The influence of impeller geometry on stirred mill performance

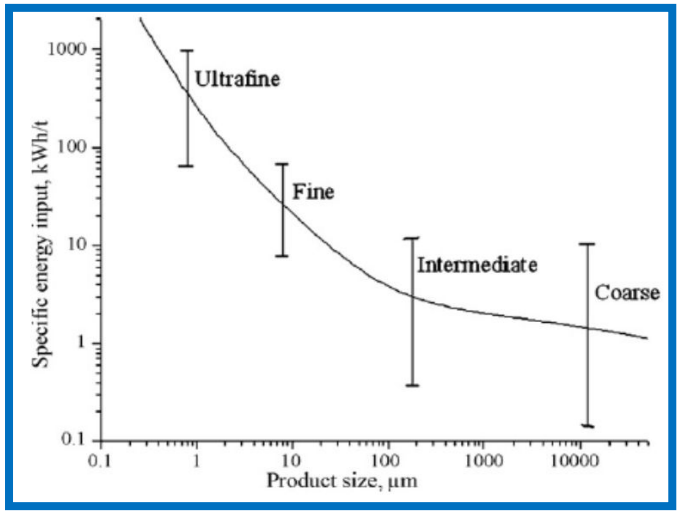
Collins Lekgoro[1,3], Sandile Nkwanyana[1], Niyoshaka Lameck[1], Indresan Govender[1, 2], T. Moodley[1,2], M. Ramakokovhu[3]

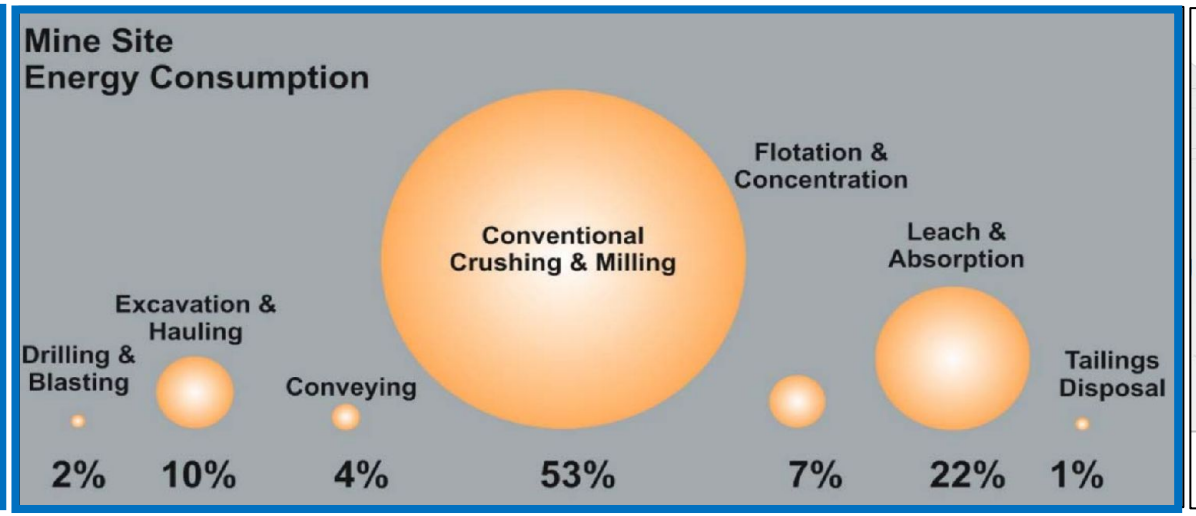
[1]Mintek, P/Bag X3015, Randburg, Gauteng, 2121, South Africa

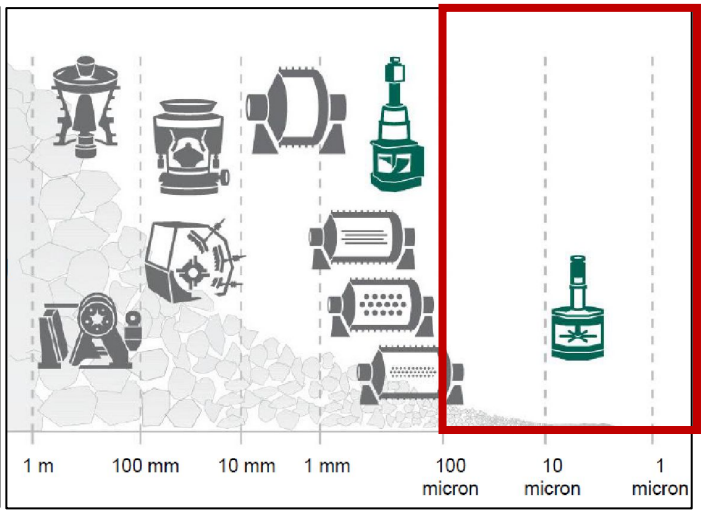
[2] School of Engineering, University of KwaZulu-Natal, Durban, South Africa

