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An Efficient No-Core Cut Pocketing CAM System for Wire-EDM

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Abstract - Recently, wire-EDM became a necessity for many engineering applications, particularly in the dies making. No-Core cut process is helpful for operations in which falling slug can jam the machine or wire. In this paper a proposed CAM system (called NCPP) is introduced, to overcome the limitations of the existing CAM systems in the machining of No-Core cut. The proposed CAM system (NCPP) provides pocketing of No-core cut and optimal selection of the position of starting hole (wire threading point), to minimize toolpath length. It was written for data exchange between CAD-CAM-CNC machines. This data model will become part of the ISO (Data model for Computerized Numerical Controllers) international standard. The NCPP system has been implemented in Visual C++. Many examples are used to illustrate NCPP system. The results show that, NCPP saves the machining time by significant value. This value depends on the shape and complexity of the workpiece that is being cut.

***Key Words*: EDM, Wire-EDM, No-Core Cut, No-Core Pocketing, Pocketing Slugless**

1. Introduction

Wire-EDM cutting process (Fig. 1), was primarily developed for the tool & die industry. With the advancements in cutting speed, reliability, unattended operation, and accuracy it has grown into many other industries. It is now used in medical, aerospace, automotive, defense, electronics, and extrusion applications to name a few.

The wire-EDM is a specialized form of EDM in which the electrode is a continuously spooling conducting wire, Fig. 1. The wire moves with respect to the workpiece by a numerically controlled table. The contour cutting is similar to the contour cutting in a band saw so, wire EDM sometimes called "Electronic Band-Saw" [6]. The diagram of a traveling wire EDM machine is shown in Fig. 1. The wire EDM machines have at least two controlled axes (X and Y). Most machines can tilt the wire to produce tapered work piece using two auxiliary horizontal axes (called U and V). Controlled vertical and rotary axes are also available.

The wire is usually made of brass, copper, or tungsten and typically about 0.25 mm in diameter, making narrow cuts possible. The wire is usually used only once, as it is relatively cost inexpensive. It travels at sufficiently high and constant velocity, 2.5-150 mm/s, and a constant gap (kerf) is maintained during the cut [7], Fig.2. High tensile strength, high electrical conductivity, and good wire drawing are the most important factors needed for choosing wire type and ideal cutting.

Because of its various advantages, wire-EDM continues to grow in many manufacturing industries. Wire-EDM precision –depending on the quality of the wire-EDM system, profile accuracy of down to 0.00004" (0.001016 mm) can be achieved. Many wire-EDM systems can obtain surface finishes down to 8 micro inches Ra. Once the machine is set up and running, there is time for the operator to carry out other job functions. Multiple workpiece setups can extend that amount of time.

When the machining parts are small, it becomes difficult and inefficient to manually handle the slugs which result from the wire-EDM process. In this case the dropout slug may cause machine or wire damage. To solve this problem, a specialized EDM pocket machining cycle that erodes all the material inside a given cavity, eliminating the slug. This pocket machining cycle is mainly called "No-Core cut" and is mainly used, in the case of cutting the small shapes of closed contours.

No-Core cut has dramatically changed the approach to the machining of workpieces containing small openings. Rather then producing a dropout slug, which could disturb the machining process, the most efficient erosion paths to fully erode the material within a contour are calculated. No-Core process is ideal for planning and implementing maximum unattended utilization of wire-EDM machines.

The computer allows the economical programming of the wire-EDM path of complex parts that could not be manually handled. Computers can perform the required mathematical calculations quickly and accurately, and the computation errors, so commonly appearing in manual calculations, are eliminated in the computer-aided programming.

