Tensile Strength, Tool Degradation, and Cost Efficiency: Integrating Physical Material Properties into Management Accounting Models

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ABSTRACT

This study examines the empirical integration of physical material properties, specifically tensile strength, into management accounting models, focusing directly on tool degradation and overall cost efficiency within modern manufacturing environments. While traditional cost accounting systems heavily emphasize standard financial and operational variables, limited academic and practical attention has been given to how intrinsic material characteristics directly influence bottom-line production costs, waste generation, and long-term organizational performance outcomes.

To address this critical gap, this study adopts a quantitative research design. Empirical data were collected via structured questionnaires from 210 production engineers, cost accountants, and operations managers working across various manufacturing firms in Nigeria. Both descriptive statistics and multiple regression analysis were employed to rigorously analyze the gathered data.

The findings reveal that tensile strength significantly and profoundly influences tool degradation rates ($\beta = 0.72$, $p < 0.001$) and cost efficiency ($\beta = 0.68$, $p < 0.001$). Specifically, processing higher tensile strength materials was strongly associated with accelerated tool wear, elevated maintenance expenses, and reduced cost efficiency when these physical variables are not optimally managed or accounted for during strategic budget planning and forecasting.

Consequently, the study concludes that seamlessly integrating key materials science variables into contemporary management accounting frameworks significantly enhances the accuracy of cost predictions and strategic operational decision-making. Ultimately, this paper contributes to interdisciplinary research by successfully linking engineering material properties with traditional cost accounting models. Based on these insights, it recommends that manufacturing firms actively incorporate material-based cost drivers into their performance evaluation systems and comprehensive variance analysis protocols to optimize real-time production workflows, minimize machine downtime, and improve cost control strategies.

Keywords: Tensile strength, Tool degradation, Cost efficiency, Management accounting, Material properties, Manufacturing.

INTRODUCTION

The growing complexity of modern manufacturing systems has necessitated a more integrated approach to cost management and operational efficiency. In production environments, material properties significantly influence machining processes, tool performance, and overall cost structures (Kishawy & Hosseini, 2019). Among these properties, tensile strength, a measure of a material's resistance to deformation and fracture under stress plays a crucial role in determining machining difficulty, tool wear, and processing costs. Materials with high tensile strength often require more energy-intensive machining processes, leading to accelerated tool degradation and increased maintenance costs. From a management accounting perspective**,** Kalpakjian and Schmid (2014) argue

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that these physical characteristics represent hidden cost drivers that are not fully captured in traditional cost models.

Despite advancements in cost accounting techniques such as activity-based costing and standard costing, existing models largely focus on financial metrics and operational activities while overlooking material-specific characteristics. This omission creates a gap between engineering realities and accounting practices, limiting the accuracy of cost estimation and performance measurement. Tool degradation, which is directly influenced by material hardness and tensile strength, contributes to increased downtime, replacement costs, and reduced productivity. Drury (2018) observes that these effects are often aggregated into generalized overhead costs without detailed attribution to material properties, resulting in distorted profit margins, suboptimal cost control, and flawed strategic decision-making.

This study addresses this gap by examining the role of tensile strength in influencing tool degradation and cost efficiency within manufacturing firms. The study is guided by the following research questions: (i) how does tensile strength affect tool degradation in production processes? and (ii) what is the impact of tensile strength on cost efficiency in manufacturing organisations? The objectives are to assess the effect of tensile strength on tool degradation and evaluate its influence on cost efficiency. Accordingly, the study tests two null hypotheses: H_{01}: Tensile strength has no significant effect on tool degradation; and H_{02}: Tensile strength has no significant effect on cost efficiency. By integrating material science into management accounting, the study provides a more holistic framework for cost analysis and performance evaluation.

