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# Performance and Assessment of Jaw Crusher in a Cement Manufacturing Plant

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**Abstract:**

Jaw crushers are essential apparatus in cement production facilities, principally utilized for pulverizing raw materials such as limestone, clay, and other minerals. The dependability of jaw crushers strongly influences production efficiency and maintenance expenses. This research examines the repair and failure rates of jaw crushers in a cement factory, assessing prevalent failure types, their underlying causes, and maintenance solutions to enhance equipment uptime. Data was gathered from maintenance logs over a two-year duration, and statistical analysis was conducted to ascertain Mean Time between Failures (MTBF) and Mean Time to Repair (MTTR). The results indicate that wear-related failures, such as jaw plate wear and bearing failures, constitute more than 60% of breakdowns, whereas lubrication problems contribute to 25% of failures. The use of predictive maintenance and the utilization of premium replacement parts can substantially save downtime and operating expenses.

**Keywords:** Jaw crusher, failure rate, repair rate, cement plant, etc.

## Introduction:

The production of cement encompasses several phases of material processing, with crushing serving as the initial and most critical stage. Jaw crushers are extensively utilized for their superior efficiency and capacity to accommodate substantial input sizes. Frequent malfunctions and elevated repair costs may result in output losses. Comprehending failure patterns and refining maintenance techniques helps improve crusher dependability.

Jaw crushers are main crushing apparatus used in mining, aggregates, and cement sectors to reduce huge rocks and hard materials into smaller, controllable dimensions. They are crucial in cement production facilities for pulverizing raw materials such as limestone, shale, and clay prior to additional processing.

For plant equipment to operate without interruption, dependability in operation and maintenance are crucial concerns. Equipment breakdowns that occur suddenly and often items will cause a decrease in output. This is especially important for newer pieces of plant machinery that the owners have put a lot of money into. Maintenance on these devices must be precise, time-driven, and accurate. Scheduling maintenance in a timely manner becomes next to impossible without doing a systematic examination of the equipment and its component failure trends. In order to lower the maintenance cost of the plant equipment, it is important to conduct operational dependability investigations. In this investigation, we looked at the jaw crusher and its parts that failed at a big mineral processing facility. For the purpose of analysis, the plant maintenance register records failure data spanning two years. A Swedish mine has previously used TTT-plotting to ensure the operating dependability and maintenance of a fleet of diesel-operated load haul dump (LHD) equipment [1]. This study also considers the same issue but with more statistical treatments. Life Data Analysis (LDA) tests and Maximum Likelihood (ML) estimations are among the analytical methodologies taken into account in this study. Data on failures are analyzed using several statistical distributions. When estimating their parameters, the ML (maximum likelihood) approach is used [2, 3]. A 90% confidence threshold is utilized for ML estimate. There are two ways to indicate confidence bounds: one-sided and two-sided. With a certain level of confidence, two-sided limits can be used to show that the amount of interest is contained inside them. In order to compare the results obtained by the ML approach with the graphical TTT-plot, we look at the trend of component failure rates and see if they are growing or decreasing. The data is checked for independence and identical distribution (iid) using graphical methods. If you want to see how well your data fits other distributions, you may use the LDA test.

As the first step in the process of size reduction, jaw crushers are essential machinery in many sectors, including mining, quarrying, and cement manufacture. These machines are susceptible to mechanical breakdowns due to the extreme circumstances they operate in, which include high loads, dust, and abrasive materials. Thus, reliability engineering is vital for making sure they work as intended, keeping downtime to a minimum, and keeping components in good condition for longer. This study takes a look at what's new in the field of reliability engineering as it pertains to jaw crushers, both in academia and industry.

In order to increase the availability of heavy machinery, reliability-centered maintenance has been extensively used. Mossadegh et al. [4], highlighted how facilities may move from reactive to proactive methods by integrating RCM principles into jaw crusher maintenance plans. Maintenance may be prioritized according to the risk and consequences of failure with the help of RCM's methodical identification of important components.