El-Midany et al. [4] proposed a CAM system that provides automatic correction for maximum taper angle, and automatic creation of the programmed fixation stop. Programming time has been reduced using the automatic toolpath creation, post- processing, trace checking feature,

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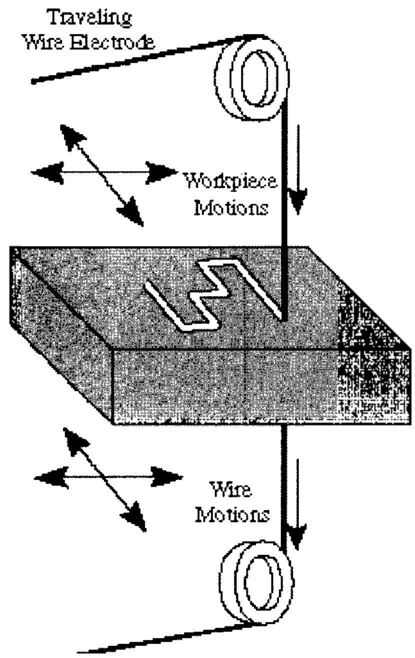


Fig. 1. Wire-EDM cutting process.

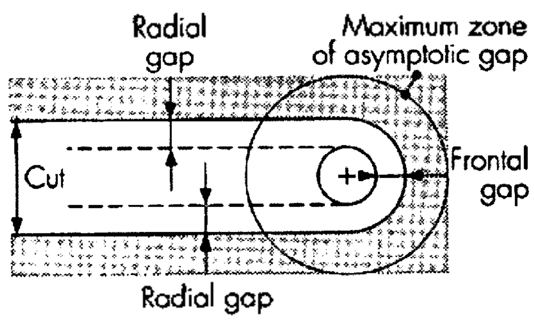


Fig. 2. Wire-EDM cutting technology.

and simulation check. Enhanced two-axis programming capabilities include, multiple operation automatic lead-in and lead-out generation, automatic corner filleting for internal, external, or all sharp intersections. El-Midany et al. [4] are not considered the No-Core cut machining in their CAM system.

In this paper a new CAM system is proposed to automatically generate the CNC ISO-code of wire-EDM No-Core pocketing path. This system is called NCPP (No-Core Pocketing Path). The NCPP system will recognize and automatically machine only the slug and pocketing-slugless No-Core cutting. Also, the No-Core pocketing path is optimized for starting hole (wire threading point).

2. The Proposed No-Core Pocketing Path System (NCPP)

The proposed No-Core pocketing path system (NCPP) consists of the following procedures: (1) generation of toolpath planning type, (2) selection of No-Core wire threading point, and (3) optimizing the selection of No-Core wire threading point.

2.1 Generation of Toolpath Planning Type

The toolpath is the path that leads wire through the machined region. It is used to remove all the material inside some arbitrary closed boundary on a flat surface of a workpiece to a fixed depth. Such a shape is frequently called a generalized pocket, or (more simply) a pocket, and the process is called pocketing. Mainly, there are two types of toolpath contour-parallel or spiral (normal, smooth and fishtail spiral) and direction-parallel or zigzag (normal and smooth zigzag) [1, 2 and 5], Fig. 3.

