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TRAVELING WIRE ELECTRICAL DISCHARGE MACHINING AS AN ALTERNATIVE METHOD OF MANUFACTURING M1 MAIN BATTLE TANK ROTARY SHOCK ABSORBER COMPONENTS

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The project sought reduction in the manufacturing costs of M1 main battle tank rotary shock absorber components by using traveling wire electrical discharge machining. Experimental processing was carried out for evaluation of quality and cost.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0. INTRODUCTION

The project described here sought reduction in the manufacturing costs of M1 Main Battle Tank rotary shock absorber components (rotor and stator) by using traveling wire electrical discharge machining instead of the traditional machining methods normally used.

2.0. OBJECTIVES

The project goals were as follows:

- Define the cost of traditional machining to form a reference base for evaluating the economic advantage (or disadvantage) of traveling wire electrical discharge machining (WEDM). The data to be analyzed included tooling costs, floor space required, reject rates, labor costs, and maintenance costs.

- Evaluate capabilities of various WEDM vendors, and choose vendors for experimental WEDM processing of rotary shock absorber rotors and stators.

- Carry out an experimental WEDM process, and evaluate components for surface finish, surface integrity, and dimensions.

- Analyze cost of WEDM manufacturing, and compare with that of traditional machining for the rotary shock absorber components.

3.0. CONCLUSIONS

General Dynamics (GD), the prime contractor, selected three vendors, two of whom actually performed WEDM manufacturing of test components. The experimentally manufactured test components were inspected in accordance with project goals. The quality was acceptable.

The project was halted before the contractor had time to analyze cost data for WEDM versus traditional machining. Preliminary analysis demonstrated that WEDM is not a cost-effective method for manufacturing M1 Main Battle Tank rotary shock absorber rotors and stators. The quality of the experimentally manufactured components is acceptable, but the cost is higher because of slow production rate in proportion to the capital cost of the necessary equipment.

4.0. RECOMMENDATIONS

The work completed at the time the project ended demonstrates that WEDM is best used:

- When a material to be machined is too hard to machine or otherwise process (i.e., forge, stamp, etc.) by traditional methods.

- When processing prototype items or short production runs where specialized tools or dies for traditional machining or processing would be impractical.

The feasibility of WEDM and other non-traditional machining methods in production applications should be evaluated in future studies.

5.0. DISCUSSION

5.1. Traditional vs. Non-Traditional Machining and Material Processing. This project was begun to investigate the feasibility of manufacturing specific items -- rotary shock absorber stator and rotor -- by a non-traditional machining method called WEDM.

5.1.1. Traditional Machining is any process which uses a cutting tool to remove material from a workpiece to attain the desired configuration, surface characteristics, and dimensions in the finished product. Examples include drilling, turning, milling, and shaping. In these processes, the drill, lathe cutting tool, milling cutter or shaping tool relies on hardness relative to the workpiece to remove material from the latter without itself suffering substantial material loss. (All cutting tools, however, are gradually consumed as a result of contact with successive workpieces).

5.1.2. Traditional Material Processing is any process such as forging or stamping, where one relies on the hardness of a die (or other tool) relative to the workpiece to deform the latter without itself deforming.

5.1.3. Non-Traditional Machining (NTM) processes use heat, electrochemistry, abrasives, or chemicals to remove material from a workpiece without depending on the hardness of a tool relative to the workpiece material.

5.1.4. Electrical Discharge Machining. One such NTM process is electrical discharge machining, or EDM. EDM is a thermal machining method, because it utilizes numerous, randomly distributed electrical sparks between a tool and workpiece to melt or vaporize minute increments of workpiece material. Electricity is merely a convenient method of supplying heat in this highly localized, yet randomly distributed manner. The bits of material, thus removed, are then swept away by a suitable fluid such as deionized water. The fluid is also a dielectric, i.e., a non-conducting medium which becomes locally conductive under sufficient electrical potential gradient, thus causing random sparking rather than smooth current flow.