Time to Failure (MTBF), Time to Repair (MTTR), and availability are common metrics used in reliability evaluations. Using exponential failure distributions, Gupta and Sharma [5], created a mathematical model to evaluate crushing subsystem reliability characteristics. Their technique was essential in improving maintenance scheduling and stockpiling replacement parts. For early defect identification, condition-based monitoring approaches are crucial. When studying jaw crushers with thermal imaging, oil analysis, and vibration signals, Kumar et al. [6] discovered that vibration data was the most sensitive indication of bearing failure. By modeling jaw plate wear with artificial neural networks (ANNs), Zhang and Liu [7], shown that predictive algorithms may greatly enhance maintenance scheduling.

Reliability analysis informs design adjustments that boost performance and make the system easier to maintain. To evaluate the crushing mechanism's stress concentration zones, Rajpal and Tiwari [8], turned to Finite Element Analysis (FEA). Jaw plate longevity was increased by 25% as a result of their enhanced design. The reliability enhancement program that was implemented in an Indian cement factory was detailed in the publication by Singh et al. [9]. Unscheduled jaw crusher shutdowns were reduced by 30% because to the program's combination of real-time monitoring and failure analysis. A mining business in South Africa enhanced their maintenance approach after using Weibull analysis to identify worn component failure trends. In order to use the Runge-Kutta fourth-order (RK4) approach to simulate the failure and repair rates of a jaw crusher, a differential equation describing the dependability of the system is required. We will utilize a simple differential equation for failure and repair rates based on system availability, rather than the usual methods of Markov chains or reliability growth models.

**Model for System Reliability;**

Assume that:

Failure rate (λ) = Number of failures per unit time (e.g., 0.002 failures/hour).

Repair rate (μ) = Number of repairs per unit time (e.g., 0.1 repairs/hour).

The system can be in two states:

Operational ($f_1$) and Failed ($f_2$)

The differential equations for state probabilities are:

$$\frac{df_1}{dt} = \mu f_2 - \lambda f_1$$

$$\frac{df_2}{dt} = -\mu f_2 + \lambda f_1$$

Where $f_1 + f_2 = 1$.

**Calculation of the Solution Using the RK4 Method:**

Assuming that:

The value of λ is 0.002, which represents the failure rate, with one failure occurring every 500 hours.

The value $\mu$ is 0.1 (repair rate, mean repair time = 10 hours)

With boundary condition $f_1(0) = 1$.

**Steps in the Implementation of RK4:**

For each time step h, compute:

1. $k_1 = h\, f(t_n, y_n)$
2. $k_2 = h\, f( t_n + h/2, y_n + k_1/2)$
3. $k_3 = h\, f(t_n + h/2, y_n + k_2/2)$
4. $k_4 = h\, f( t_n + h/2, y_n + k_3)$
5. $y_{n+1} = y_n + 1/6(k_1 2k_2 + 2k_3 + k_4)$,

Where

$\phi(t, f_1) = -\lambda f_1 + \mu (1 - f_1)$

**Python Code:**

```python
import numpy as np
import matplotlib.pyplot as plt

# Parameters
lambda_ = 0.002  # Failure rate (failures/hour)
mu = 0.1         # Repair rate (repairs/hour)
f1_0 = 1.0       # Initial operational probability
t_max = 100      # Simulation time (hours)
h = 1            # Step size (hours)

# Define the differential equation
def f(f1):
    return -lambda_ * f1 + mu * (1 - f1)

# RK4 Solver
def rk4():
    t = np.arange(0, t_max + h, h)
    f1 = np.zeros(len(t))
    f1[0] = f1_0

    for i in range(1, len(t)):
        k1 = h * f(f1[i-1])
        k2 = h * f(f1[i-1] + k1/2)
        k3 = h * f(f1[i-1] + k2/2)
        k4 = h * f(f1[i-1] + k3)
        f1[i] = f1[i-1] + (k1 + 2*k2 + 2*k3 + k4) / 6

    return t, P1

# Run simulation
t, f1 = rk4()
f2 = 1 - f1

# Plot results
plt.plot(t, f1, label='Operational (f₁)')
plt.plot(t, f2, label='Failed (f₂)')
plt.xlabel('Time (hours)')
plt.ylabel('Probability')
plt.title('Jaw Crusher Reliability (RK4 Solution)')
plt.legend()
plt.grid()
plt.show()
```

