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TECHNICAL GUIDES

Crushing Circuit Design: Open vs Closed Circuit Selection for Your Application

Compare open and closed circuit crushing. Design considerations, product quality, and capacity impacts for aggregate plant circuit selection.

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Circuit design fundamentally determines crushing plant performance, product quality, and operating costs. The choice between open and closed circuit crushing—and how these circuits are configured—affects capacity, product gradation, wear costs, and energy consumption. Understanding circuit design principles enables plant engineers to optimize existing operations and make informed decisions about new installations.

Understanding Circuit Configurations

Open Circuit Crushing

In open circuit crushing, material passes through the crusher once without screening and recirculation:

Process flow:

```
Feed → Crusher → Product
(All material reports to product regardless of size)
```

Characteristics:

- Simple layout with minimal equipment
- Lower capital cost
- Broader product gradation
- Higher percentage of oversize in product
- Crusher CSS determines maximum product size

Closed Circuit Crushing

Closed circuit crushing includes screening after the crusher with oversize material returning for recrushing:

Process flow:

```
Feed → Crusher → Screen → Undersize (Product)
                    ↓
              Oversize → Back to Crusher
```

Characteristics:

- Defined maximum product size (screen aperture)
- Higher equipment count (screen, conveyors)
- Higher capital cost
- Recirculating load increases crusher throughput requirement
- More consistent product gradation

Circuit Configuration Comparison

PARAMETER	OPEN CIRCUIT	CLOSED CIRCUIT
Capital cost	Lower	20-40% higher
Product size control	Limited (CSS dependent)	Precise (screen controlled)
Product uniformity	Variable	More consistent

PARAMETER	OPEN CIRCUIT	CLOSED CIRCUIT
Crusher utilization	100% new feed	New feed + recirculation
Crusher wear	Lower	Higher (more throughput)
Plant complexity	Simple	More complex
Operating flexibility	Limited	Greater

Recirculating Load Analysis

Understanding Recirculating Load

Recirculating load is the ratio of material returning to the crusher versus new feed:

```
Recirculating Load (%) = (Screen oversize ÷ New feed) × 100

Example:
New feed: 200 TPH
Screen oversize returning: 80 TPH
Total crusher feed: 280 TPH
Recirculating load: 80 ÷ 200 × 100 = 40%
```

Factors Affecting Recirculating Load

FACTOR	EFFECT ON RECIRCULATING LOAD
Crusher CSS wider	Increases (more oversize product)
Screen aperture smaller	Increases (stricter size control)
Feed size larger	Increases (requires more reduction)
Rock hardness higher	Increases (less breakage per pass)
Crusher type change	Varies (different reduction ratios)

Typical Recirculating Load Ranges

CRUSHER TYPE	APPLICATION	TYPICAL RECIRCULATING LOAD
Cone crusher	Coarse closed circuit	15-25%
Cone crusher	Fine closed circuit	25-50%
HSI crusher	Closed circuit	20-35%
VSI crusher	Closed circuit (M-sand)	30-60%

Crusher Sizing for Closed Circuits

Capacity Calculation with Recirculation

The crusher must handle both new feed and recirculating load:

```
Required crusher capacity = New feed × (1 + Recirculating load fraction)

Example for 200 TPH new feed requirement:
Expected recirculating load: 40%
Required crusher capacity: 200 × (1 + 0.40) = 280 TPH

Add 15-20% margin for variability:
Specified crusher capacity: 280 × 1.15 = 322 TPH
Select crusher rated for 325+ TPH
```

Screen Sizing for Closed Circuits

The screen must handle total crusher discharge:

```
Screen feed = Total crusher discharge
Screen feed = New feed × (1 + Recirculating load)

Required screen area = Screen feed ÷ Specific capacity

Example:
Screen feed: 280 TPH
Material: 0-40mm crushed rock
Aperture: 20mm
Specific capacity: 35 t/h/m² (from manufacturer data)
Required area: 280 ÷ 35 = 8.0 m²
Select 6' × 16' (1.8m × 4.9m) = 8.8 m² screen
```

Multi-Stage Circuit Design

Two-Stage Crushing

Primary + secondary crushing for aggregate production:

```
Stage 1: Jaw crusher (open circuit typically)
   Feed: ROM rock 0-600mm
   Product: 0-150mm
   Reduction ratio: 4:1

Stage 2: Cone or HSI crusher (closed circuit)
   Feed: 0-150mm from scalping
   Product: Specified sizes to 25mm
   Reduction ratio: 3-4:1
```

Three-Stage Crushing

For finer products including manufactured sand:

```
Stage 1: Primary jaw crusher
   Feed: 0-700mm
   Product: 0-150mm

Stage 2: Secondary cone crusher
   Feed: 0-150mm (scalped)
   Product: 0-50mm
   Circuit: Open or closed

Stage 3: Tertiary cone or VSI
   Feed: 0-40mm
   Product: Final products including M-sand
   Circuit: Closed for M-sand
```

Stage Configuration Comparison

CONFIGURATION	FINAL PRODUCT	RELATIVE COST	APPLICATION
Two-stage open	-40mm or larger	1.0×	Base course, fill material
Two-stage closed	Sized aggregates to 20mm	1.3×	Road base, concrete aggregate
Three-stage open/ closed	Products to 10mm + sand	1.6×	Full aggregate range
Three-stage with VSI	M-sand to IS 383	1.8×	Manufactured sand production

Application-Specific Circuit Selection

Road Base Material (WMM/GSB)

Requirements:

- Gradation to IRC specifications
- Maximum size 40mm or 25mm
- Controlled fines content

