On interfacial instability as a cause of transverse subcritical bed forms

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Purpose

- Investigate feasibility of K-H instabilities for bed form initiation
Experimental Design

- Flume 1m wide; 15.2m long
- Flat Quartz sand Bed ($D_{50}$=0.5mm)

Table 1. Summary of Flow Parameters$^a$

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>$d$, m</td>
<td>0.152</td>
<td>0.152</td>
<td>0.153</td>
<td>0.153</td>
<td>0.153</td>
</tr>
<tr>
<td>$\bar{U}$, m s$^{-1}$</td>
<td>0.501</td>
<td>0.477</td>
<td>0.454</td>
<td>0.399</td>
<td>0.356</td>
</tr>
<tr>
<td>$S \times 10^{-4}$</td>
<td>12</td>
<td>11</td>
<td>7.0</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>$Fr$</td>
<td>0.411</td>
<td>0.391</td>
<td>0.370</td>
<td>0.326</td>
<td>0.290</td>
</tr>
<tr>
<td>$Re$</td>
<td>75936</td>
<td>72331</td>
<td>69568</td>
<td>61093</td>
<td>54580</td>
</tr>
<tr>
<td>$u_*$, m s$^{-1}$</td>
<td>0.030</td>
<td>0.026</td>
<td>0.022</td>
<td>0.017</td>
<td>0.016</td>
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<tr>
<td>$\tau_*$, Pa</td>
<td>0.902</td>
<td>0.650</td>
<td>0.481</td>
<td>0.291</td>
<td>0.242</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.111</td>
<td>0.080</td>
<td>0.059</td>
<td>0.036</td>
<td>0.030</td>
</tr>
</tbody>
</table>

$\theta_{cr}$ = 0.035
Mechanistic Model of Interfacial Instability

\[(u_1 - u_2)^2 < gL(\rho_2^2 - \rho_1^2)/(2\pi\rho_1\rho_2)\]

- Measured or Calculated
  - Grain vel. (Surface & Depth avg.)
  - Flow vel. (z= 5,2.5mm)
  - Shear vel.
  - Depth of transport layer
  - Transport rate
  - Mass of sand/water in transport layer
  - Active layer volume
  - Combined density

\[L_{H-K} = \frac{2\pi(u_1 - u_2)^2 \rho_1\rho_2}{g(\rho_2^2 - \rho_1^2)}\]

(Liu 1957)
Bed-form Initiation

1. Cross-hatch pattern
2. Chevron scallops
3. Migration and incipient crests
4. Crests straighten
5. Bed form grows
Link with K-H Waveform?

- Attempted to solve $L_{H-K}$ using measured and calculated variables
- Issues measuring $u_p$ and active transport layer thickness
- Compounded error range of 37-47% for values of $L_{H-K}$!
Conclusions

• There are at least 2 bed form initiation processes
  – Near entrainment threshold, bed defect dominates (see Venditti et al. 2005)
  – At flows well exceeding threshold, instantaneous process dominates

• K-H instabilities may be the initial mechanism (which means turbulence may not be necessary)

• Once K-H scales are exceeded, flow separation processes take over
A couple of references


More Videos:
http://www.sfu.ca/%7Ejvenditt/research.html
-and-
http://www.sfu.ca/%7Ejvenditt/appendices.html