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ERGONOMICS IN MACHINE TOOL DESIGN

SECOND PROGRESS REPORT ON M.T.I.R.A.

RESEARCH PROJECT

APRIL 1963

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- by -

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SUMMARY

This report is the second of a series of reports, to be issued every six months, describing the progress of a research project on ergonomics in relation to machine tool design. The report covers, in broad outline, the progress made, and some projects anticipated in the ensuing year. Separate detailed technical reports will be issued from time to time, as experimental and survey data become available.

The progress reports are numbered in The College of Aeronautics Notes series. The first report, issued in October, 1962, is CoA Note 150, Part 1. The technical reports will also be numbered in the series.

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1. Introduction

As discussed in the first report, issued in October 1962, the initial contacts with industry indicated some of the problems that could be examined by the laboratory. Work has now started in most of these areas, and the progress over the last six months has been quite substantial.

It will be appreciated that, for a single worker, progress is only made in one area at the expense of neglecting others. The exigencies of experiment design, factory visits, literature searching, and the building of equipment often dictated the course of the project over a half year, but in the long term, it is hoped to fulfil the two primary requirements of basic research and the provision of an ergonomics advisory service to industry.

The sections of this report correspond to the potentially useful areas of study outlined in the first report, namely, systematic design methods, display design, and control design.

2. Systematic design methods

If the machine tool industry is to exploit the rapidly expanding technology (in particular the more elaborate methods of machine tool control), then systematic and logical techniques for the evaluation of human operator functions must be developed. To be successful, these working methods must be available at the design stage, rather than relying on extensive observation and modification of existing machines.

One of the difficulties encountered in the design of a complex system is that of communication of ideas and findings. Most systems are complex enough to require several designers to be working on a given problem. The system is broken down into sub-systems for each individual to deal with, and the individually designed sections must be compatible and fulfil the major system objectives. As the control methods available become more diverse, and the emphasis of function of the human operator changes from a power producing element to a decision making element, the importance of logical design methods increases. A systematic design method can be an aid to thinking, a means of communication between engineering designers and also a common meeting point for the several contributors to the design process - engineers, ergonomists, industrial designers, and managers. These methods can help to guarantee that major design policy decisions are properly considered, that no critical feature is overlooked, and may generate ideas for further research.

Work carried out in this area has, so far, been in the form of

participation in seminars and discussion with other members of the laboratory staff. The trend is towards a much closer identification of ergonomics and systems design, so that the role of the human operator is properly co-ordinated with the application of technologies. In the future, it may prove possible to apply some of these developing ideas in the machine tool context.

3. Display design

3.1 Legend plate design

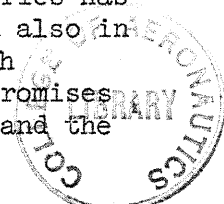
The design study detailed in the first report of this series has created considerable interest in the engineering industry and also in the ergonomics field. Some contact has been established with manufacturers of legend plates, to ensure that the right compromises are achieved between the satisfactory ergonomic requirements and the limitations of the manufacturing processes.

The work is now being extended to experimental validation of the design principles, using error-rate and setting time as criteria. The weighting given to these two performance measures will have to be carefully related to the actual machine tool situation; for instance, an experienced, or careful and conscientious operator may accept longer setting times as the price of not making any setting errors. The experimental design envisages the measurement of the performance of both unskilled and experienced operators, enabling some evaluation to be made of the training times involved with the different types of legend plate design.

The building of experimental equipment is at an advanced stage, a mock up of the lathe headstock having been built, and the active co-operation of a legend plate manufacturer makes it possible to use actual plates manufactured to the standards commercially available to machine tool makers.

3.2 Indicator plate symbols

A draft British Standard on Symbols for Machine Tool Indicator Plates was issued in April, 1962 and was open for comment until May of that year. Unfortunately, the Standard did not come to our notice until September, 1962, during the early stages of the research project. Section 2.2 of the first progress report passed some adverse comments on this Standard. These comments were subsequently forwarded to the Machine Tool Trades Association representatives on the British Standards Institution Committee, who then requested an elaboration of these comments. While aware of the impending finalisation of the Standard, it was felt that it would be remiss if a research project specifically devoted to ergonomics in machine tools did not make some constructive contribution, and also justify some of the original remarks.



The response to this request could have taken one of two forms; either a brief survey of the problem with practical examples of improved symbol design, or a comprehensive evaluation of the basic psychological principles involved and a complete reappraisal of the Standard. The first approach could leave too many possible points of criticism on the basis of incompleteness, and no possibility for subsequent validation and experiment. Work is in progress on a reappraisal of the Standard and on the preparation of a revised interpretation to make the symbols more meaningful by the application of basic psychological principles of perception of forms and shapes. At the time of writing, the redesign of the symbols has been completed, and the difficulties initially encountered in obtaining a satisfactorily high standard of reproduction of the symbols for the report have been overcome.

