REDESIGN OPTIONS ENABLED BY CAM SOFTWARE USED IN CONJUNCTION WITH CNC MACHINES

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ABSTRACT

The use of CAM Software in conjunction with CNC machines, facilitates various product redesign options especially for 3-dimensional profiles. This paper examines a number of beneficial possibilities for a pair of injection mould inserts.

1.0 INTRODUCTION

Numerical control (NC), as first advanced by John Parsons and Frank Stulen in the 1940's [5], and its various evolutions to Computer Numerical Control (CNC) as we have today, have made a dramatic impact on manufacturing. As revolutionary, has been the developments in Computer Aided Design (CAD) and Computer Aided Manufacture (CAM) Software. Today CAM Machining Software offers a superb facility in translating CAD data into Machine Instructions that enables superior productivity and capability over traditional methods.

The study looks at the manufacture of Injection Mould Inserts to produce a bottle opener. The opener has a number of curved profiles for aesthetic appeal, that is difficult to machine by traditional equipment. The use of CNC machines and CAM software for the manufacture of the mould insert pair, enables possibilities that are not viable with traditional machining methods.

For this study, the CNC Machine used was a Vertical Machining Centre, Model No. CNC-5-A, produced by Yang Iron Works, Taiwan. The CAM Software used was "SMARTCAM" developed by Point Control of Eugene, Oregon, USA (now CAMAX Manufacturing Technologies).

2.0 THE PRODUCT

The bottle opener is shown in **Figure 1** and consists of a metal insert clamped between a pair of identical plastic holders, glued together.

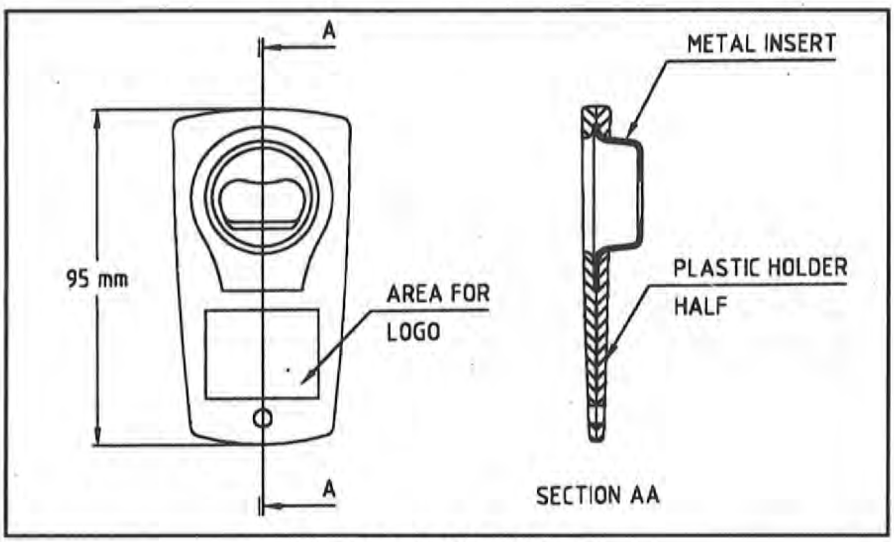

Figure 1: **Bottle Opener**

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The mould insert pair is to be designed for moulding the plastic holders and is retained on a mould base master. Thus, adequate consideration must be made for positioning the cavity/cores on the mould insert to permit clearing of the cooling channels by the ejector pins and also to adequately access the runner system of the mould base.

3.0 MOULD MATERIAL SELECTION

The mould is to be designed for a product output of 20,000 pieces per annum. This being a relatively low volume, the material selected for the mould insert pair is a prehardened steel AISI P20, with a hardness of HRC 30-35. The softer prehardened steel is also easier to polish.

Traditional machining offers two (2) main methods to manufacture 3-dimensional profiles:

(i) Graphite electrodes, usually at least two (2), would be made to the cavity shape and the process of EDM (electrical discharge machining) used to produce the cavity from heat-treated steel, which would subsequently be polished to a mirror finish.