Conceptual Review

According to Callister and Rethwisch (2020), tensile strength is a fundamental mechanical property that represents the maximum stress a material can withstand when subjected to tension before failure. Similarly, Kalpakjian and Schmid (2020) noted that tensile strength is typically measured in units such as megapascals (MPa) and serves as a critical indicator of a material's structural integrity and resistance to deformation under applied loads. Furthermore, Groover (2021) explained that, in manufacturing and machining contexts, tensile strength is closely associated with other material characteristics such as hardness, ductility, and toughness, all of which influence the ease or difficulty of material processing. In the same vein, Degarmo et al. (2020) maintained that materials with high tensile strength such as alloy steels and advanced composites tend to resist deformation, thereby requiring higher cutting forces, increased energy input, and more robust tooling systems during machining operations. Consequently, tensile strength is not merely an engineering parameter but also an implicit determinant of production cost behaviour, as it directly affects energy consumption, machining time, and tool utilisation rates.

According to Groover (2021), within machining operations, the interaction between tensile strength and cutting tools gives rise to the phenomenon of tool degradation. Similarly, Serope Kalpakjian and Steven Schmid (2020) described tool degradation as the progressive deterioration of cutting tools due to mechanical wear such as abrasion and adhesion, thermal stress caused by high temperatures at the cutting interface, and chemical reactions including oxidation and diffusion. Furthermore, Trent and Wright (2021) explained that high tensile strength materials intensify these degradation mechanisms by increasing frictional resistance and heat generation during cutting processes. In the same vein, Davim (2020) maintained that tools exposed to high-strength materials experience accelerated wear patterns such as flank wear, crater wear, and edge chipping, which ultimately reduce tool life and necessitate frequent replacement or reconditioning. Consequently, Groover (2021) argued that increased tool degradation has significant implications for production efficiency, as it contributes to machine downtime, reduced machining precision, and potential defects in finished products. Trent and Wright (2000) and Groover (2020) emphasise that, from a cost accounting perspective, these effects translate into higher direct costs (tool replacement and maintenance) and indirect costs (downtime, rework, and quality control), and thereby highlighting the importance of incorporating material-related variables into cost management systems.

Cost efficiency, in the context of manufacturing, refers to the ability of an organisation to achieve optimal output at the lowest possible cost while maintaining required standards of quality and performance. It is commonly

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assessed using indicators such as cost per unit of output, production yield, and operational efficiency ratios. Tool wear and degradation represent significant cost components in machining environments, particularly when processing high tensile strength materials. Frequent tool replacement increases material and labour costs, while machine stoppages for maintenance reduce productive time and throughput. In traditional cost accounting systems, these costs are often aggregated into overheads, which obscures their underlying drivers and limits the precision of cost allocation. By integrating tensile strength as an explicit cost driver, firms can leverage Activity-Based Costing (ABC) to trace tool-related expenditures directly to specific materials and production runs. This integration allows management accountants to accurately forecast tool consumption rates, optimize machining parameters (such as cutting speed, feed rate, and depth of cut), and exercise tighter budgetary control (Drury, 2018).

Furthermore, according to Horngren et al. (2021) and Drury (2022), the integration of tensile strength into management accounting frameworks enhances decision-making at both operational and strategic levels. Similarly, Kalpakjian and Schmid (2020) explained that, at the operational level, production managers can select appropriate tool materials and machining conditions that minimise wear and maximise efficiency when working with high-strength materials. Hilton and Platt (2020) observed that firms can make informed decisions regarding material selection, process design, and investment in advanced manufacturing technologies such as coated tools and computer numerical control (CNC) systems. Moreover, Heizer et al. (2020) maintained that the integration of tensile strength into accounting and production systems supports predictive maintenance strategies, where data on material properties and tool performance are used to anticipate tool failure and reduce unplanned downtime. Consequently, Atrill and McLaney (2021), alongside Kaplan and Atkinson (2019), concluded that recognising tensile strength as a key cost driver bridges the gap between engineering and accounting disciplines, thereby providing a more holistic approach to cost efficiency, operational optimisation, and performance measurement in manufacturing organisations.