5.1.5. A common way to use EDM in the tool shop is to have a shaped tool as one electrode, and the workpiece (as in any EDM process) as the other (See Figure 5-1). The tool is gradually lowered onto the workpiece, whereupon random sparking removes increments of workpiece material. As the tool slowly moves downward, a cavity conforming to the tool shape forms in the workpiece. Insofar as material removal is caused by localized melting/vaporization rather than physical cutting, the tool material can be a readily machinable substance such as graphite. The workpiece can be of any hardness. A major limitation of all EDM processes is that both tool and workpiece must conduct electricity.

5.1.6. The EDM variant (WEDM) used in this project employs a wire as the tool electrode. The process starts with the wire in a suitable position, either external to the workpiece or in a starting hole previously drilled to permit wire access. The wire is slowly moved against, then into, the workpiece (See Figure 5-2). As the wire advances, random sparking along the length of the wire/workpiece interface removes workpiece material, one particle at a time. The particles are swept out of the way by a fluid stream which, as in all EDM processes, is also a dielectric.

The wire is advanced forward along a programmed path, parting the workpiece in the manner of a jig-saw cutting an arbitrary shape out of wood. The wire also moves along its own axis, from a supply reel to a takeup spool. This is done because the sparking action also erodes the wire material and will thin the wire until it breaks unless fresh wire is continually provided. The wire loses only a little of its diameter as it moves from supply to takeup, and, once used, is discarded. The cost incurred by discarding the wire is low, as it is not made of anything scarce or difficult to process.

5.2. WEDM and M1 Rotary Shock Absorber Components Testing. WEDM is especially suited for cutting complex two-dimensional shapes of constant thickness. Such shapes may require a number of separate operations when one uses traditional machining methods. On the other hand, WEDM can cut any 2-D shape, however complex*, in either one operation or, at most, a roughing cut followed by a skim cut. The M1 main battle tank rotary shock absorber rotor and stator are examples of complex 2-D shapes of constant thickness (See Figure 5-3).

* Some WEDM machines can tilt the wire axis, to permit a degree of three-dimensionality in the shape of the finished product.

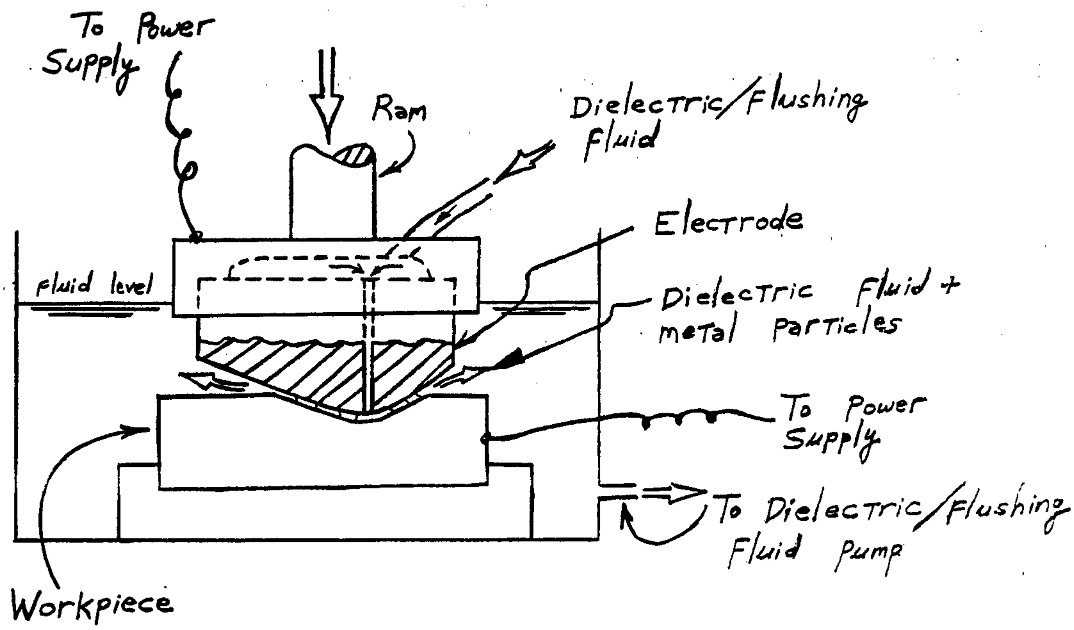


FIGURE 5-1. Shaped-Tool or Ram EDM.