(ii) A model of the cavity is made by some method and the process of copy milling is then used to cut out the cavity for subsequent heat treatment and polishing.

A major difficulty in both these traditional methods is that of making the graphite electrode for EDM or the model for copy milling. Without the use of CNC machines, these patterns are very time-consuming to make to close tolerances.

By contrast, CNC machines with CAM Software permits direct machining of the prehardened steel using carbide cutters. Even with hardened mould inserts, of say 50 HRC, direct CNC machining is possible using ceramic cutting inserts.

4.0 CORE ELIMINATION

Figure 2 shows a design of the mould insert pair for traditional manufacturing methods. Some of the manufacturing difficulties are:-

(i) The core pin "C1" in the cavity presents some difficulty in that the Radius R0.8 follows a curved 3-dimensional profile that is difficult to achieve in traditional manufacture. Once the profile is achieved, the core pin must be keyed in placed to prevent rotation and quite some hand finishing is required to achieve good blending and finishing. Because a core pin is used, a witness mark around the core pin is unavoidable.

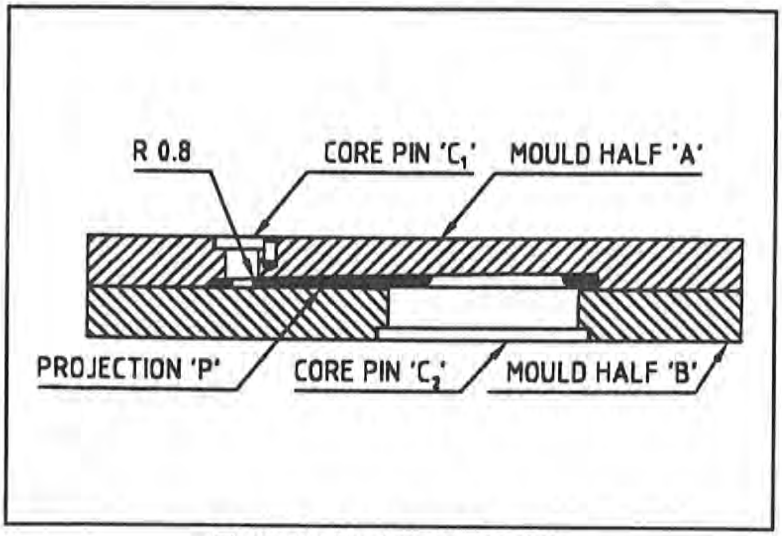

Figure 2: **Traditional Design**

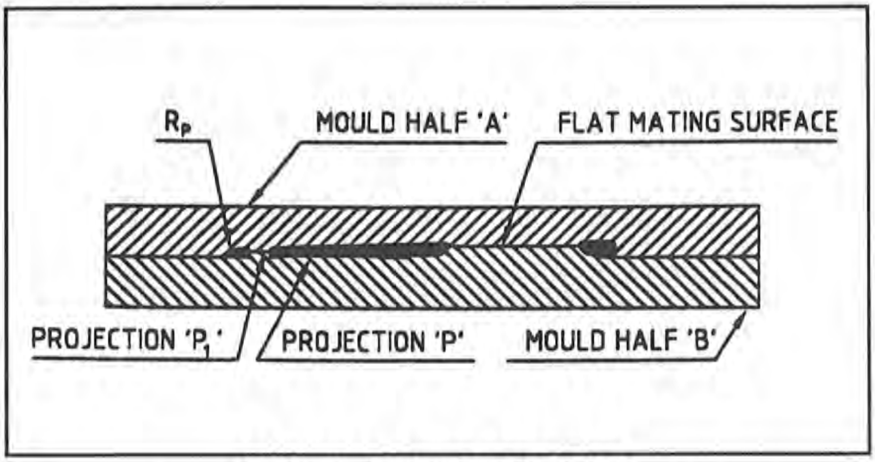

Figure 3: **Design for CAD/CAM**

(ii) The core pin "C2" on the mould half 'B' would also present some difficulty in having its top blended exactly to the cavity surface to prevent flash during moulding.

