114
~~8~~
10/30/91

M. L. L.

(2)

CNC Electrical Discharge Machining Centers

S. R. Jaggars

KCP-613-4398

Published October 1991

Final Report

Prepared for the United States Department of Energy Under Contract Number DE-ACO4-76-DP00613.

Allied-Signal Aerospace Company
Kansas City Division

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America.

This report has been reproduced from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, Tennessee 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Rd., Springfield, Virginia 22161.

A prime contractor with the United States
Department of Energy under Contract Number
DE-ACO4-76-DP00613.

Kansas City Division
P.O. Box 419159
Kansas City, Missouri
64141-6159

KCP-613-4398
Distribution Category UC-706

KCP--613-4398

DE92 002084

CNC ELECTRICAL DISCHARGE MACHINING CENTERS

S. R. Jaggars

Published October 1991

Final Report
S. R. Jaggars, Project Leader

Technical Communications
Kansas City Division

Allied-Signal Aerospace Company

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CNC ELECTRICAL DISCHARGE MACHINING CENTERS

KCP-613-4398, Final Report, Published October 1991

• Prepared by S. R. Jaggars

• The need for computer numerical controlled electrical discharge machining at Allied Signal Inc., Kansas City Division was evaluated. The study revealed that this capability could be used to fabricate selected parts to closer tolerances and improved surface finishes with greater efficiency than by using existing methods.

BB:ljs

TR3/aa

CONTENTS

Section	Page
SUMMARY	11
DISCUSSION.	13
SCOPE AND PURPOSE	13
PRIOR WORK.	13
ACTIVITY.	13
<u>Background Information.</u>	13
<u>Design and Preparation of Machining Samples,</u> <u>Sample Blanks, and Electrodes</u>	14
<u>Fabrication and Evaluation of Machined Samples.</u>	16
<u>Summary of Machining Results.</u>	19
<u>New Technology Machines Versus Old Technology</u> <u>Machines</u>	19
<u>Uses, Benefits, and Future of CNC EDM Machining</u> <u>Centers at KCD</u>	26
ACCOMPLISHMENTS	27
REFERENCES.	39

ILLUSTRATIONS

Figure		Page
1	AISI-A6 Tool Steel EDM Sample 1.	15
2	Copper EDM Electrode Number 1.	16
3	AISI-A6 Tool Steel EDM Sample 1 Blank.	17
4	Sintered Tungsten EDM Sample Number 2.	18
5	Sintered Tungsten EDM Sample Number 2 Blank.	19
6	Copper EDM Electrode Number 2.	23
7	6061-T6 Aluminum EDM Sample Number 3	24
8	6061-T6 Aluminum EDM Sample Number 3 Blank.	25
9	ETP Copper EDM Electrodes 3-1 and 3-2.	26
10	Material Blanks With Tooling Electrodes (P139703) (P139696) (P139702).	27
11	Sample 1 Cut on Machine A-1 (P139704).	30
12	Sample 2 Cut on Machine A-2 (P139699).	31
13	Sample 3 Cut on Machine A-3 (P139701).	32
14	Sample 1 Machined on Vendor B Machine (P139705).	33
15	Sample 2 Machined on Vendor B Machine (P139698).	34
16	Sample 3 Machined on Vendor B Machine (P139700).	35
17	Sample 1 Produced on the KCD Machine (P139967).	36
18	Sample 3 Produced on the KCD Machine (P139966).	37

TABLES

Number		Page
1	Machining Results on Sample 1	20
2	Machining Results on Sample 2	21
3	Machining Results on Sample 3	22

SUMMARY

Computer numerical control (CNC) electrical discharge machining (EDM) centers were investigated to evaluate the application and cost effectiveness of establishing this capability at Allied-Signal Inc., Kansas City Division (KCD). In line with this investigation, metal samples were designed, prepared, and machined on an existing 15-year-old EDM machine and on two current technology CNC EDM machining centers at outside vendors. The results were recorded and evaluated. The study revealed that CNC EDM centers are a capability that should be established at KCD.

From the information gained, a machine specification was written and a machine was purchased and installed in the Engineering Shop. The older machine was exchanged for a new model. Additional machines were installed in the Tool Design and Fabrication and Precision Microfinishing departments.

