UNDERGRADUATE REPORT

SYSTEMS RESEARCH CENTER

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Microstructural Analysis Pertaining to Quality Control of Machined Surfaces

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Abstract

The microstructures of a low carbon steel, an aluminum alloy, and a brass alloy were studied for input to highly theoretical mathematical models of machining operations. This was accomplished through production and analysis of samples of the actual pieces of each alloy which were to be machined. The microstructural content of each sample was analyzed through the use of a light microscope as well as a scanning electron microscope. The microstructure of the low carbon steel was found to display some processing defects through lack of a random distribution of microstructures. Thus this alloy, in this condition, was determined not to be ideal for input to these mathematical models. The microstructures of both the aluminum and the brass alloys were found to be extremely homogeneous. Thus upon input, these alloys as well would not introduce a random aspect to these models.

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1. Introduction

Quality control is one aspect of manufacture which has always been of some significance to the manufacturing industry. After all, without limits and tolerances there is no scientific method to determine when a product is finished. Specifically, surface characteristics of machined parts represent one of the major factors by which to evaluate products for quality. Additionally, tool wear is a major source of damage to these machined surfaces.

Unfortunately within the manufacturing industry, product quality has historically conflicted with and most often been superceded by plant productivity. All to often the main, if not only, concern of manufacturers was the quickest way for them to turn the largest profit. However with the recent resurgence of the conservation movement, manufacturers have been forced to reprioritize the various aspects of manufacturing in accordance. Correspondingly, the importance of quality control within the manufacturing industry has increased dramatically. Specifically, the concept and practice of continuing a machining operation until the wear of the machine tool exceeds the limiting value and thus one or many defective parts are produced is no longer acceptable. As a result, the need for an on-line monitoring system for quality control has been most graphically illustrated.

Many tool wear sensing methods have been developed. However as a direct result of undesirable qualities related to both cost and effectiveness, these methods have not yet been made available for use in industry. In light of this, an experimental series of mathematical models to theoretically predict machined surface topographies has been developed at the Systems Research Center of the University of Maryland. These models are based upon a correlation between the machine tool wear mechanism and the dynamic variation of the on-line detected cutting force. Specifically, these models detect the dynamic variation of the cutting force during machining and instantly trace the position of the cutting tool. Thereby numerically reconstructing the surface texture formed by the machining process. Each of these models represents a specific machining operation. The machining operations are described by tool geometry, tool path geometry, and certain cutting parameters. Input to these models is obtained solely from microstructural analyses of the materials to be machined. These models will be tested through comparison of their outputs with the actual machined surface topographies of several distinct sample materials. Thus, microstructural analysis of the sample materials has become necessary.

2. Basic Methodology

Due to possible inconsistencies which exist within large production batches of any metal, microstructural analyses must be performed on the identical pieces of stock which are to be machined. This is accomplished by cutting a one quarter of an inch thick sliver off of each piece of stock before it is prepared for machining. Several small cube shaped samples are then cut out of each sliver and used as material samples (see Appendix A, Figure 2). The material samples must then undergo a multi step procedure of microstructural analysis (see Appendix A, Figure 1).

2.1 Preparation, Stage I

Each material sample is placed in a cap lug (see

Appendix A, Figure 3). The cap lugs are then filled with epoxy and allowed to set overnight. Upon hardening, the epoxy, encasing the samples, is pryed from the cap lugs.

2.2 Preparation, Stage II

The epoxy which has seeped under the samples must be slowly removed through coarse sanding until the desired material surfaces are exposed. Those surfaces are then finely sanded with both 400 and 600 grit sand papers, in respective order. The sanded surfaces are then finely polished with a metallographical polishing powder until ultimately all of the sanding scratches are removed. The surfaces must be both smooth as well as flat at this point. Chemical etching of the polished surfaces is required in order to provide contrast in color of the microstructures. Thus, finally, to enable microscopic analyses, the polished surfaces are treated with etchants specifically designed for each material.

2.3 Microstructural Identification

The freshly etched samples should then be carefully examined under a microscope. Several representative portions of each sample should be located and photographed in turn. The sample photographs are then analyzed through comparison with reference texts and papers. The purpose of these analyses is the identification of the microstructural constituents within each of the samples.

2.4 Data Coding

The sample photographs are digitized (see Appendix B) through the use of a digitizing scanner. The digitized photographs can then be stored in computer files as binarily coded data. The microstructural analysis data, in this form, is ready for input to the mathematical models.