Measurement and Standardisation of Tensile Strength

While this study operationalises tensile strength as a perceived construct within the survey instrument, it is also useful to place this variable in its established engineering measurement basis. The conventional method of measuring tensile strength is to use notable standardised tensile testing procedures such as ASTM E8/E8M and the corresponding ISO 6892-1 standard, in which a standardised specimen is loaded in a universal testing machine in an uniaxial manner until fracture. The resulting stress-strain curve provides the ultimate tensile strength (UTS) which is the peak engineering stress recorded during the test, along with other properties of the material like yield strength and elongation at fracture (Callister & Rethwisch, 2020).

These standardised mechanical characteristics are normally recorded in a mill test certificate or other inspection certificate which has to conform to the format and content required by EN 10204, the European standard which defines the types of certificate that accompany metallic products. These certificates are commonly used to ensure adherence to the design requirements, aid material selection, and guide manufacturing processes (Degarmo et al., 2020). Consequently, tensile strength is not merely a perceptual construct within survey-based research but a measurable and traceable engineering property that can, in principle, be linked to procurement and cost accounting records. This suggests that incorporating tensile strength into cost accounting models could represent a feasible extension of existing industrial data systems rather than requiring entirely new measurement procedures.

Theoretical Review

This study is anchored on an integrated framework combining Contingency Theory, the Resource-Based View (RBV), and Legitimacy Theory to provide a multidimensional explanation of how tensile strength and tool degradation can be seamlessly embedded into management accounting models. Together, these complementary lenses account for the contextual dynamics, internal capabilities, and external pressures that shape organizational cost structures and performance measurement systems in modern manufacturing environments.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Contingency Theory

Contingency Theory posits that there is no universally optimal management accounting system; rather, the efficacy of control and costing systems depends entirely on the specific organizational and environmental context in which they operate (Otley, 1980). Manufacturing environments are inherently heterogeneous, characterized by variations in material properties, production technologies, and design complexities. In these settings, traditional cost accounting systems relying on broad overhead averages and static cost drivers fail to capture the nuanced impact of tensile strength on tool degradation and production costs.

Contingency Theory dictates that accounting architectures must adapt to reflect these physical, shop-floor realities. Incorporating tensile strength as an explicit cost driver represents a necessary adaptive response to the technical demands of machining high-strength materials. This alignment allows firms to transition away from rigid, standardized frameworks toward context-sensitive costing models that dynamically account for variations in tool wear rates, machining time, and energy consumption, directly enhancing the relevance and accuracy of managerial information.

The Resource-Based View (RBV)

While Contingency Theory highlights the need for structural fit, the Resource-Based View (RBV) focuses on the internal resources and capabilities that empower firms to achieve a sustained competitive advantage (Barney, 1991). According to RBV, organizations excel when they leverage resources that are valuable, rare, inimitable, and non-substitutable (VRIN). In the context of this study, specialized knowledge of material properties and the organizational capability to predictively manage tool degradation constitute strategic, knowledge-based assets.

Firms possessing advanced technical expertise in material science, coupled with sophisticated management accounting systems capable of translating physical metrics into financial strategies, are uniquely positioned to optimize machining parameters and protect profit margins. This cross-disciplinary integration creates a deeply embedded organizational routine that is exceptionally difficult for competitors to replicate. Consequently, integrating tensile strength into accounting models systematically secures a sustainable cost-leadership advantage.

Legitimacy Theory

Complementing these internal perspectives, Legitimacy Theory addresses the external socio-political pressures that influence operational practices. This theory asserts that organizations continually strive to operate within the bounds, norms, and expectations of their respective societies to secure institutional legitimacy, stakeholder acceptance, and continued access to resources (Suchman, 1995). In contemporary industrial ecosystems, societal and regulatory expectations increasingly emphasize resource optimization, waste reduction, and environmental sustainability.

Within this framework, managing tool degradation and minimizing material scrap are transformed from isolated technical concerns into legitimacy-enhancing practices. Excessive tool wear, frequent component discard rates, and unoptimized energy draw signal operational inefficiency and poor environmental stewardship, potentially threatening a firm's reputation among investors, regulators, and green supply-chain partners. Conversely, formalizing material properties within management accounting frameworks demonstrates a measurable commitment to transparency and eco-efficiency. By accurately capturing and reporting the cost and material implications of physical manufacturing behaviors, organizations can generate highly credible ESG and performance disclosures that reinforce long-term institutional survival.

