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Hausner Ratio and Carr Index

Interpretation Guide

From result to mechanism to next test

Use this guide when:

- a Hausner Ratio or Carr Index result is unexpectedly high or has changed;
- a value is being used to support a process or equipment decision;
- you need to distinguish aeration, packing geometry, cohesion, or test-history effects;
- you need to decide what to measure next.

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How to Use This Guide

Hausner Ratio and Carr Index quantify the difference between an initial bulk packing state and the denser state produced by tapping. They can show that a powder rearranged substantially during the test. They cannot determine why that rearrangement occurred.

INTERPRETATION ROUTE

1. **RESULT**
   Record what was measured.
2. **CONTEXT**
   Check how the sample reached its starting state.
3. **MECHANISM**
   Compare supporting and contradicting evidence.
4. **DECISION**
   Define what the result is being used to decide.
5. **NEXT TEST**
   Select the measurement needed to resolve what remains unknown.

INTERPRETATION RULE

The classification range describes the size of the density change. It does not identify the physical mechanism behind it.

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Before You Interpret the Result

Four checks should come before classification. A changed ratio is not automatically a changed powder property.

1. Was the measurement comparable?

- Same method or SOP
- Same cylinder size and sample mass
- Same filling procedure
- Same tapping conditions and endpoint criterion
- Acceptable replicate agreement

If no: repeat under comparable conditions before interpreting a difference.

2. Was the starting powder state comparable?

- Freshly produced or recently milled
- Conveyed or transported
- Vibrated or stored
- Pre-compacted or consolidated
- Aerated during handling
- Exposed to different humidity or temperature

If no or unknown: the difference may reflect sample history rather than a changed powder property.

3. Does the laboratory state represent the process state?

- Does the process powder arrive loose and freshly poured?
- Has it already been conveyed, stored, deaerated, vibrated, or consolidated?
- Does the process impose a different stress or residence history before the point of concern?

If the states differ: the laboratory ratio may describe a transition that does not occur in the same way in the process.

4. Is this an isolated value or a change from baseline?

- Established material-specific baseline: stronger interpretation value
- First result on a new material: screening information only

A shift from a stable baseline is usually more informative than an isolated classification value.

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Interpret the Number

WORKED EXAMPLE

Bulk density: 0.48 g/mL

Tapped density: 0.65 g/mL

HR = 0.65 / 0.48 = 1.35

CI = ((0.65 - 0.48) / 0.65) x 100 = 26.2%

CONVENTIONAL CLASSIFICATION

Carr Index (%)	Hausner Ratio	Conventional description
≤10	1.00-1.11	Excellent
11-15	1.12-1.18	Good
16-20	1.19-1.25	Fair
21-25	1.26-1.34	Passable
26-31	1.35-1.45	Poor
32-37	1.46-1.59	Very poor
>38	>1.60	Very, very poor

WHAT THE CLASSIFICATION CAN DO

- Describe the magnitude of the packing-state change
- Flag drift from an established baseline
- Compare similar materials tested under equivalent conditions
- Trigger further investigation

WHAT IT DOES NOT ESTABLISH

- Cohesion or arching tendency
- Wall adhesion or hopper geometry
- Feeder suitability or permeability
- The active segregation mechanism

Classification ranges adapted from USP General Chapter ‹1174› Powder Flow, Table 2 (official revision effective 1 May 2024).

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Mechanism Triage Matrix

Mechanisms are not mutually exclusive. Evidence may support more than one pathway at the same time. Start with observations and evidence - never select a mechanism from the HR or CI range alone.

AIR AND STARTING STATE

Aeration and slow air release

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Very low freshly poured bulk density; visible settling; behaviour differs before and after rest; refill or transfer creates temporary instability.	Bulk density increases with rest time; volume decreases without external load; process density differs from freshly poured density; stabilization takes time after filling.	Volume remains stable after filling; similar result after pre-deaeration; symptoms persist after air effects are controlled.	Rest-time density profile; deaeration behaviour; permeability; process-state bulk density.

PACKING GEOMETRY

Irregular particle shape

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Angular, elongated, rough, or platy particles; high void volume; inefficient initial packing; material may still discharge reasonably well.	Imaging confirms non-spherical morphology; little resting-time density change; limited humidity sensitivity; weak evidence of cohesive strength development.	Nearly spherical morphology; strong humidity dependence; strong consolidation sensitivity; time-dependent settling dominates.	Particle imaging; shape analysis; PSD; shear testing if the process decision requires it.

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PACKING GEOMETRY

Particle size distribution and packing structure

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Broad or multimodal PSD; fines occupy voids between coarse particles; strong packing changes during tapping; batch variation tracks PSD changes.	Fines or coarse fraction changed; bimodal or broad distribution; HR/CI shift tracks PSD; packing density changes without matching moisture change.	Stable PSD across compared lots; narrow distribution; stronger correlation with humidity or sample history.	Full PSD comparison; fines-fraction analysis; size-class comparison; imaging where agglomeration is suspected.

COHESION AND SURFACE FORCES

Cohesive fines and consolidation

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Fine powder; agglomeration; poor discharge; arching or ratholing; erratic feeding; behaviour worsens after storage or under load.	High fines fraction; increased unconfined strength under consolidation; handling difficulty worsens with load; HR/CI drift tracks fines change.	Coarse free-flowing material; low strength under consolidation; behaviour dominated by air release; stable handling despite a high index value.	Shear cell; PSD with adequate fines resolution; agglomerate imaging; process observation under representative load.

