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The present invention relates to a process for
5 machining a finished profile from a rough profile and
the device for implementing this process.

Processes are known for machining a finished
profile in which the rough profile is machined following
movements parallel to the finished profile. In general,
10 these processes have the disadvantage of causing the
depth of cut or thickness of the shaving to vary, so
in not using the tool to the maximum of its capacity.

It is also known to start from a rough profile
simulating the shape of a cylindrical bar and to machine
15 it in a direction parallel to the axis of the spindle.

This other process has the drawback, when using rough
diecast profiles or cast profiles having a profile close
to the finished profile, of wasting time by useless movements
of the tool between the rough profile assuming the shape
20 of a cylinder and the rough cast profile.

The aim of the present invention is to overcome
the drawbacks of the prior art, that is to say to use
the tool to the maximum of its capacity and to limit
as much as possible the unproductive movements of the
25 tool.

This result is reached by a process for machining
a finished profile by means of a digitally controlled
machine, characterized in that it comprises the following
steps:

30 1. Introduction of a description of the finished
profile, then of the rough profile, into a first and
second storage means respectively ;

2. Processing the description of the finished
profile so as to delete, after analysis, the profile
35 portions having a concavity and storage of the description
of the profile portions having a concavity in a third
storage means;

3. Storage of the "so called purified" profile,

i.e. freed of the concave portions, in a fourth storage means;

4. Formation of the preliminary shape of the purified finished profile in successive passes by moving the tool between the coordinates supplied by the memory of the purified finished profile and the memory of the rough profile.

Another aim of the invention is to obtain maximum cutting capacity during machining of the finished profile, even in the concave parts.

This additional result is attained with a process which is characterized in that, during the operation for turning a complex concavity, the digital control:

a. Recovers the profile of a concavity stored in the third storage means and examines the profile portions situated to the right and to the left of a programmed descending straight line;

b. Eliminates, from the profiles situated to the right or to the left of the descending straight line, the concavities included in one of the right hand or left hand profiles, for transforming the complex concavity into a simple concavity ;

c. Effects the operation for machining the simple concavity ;

d. Reiterates the preceding operations on another simple concavity of the complex concavity.

A third aim of the invention is to provide a device for implementing the process of the invention.

This third result is obtained by means of a device comprising:

- means for delivering, to a microprocessor connected to a bus, a program defining the rough profile and the finished profile, said microprocessor, after compilation, addressing said rough and finished profiles respectively into first random access memories (RAM);

- second read only memories (ROM), connected to the bus, comprising respectively the parameters of

the machine-finishing machine to be controlled and a software;

- means for processing the finished profile so as to remove the concavities therefrom and to elaborate a so called purified finished profile;

- a third RAM for receiving the description of the concave parts;

- a fourth RAM for receiving the so called purified finished profile, i.e. no longer comprising any concavities,

- means for providing the connection and transmission of controls between the bus and the machine to be controlled.

Other features and advantages of the invention will be more clearly understood from the following description, made with reference to the accompanying drawings in which:

Figure 1 is a schematical view of means for implementing the machine finishing process of the invention

Figure 2 represents the machining passes of the tool between a rough profile and a finished profile according to the machine finishing process;

Figure 3 is a side view of a finished profile having grooves;

Figures 4 and 5 are sectional views of a simple concavity or groove and illustrations of the steps for machining this groove ; and

Figure 6 is a sectional view of a complex concavity.

In Figure 1 is shown a machine tool 1 supporting a work piece to be machined 2. This machine tool comprises a tool holding turret, not shown. The different control members and the different sensors of this machine tool are connected by an electronic card 3 playing the role of axis coupler, which is connected to a bus 4. The purpose of card 3 is to provide connection with the sensors which read the position of the moving parts of the machine and to control their moving speed. Bus 4 is connected to a microprocessor 5 and to an assembly of memories 7-8-9, comprising respectively at least one RAM 7, an

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EEPROM 8 and a REEPROM 9. The REEPROM contains the codes, instructions and software for operating the device.

The EEPROM contains the parameters of the machine, i.e. the definitions of the strokes of the moving members
5 and of the servo control gains. The RAM may be formed by an assembly of random access memories and contains all the rest of the data required for operating the device, as will be explained hereafter.

Bus 4 is also connected to a card 6 playing
10 the role of series coupler and providing transmission and shaping of the signals which transit through the bus and are intended for an assembly 10 comprising a control keyboard and a display means.

A second series coupling card provides the
15 connection between the bus and a ribbon reader 12.