The Engineering Shop machine will be principally used for the following purposes: producing deep cavities in small corner radii, machining simulated casting models, machining difficult-to-machine materials, and polishing difficult-to-hand polish mold cavities.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was qualify and quantify the need to establish CNC Electrical Discharge Machining (EDM) centers at Allied-Signal Inc., Kansas City Division (KCD).

Between January and February 1987, three metal samples and copper electrodes were designed, prepared, and machined. Two of these samples were machined on an existing 15-year-old conventional EDM in the Engineering Shop. All three samples were machined on new machines at vendor locations. The machining of each was observed and cutting times were recorded. The results were then inspected and evaluated.

PRIOR WORK

In 1972, an EDM was installed in the KCD Engineering Shop. This machine has been mostly used to machine features that could not be machined by conventional methods. All movements are in thousandths of an inch and are read on graduated hand wheels.

All features machined with this equipment required an electrode the same shape as the feature with a few thousandths of an inch allowance for overburn. Machining can only occur during a single axis movement. The electrode spindle will rotate but it has no precision capability.

The power generator includes a bank of approximately 50 tubes that are becoming more and more difficult to obtain. Several electrodes or redressing of electrodes are required for most jobs because of high electrode wear ratios. All electrodes are changed manually.

ACTIVITY

Background Information

EDM is a controlled metal removal process by an electrical discharge between a conductive workpiece and a conductive electrode that are separated by a dielectric fluid. A spark generates an intense localized surface heat that vaporizes a microscopic portion of the workpiece. This is repeated many times each second to erode away the workpiece in the path of the electrode. The dielectric fluid flushes the chips and cools the eroded area. The process leaves a thin recast layer where the melted materials rehardens on the surface.

Numerically controlled traveling wire electrical discharge machining is a special form of EDM where the electrode is a conductive wire that is continuously fed from a supply spool to a take-up spool.¹ The wire moves along a numerically controlled, preselected path to produce the desired configuration. Deionized water is normally used as the dielectric fluid.

One of the newest developments in the EDM field has been combining CNC with a vertical machine tool.² This type of CNC EDM machining center is sometimes referred to as a ram or sinker. These machines feature simultaneous continuous path control of three or four axes. They are capable of holding contour tolerances within ± 0.0002 in. (inch) and surface finishes better than 4 AA microinch. Complex shapes can be produced with simple shaped electrodes. Electrode wear has been greatly reduced. Many parts can be roughed and finished with the same electrode. The electrodes are normally made from graphite, copper, or copper tungsten. As with most EDM there is basically no tool pressure, substantially no burrs are formed, and material hardness is not a major factor. Four- to forty-position programmable automatic electrode changers are available. The fourth axis is normally the spindle movement which can be rotated or precision indexed. The dielectric fluid used is normally a light oil. The machines can be equipped to evacuate the cutting vapors. Fire prevention devices sense and extinguish a fire in the work tank. The combination of all the features mentioned offers machine ability to run for extended periods with little or no operator intervention.

Design and Preparation of Machining Samples, Sample Blanks, and Electrodes

Three machining samples were designed to demonstrate and evaluate two current technology CNC EDM machines at outside machine tool builder locations and one existing KCD Engineering Shop EDM machine. These samples were designed to be representative of part shapes and materials common to KCD. Shapes could not be too complex because of available time limitations at outside locations. Also, it should not be concluded that this report implies EDM was the best method of producing these samples. Copper electrodes and blanks for each sample were then designed and three sets of each were prepared. One set was to be used on each of three machines. Copper was selected over graphite because of its availability. No flushing holes were allowed in any of the electrodes which intentionally produced a worse case situation.

Sample 1 (Figure 1) was to be produced by plunging the electrode (Figure 2) into the blank (Figure 3). Tool steel (A6) was selected because this material is commonly used for tooling at KCD. The 0.500 by 2.000 by 1.000 in.-deep cavity was chosen to measure the metal removal rate on 1 cubic inch of steel, which is the EDM Industries gage for metal removal rate.

VIEW AA

MATERIAL: AISI-A6 TOOL STEEL

Figure 1. AISI-A6 Tool Steel EDM Sample 1

Sample 2 (Figure 4) was to be produced from the blank in Figure 5 by a combination of plunges and indexes of the electrode shown in Figure 6. This demonstrated the use of the fourth axis which is generally called the C axis, consisting of the electrode spindle rotation. Pure tungsten was selected as the material, because it is very difficult to machine and has a slow removal rate.

