COMPUTER AIDED MACHINING OF AN ACOUSTIC HORN FOR ULTRASONICALLY AIDED EDM

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ABSTRACT: The paper deals with the process of computer aided machining (CAM) of ultrasonic horn, included in an ultrasonic chain used at ultrasonic assistance of electrical discharge machining (EDM). The assistance with ultrasonics of EDM process (EDM+US) leads to technological parameters improvement in terms of machining rate, volumetric relative wear and surface quality. Nevertheless, the lack of flexibility of EDM+US technology due to time consuming for resonance condition achievement, supposing several iterative stage, is an important disadvantage. CNC machining of ultrasonic horn is a strong support for amelioration of this drawback. The paper presents a CAM application developed in AutoLISP under AutoCAD used for accurate fabrication of ultrasonic horn on CNC lathe, easily covering the needed iterations to equalize the own frequencies of transducer and horn.
KEY WORDS: Ultrasonic horn, CAM, AutoLISP, EDM.

1. INTRODUCTION

The electrical discharge machining (EDM) aided by ultrasonic (US) assistance (EDM+US) through vibrations of the electrode-tool of ultrasonic frequency normal on machined surface has spectacular improvement of main technological parameters – when is applied to finishing and micromachining – as machining rate, volumetric relative wear, and surface quality [1, 2, 3, 4].

2. TECHNOLOGICAL FLEXIBILITY

Nevertheless, the EDM+US technology has an important drawback due to the lack of flexibility. This is derived from the critical technological condition to be fulfilled that the ultrasonic chain works at resonance, which supposes the equality between the own frequencies of the main components of ultrasonic chain: ultrasonic transducer and ultrasonic horn that includes also the electrode-tool as integrated part [5]. In fig. 1, the components of ultrasonic chain are presented, where the transducer own frequency is considered as entry date, and the horn have to be machined.

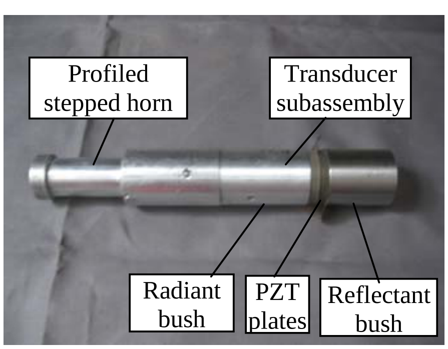

Figure 1. Ultrasonic chain assembly

Fabrication on classic machine-tools is highly time consuming because, resonance condition supposes fabrication of ultrasonic horn at longer length, corresponding to lower own frequency, followed by several length shortening, increasing its own frequency till the equality between own frequencies of transducer and ultrasonic horn is attained.

CNC machining has the obvious advantage of accuracy of horn dimensions, and most of all, it can be easily associated with Computer Aided Engineering (CAE), which based on Finite Element Method simulation can provide many other constructive solutions for the horn to faster achieve resonance condition, which are rapidly transferred to CAM [6, 7, 8, 9].

3. CAM STAGES OF PROFILED STEPPED ULTRASONIC HORN FABRICATION

The proposed work environment is AutoCAD, especially because of its widespread in industry and the possibility of developing applications written in related programming languages.

The AutoLISP programming environment is a very versatile and intuitive language where some very interesting applications can be developed in association with many of issues related to manufacturing engineering and computer aided design [10].

The profiled stepped horn belongs to shaft workpieces family and will be obtained through turning on a CNC Machine SP 250 CNC.

The proposed turning machine uses a CNC646 automation unit.

The program is automatically written by an AutoLISP application that runs in AutoCAD, especially designed for turning processes, and developed both as industrial and educational purposes.

The application starts from a turning part design that is inserted in AutoCAD using standard interface commands.

The specific horn profile requested by the application of EDM+US process is analyzed and the NC program is postprocessed as CNC646 NC code.

Alternative CNC codes can be easily introduced after a postprocessor code is written. This extension can be introduced on demand in order to adapt the program to other CNC equipments.

A backploting option can be used in order to test the accuracy of the NC program and verify the shape and the dimensions of the generated profile, which includes at the top, the electrode-tool as integrated part of ultrasonic chain – fig. 2.