(iii) In some insert designs, the projection "P" may be created by an insert pocketed in mould half 'B'.

With the use of the CNC machine and SMARTCAM software, mould design can be simplified as shown in **Figure** 3.

Of particular note are the following:-

(a) There are no separate core pins in either cavity or core. This reduces the manufacturing time for core pins and the time to fit them to the cavity.

(b) The holes in the product are made by projections in both cavity and core that meet on flat surfaces which are easiest to fit for reduced flash.

(c) Because CAD/CAM is so effective, the projection "P" can easily be incorporated into the mould half.

(d) The availability of the projection "P1" from the cavity to the parting line, enables the positive retention of the moulded product to the core half for proper ejection.

5.0 PRODUCT MODIFICATION TO ENSURE EASE OF MANUFACTURE

The product as shown in **Figure 1** gives a thickness variation of between 3-4 mm. The radius around the periphery can be varied, but if we use a radius greater than 3 mm, it means the parting line will interface along points formed by the curved ball end of the mill, which makes it difficult to hold profile tolerance.

By choosing the parting line profile to be R3 mm, the parting line is cut above the radius of the ball end mill, leading to a better accuracy of the parting line profile which is easier to match for back-to-back mouldings. A beneficial off-shoot is simpler CAM software usage.

6.0 SIMPLIFYING THE APPLICATION OF CAM SOFTWARE

One way of generating NC code for the mould core and cavity is to create complete meshes for each surface and then apply programme routines to offset the cutting tools to obtain the profiles required. However, time spent on the software for mesh generation can be reduced by only creating those meshes needed to finish the insert.

In the specific product, the following time saving facilities can be used:

(a) The radius around the profile "Rp" is the same throughout the profile perimeter and is such that the straight part of the ball and mill will cut the parting line profile. Therefore, to cut this radius "Rp" around the profile, a mesh need not be generated. Rather, by offsetting a profile a distance "Rp" from the parting line profile, and projecting to a base mesh, the parting line profile could be cut with a ball end mill. The saving here is the use of a tool path line only without the generation of a mesh for the "Rp" profile.

(b) In selecting the tools for machining the cavity and core, ball end mill limiting sizes are R3.5, R3 and R1, because of the product dimensions.

For better finish, it is advantageous to use tools of larger radii. The larger tools are also stronger, less likely to break and can be run at faster feeds to speed up completion of the job.

Thus the machining sequence chosen is to rough using a 10 mm end mill followed by finishing with ball end mills in the order ϕ7, ϕ6, ϕ2.

(c) To effect savings in the time to generate cutter paths for the finish ball mills, the "Project" command of SMARTCAM can be used to good effect, together with 2-dimensional roughing routines.

For example, if the ϕ7 ball end mill is to be used, create an island around the cores, and offset from the cores by 3.5 mm. Then use the 2-dimensional roughing routines to generate a cutter path between the outer profile and the islands. Finally, project to the base mesh of the product to obtain the actual cutting profiles. This process can be repeated for the ϕ6 and ϕ2 ball mills to cut the areas uncut by the previous cutters (See **Figure 4**).

Thus by understanding how the cutters can most efficiently be used to produce the product, simple and quick commands can be selected from the software package to speed up the final machining, without going through all the steps commonly used for cutter path generation.