Recommended circuit:

```
Primary jaw → Scalping screen → Secondary cone (closed circuit)
                    ↓
               Direct to WMM stockpile

Closed circuit controls maximum size
Screen at 40mm or 25mm depending on specification
```

Concrete Aggregate Production

Requirements:

- Multiple size fractions (20mm, 12mm, 6mm)
- Controlled flakiness index
- Tight gradation limits

Recommended circuit:

```
Primary jaw → Scalping screen → Secondary cone (closed at 25mm)
                                        ↓
                                Product screen (multi-deck)
                                     ↓   ↓    ↓
                                  20mm 12mm  6mm stockpiles

Closed circuit ensures no oversize
Multiple screen decks separate products
```

Manufactured Sand (M-Sand) Production

Requirements:

- IS 383 Zone II gradation
- Low micro-fines content
- Proper particle shape

Recommended circuit:

```
Primary jaw → Scalping → Secondary cone → Tertiary VSI (closed at 4.75mm)
                                                  ↓
                                            Sand classification
                                             ↓           ↓
                                         M-sand       Reject/silt
```

Circuit Optimization Strategies

Balancing Recirculating Load

Optimal recirculating load varies by objective:

OBJECTIVE	RECIRCULATING LOAD TARGET	STRATEGY
Maximize new feed capacity	Minimize (15-25%)	Wider CSS, larger screen aperture
Product shape improvement	Higher (40-60%)	Tighter CSS, multiple passes improve shape
Tight gradation control	Moderate (25-40%)	Balance throughput vs quality
Minimize wear costs	Minimize (15-25%)	Reduce crusher throughput

CSS vs Screen Aperture Relationship

Optimizing the relationship between crusher CSS and screen aperture:

```
Rule of thumb:
Screen aperture ≈ 1.2 to 1.5 × Crusher CSS

Example for 25mm screen product:
Screen aperture: 25mm
CSS range: 25 ÷ 1.5 to 25 ÷ 1.2 = 17 to 21mm
Optimal CSS: 19-20mm

Tighter CSS (17mm): More recirculation, better shape
Wider CSS (21mm): Less recirculation, higher capacity
```

Reducing Recirculating Load

Strategies to reduce recirculation when capacity-limited:

- Open CSS slightly (within product spec allowance)
- Increase screen aperture if product spec allows
- Upgrade to higher-reduction-ratio crusher
- Improve scalping to reduce crusher feed size

- Add pre-screening to bypass already-sized material

Economic Analysis: Open vs Closed Circuit

Capital Cost Comparison

Additional equipment for closed circuit:

EQUIPMENT	APPROXIMATE COST (RS)
Product screen (6'×16')	30,00,000
Return conveyor (20m)	8,00,000
Structural steel	5,00,000
Electrical and controls	3,00,000
Total additional	**46,00,000**

Operating Cost Comparison

Annual operating costs for 200 TPH plant:

COST ITEM	OPEN CIRCUIT	CLOSED CIRCUIT
Crusher wear (40% higher throughput)	Rs 15,00,000	Rs 21,00,000
Screen wear and maintenance	-	Rs 3,00,000
Additional power (screen + conveyor)	-	Rs 2,50,000
Product value uplift (per IS specs)	-	(Rs 15,00,000) credit
Net annual impact	**Rs 15,00,000**	**Rs 11,50,000**

Payback Calculation

```
Additional capital: Rs 46,00,000
Annual savings: Rs 15,00,000 - Rs 11,50,000 = Rs 3,50,000
(Plus product value improvement not quantified)

Simple payback: 46,00,000 ÷ 3,50,000 = 13 years

If product commands Rs 50/tonne premium:
Annual production: 500,000 tonnes
Premium value: Rs 2,50,00,000
Revised payback: < 1 year
```

Circuit Monitoring and Control

Key Operating Parameters

PARAMETER	MONITORING METHOD	CONTROL RESPONSE
Crusher power draw	kW meter	Adjust feed rate, CSS
Screen efficiency	Sample undersize in oversize	Adjust stroke, check blinding
Recirculating load	Belt scale on return	Adjust CSS if excessive
Product gradation	Shift sampling	Adjust screen/CSS as needed
Crusher level	Level sensor	Adjust feed rate

Automation Opportunities

Modern crushing circuits benefit from automated control:

- **Crusher CSS control:** Automatic adjustment based on power draw or product size
- **Feed rate control:** Maintain optimal crusher chamber loading
- **Bin level management:** Balance surge capacity and continuous operation
- **Quality tracking:** Online gradation monitoring with feedback control

Troubleshooting Circuit Problems

High Recirculating Load

CAUSE	SYMPTOM	SOLUTION
CSS too wide	Coarse crusher product	Close CSS
Worn crusher liners	CSS opened, poor crushing	Replace liners
Screen blinded	Material not passing through	Clean or replace screen
Feed too large	Low reduction efficiency	Improve primary crushing

Low Screen Efficiency

CAUSE	SYMPTOM	SOLUTION
Overloading	Deep bed, carryover	Reduce feed rate
Blinding	Material stuck in apertures	Clean deck, check media type
Incorrect stroke	Poor stratification	Adjust to manufacturer spec
Wrong media	Pegging or plugging	Change to appropriate media

Circuit design decisions have long-term implications for plant performance and profitability. Careful analysis of product requirements, capital constraints, and operating costs guides selection of the optimal circuit configuration. Ongoing monitoring and optimization ensure circuits deliver their designed performance throughout the plant lifecycle.

Topics: #Circuit Design #Closed Circuit #Crushing #Open Circuit

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