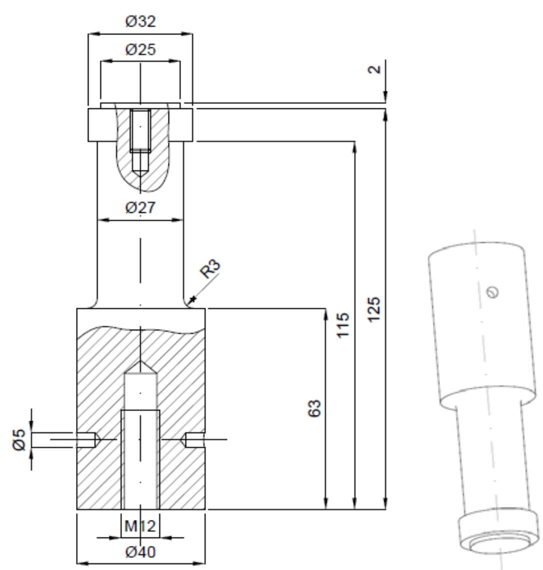

Figure 2. The profiled stepped horn

The specific coordinate system for turning is presented in figure 3.

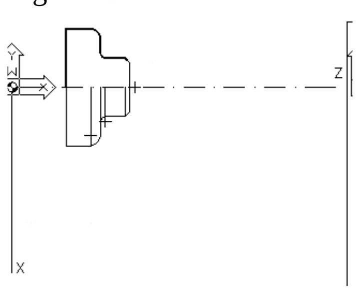

Figure 3. NC axes for turning and AutoCAD User Coordinate System

As one can observe, the horizontal axis is Z and the vertical is X and positioned downwards, total different with classic AutoCAD UCS mentioned by the UCSICON.

The particular axes position will introduce some difficulties in generation of NC pathways but these problems are easily solved using the proposed application.

The contour of the part to be processed is drawn above the horizontal axis having an axial symmetry. Below the axis is represented the contour that will be generated through the post processor in order to verify the accuracy of program generation – fig. 4.

The contour must be generated as AutoCAD polyline and the vertex sequence is started from the biggest abscise value.

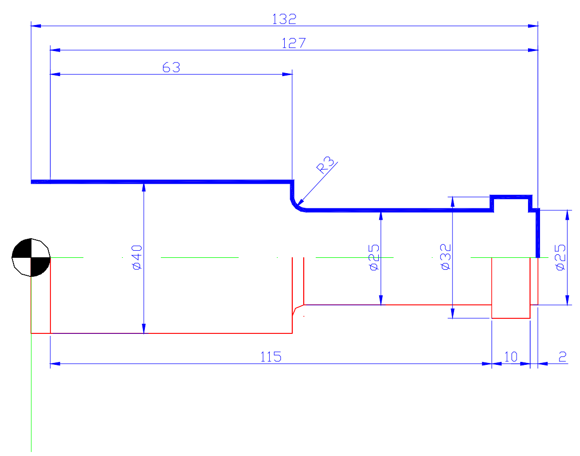

Figure 4. The horn stepped profile and the generated NC path

The shaft is represented below in red, and the profile shows that the requested polyline was accepted and is accurate enough.

The application starts with a dialogue box that suggest to configure the parameters or to simulate the NC program (fig. 5). It should be noted that the simulation can be used in order to verify a NC program that is already resident on computer as result of an automatic program generation or from other source, written in CNC646 code.

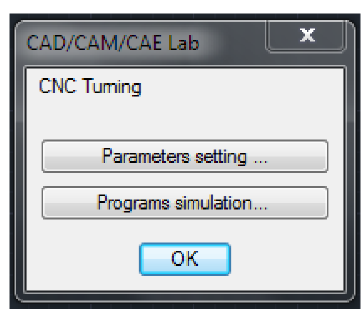

Figure 5. Initial dialog box for turning

The parameters are consistent with the process of turning and are done by following a sequence of dialogue boxes for global parameters, rough turning parameters and finishing turning parameters – fig. 6, 7, 8.

The parameters as the feed rate, machining speed, cut depth, contouring type, spindle spin and origin shift are done by dialogue for specific turning phases.

The roughing and finishing parameters are distinctively described in different dialogue boxes.

This information is processed and used into the automatic generation of the NC program.

The user must have some preliminary knowledge on turning processes and using NC code in order to give accurate values that are not to be tested and validated by the program.