[3] Tshwane University of Technology, South Africa

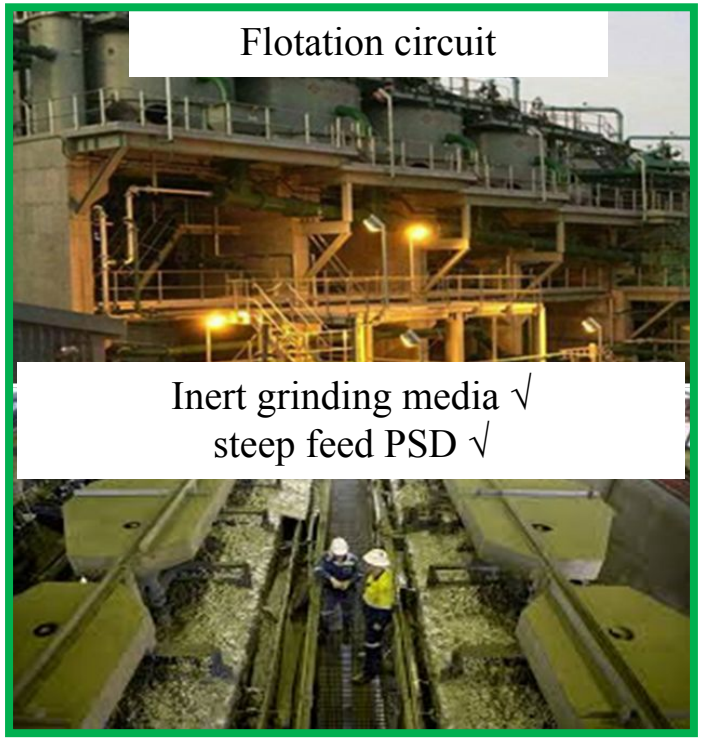
Introduction

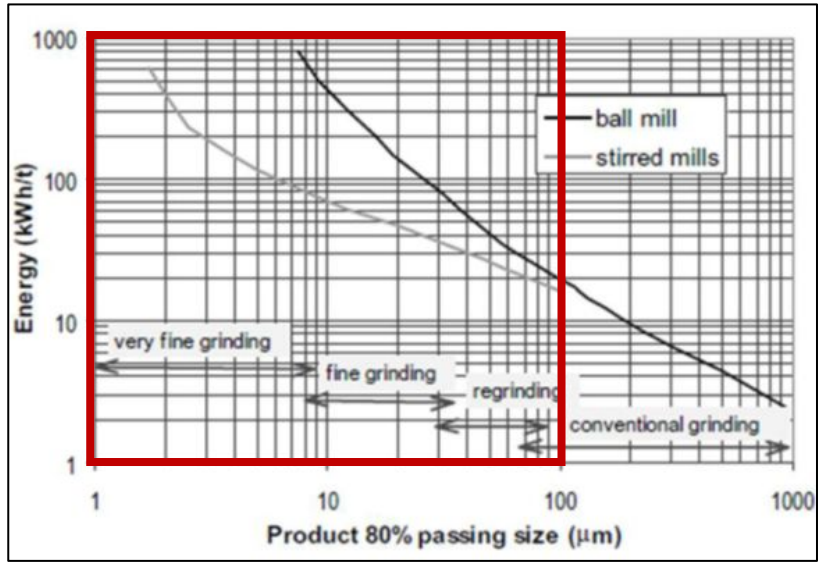






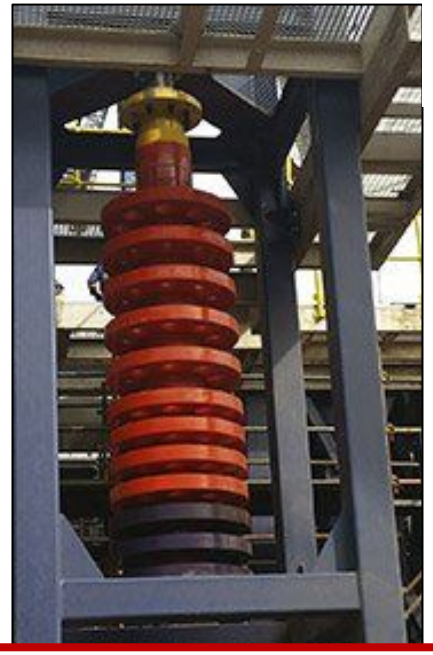
- Energy requirements for size reduction increases exponentially with product fineness.
- Grinding equipment with a superior energy efficiency is key to the viability of projects that require fine/ultrafine grinding.
- Stirred mills are more energy efficient than ball-mills in fine/ultrafine grinding.
- Most stirred mills use inert ceramic beads.
- Stirred mills produce a product with a steep PSD compared to ball mills.