The process for machining a preliminary shape is implemented by means of the device described with reference to Figure 1. When for example it is desired to machine the work piece 2 according to the finished
20 profile represented by the outline P1 to P7 of Figure 2, and when work piece 2 has been obtained for example by casting or diecasting with a rough profile defined by points A, B, C, D of Figure 2, the programmer feeds into the device, either from the ribbon reader 12 or
25 from the keyboard with checking on the display device, the program which defines the finished profile of the work piece and its rough profile, as well as the indications which define whether the preliminary shape is to be effected parallel to axis X or parallel to axis Z.

30 Similarly, in its instructions, the program will define the extra thickness along axis X and Z which will have to be allowed so that, at the end of machining, a cycle may be initiated for finishing the piece which will finish it with the desired accuracy and finish.

35 The program will also define the depth of cut, the speed of advance of the tool and the spindle speed.

These precise details will be defined in the format explained below:

N_{p1} to N_{p7} : definition of the finished profile: preliminary shape of N_{p1} to N_{p7} , the order of the sequences giving the machining direction.

5 XA ZA : stopping coordinates for the first
preliminary shape cuts.

 I, K: extra thickness at X and Z.

 P or R: depth of cut:

 . P longitudinal preliminary shape

10 . R transverse preliminary shape

 F - S : advancing speed and spindle speed

 P or R, F, S may be modified during preliminary
shaping.

An example of programming for defining the
15 rough and finished profiles of Figure 2 is given below:
Programming:

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N10 G X0 Z0: initialization at X and Z for beginning
the preliminary shaping
20 N20 G79 N100: jump to sequence calling the preliminary
shaping cycle

N30 G1 XP7 ZP7
N40 XP6
25 N50 A 45 B-
N60 A 180 XP4 ZP4 .....Definition of the finished
N70 A 60B- profile
30 N80 A 90 XP2 ZP2
N90 XP1 ZP1
N100 G64 N90 N30 XA ZA I K P F S Preliminary shaping zone
N120 XB ZB
35 N130 XC ZC: Sequence of change of } Definition of the rough
N140 XD ZD : values of P, F, and S } profile
N150 XE ZE

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N160 G 80 X Z : End of preliminary shaping program (backing off)

N170 G77 N30 N90 G41 T D F S.: Carrying out the finishing.

This example does not comprise any grooves; however, in the case shown in Figure 3, the finished profile may comprise two grooves F and G.

In this case, the programmer will consequently modify his finished profile program.

The program below corresponds to the one written by the programmer in the case of a profile conforming to the one shown in Figure 3:

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N10 GX0 Z0
N20 G79 N100
N30 G1 XP15 ZP15
N31 XP14
N32 XP13 ZP13
N33 ZP12
N34 XP11 BR11 BR11 = radius of the groove
N35 ZP10 BR10 BR10 = radius of the groove
N36 XP9
N37 ZP8
N38 XP7 ZP7
N39 XP6
N40 XP5 ZP5
N41 XP4
N42 XP3 ZP3
N43 XP2
N44 ZP1

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The program will be stored in a zone of the RAM 7.

It will be assumed that the program of the rough profile is stored in zone 70 of the RAM; the device will then operate in the following way during the processing

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of a preliminary shaping cycle:

Once the finished profile has been introduced into zone 71 of the RAM 7, the microprocessor searches for concave parts of the finished profile, by searching first of all for grooves such as F (Figure 3). For that, by means of the software included in memory 9, the microprocessor compares the values of the words contained in the memories and searches to see if there exist any X^*_{i+1} such as

$$10 \quad X^*_{i+1} \geq X_i \quad (1)$$

In the example, this will be X_{p13} .

Then, it searches for the largest of the X^*_{i+1} satisfying the relationship (1). In the example, this will be X_{p13} .

This operation is only carried out when several grooves are included successively one in the other.

Finally, the microprocessor seeks, among the values X'_i preceding the value X^*_{i+1} , for the one which is equal to or greater than X^*_{i+1} . In the example considered, X'_i corresponds to X_{p9} . The microprocessor then takes the portion of the program between the two addresses N32 and N36, where the values X_{p13} and X_{p9} are respectively located, and stores this program portion in a second zone 72 of the RAM 7, which zone will be called "storage zone for finished groove profile programs". After this operation, the program of the preliminary shape of the finished profile no longer comprises instructions N33 to N36 inclusive. Similarly, for grooves whose concavity is orientated along Z, the microprocessor 5 will search in the contents of zone 71 to see if there exist any Z^*_{n+1} such as $Z^*_{n+1} < Z_n$. In the example considered, it is a question of Z_{p5} . Then, the microprocessor searches for the largest among the Z^*_n preceding Z^*_{n+1} . In the example, it is a question of Z_{p3} at address N42. Finally, the microprocessor searches for the address where a Z_n is located which is greater than or equal to Z^*_n . In the example, this will be N38. The microprocessor eliminates

from the program of the finished profile the instructions between addresses N39 to N42 inclusive, and will store these instructions in the zone of the RAM 7.