3. Work Which Has Been Done

To date this research has been performed with models representing various turning operations. Turning operations were chosen as the initial focus of this research due to their relative simplicity with respect to other machining operations. When considering a turning operation, there are only three cutting parameters of relevance, i.e., feed (f), depth of cut (d), and cutting speed (v), (see Appendix A, Figure 4).

Specimens of three dissimilar materials were obtained for testing and verification of these models. Specifically, one twelve inch long piece of three inch diameter round stock of each 1020 low carbon steel, 6061 T6 aluminum alloy, and a brass alloy (50% copper) was used. Several material samples of each of these specimens were produced and analyzed for input to the machining models.

4. Discussion of Results

4.1 Low Carbon Steel

Upon microscopic analysis, the steel samples were found to display an unexpected phenomenon. The distribution of microstructures within the material was not entirely random. Rather, the majority of the harder pearlite structures had been aligned in one particular direction within the axial planes. This is believed to be a direct result of the fact that these samples were of a material which had been cold rolled during production. As a result, the pearlite structures had been reoriented in the direction of rolling; thus destroying their random orientation (see Appendix B, Photo 1). A photograph taken of the cross-section of the same sample as that in the previous photograph shows that the randomness of microstructures was not altered in this, the cross-sectional, plane (see Appendix B, Photo 2). (Photos 1 & 2: Pearlite structures appear as dark areas while softer ferrite structures appear as light areas). Consequently, the completely random orientation of microstructures which was desired in these samples was not present. Despite this the data obtained from this sample was acceptable for use as an initial verification of the accuracy of the machining models.

4.2 Aluminum Alloy

Upon microscopic analysis, the aluminum alloy samples were found to be significantly more homogeneous than those of the low carbon steel (see Appendix B, Photo 3). As a result, microstructural analysis of these samples through the use of a scanning electron microscope was determined to be necessary. Through this analysis, the microstructure of the aluminum alloy samples were statistically analyzed. As a result of this analysis, these samples were found to contain only microstructures with cross sectional areas of no more than 60 square microns. This fact is of extreme significance since machining tools are insensitive to microstructures of such a small size. Thus, from the perspective of a machining tool, this material might just as well be a homogeneous solid possessing the same hardness value.

4.3 Brass Alloy

As with the photographs obtained from the aluminum alloy samples, scanning electron microscopy was determined to be required to statistically analyze the microstructure of the brass samples as well. Upon microscopic analysis through the use of a scanning electron microscope the brass alloy samples were also found to contain microstructures with cross-sectional areas of no greater than 60 square microns (see Appendix B, Photo 4). Similarly, the implication of this fact is the same for these material samples as for those of the aluminum alloy.

5. Conclusions and Recommendations

5.1 Implications of the Research Results

The results obtained from the microstructural analysis of the three chosen specimen materials do not represent ideal input for the machining models to be tested. However, these microstructural analyses still do serve a valuable purpose with respect to the machining models. These analyses can and should be used for initial testing and verification of the machining models. However as a precautionary measure, additional and more appropriate (ideal) test data should be used for final verification of the accuracy of these machining models.

5.2 Future Potential of the Machining Models

These on-line monitoring systems for quality control are of a great significance to industry because they represent a feasible tool for the control of the surface quality of various machined surfaces. However, these systems also have the potential to eventually provide information on the correlation between certain cutting parameters and the machine tool life associated with any one machining operation. Therefore, from a practical perspective, these systems also have the potential to assist in the decision making process of selection of cutting parameters through comparison of the simulation results with blueprint specifications.

In summary, despite the less than ideal research data which was obtained, this research has laid the basis for valuable input into an experimental systems engineering approach toward product quality control. Specifically, this study, in part, could make feasible the design and operation of automated on-line quality monitoring systems. Thus extremely high levels of product quality may be achieved without incurring compromises in plant productivity.

