Scand J Work Environ Health 1981;7(4):115-119
Issue date: 1981

The determination of effective injury controls for metal-cutting lathe operators.

by Etherton JR, Trump TR, Jensen RC

Key terms: determination; effective injury control; handtool; hazard analysis; injury control; lathe operator; machine safety; man-machine system; metal-cutting lathe; metal-cutting lathe operator

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/7330620

Print ISSN: 0355-3140 Electronic ISSN: 1795-990X

Scand j work environ health 7 (1981): suppl 4, 115—119

The determination of effective injury controls for metalcutting lathe operators

by John R Etherton, MEA,[1] Thomas R Trump, MA,[2] Roger C Jensen, MSE [1]

ETHERTON JR, TRUMP TR, JENSEN RC. The determination of effective injury controls for metalcutting lathe operators. *Scand j work environ health* 7 (1981): suppl 4, 115—119. Operators of metalworking lathes are one of the largest manufacturing machine worker populations in the United States. Machines (other than vehicular) account for over 10 % of occupational injuries each year. An estimated 3,400 operators of metalworking lathes suffer lost-time injuries annually in the United States. Some of these are fatal. Therefore an investigation was undertaken to determine methods for reducing injuries to lathe operators. Three methods were used: (i) review of injury reports, (ii) human factors analysis, and (iii) fault-tree procedures. The investigation followed the man-machine systems approach of looking for injury-producing dysfunctions between the lathe and the lathe operator. The major sources of injury were found to be chips and workholding devices. Secondary tasks were found to be more hazardous than is generally recognized. The use of three methods for approaching the problem was found to be useful in that injury controls were identified which are likely to be adopted because of their potential for improving safety without adversely affecting productivity.

Key terms: handtools, hazard analysis, machine safety, man-machine systems.

Machines are the source of approximately 10 % of the compensable workplace injuries that occur in the United States. This study focuses on the operation of metalworking lathes because this machine ranked second highest in a quantitative prioritization of the safety needs of 29 metalworking machine tools in the United States (17). Starr & Whipple (15) have suggested the use of such a quantitative assessment to establish "risk targets" as a first step toward the development of creative methods in risk control.

There are approximately 144,500 American workers classified as metalworking lathe operators. Statistical evidence indicates that every year 3,400 of these workers will suffer a lost-time injury. Informal discussions with workers and shop supervisors indicate that the severity of most of these injuries is perceived to be low. However, during the first three months of this project three lathe operators were killed within 100 km of the National Institute for Occupational Safety and Health (NIOSH) facility in Morgantown, West Virginia.

Man-machine systems research (6, 11, 13) seeks methods to deal with the complexities of fitting man and machine together in order to meet some operational goal. From a safety point of view a system fails to meet its operational goal if traumatic injury disables the human element in the system. From a productivity point of view a serious injury to one machine operator not only interrupts production on that machine, but also has a prolonged adverse effect on the production rates of other workers in the area (5).

Metalworking lathes are versatile machine tools which rotate a workpiece of metal or other materials against a fixed tool to cut cylindrical forms. Shafts, rollers, and discs are typical products. The task of actually cutting the material is

[1] Division of Safety Research, National Institute for Occupational Safety and Health (NIOSH), Morgantown, West Virginia, United States.
[2] Applied Science Associates, Inc, Valencia, Pennsylvania, United States.

Reprint requests to: Mr JR Etherton, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, WV 26505, USA.

0355-3140/81/080115-5

generally referred to as the primary operation. Current safety guidelines (1) emphasize the hazards of performing primary lathe operations such as pinch points between cuttings and tools, flying objects such as thrown cuttings and or loose workpieces, and the possibility of being struck by or caught by rotating workpieces. However, Degarmo (7) has estimated that less than 50 % of an operator's available time is actually spent in the primary task of cutting material. Secondary tasks performed by the lathe operator include securing (setting up) the workpiece in the lathe, installing the proper cutting tool, selecting and setting the controls for lathe speeds and feeds, engaging and disengaging the chuck rotation (speed) and cutting tool movement (feed) controls, gaging the work for depth of cut, and hand filing and polishing the surface of the rotating workpiece.

Generally, lathes tend to be manually operated in situations which need the adaptability of a skilled machinist. These situations include the machining of most one-of-a-kind parts, repair parts, and prototypes. However, people have limited adaptive motor responses (8). For example, a lathe operator can neither see well enough nor move fast enough to avoid a heavy metal workpiece which suddenly comes loose and is thrown from a lathe rotating at 450 r/min.

Several investigators have looked at the ergonomics of lathes, including postural comfort (10), control configurations (4, 12, 14), and work pace (3). Generally these investigators indicate that the typical lathes found in workplaces throughout the world are not very well designed for human comfort, efficiency, or safety. The present investigation was undertaken with the goal of finding practical methods for reducing the risk of injury to machinists who must operate these poorly designed lathes.

Methods

Three complementary methods were applied: (i) a review of injury reports, (ii) a human-factors evaluation based on in-plant observation and task analysis of lathe operators at work, and (iii) a fault-tree analysis.

