

CUTTING PIPE CONTOURS – NEW APPLICATION FOR ROBOTS IN SHIPBUILDING

Summary

A newly developed 8-axis pipe contour cutting machine will be presented which integrates a standard robot and allows a rather unlimited range of cut contours. The use of robots for pipe fabrication is a further step ahead in shipbuilding industry to save man-hours and to increase quality. Cutting pipes of different materials with flame or plasma process will be compared, types of different machines using chucks or rotating rollers will be described as well as integrated conveying systems. High quality demands sensing of pipe diameter tolerances and adjusting the geometry of each cut as required to the shape of the pipe in that area. Another focus is safety around this robotized machine including fume extraction in case of plasma cutting. The features of the BurnPro-R software will be explained which allow easy programming by the machine operator. A 3D Graphical Visualization of the cut and recipe defined are created for operator verification. Direct data download from a PC being linked upstream with shipyards CAD-system is provided.

Key words: pipe, robot, quality, cutting, safety, software, CAD system

REZANJE CIJEVNIH KONTURA – NOVA PRIMJENA ROBOTA U BRODOGRADNJI

Sažetak

.Biti će predstavljen nedavno razvijeni 8-osni stroj za rezanje cijevnih kontura, koji sačinjava cjelinu sa standardnim robotom i omogućava skoro neograničen niz reznih kontura. Uspoređivati će se rezanje cijevi iz različitih materijala upotrebom plinskog (kisik-plin) i plazma rezanja. Objasniti će se tipovi različitih strojeva koji koriste zahvatne glave (čeljusti) ili rotacijske valjke, kao i cjeloviti transportni sistemi. Visoka kvaliteta iziskuje mjerenje tolerancija cijevnog promjera i podešavanje geometrije svakog reza, a prema zahtjevima oblika cijevi u tom području. Sigurnost u području rada robot-stroj, uključujući odsisavanje plinova nastalih kod plazma rezanja veoma je važno prokomentirati. Osobine BurnPro-R programa objasniti će lakoću programiranja operatera na stroju. 3D grafički prikaz reza i definicija granica i parametara rada pripremljeni su za potvrdu operatera. Mogući je direktan prijenos podataka sa PC-a koji je spojen na CAD sistem brodogradilišta.

Ključne riječi: cijev, robot, kvaliteta, rezanje, sigurnost, software, CAD sistem

1. Introduction

Shipbuilding is not a series production. Production lot size normally is just “1”. Robot applications mostly can be found in series production, mainly in automotive industry. It took some time before robot controls and software became flexible enough to guarantee economic fabrication of small series and single pieces. A precondition was the development of CAD/CAM systems allowing direct data download from a CAD-system to the robot controller and avoiding time consuming single job programming by teach-in mode. Meanwhile many shipyards have robots in use for welding of micro-panels and of large volume sections. A further robot application became cutting of all kinds and shapes of stiffeners and profiles.

Pipe fabricating is, besides hull fabricating, another important sector of shipyards own fabricating. But in most yards pipe fabricating methods are still traditional, therefore time consuming and needing very skilled personnel. There was a request to modernize the fabricating of large diameter pipes by use of modern robot technology.

The application of robots for pipe fabricating is a further step ahead in shipbuilding industry to save man-hours and to increase quality, *Fig. 1*.



Fig. 1. Typical Cut Samples

Slika 1. Tipični uzorci rezova

There is a tremendous saving of work hours if manual cuts can be replaced by use of an automated robot saddle and hole cutting machine, *Fig. 2*.