3.3 Machine manuals

An interesting philosophy has been developed concerning operation and maintenance manuals, arising out of the general discussions, amongst the staff of the laboratory, on ergonomics and systems design. The design of manuals is part of the system development cycle. The manual is essentially a part of the display of the machine - an off line display admittedly - but nevertheless a source of information for the operator about the performance of the machine. As such, it is one of the links in the man/machine loop which must be the concern of ergonomists, and some effort has been devoted to stating some general principles that can be used in preparing the content, layout, and presentation of manuals.

As with the legend plate study, the impetus for this particular project has come from one of the M.T.I.R.A. who has provided the raw material, in the form of an existing machine manual, for study.

4. Control design

4.1 Large machine controls

The problems of the design of control interfaces for machines physically much larger than the operator is causing machine designers some concern. Many of the problems arise because of the exploitation of more elaborate electrical and hydraulic control techniques, which enable remotely located control pendants to be used. The designer's problem is one of deciding what to provide on these pendants, rather than how to achieve a particular control operation.

In any situation potentially utilising the knowledge from the field of ergonomics, it is instructive to examine the likely benefits of its application, and the impact which can be made on an area such as machine tool design. Indeed the effectiveness of ergonomists is dependent on their ability to recognise the worthwhile problems in

the industrial context. This procedure can be rationalised by applying these general criteria:-

- (a) Are there sufficient man/machine units to justify investigation?
- (b) Are the machine units sufficiently costly to justify possible economic improvements?
- (c) Does the cost in terms of human loss - injury or death - justify any improvements?

The original request for work in this field was orientated towards large boring machines, and on the face of it there are not really sufficient man/machine units in the U.K. (approx. 400) to justify extensive investigation (c.f. lathes - some 250,000). Nor are they particularly dangerous machines and they do not therefore adequately justify inclusion under the third criterion. Some preliminary survey work, carried out with the co-operation of some heavy plant manufacturers, has shown however, that there is a large number of machines of different types which pose similar problems of pendant design. There is often within one plant a representative selection of 4 or 5 machine types, each with this common feature of mobile control stations; e.g., one plant has two borers, one large surface grinder, two plano millers and two large planers. This common characteristic, combined with the high cost of this class of machine, brings the problem into the class of those worth studying.

Considerable controversy exists between customer and manufacturer in relation to the type of control functions required, control differentiation (e.g., selection versus actuation of power circuits), and the necessary instrumentation requirements (provision of horsepower, motor current, feed rate, cutting rate, and spindle speed indications). Physical size of the pendant is considered important since it obstructs the work and restricts movement in the workplace.

These preliminary observations over the last six months have helped to define the problem. A more rigorous approach and the systematic collection of data is now required.

There would appear to be three methods of data collection:

- (a) Systematic observation determining such features as frequency and sequences of use.
- (b) Synthesis of task functions from casual but protracted observation.
- (c) Critical incident analysis - the evaluation of significant failures of the man/machine combination giving rise to errors and accidents.

Method (a) using, for example, film techniques is not very practical, because of the mobility of the control station. In addition, at one particular firm they appear reluctant to permit the use of a camera; no doubt they are a little sensitive to shop floor reaction, having just had a strike over redundancy.

The second method is a possibility, since the firms co-operating will permit any amount of direct on floor observation to be made over any period required, and their general reaction to the project is encouraging, since they feel an attempt is being made to analyse their requirements.

A critical incident survey of errors and accidents may prove to be a useful method of collecting data. At one firm visited, the method study department is sensitive to any factors such as errors, accidents, cutter breakages, etc., which increase production time. Since contract rates need to be adjusted to account for these increases in production time, a record exists of all situations where the error could have been caused by the operator. These records are available and arrangements have been made to conduct a survey to determine whether there is any definable pattern of mistakes attributable to bad man/machine relationships.

With either of these two possible methods (method (b) or (c)), the time and effort involved in the collection and analysis of data may be considerable, and with the present resources some compromise will have to be made between the time available for laboratory work and this type of 'shop floor' study.

4.2 Control dynamics

The dynamic features of machine tool controls, and their relationship to the human operator, are the subject of some current experimental work. A specific study of displacement time patterns for the capstan slide of a capstan lathe has been initiated. Arising out of this work, a capstan star wheel experimental rig has been built, and instrumentation work is in progress to examine in more detail the specific performance problems associated with capstan star wheel design.