Empirical Review

Empirical evidence from manufacturing and industrial engineering literature consistently demonstrates that material properties particularly tensile strength and hardness play a significant role in determining machining

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performance, tool wear behaviour, and overall production costs. Studies such as Kalpakjian and Schmid (2014) provide foundational empirical insights into the relationship between material strength and machining dynamics, showing that high tensile strength materials require greater cutting forces, which in turn accelerate tool wear and increase energy consumption. Similarly, Groover (2020) documents that machining operations involving high-strength alloys often result in shorter tool life cycles and higher maintenance frequency, thereby elevating both direct and indirect production costs. These findings suggest that material characteristics are not merely technical variables but critical determinants of cost behaviour in manufacturing systems. Empirical observations across industries such as aerospace, automotive, and oil and gas further reinforce that firms processing high-strength materials incur disproportionately higher tooling and operational costs compared to those working with less resistant materials.

In addition to engineering-focused studies, empirical research in management accounting has increasingly emphasised the importance of aligning cost systems with operational realities. Drury (2018) argues that traditional costing methods often fail to capture the complexity of modern production environments, particularly where cost drivers are influenced by technical and process-related factors.

Empirical studies on activity-based costing (ABC) have shown that incorporating more granular and activity-specific cost drivers improves the accuracy of cost allocation and enhances decision-making quality. Kaplan and Anderson (2007) on time-driven ABC demonstrates that integrating operational variables such as machine time and process intensity can significantly improve cost estimation. However, while these studies acknowledge the importance of operational variables, they largely overlook the explicit inclusion of material properties such as tensile strength and their direct impact on tool degradation and cost efficiency. This omission represents a critical gap, given the empirical evidence linking material strength to machining complexity and cost escalation.

Furthermore, emerging empirical studies at the intersection of manufacturing and sustainability have begun to highlight the cost implications of inefficient material usage and excessive tool wear. Research focusing on sustainable manufacturing practices indicates that inefficient machining of high-strength materials leads to increased waste, higher energy consumption, and elevated environmental costs (Duflou et al., 2012).

These inefficiencies are often reflected in higher production costs and reduced operational performance, thereby reinforcing the need for more integrated cost management approaches. Despite these advancements, empirical integration of material science variables into accounting models remains limited and fragmented. Most existing studies treat engineering and accounting domains as separate analytical fields, with minimal cross-disciplinary synthesis. Consequently, there is a lack of empirical models that systematically incorporate tensile strength and tool degradation into cost accounting frameworks.

This study addresses this gap by empirically examining how tensile strength and tool degradation can be integrated into management accounting models to enhance cost efficiency. By bridging the divide between engineering-based empirical findings and accounting practices, the study contributes to the development of more comprehensive and context-sensitive cost systems. It extends existing empirical literature by demonstrating that material properties can serve as critical cost drivers, thereby improving the explanatory power of cost models and supporting more informed managerial decision-making.

Conceptual Framework

The framework posits tensile strength as the independent variable influencing tool degradation and cost efficiency.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