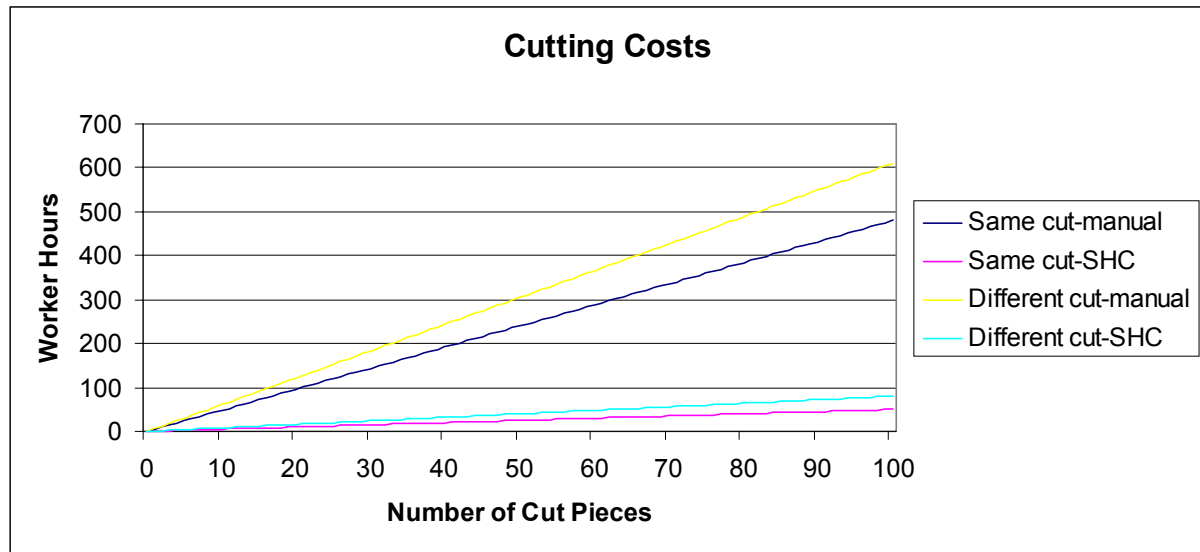


Fig. 2. Cutting Costs

Slika 2. Troškovi rezanja

2. Machine Types

Interesting enough there had been developed two different concepts of machines and used for the same task of cutting complex pipe saddles and holes. Chuck driven machines were always operated in Europe and Japan/Korea whereas roller driven machines had been preferred in USA.

Chuck driven machines have the disadvantage that the pipe is clamped at one end only and that the idling support rollers manually have to be set to height to match the pipe outer diameter. Also the idling roller supports have to be moved in length direction with respect to stock and finished part length, *Fig. 3*.

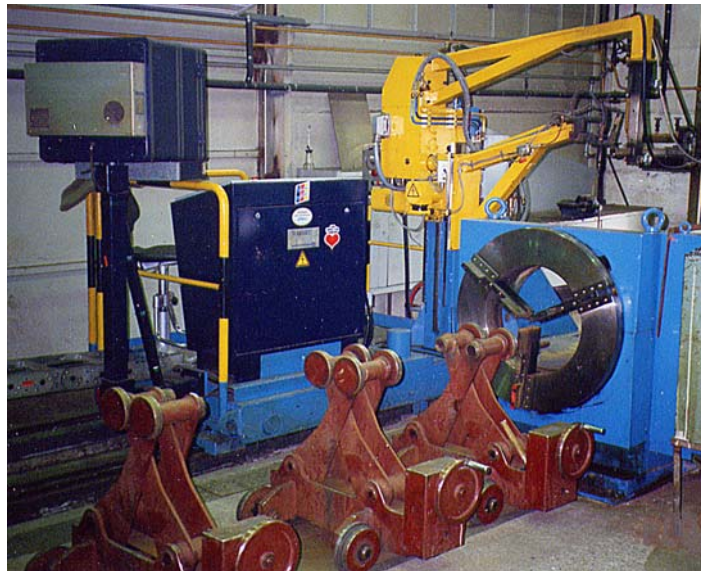


Fig. 3. Chuck Driven Machine

Slika 3. hrvatski prijevod

But chuck driven machines have the advantage to allow ground contact through the clamping chuck in case of plasma cutting. Pipes lying on a roller driven machine need to be connected with a rotating power coupling guaranteeing perfect ground contact.

The roller driven machine has the main advantage of not needing any setting works in case of diameter or pipe length change. The exact alignment of the common axis of the rollers guarantees that there is no longitudinal movement of the pipe during rotation, *Fig. 4*.



Fig. 4. Roller driven machine

Slika 4. Stroj pokretan valjcima

3. Pipe Handling – Material Flow

Roller driven pipe cutting machines can easily be integrated into conveyors with load tables and kick-off stations avoiding any need of cranes for loading stock pipes and for unloading cut pieces thus guaranteeing optimal material flow. For this purpose the roller length conveyor being part of the cutting machine will be lowered down during cutting operation to allow pipe rotation and to avoid damage of the transport rollers, *Fig. 5 and 6.*

Fig. 5. Integrated Transport Rollers
Slika 5. Integrirani prijenosni valjciFig. 6. Integrated Kick-out Arms
Slika 6. Integrirane ruke za izbacivanje

4. Axis Control

Numerous types of machines had been developed over the decades for the purpose of pipe contour cutting, earlier machines with lever controls and scales for manual parameter setting not allowing optimal bevel cuts. The latest generation is using CNC controls to synchronize different linear and rotating axis (up to three linear and three rotating axis). Further developments are described in next chapter below.

5. Use of Robot

A newly developed 8-axis pipe contour cutting machine integrates a standard robot and allows a rather unlimited range of cut contours. It is even possible to retrofit existing machines with this new technology, *Fig. 7*.



Fig. 7. Robot Saddle and Hole Cutting Machine

Slika 7. Postolje robota i stroj za bušenje rupa

As robots and their main controls themselves are a series production, the adaptation of this common product can provide a more economical machine than the more custom built machines of the past. Normally, the main control allows easy expansion to include control of loading tables, conveyor sections, kick out devices, flame control valves, and other equipment.