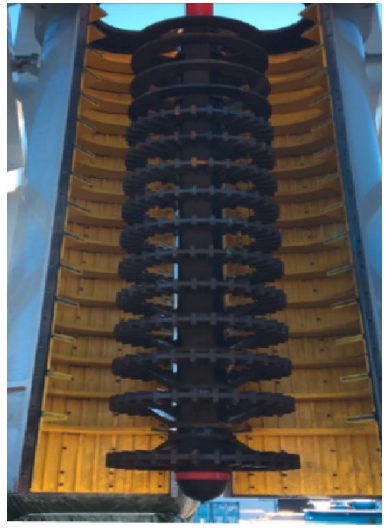


Pin disc impeller

Fluidized stirred mills



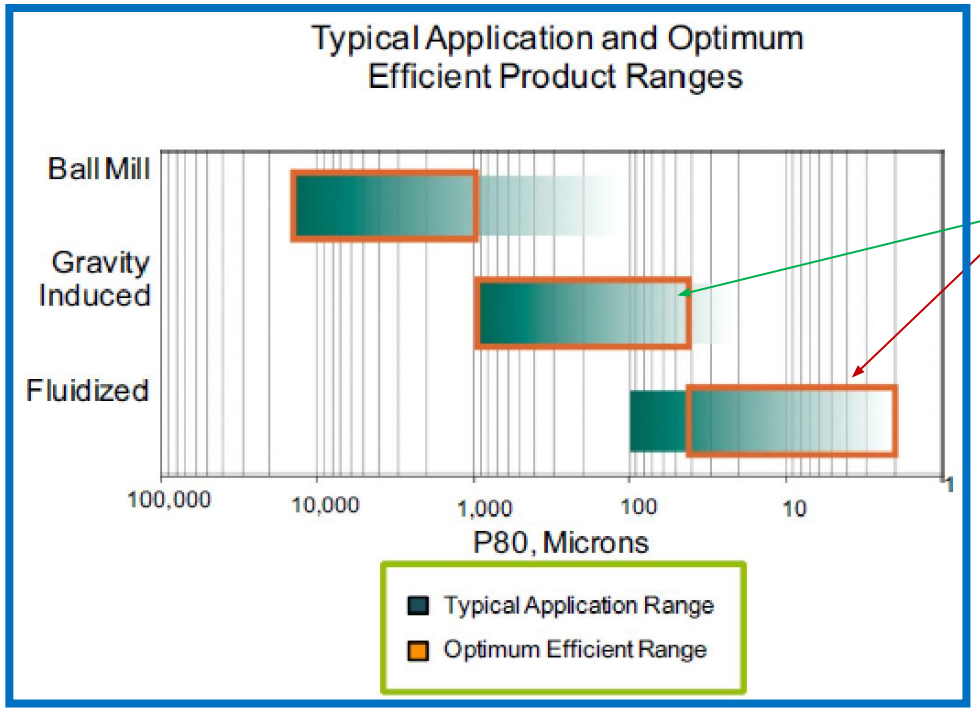
Perforated disc impeller



Modified ring disc impeller

Screw impeller

Gravity induced stirred mill

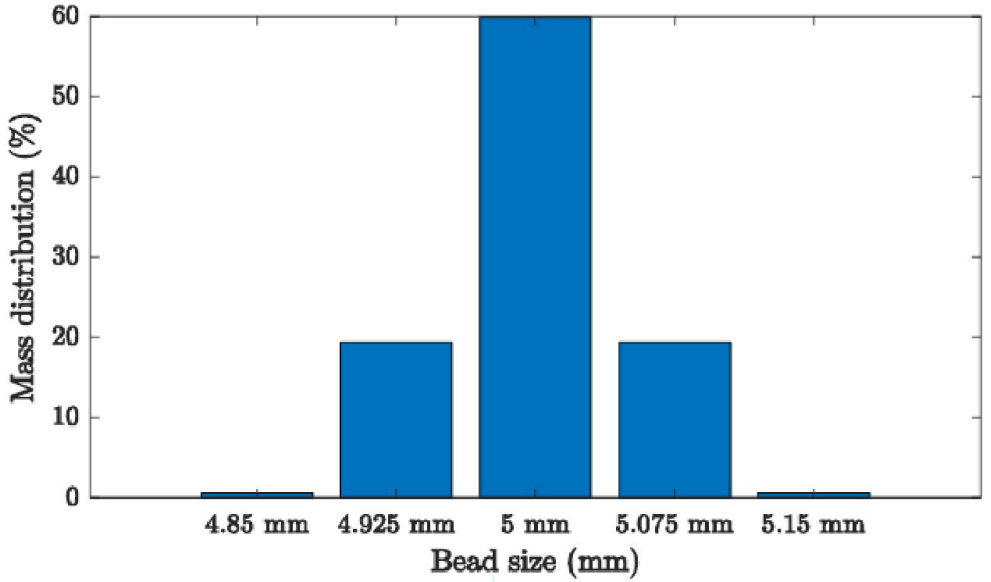


- In some cases, the feed F_{80} is suitable and target product P_{80} is achievable in all fluidized stirred mills.
- In such cases, how does the grinding performance of the fluidised stirred mills compare?
- The grinding performance can be inferred from the collision environment.
- DEM simulations were conducted (using Ansys ROCKY®) to explore the collision environment created by vertical fluidised stirred mills.