The contour-parallel toolpath comprises of a series of

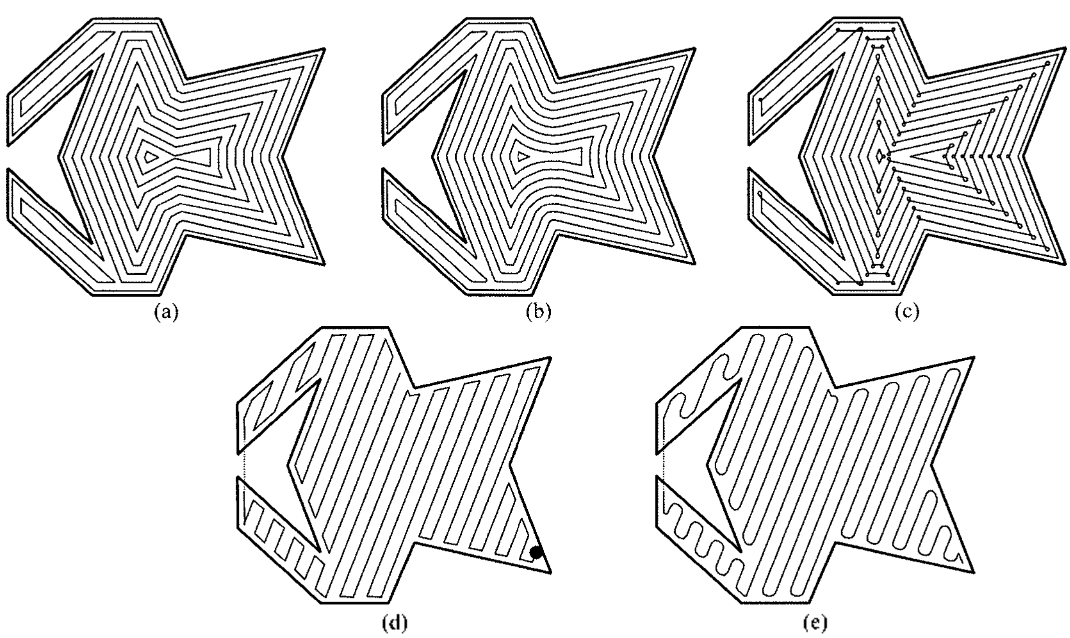


Fig. 3. Toolpath generation type. (a) Normal spiral, (b) Smooth spiral, (c) Fishtail spiral, (d) Normal zigzag, (e) Smooth zigzag.

contours that are parallel to the boundary of the 2D cross-section. Whereas, direction-parallel path is the path segments correspond to back and forth motion in a fixed direction within the boundary of the 2D cross-section.

El-Midany et al. [3] proposed a feedrate machining time model that takes into account CNC machine acceleration and deceleration for automatically identifying the most productive toolpath pattern. This model is then used to compare the total machining time for common five types of toolpath patterns (shown in Fig. 3). The results show that the optimal toolpath pattern is dependent on part geometry, physical characteristic of used CNC machine tool (accelerator and decelerator, continuous path, look ahead, and etc.) and cutting conditions (tool diameter, feedrate, and etc.). In this paper the fishtail spiral toolpath is used to improve characteristics of wire toolpath. Adding fishtail satisfies there is no-cutting regions or removes overcutting regions. And, improve machining efficiency particularly in wire-cut high depth machining.

To construct the fishtail a circle is added at the extension of any two sharp corner in spiral toolpath, Fig. 4-a. The radius of this circle depends to physical characteristics of peripheral devices of CNC machines tool and the angle between the two sequence lines that being calculated for fishtail. To avoid any damage of the boundary, it is canceled adding fishtail to the first offset polygon, Fig. 4-b.

Fishtail Algorithm

```
int CPolygon::AddFishTail (float rad)
{
    Point p1, p2, p3, point; int j=0; CArc arc; CPolygon poly; CLine ArcLine;
    for (int i=0;i<=Line.GetUpperBound();++i)
    {
        float angle=Line[i].GetAngle(Line[GetNext(i)]);
        if ((i != Line.GetUpperBound() && Line[i].FishTail (Line[GetNext(i)],rad,p1,p2,p3)))
        {
          if (Line[GetNext(i)].InSide(Line[i].Point1( ))==1)
                    ArcLine.Set(p1,p2,p3,2);
          else
          {
                    Line[i].IntSect(Line[GetNext(i)],point);
                    p3=p3.Mirror(point);
                    ArcLine.Set(p1,p2,p3,3);
          }
          poly.Line.Add(Line[i]);
          poly.Line.Add(ArcLine);
          ++j;
        }
        else
          poly.Line.Add(Line[i]);
    }
    *(this) = poly;
    return j;
}
```

2.2 Selection of No-Core Wire Threading Point

The passing of wire through the upper head, workpiece, and lower head of the machine, is known as wire threading, Fig. 5. The position of No-Core wire threading point will affect toolpath length and the total machining time.

NCPP contains a module that is used to calculate the optimal position of No-Core wire threading point. This position is mainly selected based on the shape of the workpiece geometry. The No-Core wire threading point module consists of the following steps:

1- Calculate the toolpath of workpiece geometry, Fig. 6-a.

2- Find the Last Offset Contour (LOC), and calculate the center of this contour, as shown in Fig. 6-b.

3- Select the position of center of the LOC as the No-Core wire threading point, as shown in Fig. 6-c.

4- Re-Calculate the toolpath of the workpiece geometry and takes into account the starting hole that is considered as an island in toolpath calculations, Fig. 6-c.

2.3 Optimizing Selection of No-Core Wire Threading Point

Because of the shape of the workpiece geometry, in some cases the toolpath may be contains more than one LOC, as shown in Fig. 7.