Injury report analysis

Injury reporting systems in the United States are not very suitable for prevention-oriented research (16). However, there are some sources of injury data which can be useful for identifying common injury patterns associated with various factors of interest. In the search for lathe injury data, worker compensation files produced the greatest volume of lathe injury information. An intensive search for detailed lathe injury reports produced 538 understandable reports.

A reviewer familiar with lathes and lathe operation reviewed the injury reports and established data sets of significant repetitions of conditions or events. A causal factors approach, as expounded by Benner (2), was followed in this analysis. Such an approach avoids looking immediately for the single cause of injury. Rather, information is sought on the coincidence of events or conditions influencing a systemic cause and effect interaction. The injury is viewed as the culminating event of a time-dependent process. With the process defined, it should be possible to focus special attention on the human, the equipment, and the environmental elements of the process for which preventive measures can be applied. Worker's compensation injury reports focus primarily on the overt behavior or activity of the worker. Little information is found about the equipment or environmental factors which may have influenced that behavior. Therefore, the method for analyzing these reports involved classifying general types of operating activities and dysfunctions which existed between the operator and the work.

Human factors evaluation

The second method involved making observations of the worker at the machine and evaluating the fit between operator and lathe. Eight manually operated metal-cutting engine lathes which were used in manufacturing operations were identified. A researcher observed each of these during one or more operations and used a task analysis technique for identifying potential injury situations during the performance of work. A further analysis was made of these lathes against a human factors checklist designed to determine whether the controls, dials, charts, and locks were visible, identifiable, accessable, and functionally operable.

In the task analysis a potential injury situation was defined as a situation in which there was reasonable potential for immediate worker injury resulting from the worker's actions (eg, worker placed his hand close to the paths of revolving workpiece bolts while talking to a fellow worker) or delayed worker injury resulting from some recurring activity (eg, worker repeatedly bumped knee on the chip pan). Identifying a potential injury situation during the observation of lathe operations required the recognition of human errors and possible errors occurring in the tasks, followed by "playing" of accident scenarios in the mind's eye for each of the possible human errors recognized.

Fault-tree logic assessment

The third method used was a fault-tree logic analysis to ensure that all injury types associated with the system would be addressed. The fault-tree approach was applied as a logic check on the thoroughness and inclusiveness of the data obtained with the other methods. It also became the framework for introducing possible preventive actions. The basic steps used in this analysis were:

1. Identify groups of injuries from the same accident type that had similarities in contributing events and resulting events. Twenty-two groups of injuries were identified.

2. Develop 22 fault-tree diagrams which logically represent every combination of events and conditions that could possibly cause an injury of the type identified at the top of the diagram.

3. Verify the logic by matching the data developed with other methods to branches of the fault trees.

4. Identify countermeasures wherever possible on branches of the 22 fault trees.

5. Consolidate the countermeasures (many are repeated) into a final list.

As an example, fig 1 shows a fault tree with a common injury sequence in which the worker loses physical control of a file which leads to the hand holding the file slipping against the workpiece. This situation can result in a broken hand, a bloody gash to the forearm, or even a serious head injury if the worker falls against the rotating chuck or workpiece. Countermeasures which would prevent this accident would be to provide the worker with polishing tools suited for the job, to train the worker to hold files firmly with both hands and with the upper hand away from the chuck, and, if possible, to provide handles for both ends of the file to encourage the worker to use both hands while filing.

Results

The review of 538 injury reports produced the following information about the circumstances involved in injuries to lathe operators. First, the principle sources (or objects) of injury and the percentage of total cases associated with each were found to be the following:

Chuck or workholding device	23 %
Cuttings and chips	23 %
Workpiece	15 %
17 other sources	39 %

Second, an assessment of the task being performed at the time of injury revealed that 83 % of the injuries occurred while the operator was performing a manual secondary task (setting up, loading/unloading, measuring, filing/deburring, polishing,

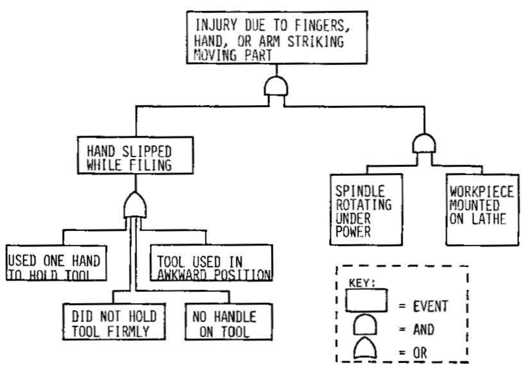

Fig 1. Example of part of a fault-tree diagram.

cleaning/clearing). The remaining 17 % of the injuries involved the primary tasks associated with cutting the material.

The third use of the injury reports was to determine the component of the man-machine system which dysfunctioned. The following list shows nine types of man-machine dysfunction and the percentage of cases attributable to each.