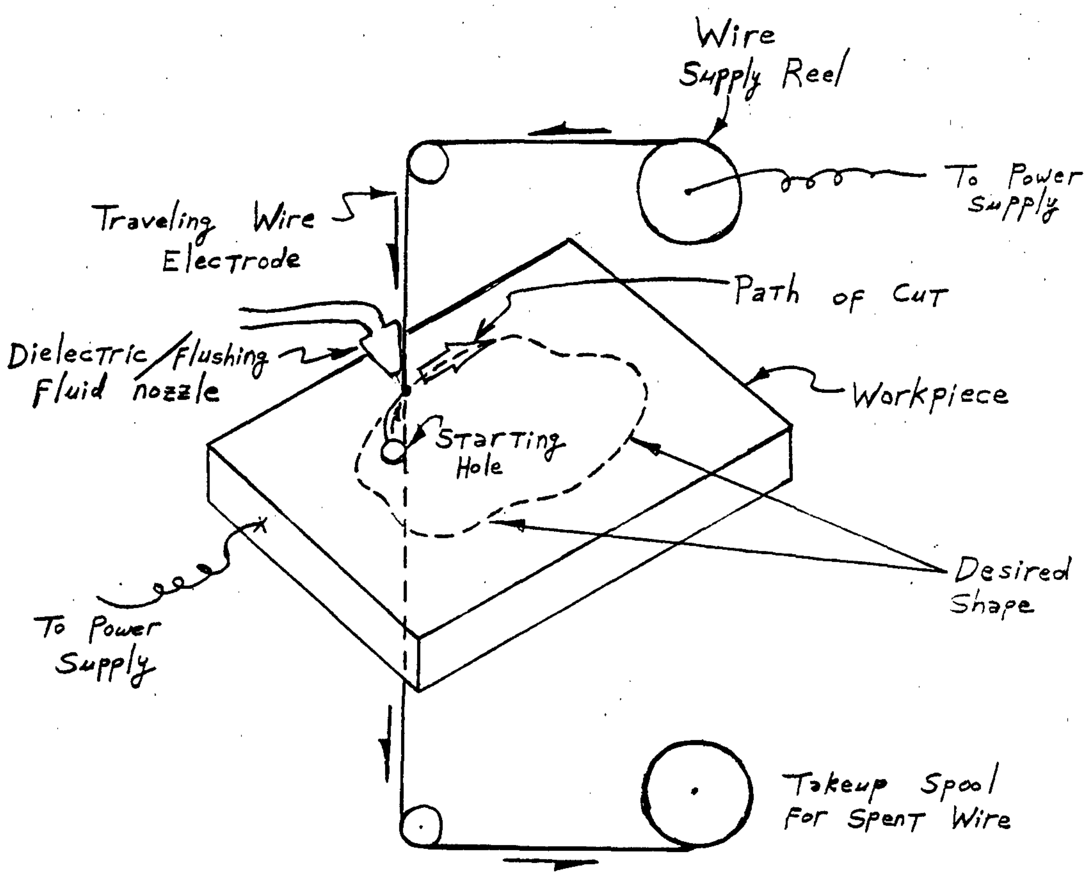
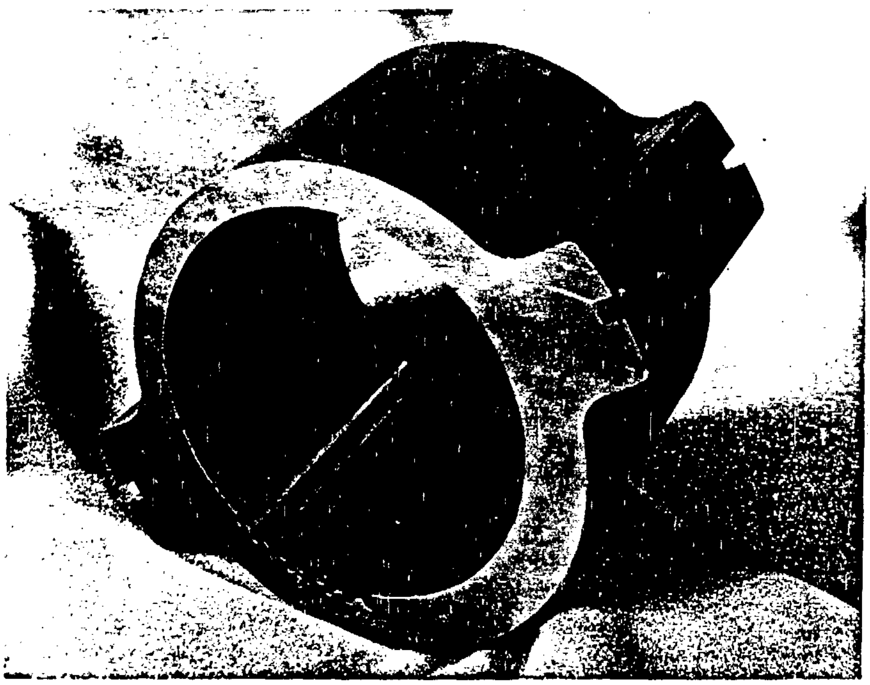


