SEMTAP
(Serpentine End Match TApe Program)

The Easy Way to Program Your Numerically Controlled Router for the Production of SEM Joints

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Abstract

SEMTAP (Serpentine End Match TApe Program) is an easy and inexpensive method of programing a numerically controlled router for the manufacture of SEM (Serpentine End Matching) joints. The SEMTAP computer program allows the user to issue commands that will accurately direct a numerically controlled router along any SEM path. The user need not be a computer programer to produce a variety of SEM patterns.

Serpentine End Matching (SEM) is a new method of precisely end-joining short pieces of dimension lumber in an esthetically pleasing manner (Gatchell et al. 1977). SEM camouflages the end joint so well that, at best, the joint cannot be detected. The SEM joint is disguised as a part of the grain pattern of the two pieces of wood that are joined together.

Assuming that grain and color requirements are met, the acceptance or rejection of a SEM joint depends on how well the two curves that form the joint fit together. The manufacture of SEM joints requires a precise machining technique; this requirement is easily met by using a numerically controlled router.

A SEM joint is composed of many arcs that resemble a single continuous curve. Computing these arcs manually has been time consuming and impractical, but now this is unnecessary. With the aid of a computer any number of SEM patterns can be easily and inexpensively produced.

Numerically Controlled Routers

Numerically controlled routers are used primarily for continuous path machining, or contouring. Similarly controlled machines such as drills and boring machines are used in point-to-point operations. The basis for positioning or locating the points in both operations is the rectangular coordinate system; any point in a given plane is described by a unique set of coordinates in that plane.

The primary difference between contouring and point-to-point operations is the way the cutting tool moves from one point to another. The primary concern in point-to-point operations is the precise location of the points; the path from one point to another is irrelevant because it occurs outside of the work piece.

In contouring, the path between points is as important as the location of the points because the machining operation is continuous through and between these points. The path taken by the cutting tool between these points is determined by interpolation.

Three types of interpolation are used in numerically controlled routers: linear, circular, and parabolic. All numerically controlled routers perform linear interpolation, and many perform linear and circular interpolations; but only a few perform all three functions. Only linear interpolation is required if straight lines and a few simple curves are desired. However, if most of the routing is done in arcs and requires a close tolerance, linear interpolation is impractical. A combination of linear and circular interpolation will perform all but the most complex contouring jobs.

Complicated aerodynamic designs and free-form designs used by the automobile industry require expensive additional parabolic interpolation. Because providing parabolic interpolation in numerical control units is costly, only linear and circular interpolation were considered for manufacturing SEM joints.

When the same command points were used for linear or circular interpolation, the error that resulted from linear interpolation was almost eight times greater than that from circular interpolation. For precision, circular interpolation should be used as often as possible for describing SEM router bit paths.

As with any computer, the numerical control unit that directs the router is only as accurate as the instructions it is given. The control unit receives instructions from a perforated or punched tape. If the curves become the least bit complex, the trigonometric and geometric analogues become complicated. Because of the large number of computations and the increased chance for human error, computing SEM patterns manually is impractical.

SEMTAP (Serpentive End Match TApe Program) eliminates these problems; this FORTRAN program is very easy to use, and the user need not be a computer programer to produce a variety of SEM patterns quickly and inexpensively.

SEMTAP

Two paths are required to produce a SEM joint. If a router bit is moved through a piece of wood along a curved path, the two pieces of wood that are produced will not fit together because the rate of curvature is different for each piece of wood (Fig. 1). If the pieces are to fit, two router bit paths must be used—one on either side of the desired glue line (Fig. 2).

SEMTAP enables the user to issue commands that will accurately direct a numerically controlled router along any SEM path. SEMTAP uses the sine function to describe SEM joints; each SEM pattern requires a router bit path on either side of the sine wave. These paths must be parallel to the sine wave, and offset a distance equal to the radius of the router bit.

Only three pieces of information are required by SEMTAP to produce commands for each SEM pattern: the amplitude and period of the sine wave describing the SEM joint, and the radius of the router bit that will be used in cutting the joint. By changing the amplitude or period or both, a variety of SEM patterns can be produced. To obtain the required accuracy, measurements of the radius of the router bit must be within 1/1000 of an inch.