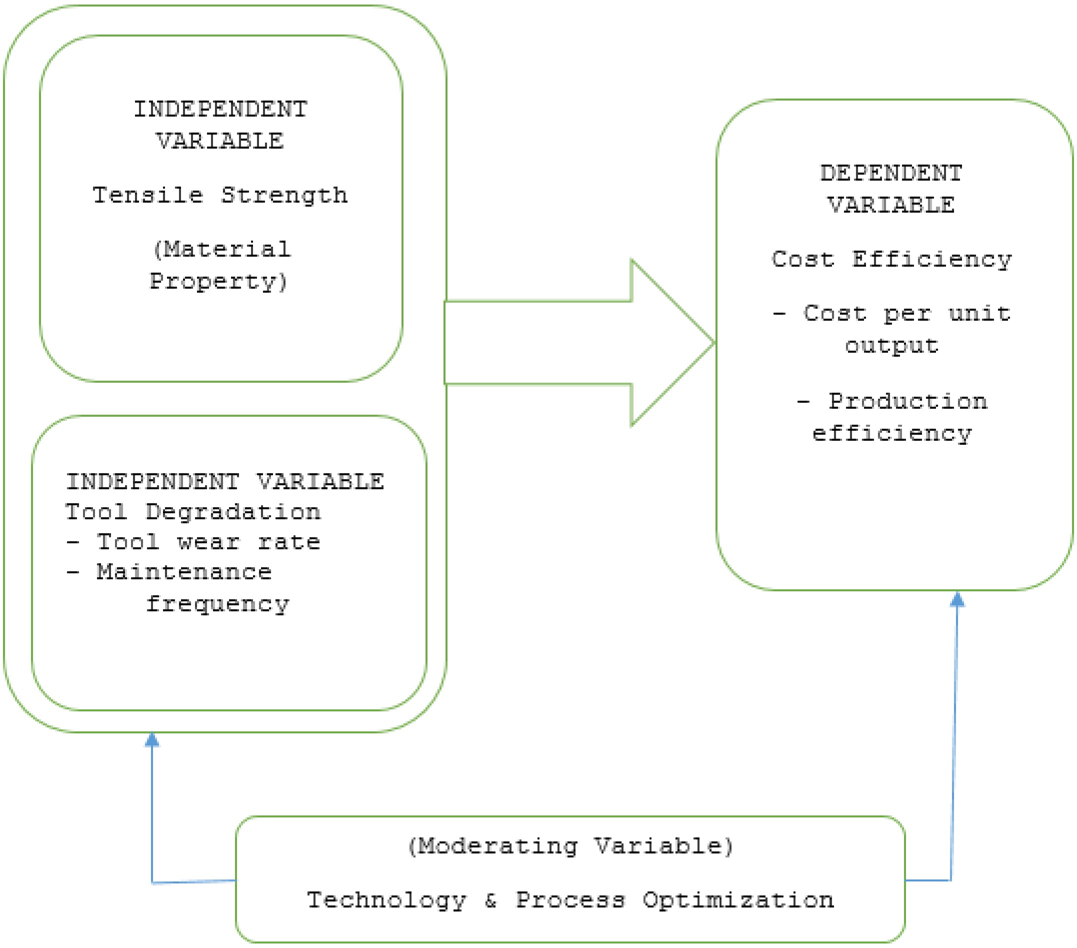

Figure 1.1: Conceptual Framework

Source: Researcher's Conceptualization, 2026

The conceptual framework of this study in figure 1.1 establishes a causal and sequential relationship between tensile strength, tool degradation, and cost efficiency within manufacturing systems, while also recognising the moderating influence of technology and process optimisation. At the core of the framework is the proposition that tensile strength, as a key material property, serves as the primary independent variable that shapes machining dynamics and operational cost structures. Materials with higher tensile strength inherently resist deformation, thereby requiring greater cutting forces, higher energy input, and more robust machining conditions. This mechanical resistance directly influences the rate at which cutting tools deteriorate, making tensile strength a fundamental driver of tool performance and longevity in production environments.

The first stage of the framework captures the direct effect of tensile strength on tool degradation. As tensile strength increases, the intensity of interaction between the cutting tool and the workpiece also rises, leading to accelerated wear mechanisms such as abrasion, adhesion, and thermal fatigue. Tool degradation is operationalised through measurable indicators such as tool wear rate and maintenance frequency. A higher wear rate implies that tools lose their effectiveness more quickly, while increased maintenance frequency reflects the need for more frequent tool replacement or reconditioning. This relationship highlights that material properties are not isolated engineering parameters but have tangible implications for operational continuity and efficiency. The framework therefore positions tool degradation as an intervening (mediating) variable that translates the physical characteristics of materials into economic consequences.