Figure 2. Copper EDM Electrode Number 1

Sample 3 (Figure 7) was designed to demonstrate the ability to produce a complex shape from a solid blank (Figure 8) using two simple shaped electrodes shown in Figure 9. Aluminum alloy (6061-T6) was selected as the material because this material is commonly used. This sample is representative of a typical aluminum casting having internal corners with very small radii.

Figure 10 shows the three material blanks with their individual "used" electrodes.

Again it needs to be emphasized that these samples were designed to measure machining speed, tolerance capabilities, and surface finish capabilities of the machines involved.

Fabrication and Evaluation of Machined Samples

One each of three samples was machined on the showroom floor of two current technology CNC EDM machine tool builders. Results were observed and recorded.

Figure 3. AISI-A6 Tool Steel EDM Sample 1 Blank

Vendor A chose to use three different machines to machine the three samples. Sample 1 (Figure 11) was cut on machine A-1; sample 2 (Figure 12) was machined on machine A-2. The cavities on Sample 2 were not finished to final depth because of the slow cutting rate and a limited available time at this outside location. Sample 3 (Figure 13) was cut on machine A-3. These three machines have basically the same technical capabilities but different size capabilities.

Vendor B machined all three samples (Figures 14, 15, and 16) on a single machine. Again, the cavities on Sample 2 (Figure 15) were not finished to final depth because of the slow cutting rate and the limited time.

Figure 4. Sintered Tungsten EDM Sample Number 2

The existing KCD Engineering Shop machine was used to machine Samples 1 and 3. Figure 17 shows the Sample 1 produced on the KCD machine and the electrode used. This electrode was a duplicate of the ones used on the vendor machines. The cavity was only machined to approximately 30 percent of the depth intended because of the excessive time required.

Figure 18 shows Sample 3 machined on the KCD machine and the two electrodes used. These electrodes had to be machined to the final part shape with a few thousandths allowance for overburn because of the lack of CNC capability. Again machining was concluded at approximately one-third of the depth intended because of the excessive time required.

Figure 5. Sintered Tungsten EDM Sample Number 2 Blank

Sample 2 (tungsten) was not machined on the KCD machine because it did not have the capability of indexing the spindle.

Summary of Machining Results

Tables 1, 2, and 3 show the machining results of the three samples on the three machines. It must be understood that time restraints caused the tests to be only comparisons, and the results do not in many cases represent the total capabilities of the equipment involved.

New Technology Machines Versus Old Technology Machines

The improvements are given in the following listing.

- Much greater roughing and finishing speeds occurred in all materials.

Table 1. Machining Results on Sample 1 (A6 Tool Steel)

Machine	Inspection Results (inches)						
	Rough Machining Speed (in. ³ /h)	Finish Machining Time (min)	0.500* +0.002	2.000 +0.002	1.000 +0.002	0.045 +0.005 Radius (4 places)	0.015 Radius Maximum (All around)
KCD	0.04	312	<u>0.5050**</u> 0.5054	<u>2.0048**</u> 2.0052	<u>0.2999**</u> 0.3004	0.050	0.010
Vendor A	1.11	230	0.550**	2.0469**	<u>0.993**</u> 0.994	0.030**	0.010
Vendor B	1.07	83	<u>0.4969**</u> 0.4976	<u>1.9980</u> 1.9988	<u>0.9994</u> 0.9998	0.050	0.020**
						<u>0.4487</u> 0.4492	<u>0.4500</u> 0.4519
						0.4745** 0.4748	607** 100
							190*
							63AA Finish

*Column headings denote required dimensions.

**These features are out of drawing tolerance.

Table 2. Machining Results on Sample 2 (Tungsten)

Inspection Results (inches)										
Machine	Rough Machine Speed (in. ³ /h)	Finish Machining Time (min)	1.950* +0.001 Diameter	0.300 +0.002	160 Degrees and 0 Minutes** (1 Minute = 1/60 Degree)	0.100 +0.001	0.200 +0.001	Maximum (2 places)	0.010 Radius Maximum (4 places)	0.010 Radius 32AA Finish
Vendor A	0.035	***	1.935**	0.0976** 0.0982	160 Degrees and 0 Minutes** (1 Minute = 1/60 Degree)	0.107**	0.214**	0.030**	0.010	72** 62
Vendor B	0.060	52	1.938**	0.190** 0.195	161 Degrees and 0 Minutes** (1 Minute = 1/60 Degree)	0.1058** 0.1083	0.2124** 0.2141	0.020**	0.015**	130** 52

*Column headings denote required dimensions.
 **These features are out of drawing tolerance.
 ***No finish cuts were taken.