The printout by SEMTAP includes all of the necessary preparatory ("G") codes and miscellaneous ("M") command codes (Fig. 3). These commands can easily be transferred from the printout to a punched tape.

The following is a list of the G and M codes used in SEMTAP:

- G01: Linear interpolation
- G02: Clockwise circular interpolation
- G03: Counterclockwise circular interpolation
- G04: Dwell
- G90: Absolute input mode (all X and Y values are measured from zero)
- G92: Absolute offset (used to set starting point at zero)
- G94: Inch per minute programing that permits feed speeds (speeds at which the router bit travels) to be read in direct inches per minute
- M02: End of program
- M04: Head up
- M08: Head down

These commands may be indicated by different G or M codes in some control units; however SEMTAP could still be used as is, and proper substitutions could be made before the tape is punched. SEMTAP may also be altered to print desired codes directly.

The command points are printed in absolute mode, that is, all command points (represented by X and Y) are referenced to zero. In circular mode (G02 or G03), the radius components "I" and "J" are referenced to the previous command point; "I" is the distance in the X direction, and "J" is the distance in the Y direction from the center of the arc to the reference point. The

Figure 1.—If a router is passed through a piece of wood along a curved path. . .

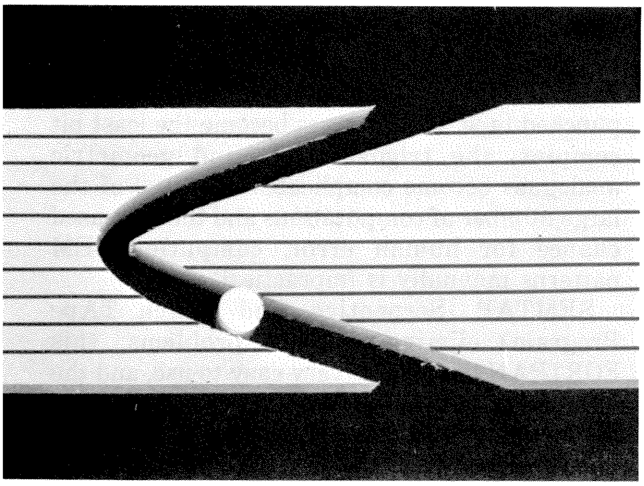

Figure 1A.—. . .the resulting pieces do not fit together.

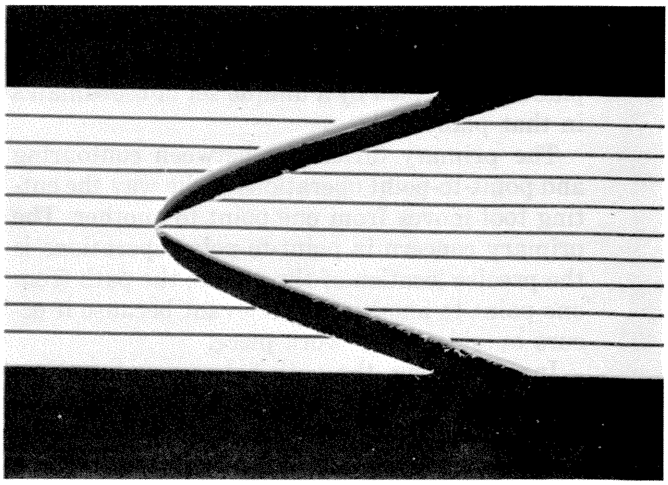

Figure 2.—Two router bit paths are necessary. . .

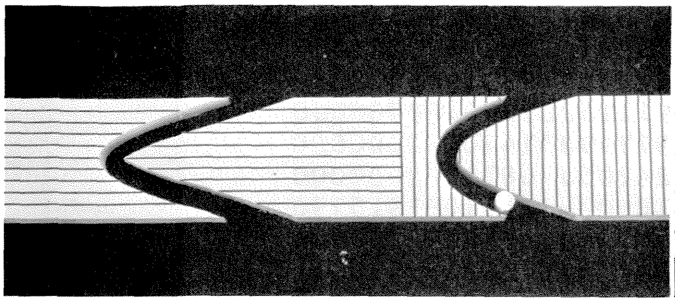

Figure 2A.—. . .if the pieces are to fit.