The new finished profile program, freed of the concave portions, is stored in a third zone 73 of the RAM. Once this operation has been carried out, the microprocessor will start from the new finished profile defined in memory zone 73, which profile comprises no concave parts and will effect a translation along X by a value I, and along Z by a value K of the new finished profile, while adding a value K to each memory word containing a value Z and a value I to each memory word containing a value X. Finally, from this table defining the new translated finished profile, stored in a fourth zone 74, or else elaborated as they are required by the microprocessor from table 73, the microprocessor calculates the coordinates of the points representative of the movement of the tool and transmits the values representative of the movements to be carried out to coupler 3 for servo controlling the machine. In the case of a preliminary shape produced parallel to axis Z, the microprocessor will determine, using its software, the last point preceding a variation of ΔX on the rough profile and will order the movement of the tool from the rest position X_0, Z_0 as far as point B (Figure 2).

The microprocessor calculates the coordinates of point X_1, Z_1 along the straight line BC, at which the variation of ΔX is equal to the cutting depth set by the program. The microprocessor orders the movement of the tool from point B to the point of coordinates X_1, Z_1 , then from point X_1, Z_1 to point $X_1, Z_a + K$.

The tool then rises to $X_a + I; Z_a + K$ and, passing through point B, goes to the point of coordinates X_2, Z_2 which corresponds to a new ΔX equal to the cutting depth P. The tool then moves from point X_2, Z_2 to point $X_2, Z_{p2} + K$, then rises towards point $X_{p2} + I, Z_{p2} + K$ and then goes to point $X_{p2} + I, Z_a + K$. The tool finally rises at $X_1, Z_a + K$, turns back to the rough profile

and comes along straight line BC to position itself at X_3Z_3 . The cycles may thus continue until the tool reaches the point of coordinates X_c, Z_c .

It will be readily understood that the tool,
5 starting from the positions worked out by the microprocessor from the rough profile data, loses less time in useless movements and is always in the act of cutting, except in the backing off and return phases of the tool to the next point on the not yet machined rough profile. With
10 respect to the conventional process which consists in using as rough profile the image of a cylindrical bar, the time for movement of the tool in the hatched zone is saved. These movements are especially penalizing in so far as movements of the tool effected in the cutting
15 direction are concerned for, in the backing off and return phases of the tool, a greater speed of movement may be used. Furthermore, since the finished profile is formed without the grooves, tools 13 of the type shown in Figure 2 may be used, with a single cutting edge 14 turned in
20 the cutting direction.

These tools have a greater strength and cutting capacity than tools having two cutting surfaces and so allow greater cutting depths and so more rapid preliminary shaping. Then, in the case where the preliminary shape
25 of the finished profile must have grooves, the programmer, in the execution program stored in memory 9, writes in two instructions G65 controlling first of all machining of the groove portion at the right of a descending straight line, then machining of the groove portion on the left
30 of the descending straight line.

The format of the groove cycle instruction is the following:

Format:

G65 N1 N2 A P or R X or Z I K F S

35 N1 and N2 are two sequences of the finished profile on each side of the groove.

A is the penetration angle for machining (the penetration takes place at the program speed F).

P or R are the cutting depths along X or Z.

F, S are the advancing and spindle speeds.

The order of the sequences N1 - N2 gives the part to be machined:

- 5 N1 - N2: machining at the left of the straight line A
N2 - N1: machining at the right of the straight line A.

The programmer then adds, after the preliminary shape program of the grooveless profile, the following
10 instructions:

N180 G65, P₁₂ - P₉, A, P, Z_{p9} K, F, S.

N190: tool changing instruction

N200 G65, P₉ - P₁₂, A, P, Z_{p12} K, F, S.

The microprocessor uses the groove profiles
15 of memory 72 for making the calculations by means of the software and for controlling the movements, as shown in Figure 4, causing the tool with cutting edge at the left to descend along the straight line 40 and to take a cutting depth P until the translated profile 41 is
20 reached. Then, the tool is freed from the work piece, comes back along straight line 40, makes a second plunging engagement and a second cut 2. The process is reiterated and the calculations are effected as indicated above, until the tool has removed all the material not belonging
25 to the finished profile, increased by an extra thickness as shown at 50 in Figure 5.