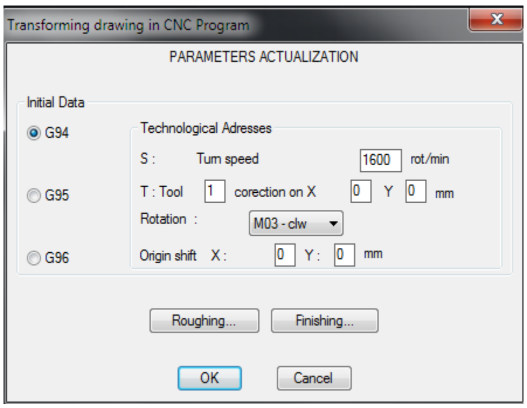

Figure 6. Global parameters

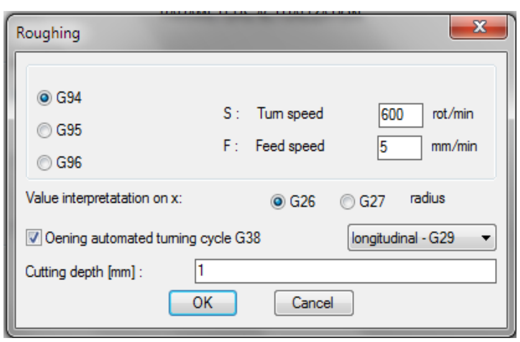

Figure 7. Rough turning parameters

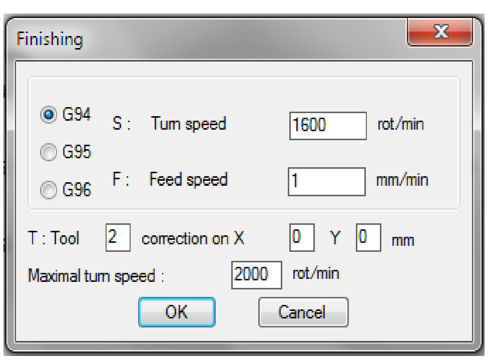

Figure 8. Finishing turning parameters

When this sequence is done the program returns in the initial dialogue and the simulation can start.

First of all it is asked to clarify if the simulation is done just for the inserted polyline contour or a NC pre generated program – fig. 9.

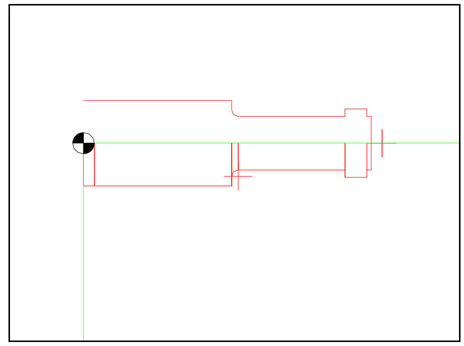

Figure 9. Simulation for the current analyzed contour.

Command: go

Analyzing CNC Program Current/File:**c**

Select a polyline: (select the contour polyline)

CNC Code Analyse ? Y/N:Y

For option “current” we will be asked to select the contour polyline in order to process the graphic information

The CNC code, just generated will be drawn as lower contour of the part in order to compare the upper profile with the down one and to validate the pathway.

The lower profile is independently generated directly from the postprocessed CNC program and is used to check if the information was correctly transcribed.

If the analysis of the CNC code is asked the Code is presented into a dialogue box.

The code can be selected line by line and in the list from below, the used NC programming addresses and their content are explained. Implicit addresses are explained for the elliptic formulation.

This feature was introduced for unskilled programmers in order to explain the automated sequence.

The generated code is referring to the three standard postures: NC machine and tool initialization, global parameters, programmed CNC paths and closing the program.

The CNC646 specific language uses a subprogram under label L1 that contain the final contour of the part.

This subprogram will be used twice, for rough turning and finishing turning, the CNC machine will generate automatically the tool pathways for each turning step.

Each step will be followed using specific machining parameters established through the above presented dialogues – fig. 10.