In this case the center of every LOC is checked, and

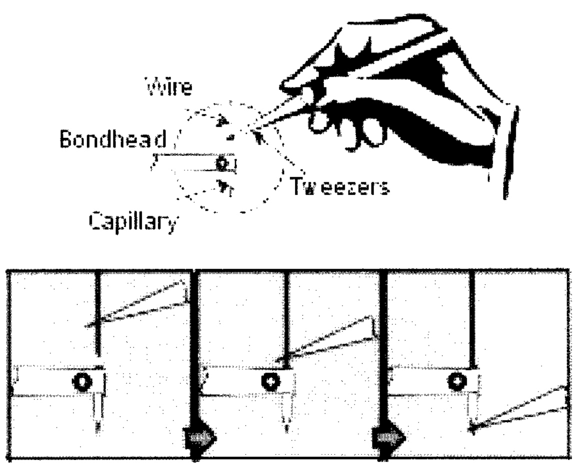
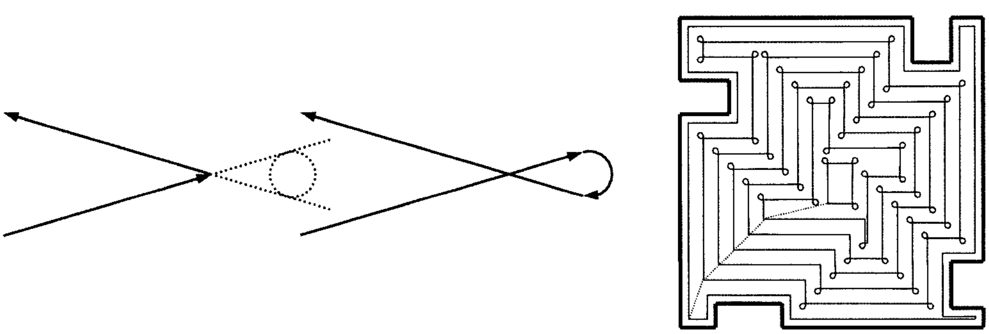


Fig. 5. Manual wire threading procedure.



(a) (b)

Fig. 4. Construction of Fishtail Spiral. (a) Add fishtail for every sequence entities, (b) Fishtail Spiral.

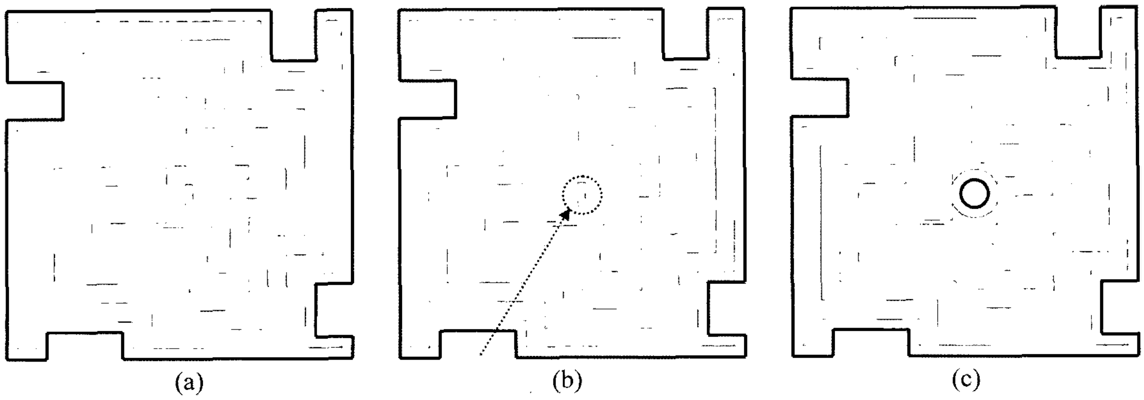


Fig. 6. Calculating wire threading point procedure. (a) Calculate toolpath, (b) Find last offset contour, (c) Center of LOC as threading point.