Overview of the simulations

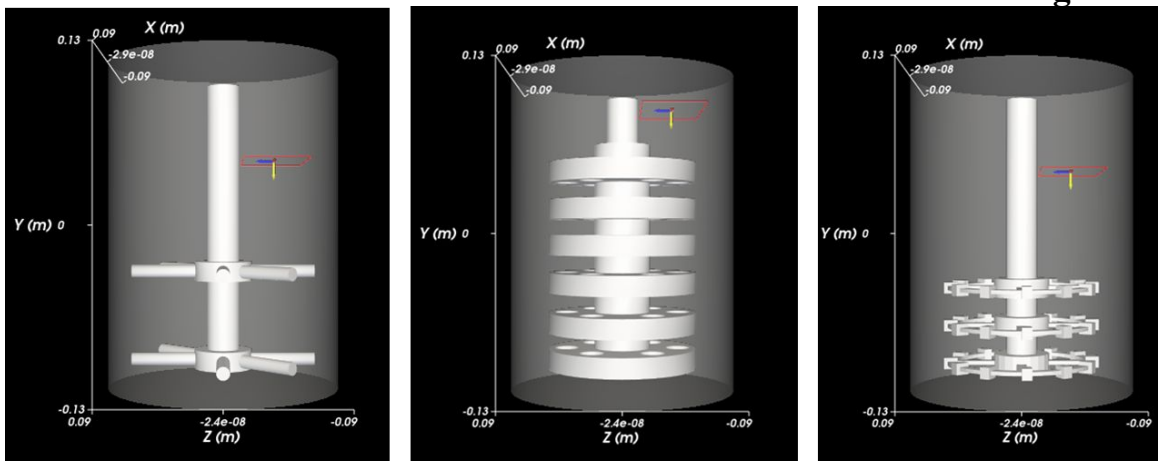
Mill dimensions and simulation set up

Mill dimensions (D×L)	18 cm × 23 cm
Tip speed	4 – 12 m/s
Mill loading	45%
Bead density	2700 kg.m^{-3}
Bead size	5 mm
Coefficient of restitution	ceramic-steel = 0.5 ceramic-ceramic = 0.6
Coefficient of friction	ceramic-steel = 0.3 ceramic-ceramic = 0.4