FIGURE 5-2. Traveling Wire EDM.



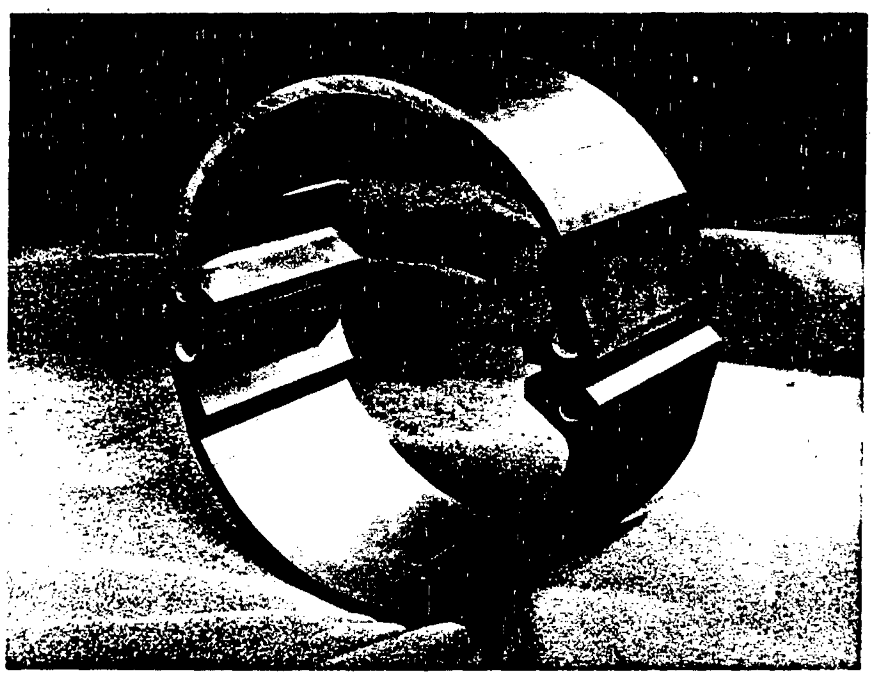


FIGURE 5-3. Rotor (Top) and Stator (Bottom).