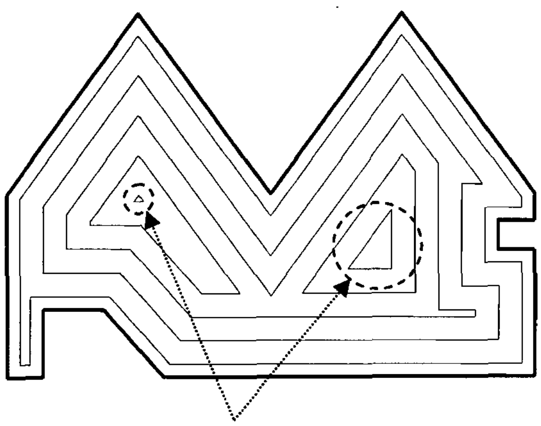


Fig. 7. Toolpath contains two LOCs.

the NCPP select the point that minimizes the total path length, as shown in Fig. 8.

After calculating the optimal threading point, the sequence of cutting for the last inner contours must be optimized. This problem is converted to a Traveling Salesman Problem (TSP) problem and is solved using the Voudouris' algorithm (GFLS) [8 and 9]. Fig. 9 shows an application example in two cases.

The first one shows the traveling toolpath before applying GFLS and the second shows the traveling toolpath after applying GFLS to optimize the traveling toolpath length.

3. Applications

The NCPP system has been implemented in Visual C++. Several examples were applied to check robustness, efficiency and quickness of the NCPP system. Figure 10, 11 and 12 show some application examples in three types of spiral pocketing (smooth, fishtail, and normal).

4. Conclusion

The paper presented a new CAM system (called NCPP), to enhance the machining of No-Core cut than other commercial software. The NCPP system provides pocketing of No-core cut and optimal selection of the position of starting hole (wire threading point) to minimize the actual machining time. Also, NCPP was design for data exchange between CAD-CAM-CNC machines.

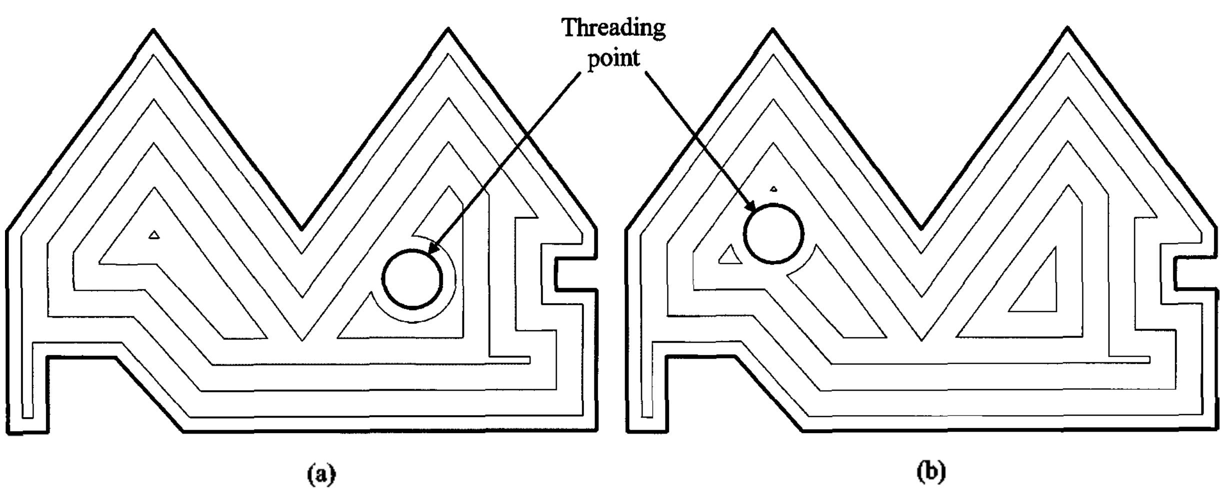


Fig. 8. Searching for the optimal position of threading point (*found in case (a)*). (a) Select 1st LOC (*Toolpath =1801.33*), (b) Select 2nd LOC (*Toolpath =1820.99*).