Then, the microprocessor orders a tool change and executes the preliminary groove shaping cycle at the right-hand side with the tool having its cutting edge
30 on the right. The procedure takes place as before; only the cutting direction has changed, and the microprocessor uses the translated finished profile 51 and the descending straight line for calculating the movements and controls. The finished profile is shown by 52 and the hatching
35 53 represents the groove portions still to be removed. The description has been made for a groove whose concavity is orientated along axis X; but the process remains identical for a groove whose concavity is orientated along the

axis of Z.

The examples of Figures 4 and 5 concern simple grooves. If a complex concavity is to be processed, such as the one shown in Figure 6, the programmer will
5 program machining of the profile of this concavity. The microprocessor will begin by processing the profile on the left of the descending straight line, formed by concavities 61 and 63 and will eliminate the concavities included in this profile. Thus it eliminates concavity
10 63 and machines profile 61.

Then, the device processes the right hand part, formed by profiles 62 and 64 and then machines profile 62 without taking into account concavity 64. Subsequently, each of the simple concavities 63, 64 will be processed as
15 explained above.

It is obvious that if the descending straight line falls in concavity 63, for example, then the left hand profile formed by 61 and the part of 63 situated at the left of the descending straight line will be machined
20 at one and the same time; then, the right hand profile formed by 62 and the part of 63 situated at the right of the descending straight line and, in this case, machining of 64 (simple concavity) should be programmed separately as explained above.

25 It is evident that any modification within the scope of a man skilled in the art also forms part of the invention.



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CLAIMS

1. A process for machining a finished profile by means of a digitally controlled machine tool,
5 characterized in that it comprises the following steps:
1) Introduction of a description of the finished profile, then of the rough profile, respectively into a first and a second storage means ;
2) Processing of the description of the finished profile
10 so as to remove, after analysis, the profiled portions having a concavity and storage of the description of the profile portions having a concavity in a third storage means;
3) Storage of the so called "purified" finished profile,
15 freed of the concave portions, in a fourth storage means;
4) Elaboration of the preliminary shape of the purified finished profile in successive cuts, by moving the tool between the coordinates supplied by the purified finished profile memory and those supplied by the rough profile
20 memory.

2. The process according to claim 1, characterized in that it comprises an additional step taking into account modifications of the cutting conditions (cutting depth, speed of advance, spindle speed) programmed at the same
25 time as the description of the rough profile.

3. The process according to claim 1 or 2, characterized by a finishing operation for finishing the purified finished profile.

4. The process according to claims 1, 2 or
30 3 characterized by an operation for turning the concavities.

5. The process according to claim 4, characterized in that, during the operation for turning a complex cavity, the digital control:

- 35 a) recovers the profile of a concavity stored in the third storage means and examines the profile portions situated on the right and on the left of a programmed descending straight line;
b) eliminates, from the profiles situated at the right



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and at the left of the descending straight line, the concavities included in one of the right hand or left hand profiles for transforming the complex cavity into a simple concavity;

- 5 c) effects the operation for machining the simple concavity
d) reiterates the preceding operations on another simple concavity of the complex concavity.

6. The process according to claim 5, characterized in that the digital control, during the operation for
10 turning the complex concavities,

a) recovers the profile of a simple concavity, stored in the third storage means and determines the profile portion situated on the right of a straight line along which the tool descends, the left hand part being stored
15 in a storage means;

b) machines, by successive passes and with a tool whose cutting face is turned to the right, this simple concavity right hand profile on the right of the descending straight line, until the tool reaches the finished profile translated
20 by a value representing the extra thicknesses at X and at Z;

c) orders a tool change and machines, by successive passes of given depth with a tool whose cutting face is on the left, the concavity profile on the left of
25 the descending straight line until the tool meets the left hand profile translated by a value representing the extra thicknesses at X and at Z determined by programming.

7. A device for implementing the process as claimed in one of the preceding claims, characterized
30 in that it comprises:

- means (6, 10, 11, 12) for delivering to a microprocessor (5), connected to a bus (4), a program defining the rough profile and the finished profile, said microprocessor, after compilation, addressing said
35 rough and finished profiles respectively into first RAMs (70, 71);

- second ROMs (8 and 9), connected to the bus



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(4) comprising respectively the parameters of the finishing machine (1) to be controlled and a software ;

- means for processing the finished profile for removing the concave parts and elaboration of a so-called purified profile ;

- a third RAM (72), for receiving the description of said concave parts (3) ;

- a fourth RAM (73), for receiving the so-called purified finished profile ; and

- means for providing connection and transmission of the controls between the bus (4) and the machine to be controlled (1).

8. The device according to claim 7, characterized in that it comprises a fifth memory (74) for receiving the values defining a purified finished profile translated at X and at Z by values defined by programming.