5.2.1. Metcut Research Associates, of Cincinnati, Ohio, recommended these components to GD (the M1 prime contractor) and TACOM as candidates for WEDM experimentation. When this feasibility study was begun, GD was manufacturing 400 complete shock absorbers per month. Each rotor and stator requires a series of machining steps, as shown in Figure 5-4. WEDM promised lower labor and tooling costs, because of its ability to do the job in fewer steps (See Figure 5-5). Another advantage of WEDM over traditional machining is that while the latter produces volumes of chips, the former needs to disintegrate to particles only a limited volume of material.*

5.2.2. General Dynamics collected substantial data on tooling costs, time and motion (i.e., transfer of a part from one machine to another, and set-up within a given machine), reject rates, and machine breakdown/maintenance costs for the existing manufacturing process. The purpose of this data gathering was to form a basis for evaluating the economics of the proposed WEDM process. To do the actual WEDM test machining, GD chose three firms as subcontactors: Mitsubishi International Corporation of Bensenville, Illinois, Elox Division of Colt Industries, and JAPAX, Inc. CNC Incorporated developed the numerical control program for the WEDM machines. Another firm was awarded a contract for experimentation with a novel metalworking lubricant developed by Boeing, for more economical drilling of locating and starting holes in the workpiece. (The former are for clamping the workpiece in a precisely defined location, while the latter are drilled all the way through to give the EDM wire a point from which to start). Both Elox and Mitsubishi supplied General Dynamics with a rotor and stator processed by WEDM. The services of JAPAX were not utilized.

5.3. Testing Results. The WEDM process failed to improve on the economics of traditional machining for the rotary shock absorber rotor and stator. The basic problem was slow cutting speed. While WEDM can cut shapes with any number of zigs and zags, the cutting rate is such that it takes 23 hours for the rotor, another 32 hours for the stator, and 55 hours to WEDM both components.** Accordingly, it would take 40 WEDM machines to produce 400 rotary shock absorber assemblies per month. The capital cost of 40 WEDM machines is such that the current production system is more economical when capital, labor, and consumable items are considered.

5.3.1. WEDM was too slow for this application for two reasons. First, EDM is intrinsically a slow process. The sparking removes material one particle at a time. These particles have to be very minute if the customer wants good surface finish and surface integrity. Today's WEDM machines utilize power supplies which supply controlled pulses to the process, thus improving the cutting speed/surface quality tradeoff. Nonetheless, WEDM cutting speeds are still limited, particularly when one desires surface quality good enough to avoid the need for subsequent surface grinding.

* This advantage, however does not apply to shaped-tool, or ram-type EDM.

** According to a letter from Elox Division of Colt Industries, addressed to Mr. Ralph Brandi of General Dynamics, dated 9 August 1985.