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Mechanism Triage Matrix

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COHESION AND SURFACE FORCES

Moisture, humidity, and other surface-force effects

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Result changes with weather, RH, storage environment, or transfer history; caking, lumping, surface adhesion, or charging appears.	Measurable moisture change; strong RH dependence; systematic environmental trend; charging after transfer; increased strength after conditioning.	Stable behaviour across controlled humidity; no moisture change; same result under dry conditions; no transfer-history dependence.	Moisture analysis; controlled humidity comparison; sorption behaviour where relevant; electrostatic assessment; shear test after conditioning.

MEASUREMENT CONTEXT

Sample history or test-procedure effects

Typical observations	Evidence that supports it	Evidence against it	Next test or check
Unexpectedly low or changed HR/CI; high initial bulk density; poor replicate agreement; operator, site, or preparation differences.	Transport, storage, or pre-compaction history differs; result changes after controlled sample preparation; tap settings, cylinder, or endpoint changed.	Fully controlled repeat procedure; reproducible shift across independent measurements and comparable sample histories.	Repeat under controlled SOP; compare as-received and standardized states; replicate and inter-operator checks; equipment verification.

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One Result, Three Different Interpretations

Same measured result

HR = 1.35 CI = 26%

Conventional classification: Poor

AERATED SPRAY-DRIED POWDER

WHAT THE RESULT MAY REFLECT
A low-density initial state containing significant interparticle air.

DO NOT ASSUME
Strong cohesion or a need for a larger hopper outlet.

SUPPORTING EVIDENCE
Density rises during resting; volume falls with time; recent conveying or production affects the result.

RELEVANT NEXT CHECKS
Deaeration; permeability; process-state bulk density.

IRREGULAR MINERAL FILLER

WHAT THE RESULT MAY REFLECT
Inefficient packing caused by angular or elongated particle geometry.

DO NOT ASSUME
That the conventional "poor" classification means severe cohesive failure.

SUPPORTING EVIDENCE
Irregular morphology; stable behaviour across humidity; limited time-dependent settling.

RELEVANT NEXT CHECKS
Particle imaging; shape; PSD; process-specific flow testing where required.

COHESIVE FINE POWDER

WHAT THE RESULT MAY REFLECT
Surface-force-driven resistance to rearrangement and strength development under consolidation.

DO NOT ASSUME
That deaeration alone explains the volume change.

SUPPORTING EVIDENCE
High fines content; agglomeration; consolidation sensitivity; humidity sensitivity.

RELEVANT NEXT CHECKS
Shear testing; fines distribution; moisture or humidity sensitivity.

The number describes the result of the test. The surrounding evidence determines what the result means.

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Match the Process Decision to the Next Test

Choose the next test from the decision you need to make, not from the HR or CI value alone.

Decision or problem	What HR/CI can contribute	What remains unknown	Relevant next measurement
Batch-to-batch QC	Detect drift from an established baseline.	What changed physically.	Review sample history, PSD, moisture, bulk density, then target the follow-up.
Incoming material comparison	Fast comparison between nominally similar materials.	Whether the difference matters in the process.	Select based on the expected failure mechanism and process condition.
Hopper outlet sizing	Screening context only.	Cohesive strength and critical arching behaviour.	Shear testing.
Mass-flow hopper design	Insufficient as a design input.	Wall interaction and required hopper geometry.	Wall friction plus relevant shear data.
Feeder instability	Shows that packing state may vary.	Air retention, stress response, process-state density, screw-channel fill.	Process bulk density; permeability/deaeration; shear behaviour according to symptom.
Post-refill instability	May flag a large loose-to-settled density difference.	How quickly the material releases air and stabilizes.	Deaeration; permeability; density versus time.
Segregation risk	Limited contextual signal.	Dominant segregation mechanism and behaviour of the actual blend.	Blend-specific PSD/density comparison and mechanism-specific segregation assessment.
Arching or ratholing	Cannot diagnose the failure mechanism.	Strength development under consolidation.	Shear testing and hopper-specific evaluation.
Storage caking	Possible screening clue only.	Time, load, and environmental effects.	Time consolidation; moisture/humidity assessment; caking-specific testing.

Field rule: choose the next test from the decision you need to make, not from the HR or CI value alone.

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The Number Changed: What to Check Before Acting

A reproducible difference deserves attention. It still needs to survive checks for method, state, and context before it becomes a process conclusion.

1. **Confirm the result**
   Repeatability, method, cylinder, sample mass, tapping conditions, and endpoint.

2. **Compare the starting state**
   Sample history, aeration, transport, vibration, storage, and consolidation.

3. **Check obvious material changes**
   PSD, fines fraction, moisture, morphology, agglomeration, and environmental exposure.

4. **Use the mechanism matrix**
   What evidence supports and contradicts each explanation? More than one pathway may remain plausible.

5. **Define the process decision**
   What are you actually trying to determine: QC drift, feeder instability, hopper behaviour, segregation, or storage response?

6. **Select the next test**
   Use the decision table on page 8 to resolve the information that remains unknown.

WHAT TO DO NEXT

PROCEDURE OR SAMPLE HISTORY CHANGED	Repeat under controlled and comparable conditions before interpreting.
RESULT CHANGED, MECHANISM UNCERTAIN	Use the mechanism triage matrix on pages 4-6.
MECHANISM PLAUSIBLE, PROCESS CONSEQUENCE UNCERTAIN	Select the next test from the process-decision table on page 8.