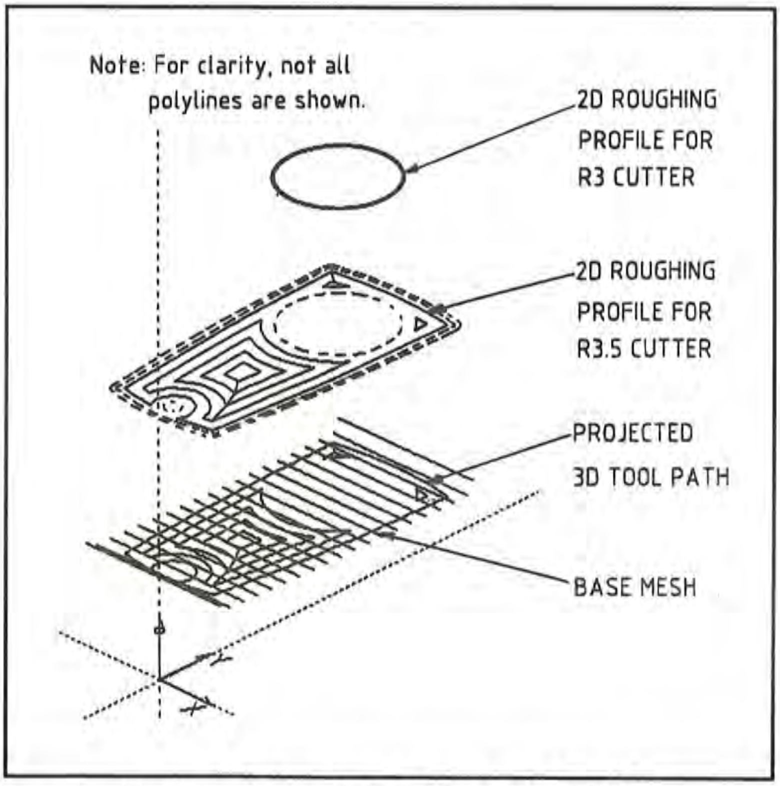

Figure 4: Selected Polylines for CAD/CAM

7.0 ECONOMIC ANALYSIS

Figures 5 and **6** show the process outlines for two alternatives, namely the traditional method using the Electrical Discharge Machining process with insert cores versus the system using CAM software with CNC.

Tables 1 and **2** give a summary of the direct costs for those elements of both processes that differ. As can be seen, the CAM software/CNC alternative gives a direct savings of US$307.00 and a man hour savings of US$200.00. When overheads are considered, savings will almost double.

In the case of multiple inserts, CNC operation additionally offers significant set up savings.

8.0 SUMMARY AND CONCLUSION

The use of CAM software with CNC machining provided a number of advantages for the manufacture