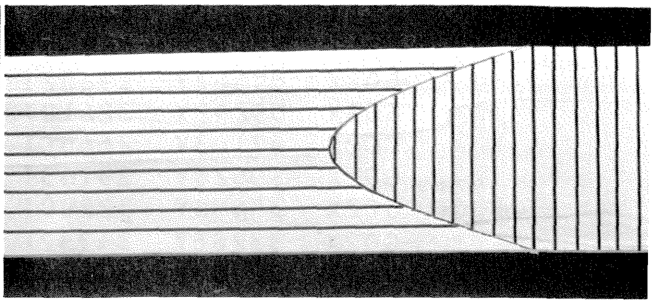

Figure 3.—Sample printout from SEMTAP that includes the necessary preparatory (G) and miscellanous (M) codes.

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AMPLITUDE =  2.50  PERICD =  5.00  BIT RADIUS =  0.250
G94G92X00000Y00000
G90
G01X  27500Y  12500F4000000
M04
G04F60000
G03X  26185Y  16039I   5730J    115F 458458
G03X  23286Y  18586I   9351J   7720F 970063
G03X  18114Y  21291I  18643J  29344F2000000
G03X   9270Y  24618I  43775J102951F2000000
G03X    758Y  27382I292718J884639F2000000
G02X -11190Y  31350I  96282J309936F2000000
G02X -18146Y  34237I  22498J  64030F2000000
G02X -21380Y  36201I   8169J  17097F1515838
G02X -22403Y  37268I   2672J   3582F 357490
G02X -22500Y  37500I    397J    299F  39748
G02X -22403Y  37732I    497J     71F  40181
G02X -21380Y  38799I   3431J   2262F 328805
G02X -18602Y  40531I  10428J  13634F1373228
G02X -11859Y  43405I  27177J  54416F2000000
G02X    -27Y  47368I  95540J265630F2000000
G02X    758Y  47618I113604J365132F2000000
G03X  12897Y  51650I  97609J314126F2000000
G03X  20380Y  54763I  24135J  68556F2000000
G03X  24118Y  56998I  10800J  22311F1982953
G03X  26460Y  59337I   6088J   8439F 832428
G03X  27500Y  62500I   4576J   3257F 449319
M08
G04F60000
G01X  82500Y  12500F4000000
M04
G04F60000
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(Continued)

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G03X  82245Y  12961I    730J    115F   59092
G03X  80530Y  14414I   5410J   4642F  570310
G03X  76113Y  16709I  15887J  25173F2000000
G03X  67667Y  19882I  41775J  98369F2000000
G03X  59242Y  22618I291115J879903F2000000
G02X  47103Y  26650I  97799J314701F2000000
G02X  39620Y  29763I  24205J  68729F2000000
G02X  35493Y  32299I  10402J  21570F1915790
G02X  33288Y  34732I   5799J   7483F  757376
G02X  32500Y  37500I   4705J   2836F  439511
G02X  33288Y  40268I   5497J     71F  439816
G02X  35493Y  42701I   7740J   4799F  728571
G02X  39094Y  44969I  13555J  17536F1773148
G02X  46407Y  48095I  29481J  58853F2000000
G02X  58456Y  52132I  97275J270319F2000000
G02X  59242Y  52382I112087J360368F2000000
G03X  71190Y  56350I  96093J309362F2000000
G03X  78146Y  59237I  22428J  63856F2000000
G03X  81124Y  61002I   8566J  17837F1582991
G03X  82336Y  62163I   3094J   4434F  432540
G03X  82500Y  62500I    452J    430F   49888
M08
G04F60000
G01X00000Y00000F4000000
M02
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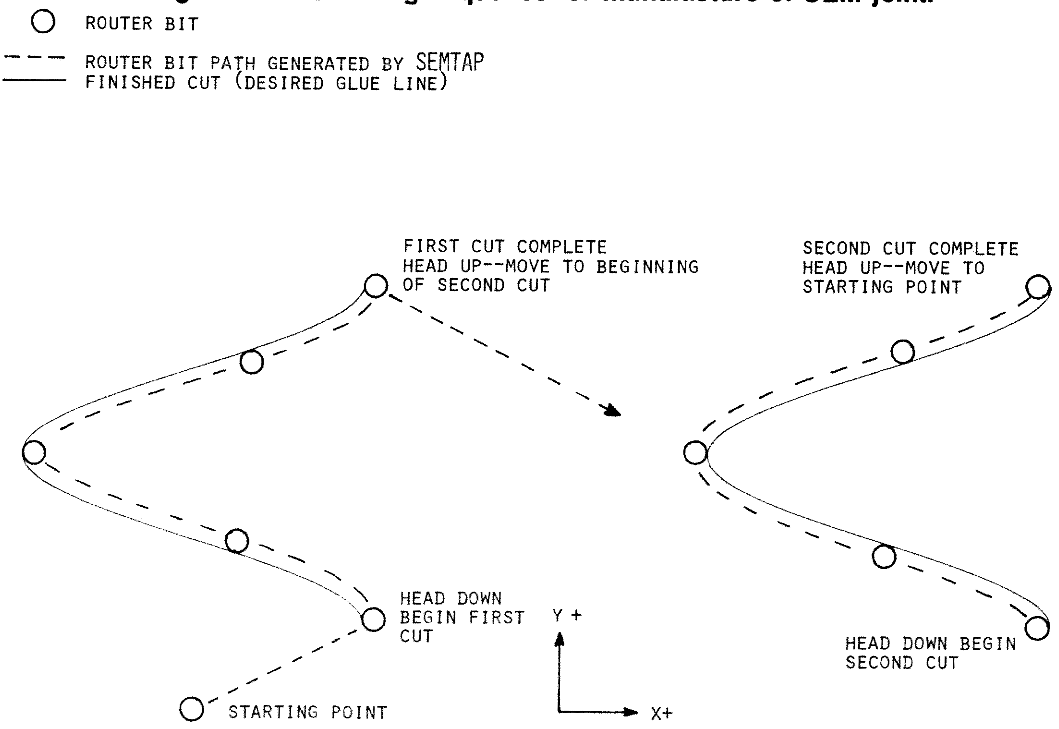
Figure 4.—Machining sequence for manufacture of SEM joint.