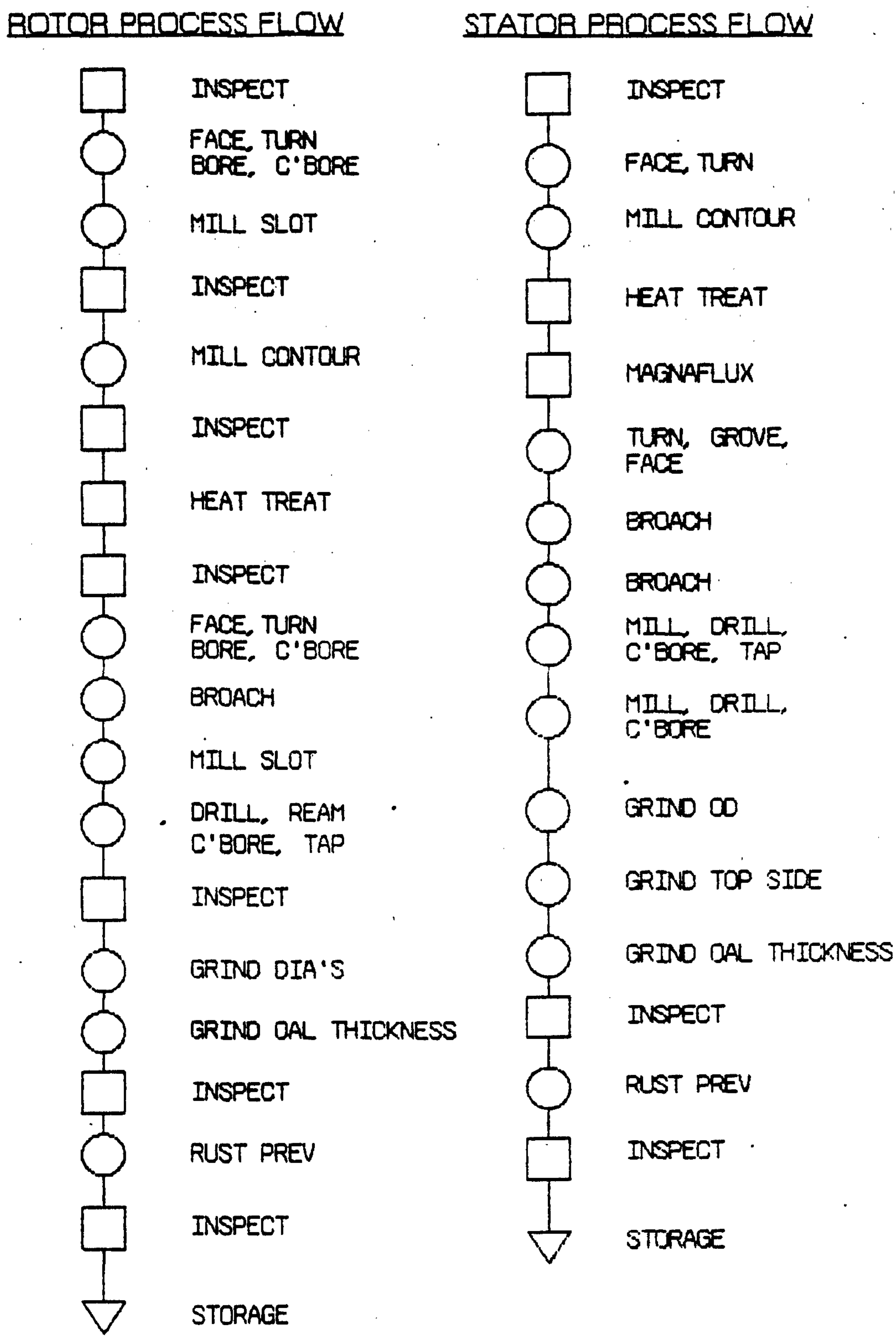


FIGURE 5-4. Manufacture of Rotor and Stator by Traditional Machining.