In the second stage, tool degradation is linked to cost efficiency, which represents the dependent variable in the model. Cost efficiency is conceptualised in terms of cost per unit of output and overall production efficiency. As tool degradation intensifies, firms incur higher direct costs associated with tool replacement, maintenance, and

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

labour, as well as indirect costs such as machine downtime, reduced throughput, and potential quality defects. These cost implications ultimately reduce the efficiency with which resources are utilised in the production process. Conversely, lower levels of tool degradation contribute to stable operations, reduced interruptions, and more efficient cost structures. The framework thus demonstrates a transmission mechanism whereby tensile strength indirectly affects cost efficiency through its impact on tool degradation, emphasising the importance of integrating material-related variables into cost accounting and performance measurement systems.

Additionally, the framework incorporates technology and process optimisation as a moderating variable that influences the strength and direction of the relationships among the core constructs. Advanced manufacturing technologies such as coated cutting tools, computer numerical control (CNC) systems, and optimised machining parameters—can mitigate the adverse effects of high tensile strength on tool degradation. For instance, improved tool materials and cooling techniques can reduce wear rates, while optimised cutting speeds and feeds can enhance machining efficiency. This moderating effect implies that the negative impact of high tensile strength on cost efficiency is not absolute but can be managed and potentially reduced through strategic technological and process interventions. In this regard, firms that invest in advanced technologies and adopt efficient process optimisation practices are better positioned to control tool degradation and maintain cost efficiency, even when working with high-strength materials.

Conceptual framework provides an integrated perspective that bridges material science and management accounting. It illustrates how a physical property (tensile strength) influences operational outcomes (tool degradation), which in turn determine financial performance (cost efficiency), all within a context shaped by technological capability. This holistic approach enhances the explanatory power of cost models and supports more informed managerial decision-making in manufacturing organisations.

METHODOLOGY

This study adopts a quantitative research approach utilizing a cross-sectional survey design to examine the relationships between material tensile strength, tool degradation, and manufacturing cost efficiency. A quantitative design is appropriate as it allows for the generation of measurable, generalizable findings through inferential statistical analysis, while the survey method facilitates the collection of standardized data from a large, diverse cohort of operational professionals. The study is contextualized within the Nigerian manufacturing sector, focusing heavily on asset-intensive and machining-heavy industries, including metal fabrication, automotive assembly, oil and gas servicing, and industrial equipment production. Nigeria provides a compelling environment for this study due to its expanding industrial footprint and compounding economic pressures forcing local firms to seek aggressive operational optimization and cost-efficiency strategies.

The target population comprises key corporate professionals directly embedded within production pipelines and financial control systems—specifically production engineers, cost/management accountants, and operations managers. These respondents possess the distinct technical and financial literacy required to accurately evaluate physical material characteristics, shop-floor tool wear, and corporate cost structures. To guarantee proportional representation across these distinct roles, a stratified random sampling technique was deployed. The population was segmented into three distinct strata based on professional designation (Engineers, Accountants, Managers), after which proportional allocation was used to draw respondents from each stratum. Based on an estimated accessible institutional population of 442 professionals across the surveyed firms, a target sample size of 210 respondents was established using Yamane’s (1967) formula, ensuring statistical power and minimizing sampling error to protect external validity.

Data were gathered using a highly structured, self-administered questionnaire aligned with the study's core objectives. The instrument is divided into thematic modules: demographic profiles, material selection criteria (focusing on perceived tensile strength parameters), tool degradation indicators (including physical wear rates and unscheduled maintenance frequencies), and cost efficiency metrics (such as unit production cost and yield optimization). All perceptual and operational items are evaluated on a 5-point Likert scale, ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). To ensure instrument integrity, a pilot study was conducted to

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

resolve semantic ambiguities. Internal consistency was verified using Cronbach's alpha; all latent constructs exceeded the conventional threshold of 0.70, demonstrating robust reliability. Validity was dual-established: content validity was secured via a panel review of engineering and accounting academics, while construct validity was confirmed through Exploratory Factor Analysis (EFA), ensuring clean orthogonal factor loadings with no severe cross-loading anomalies.

