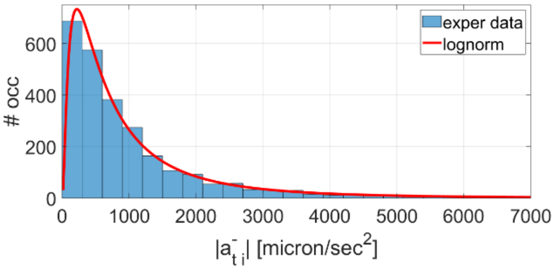

**Fig. 2.** Statistical distribution of recorded negative acceleration (fitting curve RMSE = 9.14E-6, coefficient of determination R2 = 0.998).

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