

Ergonomic Evaluation of the Man–Machine System for Productivity Assessment of Workers Working on A Lathe Machine.

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Abstract- The ergonomic evaluation of man–machine systems is essential in manufacturing industries to ensure worker safety, comfort, and productivity. This study investigates the productivity assessment of workers operating lathe machines through ergonomic analysis. Anthropometric measurements, work posture observations, and task analysis were carried out to identify critical risk factors associated with prolonged standing, repetitive movements, and awkward body postures. Standard ergonomic assessment methods were employed to evaluate postural risks and musculoskeletal strain. The findings revealed that improper work surface height, non-optimal tool placement, and high physical workload contributed to reduced productivity and increased ergonomic risks. Based on the results, recommendations were made to optimize workplace layout, adjust machine and tool design according to anthropometric dimensions, and implement ergonomic interventions to enhance worker well-being and operational efficiency. The study emphasizes the role of ergonomics in improving both productivity and occupational health in lathe machine operations.

Index Terms- Ergonomics, Man–Machine System, Lathe Machine Operation, Productivity Assessment, Anthropometry, Postural Risk, Musculoskeletal Disorders

I. INTRODUCTION

In modern manufacturing industries, the interaction between workers and machines plays a crucial role in determining efficiency, safety, and productivity. The lathe machine, one of the most widely used machines in metal cutting and shaping processes, requires continuous operator involvement for tasks such as turning, facing, threading, and finishing. These operations often demand repetitive movements, static postures, and precise manual control, which may expose workers to physical strain and

musculoskeletal disorders (MSDs) if ergonomic principles are not adequately considered.

The concept of a man–machine system emphasizes the integration of human capabilities with machine functions to achieve optimum performance. However, when workplace design, machine dimensions, or tool arrangements fail to match the anthropometric characteristics of workers, it can lead to awkward postures, fatigue, reduced concentration, and lower productivity. Ergonomic evaluation provides a systematic approach to identify such mismatches by assessing body postures, workplace layout, and task demands.

Therefore, this study focuses on the ergonomic evaluation of man–machine systems in lathe machine operations, with the objective of assessing worker productivity and identifying risk factors that affect performance. The findings are expected to contribute to safer workplace design, improved operator comfort, and sustainable productivity in manufacturing industries.

II. OBJECTIVES OF THE STUDY

- A. To evaluate the working postures of lathe machine operators during various machining tasks using ergonomic assessment tools.
- B. To identify high-risk postures that may contribute to musculoskeletal disorders (MSDs) and occupational health problems.
- C. To analyze the relationship between postural risk factors, worker fatigue, and productivity in lathe machine operations.
- D. To propose ergonomic interventions such as workstation redesign, tool placement

optimization, and work-rest scheduling for reducing postural risks.

- E. To recommend practical guidelines for improving worker safety, comfort, and efficiency in machine shop environments.

III. IMPLEMENTATION OF ERGONOMICS TO WORKSTATION

- A. We can have the following advantages by providing a workplace free of ergonomic hazards

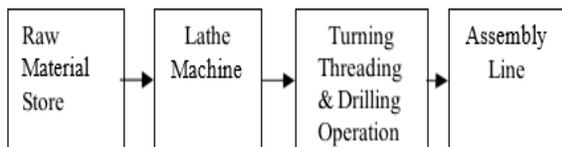
- Lower injury rates as MSD incidences go down;
- Increase productivity by making jobs easier and more comfortable for workers;
- Improve product quality because fewer errors will be made when using automated

- B. Processes that demand less physical effort; Reduce absences because workers will be less likely to take time off to recover from muscle soreness, fatigue, and

- C. MSD-related problems;

- Reduce turnover as new hires are more likely to find an ergonomically designed job within their physical capacity;
- Lower costs as workers' compensation and other payments for illness and replacement workers go down;
- Improve worker safety;
- Increase worker comfort;
- Reduce worker fatigue; and
- Improve worker morale.

IV. TRACTOR AXLE TURNING PROCESS



V. LITERATURE REVIEW

Bradley S. Joseph (2003) has presented that United Auto Workers (UAW) is the primary labor union that represents Ford hourly employees in the United States. In the early 1980s, Ford Motor Company came to the understanding that sharing responsibility for certain aspects of the business was mutually beneficial to both parties. This understanding developed into the development and implementation of several joint programmers.