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APPENDIX A

Microstructural Analysis

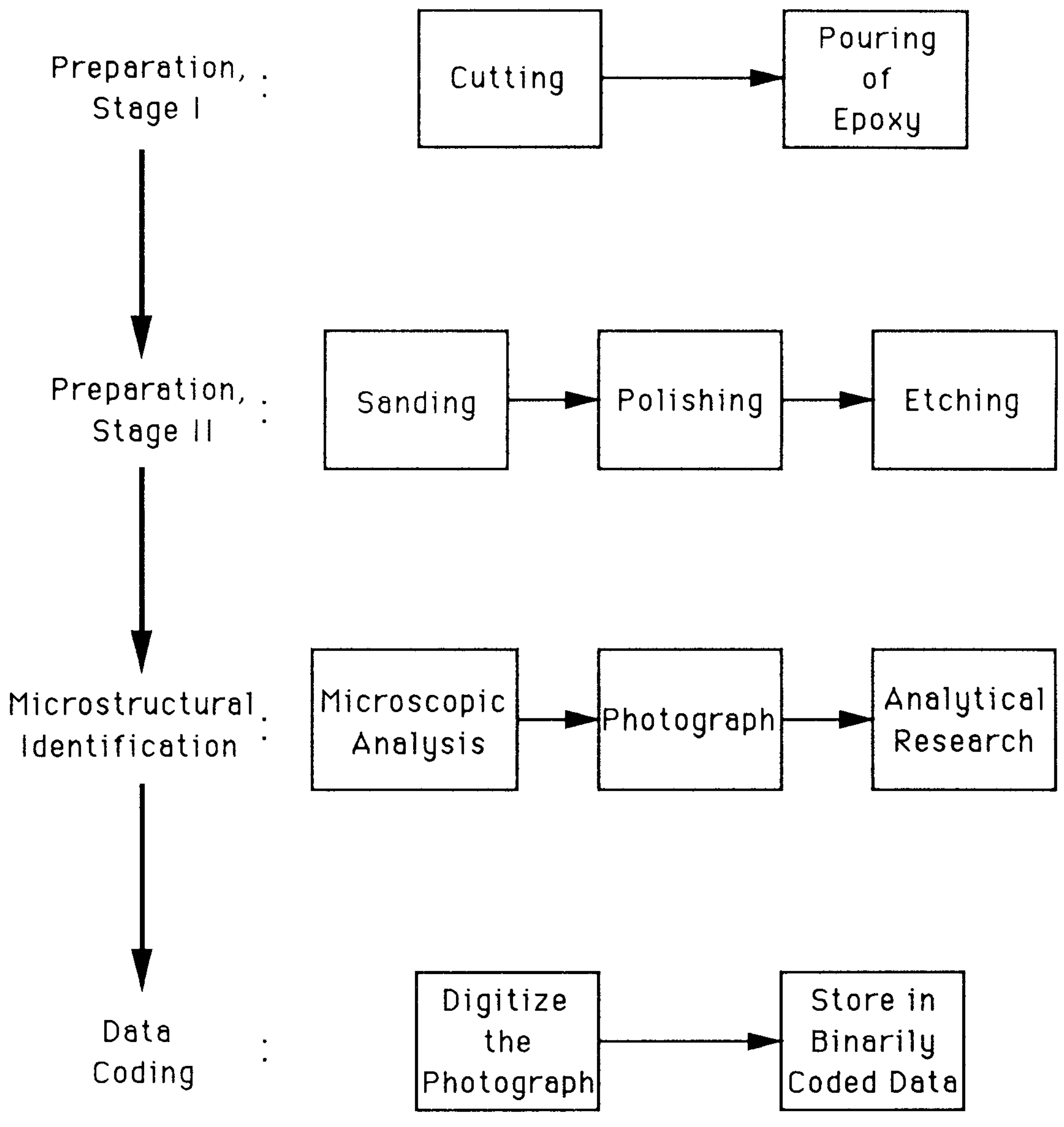

Figure 1

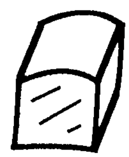