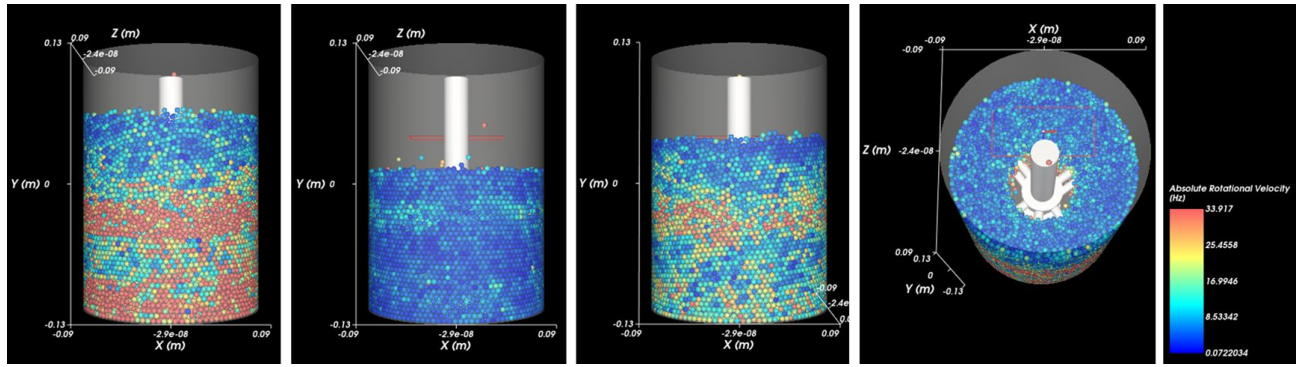
Side views **Top view**

Pin disc **Perforated disc** **Modified ring disc**



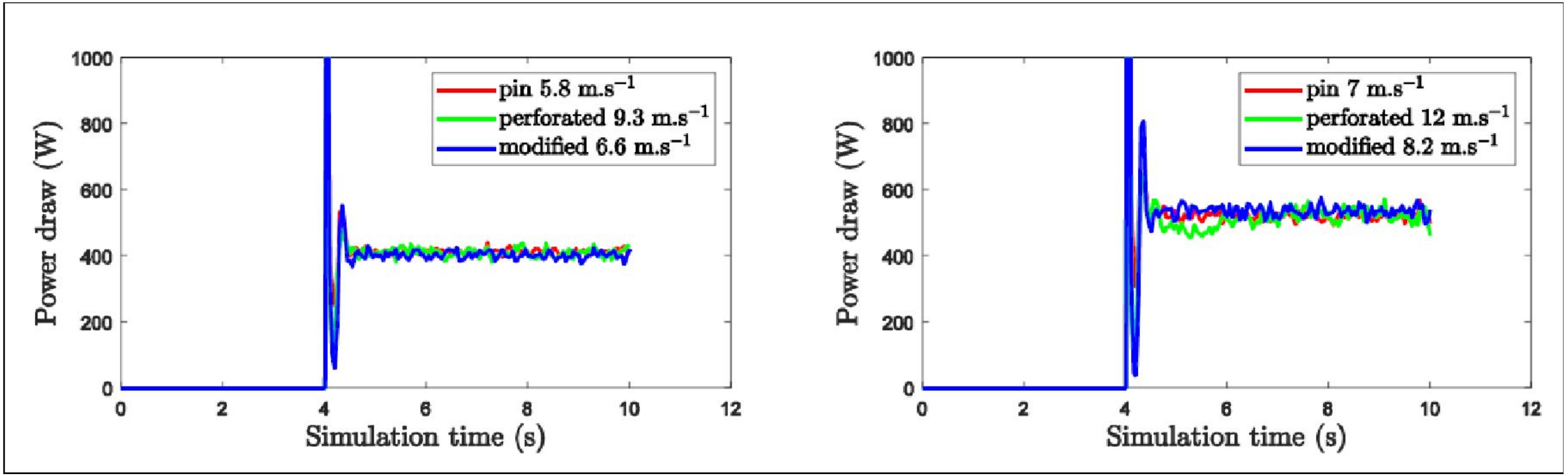
Impeller geometries

Pin disc **Perforated disc** **Modified ring disc** **Pin disc**



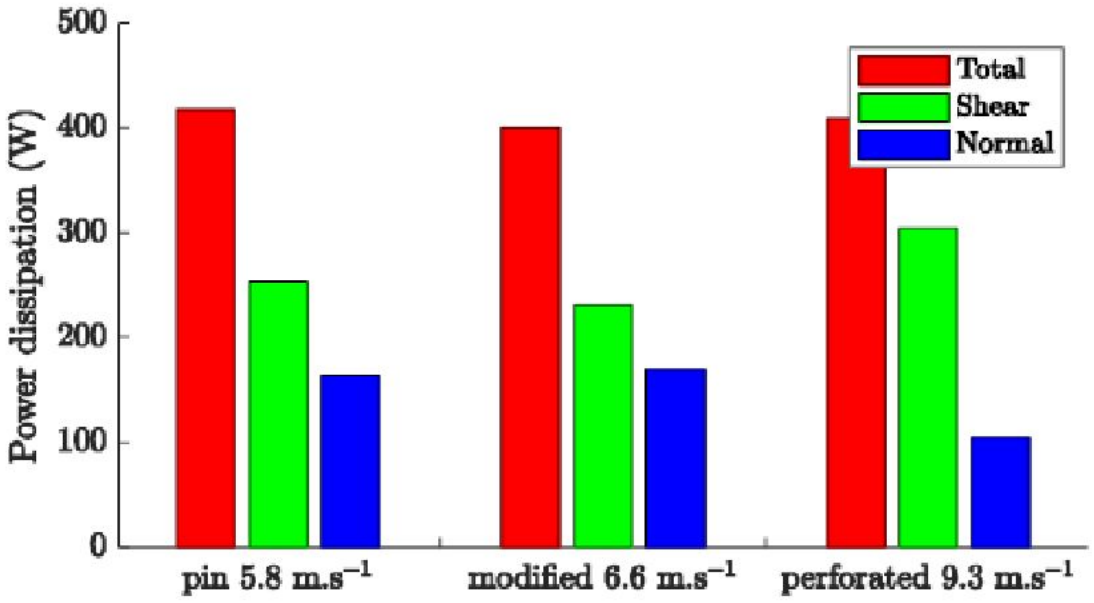
Beads rotational velocities

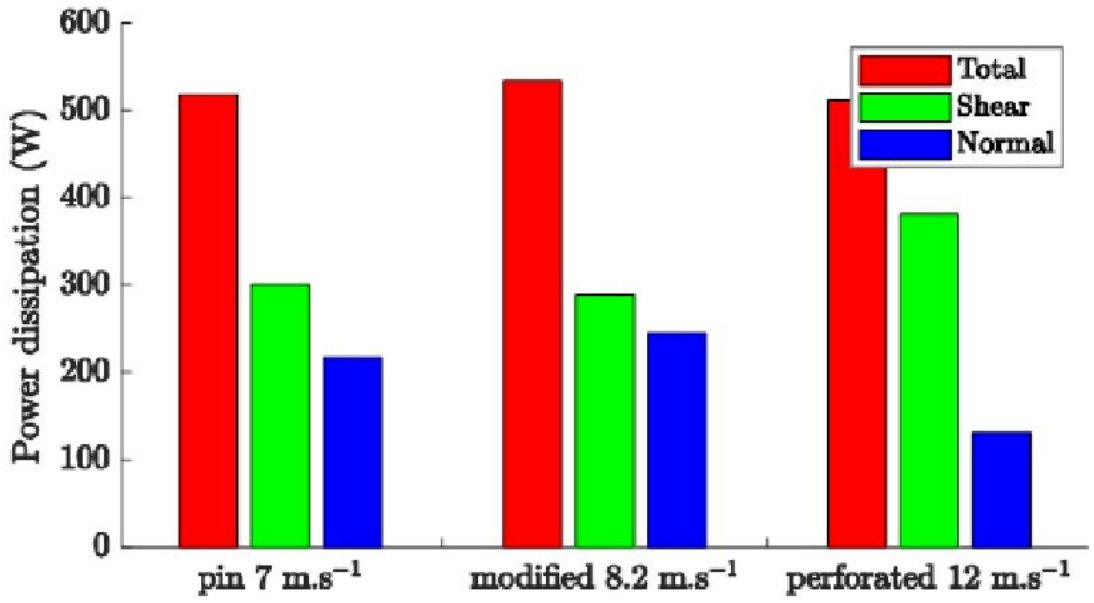
Power consumption



- Comparable power draw is key when comparing performance of grinding mills.
- Pin disc at 5.8 m/s draws comparable power as the modified ring disc at 6.6 m/s and the perforated disc at 9.3 m/s.
- Average power: pin disc @ 5.8 m/s 413 W, modified ring disc @ 6.6 m/s 402 W and perforated disc at 9.3 m/s 408 W.
- Pin disc at 7.0 m/s draws comparable power as the modified ring disc at 8.2 m/s and the perforated disc at 12 m/s.
- Average power: pin disc @ 7.0 m/s 520 W, modified ring disc @ 8.2 m/s 535 W and perforated disc at 12 m/s 521 W.