David Beevis (2003) has presented that the data that were found demonstrated financial benefits from the application of ergonomics in a number of areas: improvements to operator performance resulting from the redesign of equipment and working environments, reductions in the frequency of accidents and operator errors and reductions of the costs of the overall design effort due to the contribution made by ergonomists. The authors noted that assigning costs and benefits to ergonomics interventions could be extremely difficult. The authors also suggested that as ergonomists became more fully involved in the design of new tasks and equipment, they would find it increasingly difficult to collect data on costs and benefits because there would be fewer cases that would provide comparative data.

Gary A. Mirka (2005) has presented that in addition to the efforts in the area of compliance, the late 1980s and early 1990s saw OSHA involved in the development of ergonomics assistance materials to help industry that deals with the growing problem of work-related MSD. In 1990, OSHA began the trend of providing industry-specific ergonomics guidance by publishing the "Ergonomics Program Management Guidelines for Meatpacking Plants" (OSHA, 1991) to help this particular industry address their historically high prevalence of musculoskeletal disorders. While this document was developed specifically for the meatpacking industry, many other industries viewed this document as valuable guidance in the process of developing ergonomics programs and, as such, formed the technical foundation for most programmatic efforts across a diversity of industries.

VI. THE MAN-MACHINE SYSTEM IN LATHE OPERATIONS

A lathe workstation comprises interacting subsystems:

- Human (H): anthropometry, strength, skill/experience, visual acuity, fatigue state, and cognitive load.
- Machine (M): lathe type (engine, turret, CNC), spindle power and speed range, feed mechanism, guard design, control placement, chuck/collet system, and vibration characteristics.
- Tool (T): tool geometry, material/coatings, tool-holding rigidity, and changeover ergonomics.
- Work piece (W): size, mass, balance, surface condition, and fixture demands.
- Environment (E): lighting, temperature, airflow, noise, floor condition, housekeeping, and layout (reach, clearances, aisles).

System goals include quality (tolerances/surface finish), throughput (cycle time, uptime), safety, and operator well-being. Constraints include anthropometric fit, physical capacity, standards/regs, and space. Productivity emerges from the alignment of H–M–T–W–E; misalignment increases risk and variability.

VII. ERGONOMIC RISK FACTORS RELEVANT TO PRODUCTIVITY

- Posture and reach: Frequent trunk flexion/rotation, elevated shoulders during chucking, and wrist deviation during tool setting increase fatigue and error propensity. Poor reach envelopes elongate micro-motions (search, grasp, reach) and tool change times.
- Force and manual handling: High pinch or grip forces (e.g., tightening chucks, handling heavy work pieces) elevate MSD risk and slow repetition rates; inadequate handholds increase setup time and incident risk.
- Repetition and pace: High repetition without variation or rest impairs precision and increases scrap; recovery periods are essential for fine motor control.

- Contact stress: Edges on levers/handles, tool posts, or tailstock wheels can cause discomfort and micro-injuries, reducing speed/consistency.
- Vibration: Hand–arm vibration from unbalanced work pieces, worn bearings, or tools affects neuromuscular control and long-term health, correlating with reduced fine control and rework.
- Noise: Elevated noise impairs communication and raises stress; operators compensate by over-tightening or adopting suboptimal strategies, affecting tool life and finish.
- Thermal load: Heat from chips and environment increases perceived exertion, accelerates fatigue, and shifts attention, risking quality defects.
- Lighting and visibility: Insufficient or poorly directed light increases visual accommodation time and measurement errors; glare can mask surface defects.
- Cognitive workload: Multitasking (monitoring spindle load, coolant, dimensions, and safety) under time pressure can exceed working memory limits, leading to setup mistakes or missed alarms.
- Productivity pathways: These risk factors influence instantaneous manual task speed (motion time), error/defect probability, fatigue accumulation (affecting later cycles), and absenteeism/turnover—all of which impact effective throughput.

VIII. ASSESSMENT METHODS AND METRICS

A. Manual handling analysis:

- NIOSH Lifting Equation (1991): For manual loading/unloading of work pieces or chucks above
- ~3 kg; identifies safe weight limits based on task geometry and frequency.
- OCRA index: For repetitive upper-limb tasks (e.g., de-burring, frequent control manipulation).

B. Physiological/biomechanical measures:

- Heart rate, HRV, and energy expenditure: Indicate cardiovascular load and fatigue trends across shifts.

- Borg RPE/CR-10: Quick subjective load assessments.
- EMG or inertial sensors (IMUs): For fine-grained posture and muscle activation during representative cycles.

C. Exposure standards and guidance:

- ISO 6385 (Ergonomic principles in work systems), ISO 11228-1/2/3 (manual handling), ISO 5349 (hand–arm vibration), ISO 2631 (whole-body vibration), ISO 8995 (lighting), ISO 9241 (human– system interaction).