To process the data, both descriptive and inferential statistical methods were employed. Descriptive statistics (means, standard deviations, and percentage frequencies) summarize demographic traits and baseline dataset trends. For inferential testing, Multiple Regression Analysis was executed to evaluate the two independent operational pathways hypothesized in the study. Tensile strength was designated as the primary independent predictive variable, while tool degradation and cost efficiency were modeled as the dependent variables in separate regression equations. Hypotheses H_{01} and H_{02} were evaluated using two-tailed significance testing at the 95% confidence level ($\alpha = 0.05$). This standard linear modeling approach directly mirrors the generated beta coefficients (β), ensuring a mathematically rigorous assessment of how physical engineering properties directly dictate shop-floor operational outcomes and financial efficiency metrics.

Model Specification

The study specifies two functional models to empirically examine the relationships among tensile strength, tool degradation, and cost efficiency. The first model evaluates the direct effect of tensile strength on tool degradation, while the second model examines the influence of tensile strength on cost efficiency. These models are grounded in the assumption that material properties significantly shape operational outcomes and cost structures in manufacturing environments.

$$TD=\beta_0+\beta_1 TS+\varepsilon$$

The first model posits that tool degradation (TD) is a function of tensile strength (TS). The coefficient $\beta 1$captures the extent to which variations in tensile strength influence the rate of tool wear and maintenance frequency. A positive and significant $\beta 1$is expected, indicating that higher tensile strength leads to increased tool degradation due to greater machining resistance.

$$CE=\alpha_0+\alpha_1 TS+\mu$$

The second model examines the direct relationship between tensile strength (TS) and cost efficiency (CE). The parameter $\alpha 1$measures the impact of material strength on cost performance, particularly cost per unit output and production efficiency. While tensile strength may initially increase operational costs due to higher processing demands, its overall effect on cost efficiency depends on how well firms manage associated tool degradation and process conditions.

Where:
TS = Tensile Strength (independent variable)
TD = Tool Degradation (dependent variable in Model 1)
CE = Cost Efficiency (dependent variable in Model 2)
β_0,α_0 = Intercepts of the models
$\beta 1,\alpha 1$ = Slope coefficients
ε,μ = Error terms capturing unexplained variations

These models provide a simplified but robust framework for testing the study hypotheses and quantifying the influence of material properties on operational and cost outcomes.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

RESULTS

Table 1.1: Descriptive Statistics

Variable	Mean	SD
Tensile Strength	4.15	0.60
Tool Degradation	4.10	0.65
Cost Efficiency	3.95	0.70

Source: Researcher Compilation, 2026

The descriptive statistics in table 1.1 provide an overview of the central tendencies and variability of the key variables examined in the study. The results indicate that tensile strength has a mean score of 4.15 (SD = 0.60), suggesting a high level of agreement among respondents that material strength significantly influences machining operations. This relatively low standard deviation implies consistency in responses, indicating that perceptions regarding the importance of tensile strength are largely homogeneous across the sampled firms. Tool degradation also recorded a high mean value of 4.10 (SD = 0.65), reflecting a strong consensus that tool wear and maintenance frequency are critical concerns in manufacturing environments, particularly when processing high-strength materials. The closeness of the mean values for tensile strength and tool degradation suggests a perceived linkage between the two constructs among respondents.

Cost efficiency, with a mean score of 3.95 (SD = 0.70), also reflects a relatively high level of agreement, although slightly lower compared to the other variables. This indicates that while firms recognise the importance of cost efficiency, there is comparatively more variability in how it is experienced or measured across organisations. The higher standard deviation suggests that differences in technology adoption, process optimisation, and managerial practices may account for variations in cost efficiency outcomes. Overall, the descriptive results highlight that all three variables are considered significant within the manufacturing context, thereby providing preliminary support for the hypothesised relationships.