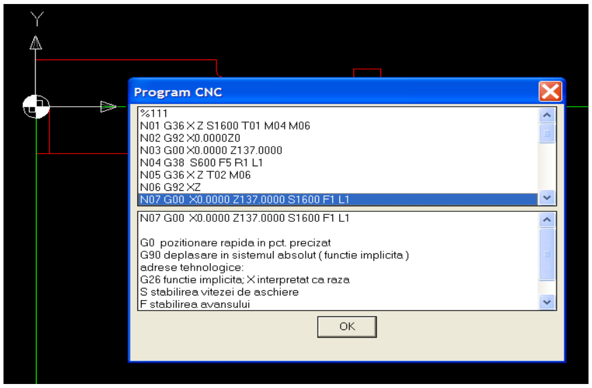

Figure 10. The CNC generated code

4. CNC CODE GENERATION

The automate generation of the CNC645 code for turning of horn profile is presented below. The code is commented in order to explain the used code sections as educational example.

```
%111
N01 G36 X Z S1600 T01 M04 M06
N02 G92 X0.0000Z0
N03 G00 X0.0000 Z137.0000
N04 G38  S600 F5 R1 L1
N05 G36 X Z T02 M06
N06 G92 XZ
N07 G00  X0.0000 Z137.0000 S1600 F1 L1
N08 G36 X Z M02
L1
N09 G01 Z132.0000
N10 X12.5000
N11 Z130.0000
N12 X16.0000
N13 Z120.0000
N14 X12.5000
N15 Z71.0000
N16 G02 X15.5000 Z68.0000 I15.5000 K71.0000
N17 G01 X20.0000
N18 Z5.0000
N19 Z0.0000
N20 G39 M22
S2000
T01|0|0||
T02|0|0||
!
```

CNC code analyse

Result after line:

%111

Start program.

Result after line:

N01 G36 X Z S1600 T01 M04 M06

G90 displacement in global system (implicit function)

G01 linear interpolation (implicit function)

technological addresses:

G26 implicit function; X interpreted as radius

M04 main spindle turns counter clockwise

M06 change activation

S cutting speed

T tool change

Result after line:

N02 G92 X0.0000Z0

G90 displacement in global system (implicit function)

G92 programmed origin shift

technological addresses:

G26 implicit function; X interpreted as radius

Result after line:

N03 G00 X0.0000 Z137.0000

G0 fast positioning in specified point

G90 displacement in global system (implicit function)

technological addresses:

G26 implicit function; X interpreted as radius

Result after line:

N04 G38 S600 F5 R1 L1

G90 displacement in global system (implicit function)

technological addresses:

G38 associated to L automate turning cycle

G26 implicit function; X interpreted as radius

G29 automate longitudinal turning cycle; after G38

S cutting speed

F feed rate

L subprogram execution, at end goto next

Result after line:

N05 G36 X Z T02 M06

G90 displacement in global system (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
M06 tool change activation
T tool change
Result after line:
N06 G92 XZ
G90 displacement in global system (implicit function)
G92 offset of programmed origin
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N07 G00 X0.0000 Z137.0000 S1600 F1 L1
G0 fast positioning in specified point
G90 displacement in global system (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
S cutting speed
F feed rate
L subprogram execution, at end goto next
Result after line:
N08 G36 X Z M02
G0 fast positioning in specified point
G90 displacement in global system (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
M02 end of main program
Result after line:
L1
subprogram start.
Result after line:
N09 G01 Z132.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N10 X12.5000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N11 Z130.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N12 X16.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N13 Z120.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N14 X12.5000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N15 Z71.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N16 G02 X15.5000 Z68.0000 I15.5000 K71.0000
G90 displacement in global system (implicit function)
G02 circular interpolation clockwise
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N17 G01 X20.0000
G90 displacement in global system (implicit function)
G01 linear interpolation (implicit function)
technological addresses:
G26 implicit function; X interpreted as radius
Result after line:
N18 Z5.0000

G90 displacement in global system (implicit function)

G01 linear interpolation (implicit function)

technological addresses:

G26 implicit function; X interpreted as radius

Result after line:

N19 Z0.0000

G90 displacement in global system (implicit function)

G01 linear interpolation (implicit function)

technological addresses:

G26 implicit function; X interpreted as radius

Result after line:

N20 G39 M22

G39 close automat cycle

M22 end subprogram

Result after line:

S2000

Maximum allowed speed

Result after line:

T01|0|0||

Tool correction

Result after line:

T02|0|0||

Tool correction

Result after line:

!

END program

5. CONCLUSIONS

The CAM application developed in AutoLISP under AutoCAD was used to achieve a profiled stepped ultrasonic horn utilized for finishing/micro-electrical discharge machining in ultrasonic field.

This approach facilitates also risk decreasing, having also possibilities of backploting before machining and other specific CAM measures before machining.

Through this CAM application, the resonance condition was attained in shorter time than when using usual classic machines, which contributed to increase the flexibility of EDM+US technology.

This is based not only of lengths shortening but some other constructive solutions of ultrasonic horn like modifications of fillet radius, steps diameters, and holes machined inside horn.

These solutions could be identified using simulation of ultrasonic horn through Finite Element Method, and the established shape, was very easy transferred in CNC program this CAM application.

6. ACKNOWLEDGEMENTS

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