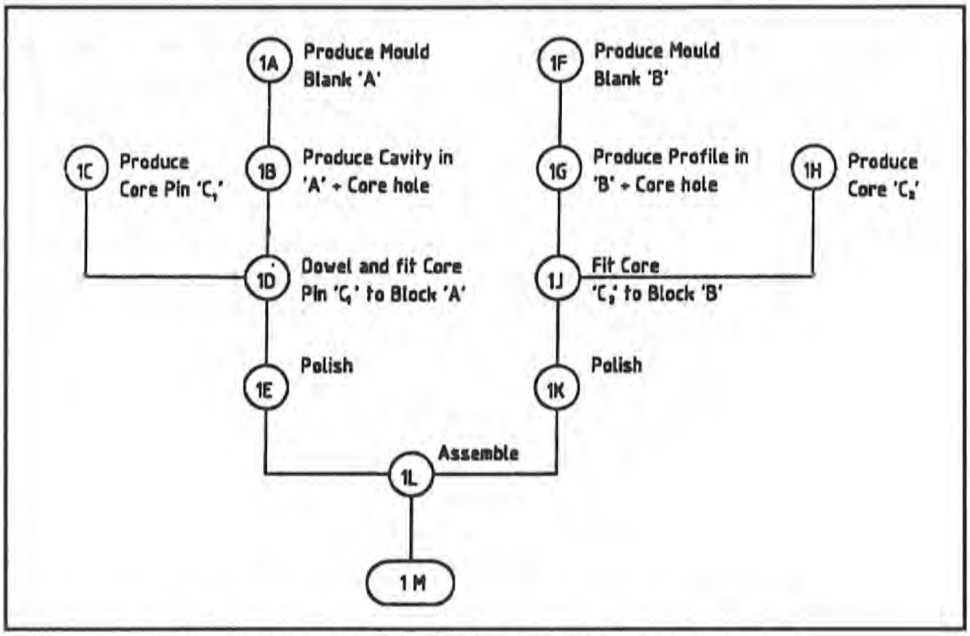

Figure 5: **Process Sheet for Traditional Manufacture**

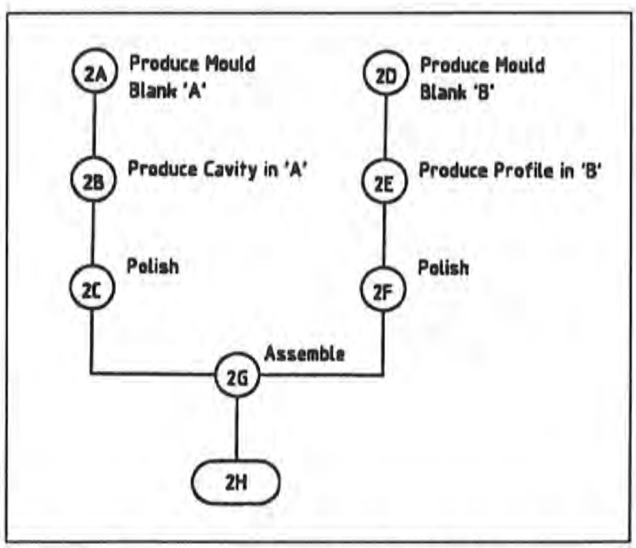

Figure 6: **Process Sheet for CAD/CAM Design**

PROCESS	DETAILS	DIRECT MATERIAL COST	DIRECT LABOUR	REMARKS
		US$	US$	
1B	Produce Cavity in "A" and Core Hole - Produce 2 Graphite Electrodes - Rough Cavity - EDM - Produce Core Holes	 100	 128 16 32 8	 Milling, filing Milling Milling, ream, CBr
1C	Produce Core Pin "C1" - Turn - File profile at top - Grind	 1	 8 8 8	 Lathe Cyl. grinding
1D	Dowel and fit Core Pin "C1" to block "A"	1	8	
1G	Produce Profile in "B" and Core Holes - Mill		64	Milling
1H	Produce Core "C2" - Mill	5	32	Milling
1J	Fit Core "C2" to Block "B"		16	
	TOTAL	107	328	TOTAL = US$435

Table 1: Direct Cost Evaluation for Selected Processes for the Traditional Manufacture of Mould Pair Insert. (See Fig. 2).

Notes:

(1) Direct labour includes set up and operation time estimates based on guidelines used by the tool-making firm of Metal Industries Company Limited, Trincity, Trinidad.

Labour cost is calculated at US$4.00/hr. for Trinidad & Tobago.

(2) Materials - AISI P20 at US$3.00/kg
Electrode Graphite @ US$4.00/in^3.

(3) Processes 1A, 1E, 1F, 1K, 1M are not included as they are also required for CAD/CAM manufacture.

PROCESS	DETAILS	DIRECT MATERIAL COST	DIRECT LABOUR COST	REMARKS
		US$	US$	
2B	Produce Cavity in "A" - CNC Milling		64	Automated programming
2E	Produce Cavity in "B" - CNC Milling		64	Automated programming
	TOTAL		128	TOTAL = US$128

Table 2: **Direct Cost Evaluation for Selected Processes for Mould Insert Pair, manufactured using CAD/CAM. (See Fig. 3).**

Notes:

(1) Direct labour includes set up and operation time estimates based on guidelines used by the tool-making firm of Metal Industries Company Limited, Trincity, Trinidad.

Labour cost is calculated at US$4.00/hr. for Trinidad & Tobago.

(2) Materials - AISI P20 at US$3.00/kg

(3) Processes 2A, 2C, 2D, 2F, 2G, 2H are not included as they are also required for Traditional Manufacture.

of 3-dimensional profiles. The example looked at in this paper not only shows a saving in cost but also the possibilities of redesign options to improve the product aesthetics and the reliability of the operation of the mould. Also explored was the use of 2D routines of the CAM software to reduce mesh generation requirements.

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