Table 3. Machining Results on Sample 3 (Aluminum)

Inspection Results (Inches)										
Machine	Rough Machining Speed (in. ³ /h)	Finish Machining Time (min)	0.750 +0.005 Radius	0.750 +0.005 (2 places)	1.000 +0.005 (2 places)	0.125 +0.010 (All Around)	0.015 Radius Maximum (All Around)	0.015 Radius Maximum (All Around)	1.180 +0.005 Depth	1.000 +0.005 Depth
KCD	0.10	***	0.7526	<u>0.7536</u> 0.7541	<u>0.7528</u> 0.7534	<u>0.1170</u> 0.1207	Not Measured	<u>0.5074**</u> 0.5114	<u>0.3637**</u> 0.3696	200**
Vendor A	1.06	103	0.748	0.748	<u>0.9989</u> 1.0015	<u>0.129</u> 0.130	0.015	<u>1.175</u> 1.179	<u>0.9972</u> 1.0004	<u>375**</u> 105
Vendor B	1.40	115	0.750	0.751	<u>0.9953</u> 0.9976	<u>0.1225</u> 0.1240	<u>0.010**</u> 0.045	<u>1.180</u> 1.184	<u>1.0000</u> 1.0035	<u>103**</u> 85

*Column headings denote required dimensions.

**These features are out of drawing tolerance.

***No finish cuts were taken.

1 THESE TWO DIAMETERS MUST BE CONCENTRIC WITHIN 0.0005 TIR

Figure 6. Copper EDM Electrode Number 2

Figure 7. 6061-T6 Aluminum EDM Sample Number 3

- Greatly improved dimensional tolerance capabilities were achieved, although this was not fully revealed with the samples that were machined. The new technology machines can produce ± 0.0002 in. tolerance on many dimensions.
- Longer electrode life occurred because of much lower electrode wear.
- There were improved surface finishes. New machines have the capability of producing mirror finishes on many parts.

Figure 8. 6061-T6 Aluminum EDM Sample Number 3 Blank

- Complex shapes can be generated using simple shaped electrodes such as rounds or squares. Four-axes simultaneous cutting is available.
- Programmable automatic electrode changers were used.
- Many safety features were incorporated including a fire prevention device that senses and extinguishes a fire and a system that evacuates cutting vapors.
- Adaptive controls optimized machine setting.

Figure 9. ETP Copper EDM Electrodes 3-1 and 3-2

Uses, Benefits, and Future of CNC EDM Machining Centers at KCD

This capability will be used to machine deep cavities with small corner radii, simulated casting models, difficult-to-conventionally machine materials, and polish difficult-to-hand polish mold cavities.

Figure 10. Material Blanks With Tooling Electrodes

ACCOMPLISHMENTS

This investigation has revealed CNC EDM machining centers to be an economical and efficient process for machining parts, fixtures, and molds at KCD. Although this process has not attained the material removal rates of most conventional processes, it is applicable to a wide range of jobs. This study provided the information and background required for the designing of machine specifications and the evaluation of the machine builders' proposals.

Since this study was started, three of these machines have been purchased by KCD.

Figure 10 Continued. Material Blanks With Tooling Electrodes

Figure 10 Continued. Material Blanks With Tooling Electrodes

Figure 11. Sample 1 Cut on Machine A-1

Figure 12. Sample 2 Cut on Machine A-2

Figure 13. Sample 3 Cut on Machine A-3

Figure 14. Sample 1 Machined on Vendor B Machine

Figure 15. Sample 2 Machined on Vendor B Machine

Figure 16. Sample 3 Machined on Vendor B Machine

Figure 17. Sample 1 Produced on the KCD Machine

Figure 18. Sample 3 Produced on the KCD Machine

REFERENCES

• 1Machining Data Handbook, Machinability Data Center. 3rd Edition, Metcut Research Associates Inc., Volume 2, 1980, pp 12-49.

• 1H. C. Crosby, "Fundamentals of EDM," 1984 Aerospace Engineering Conference: Society of Manufacturing Engineers, MR84-902, January 25, 1984, p 6.

END

**DATE
FILMED**

// 127191