feed speeds prefixed by "F" are in inches per minute.

The numerical control format for X and Y is 3.4; this means that the first three places are to the left of the decimal, the last four places are to the right. Decimal points are not printed—the number 16220 is read by the numerical control unit as 1.6220. The format for F is 3.4; the format for I and J is 2.4.

The set of commands produced by SEMTAP directs the numerically controlled router to make two cuts (Fig. 4); the first cut produces the concave part of the SEM joint; the second produces the convex part. From the starting point—zero—the router bit is moved to the point where the first cut begins. The router bit is then lowered into cutting position and the first cut begins. After the first cut is completed, the router bit is raised and moved to the point where the second cut begins. Although we used an offset of about 6 inches from the beginning of the first cut, any offset is possible. After the second cut, the router bit is raised and is returned to the starting point. This completes the cycle.

SEMTAP is written so that the feed speeds are determined by the length of the radii of the arcs describing the router bit path. The longer the radius, the faster the feed speed (up to a maximum of 200 inches per minute). This is a logical way of determining feed speeds because large circles can be machined at a faster rate than small circles on a numerically controlled router.

At higher feed speeds, a "reader-bound" condition may occur; this is when the tape reader of the control unit is unable to read the commands as fast as they are being carried out. The reader-bound condition results in unprogramed pauses during the machining operation, but these pauses can be eliminated by lowering the feed speeds.

The cost of SEMTAP is moderate; when SEMTAP has been used with an IBM-370 computer, costs were always less than $1 per run.

Summary

- SEMTAP is easy to use, Each set of commands requires only a knowledge of the amplitude and period of the desired sine wave, and the radius of the router bit.
- SEMTAP is accurate. If the radius of the router bit is measured to within 1/1000 inch, the commands produced by SEMTAP will provide all of the information needed to produce acceptable SEM joints.
- SEMTAP is inexpensive—less than $1 per run on an IBM-370 computer.

Additional information about SEMTAP or SEM may be obtained from the USDA Forest Service, P.O. Box 152, Princeton, West Virginia 24740. A program listing of SEMTAP also is available upon request.

Literature Cited

Gatchell, Charles J., Ronald Coleman, and Hugh Reynolds. 1977. **Machining the Serpentine-end matched joint.** Furniture Des. Manuf. 49(6):30-34.