Failure to recognize hazard	28 %
Protective equipment needed	16 %
Hazardous work method	14 %
Strength exceeded	13 %
Grip exceeded	11 %
Tool fit improperly	8 %
Workpiece inadequately secured	4 %
Misjudged orientation to hazard	2 %
Lost balance	2 %
Other	2 %

The human factors assessment of the lathe operations resulted in the following list of potential injury situations and conditions: (i) tripping hazards existed for slotted wooden floor mats; (ii) screws protruding from rotating setup devices could cause injury; (ii) cuttings were cleared with tools that could pull the operator into a hazardous situation; (iv) heavy workpieces had to be securely held to prevent shifting and falling; (v) hand filing of rotating workpieces required safe holding; (vi) 72.4 % of the observed lathe controls were not functionally identifiable.

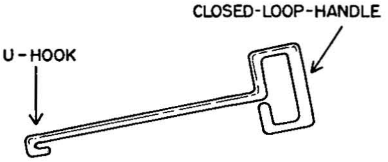

Fig 2. Example of an unsafe cutting removal tool.

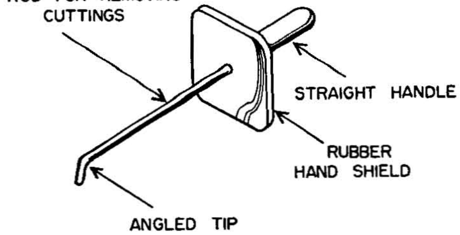

Fig 3. Suggested design for a safer cutting removal tool.

The systems safety analysis led to the development of 22 fault-tree diagrams. From these diagrams a set of 28 safety recommendations and suggestions were formed. An example of a suggestion to reduce the risk of injury during attempts to remove cuttings while the workpiece is rotating is shown in fig 2 and 3. Fig 2 shows a cutting removal tool which is unsafe because the U-hook can catch on cuttings rotating in the workpiece and the closed-loop handle can prevent the worker's hand from releasing and allow the operator to be pulled into the lathe. A suggested safer design is shown in fig 3. This cutting removal tool is designed so that the tip will not easily catch on the cuttings and the handle will allow the worker's hand to release easily if the tool does become caught.

Discussion

According to Fox (9) the adoption of the results of an investigation of this type depends on whether the results are compatible with production methods in use. The combined review of injury reports, task analyses, and fault-tree procedures used in this study point toward such compatibility. The review of injury reports establishes the need for better controls. The task analysis assures that the suggested controls are based on an indispensible understanding of how the operator and the lathe really function on the job. And the fault-tree procedure organizes a large amount of hazard information into smaller problems for which a variety of suggested solutions can be tried. Together, the applied methods (i) focus on workplace information, (ii) seek workable safety solutions, (iii) keep operator capabilities and limitations in mind, (iv) do not confound the problem with inconvenience, false security, increased risk or higher stress, (v) adapt to the jobs in question, and (vi) focus on the goal to reduce or eliminate the chance of injury.

Many other machines should be studied to determine more effective methods for controlling the risk of injury. The choice of investigation methodology can be critical because different methodologies can lead to different solutions. In this investigation of manually operated metalcutting lathes, it was found that each of the methods for analyzing the problem helped the investigators gain additional insight. Consequently, it is recommended that, in the machine safeguarding area, researchers should not limit themselves to the use of any single methodology for assessing the problem and identifying feasible solutions.

References

1. American National Standards Institute. B11.6-Safety requirements for the construction, care, and use of lathes. New York, NY 1975.
2. Benner L. Accident investigations: Multilinear events sequencing methods. J safe res 7 (1975) 67—73.
3. Branton P. A field study of repetitive manual work in relation to accidents at the workplace. Int j prod res 8 (1970) 93—101.
4. Carr R, Ashford F, Easterby R. Design of a lathe for international markets. Hum factors 8 (1966) 327—337.
5. Colvert D. Accident: Related losses make costs soar. Ind eng 11 (1979) 26—29.
6. Christensen JM. The evolution of the systems approach in human factors engineering. Hum factors 4 (1962) 7—16.
7. Degarmo P. Materials and processes in manufacturing. MacMillan, New York, NY 1962.
8. Fitts P, Peterson J. Information capacity of discrete motor responses. J exp psychol 67 (1964) 103—112.
9. Fox J. Ergonomics in production engineering. In: Singleton W, Fox J, Whitfield D, ed. Measurement of man at work: An appraisal of physiological and psychological criteria in man-machine systems. Taylor and Francis. London 1971.
10. Harten G, Derks P. A new ergonomically improved lathe. Appl ergon 6 (1975) 155—157.
11. Meister D. Human factors: Theory and practice. Wiley, New York, NY 1971.
12. Pratt F, Corlett E. The ergonomics of vertical turret lathe operation. Appl ergon 1 (1970) 302—309.
13. Sheridan T, Ferrell W. Man machine systems: Information, control, and decision models of human performance. MIT Press, Cambridge, MA 1974.
14. Singleton W. A preliminary study of a capstan lathe. Int j prod res 3 (1964) 213—226.
15. Starr C, Whipple C. Risks of risk decisions. Science 208 (1980) 1114—1119.
16. ———. Feasibility of securing research-defining accident statistics. US Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV 1978. (Publication no (NIOSH) 78—180).
17. ———. Machine guarding — Assessment of need. US Government Printing Office, Washington, DC 1975. (US Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, publication no (NIOSH) 75—173).