Figure 2: Material Sample

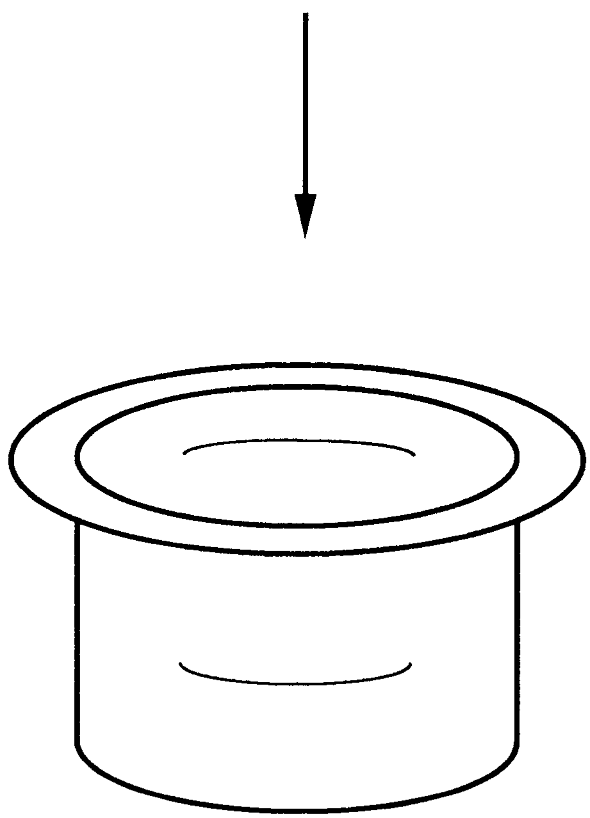

Figure 3: Cap Lug

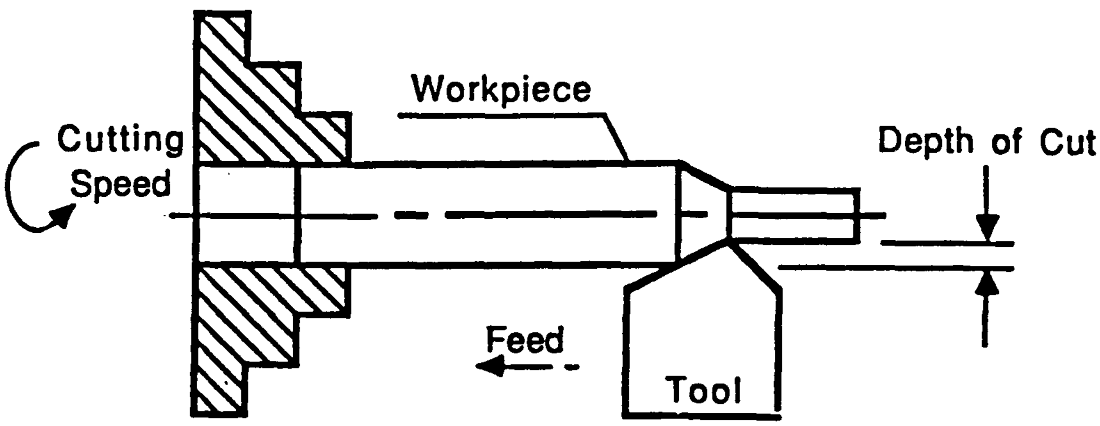

Figure 4: Turning Process

APPENDIX B