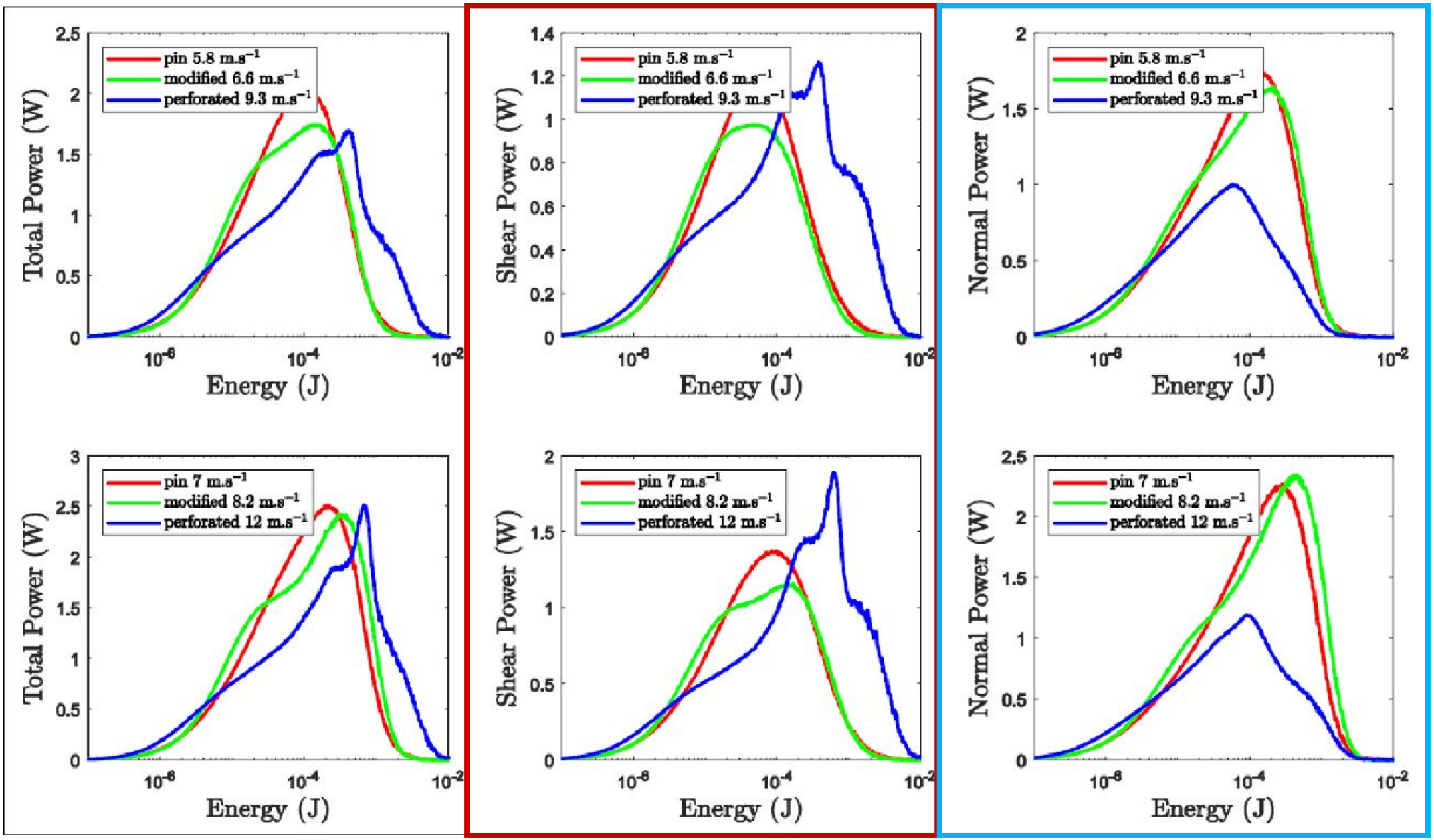
Distribution of Collision Power



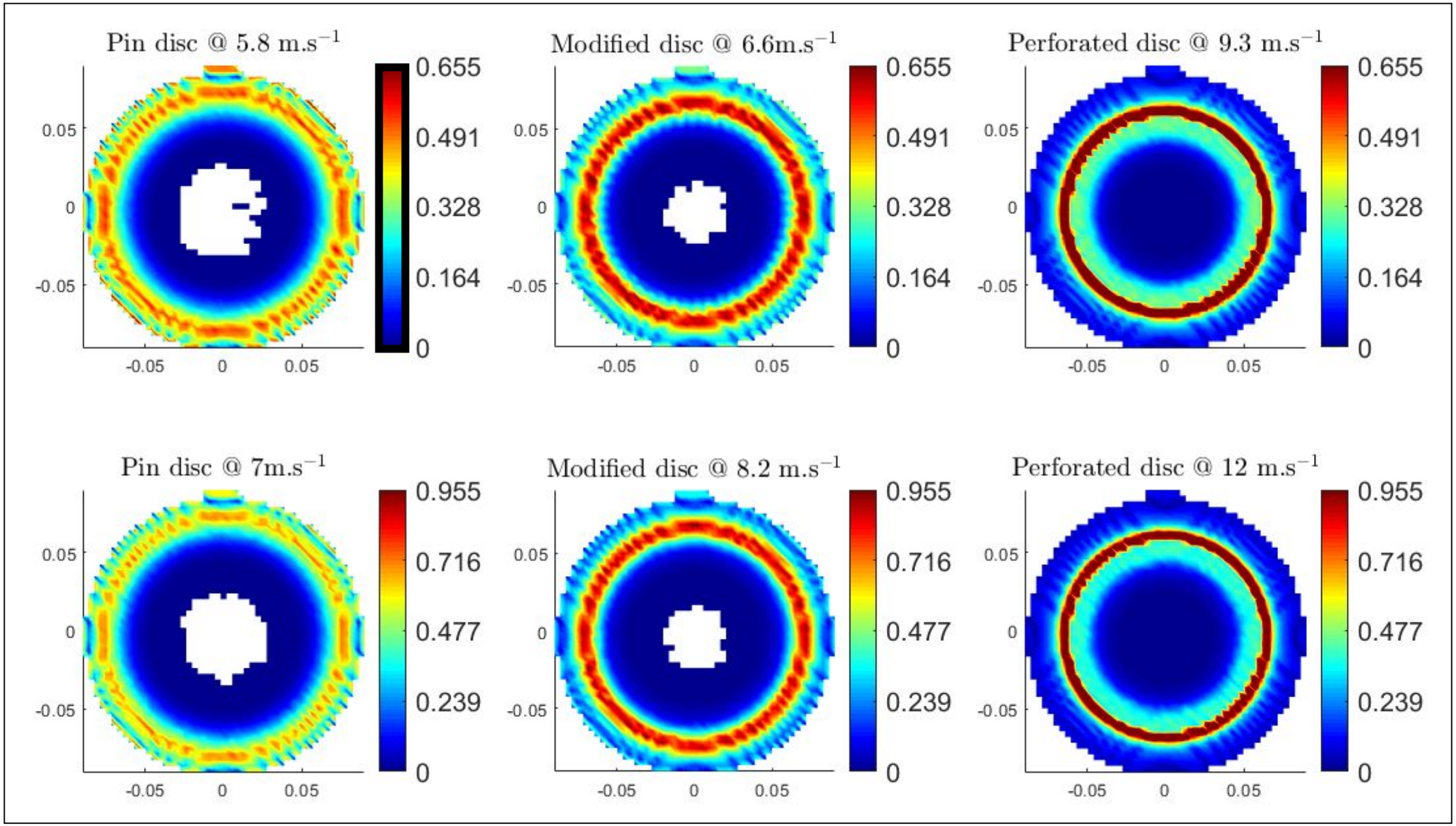


- Shear/normal ratio: 65/35 (pin disc @ 5.8 m/s), 64/36 (modified ring @ 6.6 m/s) and 75/25 (perforated disc @ 9.3 m/s).
- Shear/normal ratio: 63/37 (pin disc @ 7.0 m/s), 60/40 (modified ring @ 8.2 m/s) and 75/25 (perforated disc @ 12 m/s).
- Pin disc and modified ring disc impeller could yield similar grinding performance.
- Perforated disc grinding performance is expected to be different from that of pin disc and modified ring disc impellers.