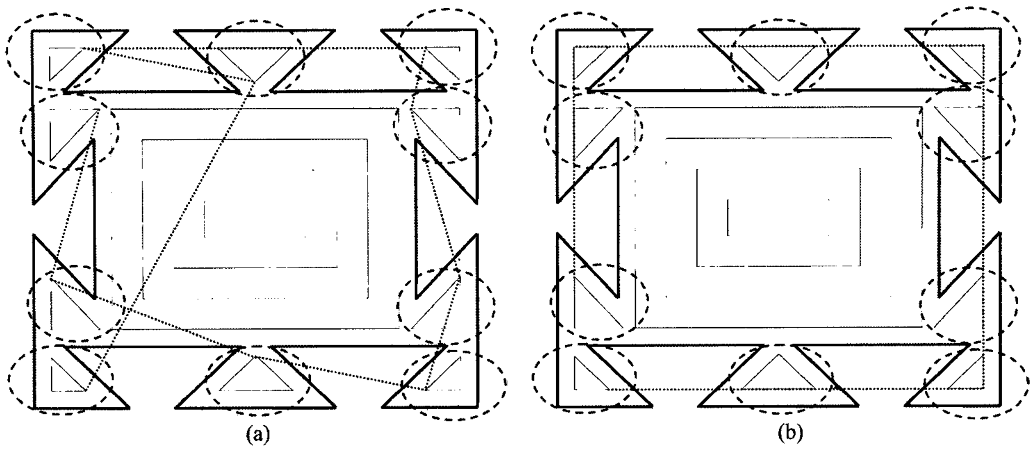


Fig. 9. Using GFLS to traveling toolpath between the inner contours. (a) Before using GFLS (*traveling length=365.3812*), (b) After using GFLS (*traveling length=287.6917*).

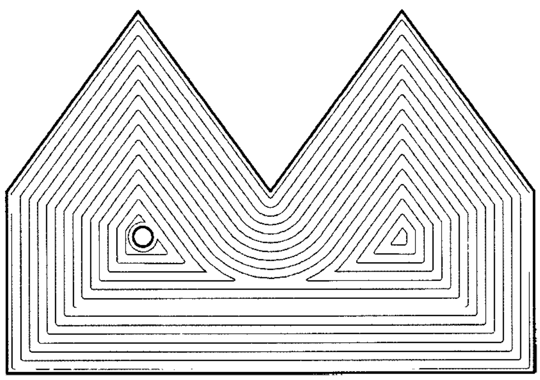


Fig. 10. Application Example (I), Pocketing of No-Core with smooth spiral

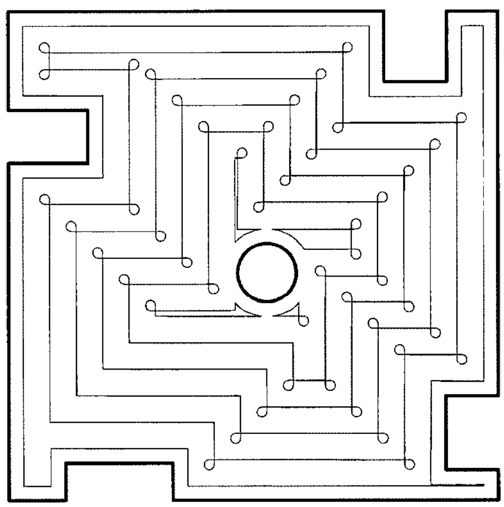


Fig. 11. Application Example (II), Pocketing of No-Core with fishtail spiral

The NCPP was tested through several application examples, and the results show robustness, and quickness of the NCPP system for pocketing No-Core cut.

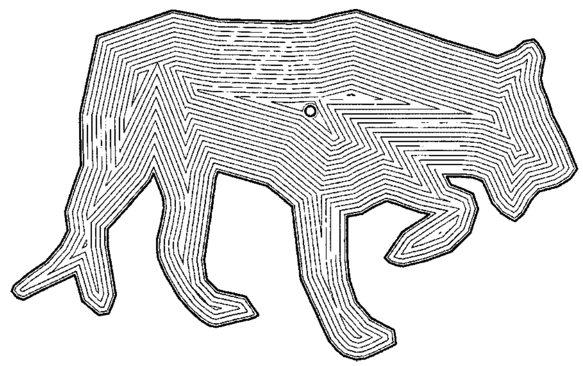


Fig. 12. Application Example (III), Pocketing of No-Core with normal spiral

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