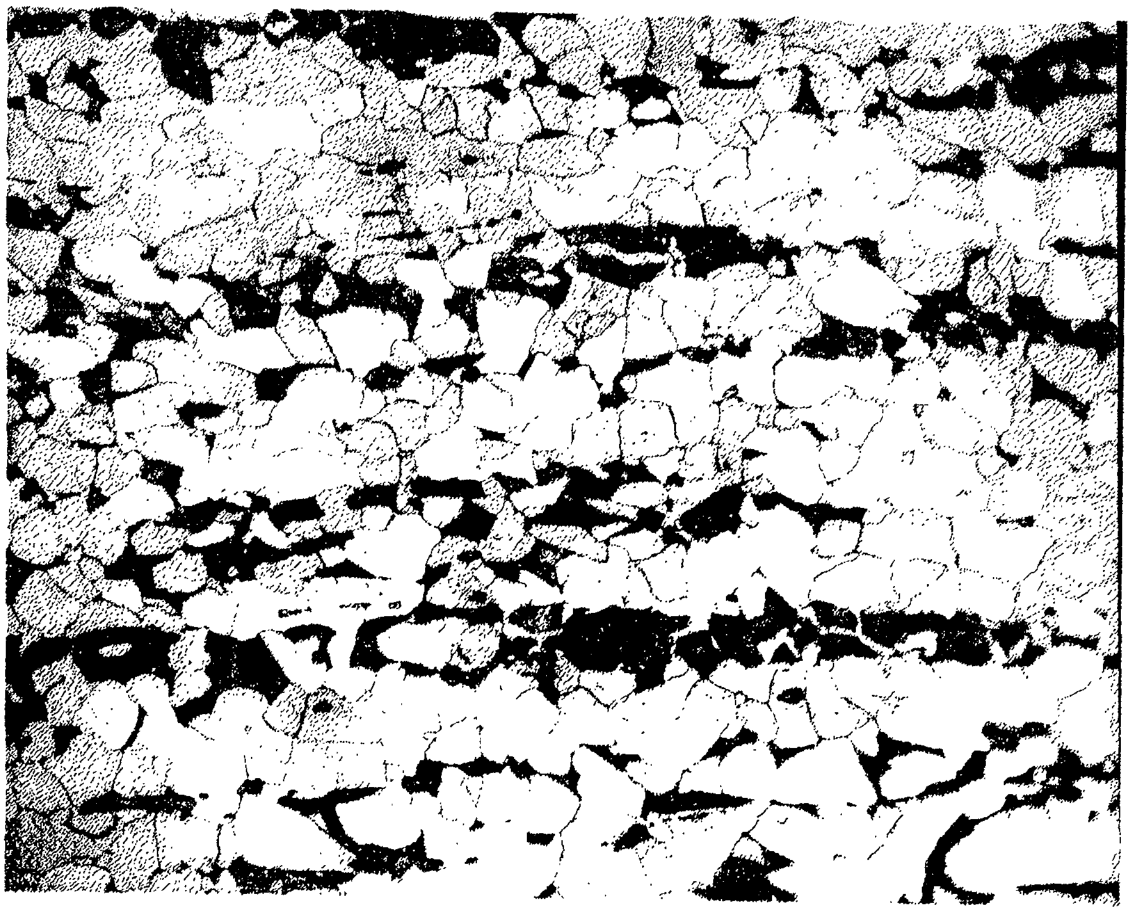

Photo 1: Steel, axial section

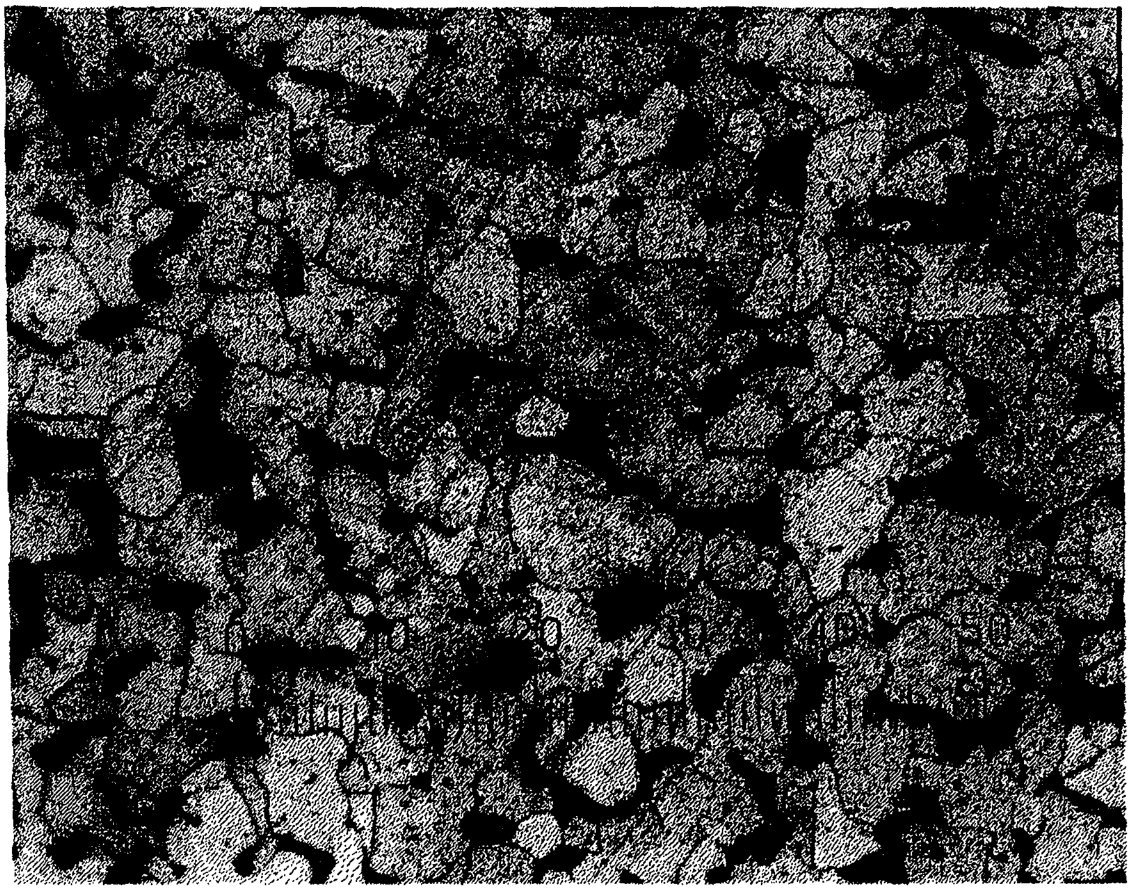

Photo 2: Steel, cross section

Photo 3: Aluminum

Photo 4: Brass