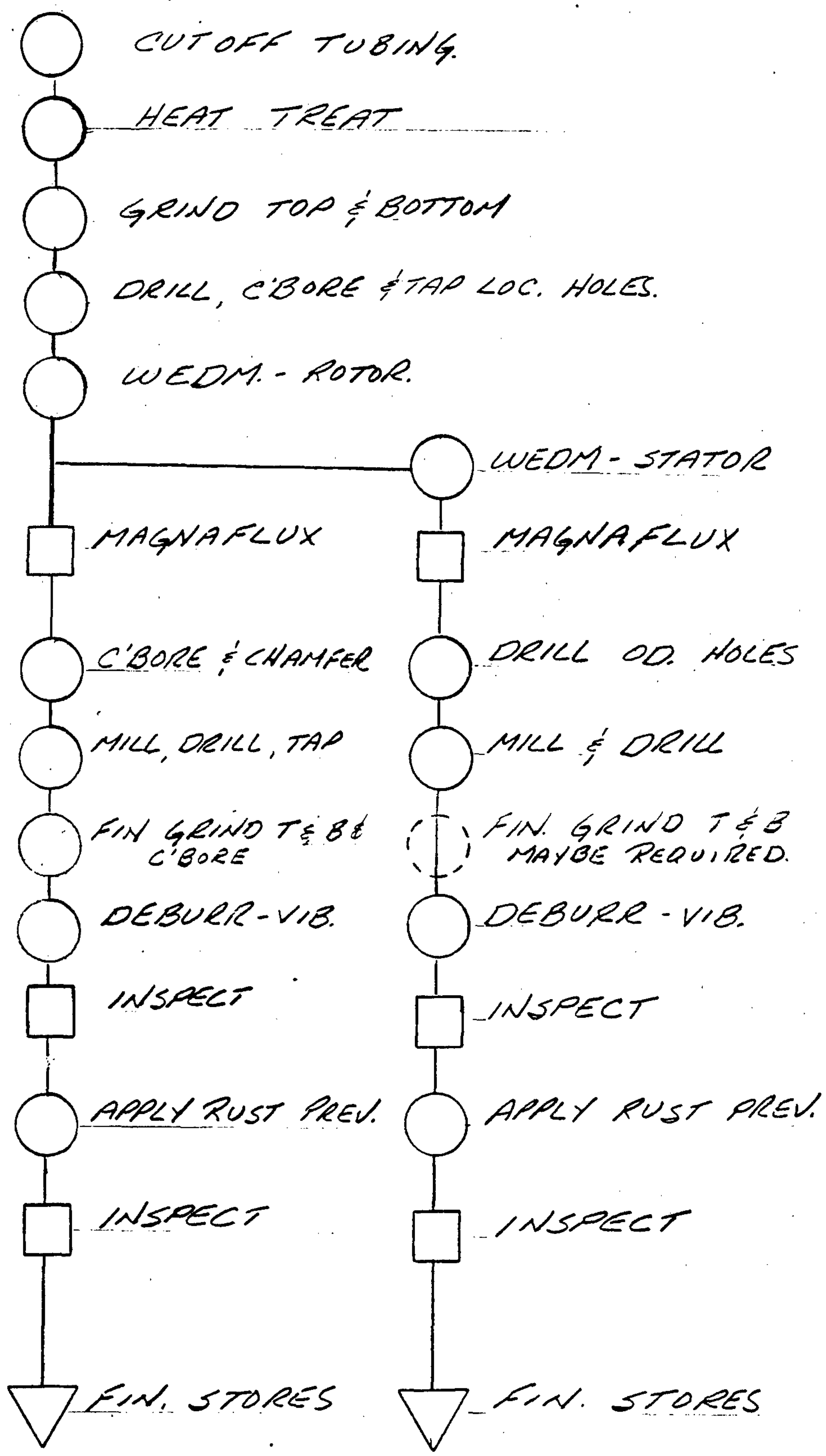


FIGURE 5-5. Manufacture of Rotor and Stator using WEDM.

5.3.1.1. In addition, the rotor and stator are 4 1/2 inches (124.3 mm) thick. This is much greater than the workpiece thicknesses WEDM normally processes in the tool and die industry. The workpiece thickness adds to the intrinsic nature of EDM in causing slow production for the aforementioned items.

5.4. Other Possible WEDM Applications. Wire EDM (also, shaped-tool or ram EDM) came to prominence because of the tool and die industry's need for a process that could handle materials that are themselves used to cut or forge/stamp/diecast other materials. When tool and die shops use EDM or WEDM to shape tool materials, the slow cutting rate is not a disadvantage because these materials would take even longer to process by any other method. Furthermore, a die, for example, once processed, can forge/stamp/diecast a number of parts during its useful life. On the other hand, if EDM or WEDM is used to shape each of these parts directly, rather than indirectly via a tool or die, its slow cutting rate is disadvantageous.

5.4.1. The place for EDM in production work is processing materials too hard to manufacture by traditional methods. If a part has to be made from a hard tool steel, it would be difficult to process by traditional methods, becuase the tools would likely be only marginally harder than the workpiece. Non-traditional machining methods, such as EDM, do not depend on tool hardness relative to the workpiece to do the job.

5.4.1.1. Another application for EDM and, in particular, WEDM, is prototype experimentation and short production runs. It would be uneconomical to produce a die or other special tool for traditionally processing a prototype part when the final configuration, chosen for production, may differ from the prototype. Accordingly, if one needs only one or a few finished items, WEDM may be economical even if the material could be processed by traditional methods. With a numerically controlled WEDM machine, changes in shape require nothing more than changing the NC parameters. Hence, one can freely experiment with various configurations before "freezing" the design for full-scale production.

5.5. The Future of WEDM. Though WEDM was an economic failure for the rotary shock absorber components, this failure must not discourage further experimentation. WEDM and other non-traditional machining methods may well succeed in other production applications, particularly those involving hard-to-machine alloys, complex shapes, or limited production. The purpose of projects like this one is to find such applications. The work of exploring and creating must go on.

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