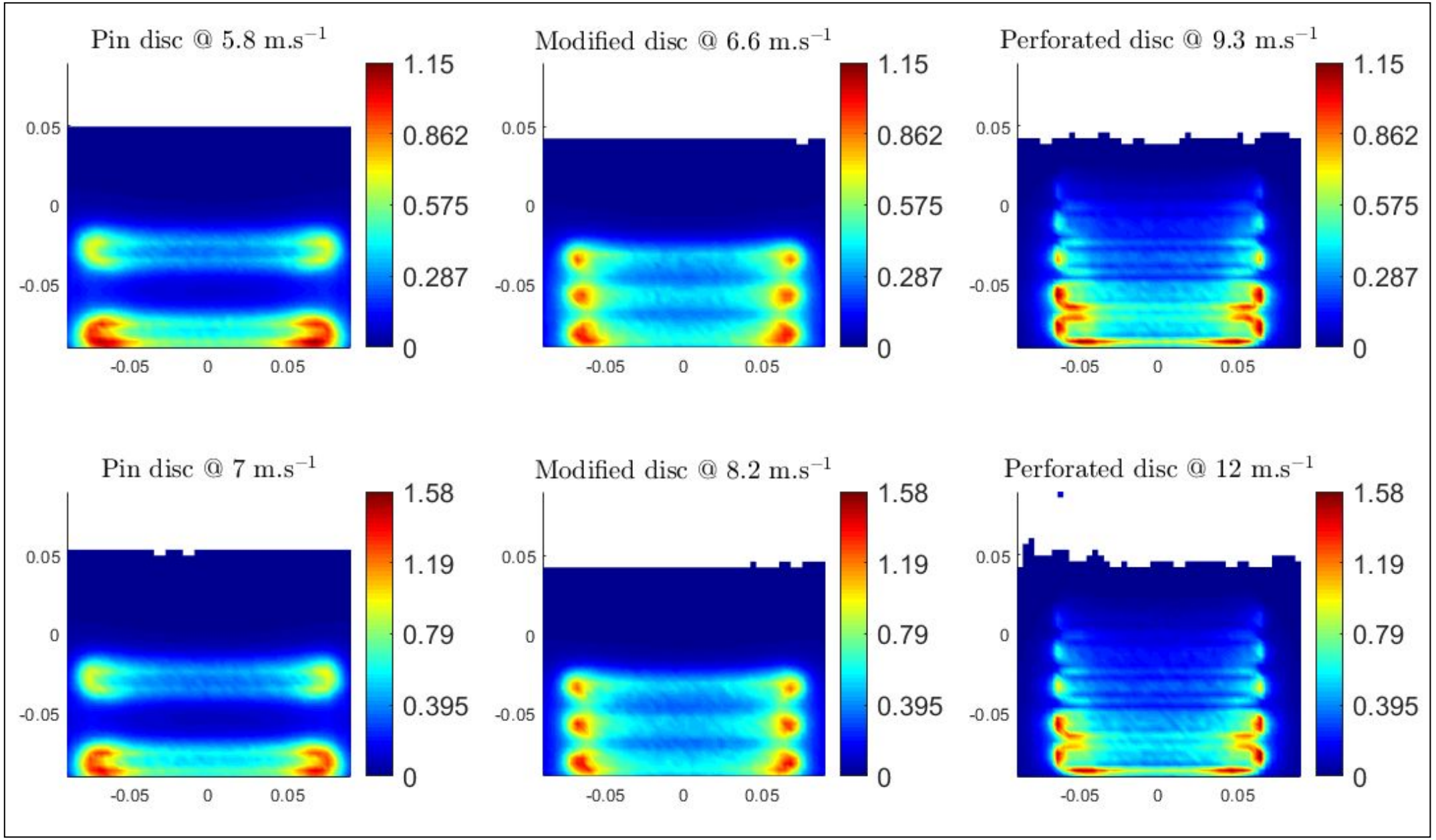
Collision Energy Spectra



Spatial Maps of Power Dissipation



Spatial Maps of Power Dissipation



CONCLUSIONS

- A mill fitted perforated disc impeller requires more discs to achieve comparable power to a mill fitted with a modified ring or pin disc impeller.
- The shear and normal components of collisions dissipate significant power and hence it can be argued the two are both important in grinding.
- It is expected that the ranking of grinding performance from the impellors, from high to low, will be:– modified ring disc – pin disc – perforated disc.
- The disc edges and the lower discs are expected to wear faster.
- It is expected that the ranking of the wear of the internals, from highest to lowest, will be: perforated disc – pin disc – modified ring disc.
- The disc diameter should be large enough to maximise power draw, but should be carefully reduced, when necessary, to ensure that the annular region of high power dissipation does not reach the grinding chamber wall.