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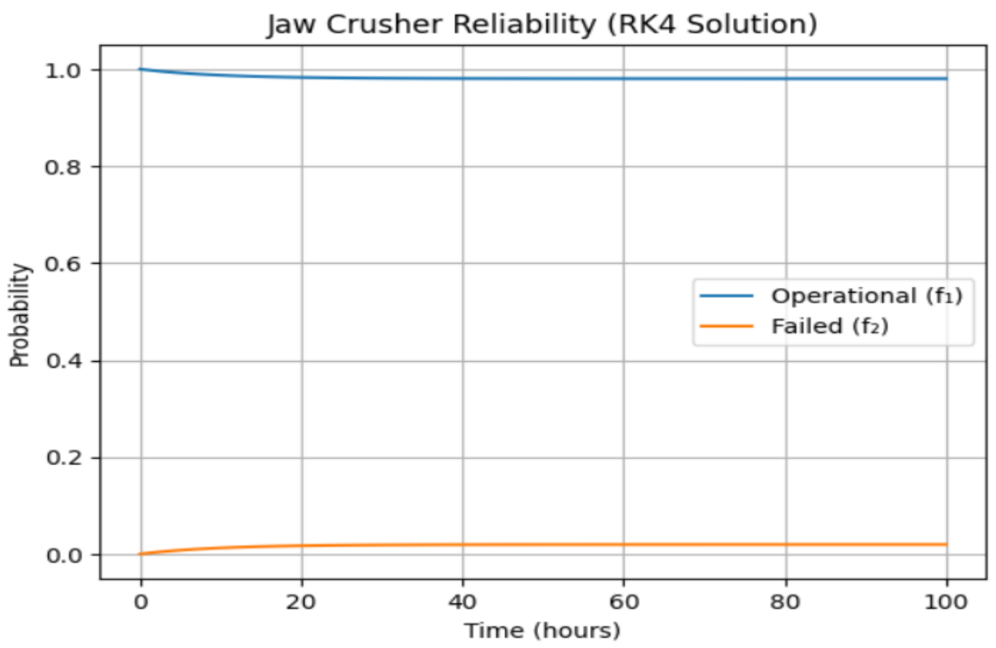

Result & interpretation:

Steady state availability (A):

$$A=\frac{\mu}{\lambda+\mu}=\frac{0.1}{0.002+0.1}\approx 98.04\%$$

Plot Output:

Initially, $f_1=1$ (fully operational).

Over time, $f_1$ decreases and stabilizes at ∼98%, while $f_2$ (failure probability) stabilizes at ∼2%.

**Conclusion:**

Reliability is a crucial factor in the planning, design, and operation of engineering systems. As the dimensions and intricacy of mining apparatus grow, the consequences of equipment malfunction become increasingly significant. An unanticipated breakdown may incur much more repair expenses compared to scheduled maintenance or repairs. The loss of productivity resulting from significant equipment breakdowns is of much greater concern. Enhancing the dependability of the equipment is one approach to alleviate the consequences of breakdowns. Reliability serves as a performance metric for the overall condition of equipment. The initial stage in enhancing dependability is the gathering and analysis of pertinent data.

Reliability is a characteristic of a product or service that is universally sought after, yet frequently found to be lacking. The dependability of a product is the assessment of its capacity to execute its function, when necessary, for a designated duration, in a certain environment. It is quantified as a likelihood. From an economic perspective, high dependability is advantageous for minimizing maintenance expenses of the systems. The dependability analysis of equipment may be categorized into two primary groups: Dependability of machinery Software dependability in the context of automated processes. In recent years, the reliability, maintainability, and availability (RAM) of systems have gained considerable importance due to the competitive landscape and total production costs. The performance of a mining machine is contingent upon the dependability of the equipment, the mining environment, maintenance efficiency, operational processes, and the technical skill of the miner, among other factors. Analyzing a machine's dependability is essential to identify required enhancements or modifications to manage competitive market pressures.

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