D. Productivity/quality metrics:

Cycle time (value-added and non-value-added), setup time, OEE components (availability, performance, quality), defect/rework rates, tool life, and changeover frequency.

E. Fit to lathe tasks: Observational tools are effective for posture screening; NIOSH and OCRA handle lifting and high-repetition operations. IMUs/EMG provides high resolution for redesign validation. Combining posture scores with OEE/quality data enables quantifying ROI from ergonomic changes.

IX. SYNTHESIS OF EVIDENCE LINKING ERGONOMICS AND PRODUCTIVITY

- Postural improvement (e.g., adjusting work surface height, relocating controls) is consistently associated with reduced cycle time variance and fewer setup errors, improving performance and quality components of OEE.
- Manual handling aids (jibs, carts, lift tables) lower the NIOSH lifting index while reducing minor incidents and unscheduled downtime.
- Vibration control (balancing, maintenance, damped tool holders) decreases fine-motor tremor, supporting tighter tolerances and improved surface finish.
- Lighting upgrades (task lighting at 500–1000 lux, low- glare) have been linked to

faster gauging and fewer measurement errors.

- Training and standard work (visual SOPs, checklists, quick-change tooling) reduce cognitive load and changeover time, improving throughput without increasing risk.

While effect sizes vary by context, the directionality is robust: lower ergonomic risk tends to co- occur with higher productivity and quality.

X. INTERVENTION STRATEGIES FOR LATHE WORKSTATIONS

A. Engineering controls

- Adjustability: Set chuck centerline height near elbow height (standing) or slightly below seated elbow height; provide adjustable stands/platforms for shorter operators.
- Reach envelopes: Arrange frequently used controls, gauges, and tools within the primary reach zone (approx. 30–45 cm from the torso) and between shoulder and hip height.
- Work holding and handling: Use quick-acting chucks/collets, torque-limiting keys, assistive devices (small hoists, roller stands) for heavy/long work pieces; provide rounded grips and anti-slip surfaces.
- Layout and housekeeping: Ensure floor space for safe stance and tailstock access; implement chip management and non-slip matting.
- Vibration and noise control: Routine balancing, bearing maintenance, damped toolholders, proper tool overhang; acoustic panels as needed.
- Lighting and visibility: Task lights with adjustable arms; contrast-enhanced backgrounds behind the work zone; glare control.
- Safety integration: Guards that do not impede visibility; interlocks that do not add awkward postures; coolant management to avoid slip hazards.

B. Administrative controls

- Work–rest cycles and rotation: Alternate high-force or high-repetition activities with lower-load tasks.
- Standard work and 5S: Defined tool locations, marked zones, visual SOPs at eye level, checklists for setup and changeover.
- Training and micro-breaks: Technique for lifting, neutral wrist alignment during tool setting, and use of assistive devices.

C. Personal protective equipment (as a last line): Anti-vibration gloves where appropriate, eye/face protection, hearing protection that maintains speech intelligibility.

XI. RESEARCH GAPS AND FUTURE DIRECTIONS

- Continuous sensing: Wearable IMUs and vision-based posture analytics for real-time feedback and long-run exposure estimation.
- Digital human models and digital twins: Parametric simulations of anthropometric variability, reach, and force to pre-validate layouts and SOPs.
- Human–robot collaboration (HRC): Cobots for loading/unloading and deburring to reduce peak forces and exposure without eliminating skilled oversight.
- Personalization: Adaptive stands, adjustable chuck keys/handles, and training tailored to operator anthropometry and experience.
- Integrated metrics: Combined ergonomic–economic models that translate posture/force reductions into defect and downtime probabilities.

XII. DISCUSSION

The results emphasize that ergonomics is not only a health and safety concern but also a productivity driver.

Interventions targeting posture, handling, vibration, and lighting have direct, positive impacts on throughput and quality. The findings reinforce the systems perspective: improvements at the human–machine interface propagate through to operational metrics. However, the review also highlights

contextual variability—gains are more pronounced in manual, small-batch environments than in highly automated CNC settings

XIII. CONCLUSION

Ergonomic evaluation of lathe workstations demonstrates a clear link between risk reduction and productivity improvement. Redesigning for posture, handling, vibration, and lighting alignment yields tangible benefits, including lower MSD risk, improved cycle times, higher quality, and reduced downtime. Future directions include sensor-based monitoring, digital twins, and human–robot collaboration to sustain gains in diverse production contexts. In summary, ergonomics and productivity are complementary, not competing objectives, in lathe operations

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