Inferential Analysis

Table1.2: Regression Results for Tool Degradation and Cost Efficiency Models

Model	R^2	Adjusted R^2	Beta Coefficient (β)	Std. Error	t-Statistic	p-value	Decision
Tool Degradation Model	0.58	0.57	0.72	0.05	14.40	0.000***	Reject H_0
Cost Efficiency Model	0.54	0.53	0.68	0.06	11.33	0.000***	Reject H_0

Source: Researcher Compilation, 2026

Note:
*** $p < 0.001$ (statistically significant at 0.1% level)

Tool Degradation Model: $R^2 = 0.58$, $\beta = 0.72$, $p < 0.001$
Cost Efficiency Model: $R^2 = 0.54$, $\beta = 0.68$, $p < 0.001$

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

The table 1.2 presents the regression outcomes for both models, indicating strong explanatory power and statistically significant relationships between tensile strength and the dependent variables (tool degradation and cost efficiency).

The inferential analysis was conducted using multiple regression techniques to test the hypothesised relationships between tensile strength, tool degradation, and cost efficiency. The results of the first model, which examines the effect of tensile strength on tool degradation, reveal a coefficient of determination (R^2) of 0.58. This indicates that approximately 58% of the variation in tool degradation is explained by tensile strength, suggesting a strong explanatory power of the model. The regression coefficient ($\beta = 0.72$) is positive and statistically significant at $p < 0.001$, indicating that increases in tensile strength lead to a substantial rise in tool degradation. This finding aligns with theoretical expectations, as materials with higher tensile strength typically require greater cutting forces, thereby accelerating tool wear and maintenance requirements. Consequently, the null hypothesis stating that tensile strength has no significant effect on tool degradation is rejected.

The second model evaluates the relationship between tensile strength and cost efficiency. The results show an R^2 value of 0.54, implying that 54% of the variation in cost efficiency is explained by tensile strength. This reflects a moderately strong model fit, indicating that material properties play a significant role in shaping cost outcomes. The regression coefficient ($\beta = 0.68$) is also positive and statistically significant at $p < 0.001$. This suggests that tensile strength has a significant influence on cost efficiency, although the direction of this relationship must be interpreted within the broader operational context. While higher tensile strength may increase machining complexity and associated costs, it may also lead to improved product durability and reduced material failure, thereby contributing to long-term efficiency gains. Based on these results, the null hypothesis that tensile strength has no significant effect on cost efficiency is also rejected.

DISCUSSION

The findings of this study provide strong empirical support for the integration of material properties into management accounting models. The significant positive relationship between tensile strength and tool degradation corroborates existing engineering literature, which emphasises that high-strength materials intensify tool wear mechanisms due to increased cutting resistance and thermal stress (Groover, 2020; Kalpakjian & Schmid, 2014). This reinforces the argument that material characteristics are critical determinants of operational performance and should be explicitly considered in cost analysis.

Similarly, the significant influence of tensile strength on cost efficiency supports the position of Drury (2018), who argues that cost systems must reflect operational realities to remain relevant and effective. The results suggest that traditional costing approaches that ignore material-specific factors may lead to inaccurate cost allocation and suboptimal decision-making. By demonstrating that tensile strength accounts for a substantial proportion of variations in both tool degradation and cost efficiency, the study highlights the need for more refined and context-sensitive costing models.

Furthermore, the findings align with the Resource-Based View by indicating that firms capable of effectively managing material-related challenges can achieve improved cost performance. They also support Contingency Theory, as the results underscore the importance of adapting accounting systems to reflect the technical complexities of production environments. Overall, the study contributes to interdisciplinary knowledge by empirically linking material science variables with accounting outcomes, thereby offering a more holistic framework for performance measurement and cost optimisation in manufacturing organisations.

CONCLUSION

The study concludes that material properties, particularly tensile strength, constitute critical but often overlooked cost drivers in manufacturing environments. Traditional cost accounting systems that ignore such technical variables risk producing incomplete or distorted cost information. Integrating tensile strength into management accounting models enhances the accuracy of cost allocation, improves operational decision-making, and aligns

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

accounting practices with production realities. Therefore, a multidisciplinary approach that combines engineering insights with accounting frameworks is essential for achieving sustainable cost efficiency and performance optimisation.

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