The control automatically computes the cutting path including the correct positioning of the hole or saddle in relation to the centerline intersection point of the joining pipes or other reference point. The operator can observe the cutting head trace prior to activating the torch. The operator can interrupt a cut and the cutting unit will semi-automatically return near the point of interruption to complete the cut. The selected cutting speed is the tangential speed of the torch and is maintained constant throughout the cut. The speed can be compensated automatically according to the torch attitude to the work piece. The control of the cutting process is integrated into the robot control including special cycles for preheating and hole piercing.

All individual cuts are calculated and oriented to the intersection point of the branch and the main pipe centerlines. The individual cut reference point is indexed to the designated sequence start point anywhere on the stock pipe. In this way a recipe of twenty cuts, or several recipes, can be indexed to a common start point to allow continuous cutting on a stock pipe.

The operator can select one of the following types of cuts:

Miter Cut - The end of the pipe is cut off straight at a selected angle. A varying bevel is applied to the cut to maintain the selected weld bevel angle to the extent possible. Entering miter angle of 90° with a 0° bevel will provide a square cut off of the pipe.

'T' Socket Branch Cut – The end cut on the branch pipe is cut to fit the corresponding hole on the main pipe.

'T' Socket Main Cut – The hole in the main pipe is cut to fit the corresponding branch end cut trace. The hole is cut maintaining a constant bevel angle to the branch axis. The

operator selects the desired bevel angle. Beveled Saddle - Branch Cut – The end cut of the branch pipe is cut to fit the corresponding saddle on the main pipe at the selected intersecting angle. A varying bevel is cut on the end cut to maintain the selected weld bevel angle between the two pipes to the extent possible. Beveled Saddle - Main Cut – The saddle in the main pipe is to fit the corresponding end cut trace at the selected intersection surfaces. ‘V’ Cut – The machine is easily programmed to cut a V-shape in the main pipe for insertion with a branch pipe of equal outer diameter at a right angle. Both Main and Branch cut are included. Slot Cut (Rectangular Hole Cut) – A rectangular slot is cut into the body of the pipe or into the end of the pipe. The bevel angle and corner radius are entered as parameters. The bevel angle is maintained between the cut and an inserted rectangular tube or plate. Selecting slot width as “0”, the machine will provide a lengthwise slit cut. Cuts can be chained in a recipe so that length wise cut with tabs will be the result. Elbow Support Cut – This cut is used for cutting a saddle on a support pipe that fits into a specific elbow. The elbow and the support pipe can have the same outer diameter, or the support pipe can be smaller. The cut bevel angle is programmed into the cut and is not selectable. Straight Cut – The machine is easily programmed to make a series of straight cuts to part the pipe into segments of predetermined length. Dual Intersection Saddle Cuts (same plane) – These cuts, similar to those used in structural offshore industry designs, can be made by programming two cuts that overlap each other.

6. Tolerance Sensing

Exact fit of branches with main pipe for proper welding demands precise cut configurations independent from pipe tolerances. Especially larger pipes may change in diameter by several millimeters caused by ovality and diameter deviation allowed by common fabrication standards. This demands sensing of pipe diameter tolerances and adjusting the geometry of each cut.

The cutting torch has to be adjusted to the outer pipe diameter by linear vertical movement (90° with respect to main pipe centerline) because adjustment along the torch centerline would cause unacceptable changes of the requested contour.

After a cutting recipe is developed, the operator has the choice to scan or not to scan the pipe by help of a laser scanner attached to the robot arm, *Fig. 8*. This is for the purpose of saving time, where we have found that pipe 8” diameter and below typically is fabricated with no or very little out of round tolerance. The scanning of the cutting area only is accomplished prior to making the actual cuts; this method allows the robot to scan the exact position of each individual cut in the recipe and adjusts the geometry of as required to the shape of the pipe in that area.

Capacity height sensors as normally being used for plate cutting machines are not applicable because a robot arm rotates and inclines the torch in any direction and the round pipe surface is not flat like a plate. The sensor risks to collide with the pipe surface or to give a wrong signal.

Height sensing through the arc voltage in case of plasma process also cannot be used because various torch inclination for requested bevel cuts result in permanently changing cutting thickness and torch tip distance. Therefore no proportional voltage signal can be derived for close loop torch position control.



Fig. 8. Height Sensor

Slika 8. Osjetnik visine

7. Flame versus Plasma Cutting

The table below is showing the main advantages and disadvantages of both flame and plasma cutting; see also *Fig. 9 and Fig. 10*.

Table 1: Main criteria for use of flame cutting respectively plasma cutting

Tablica 1: Glavni kriteriji pri odabiru rezanja plamenom odnosno rezanja plazmom

Main criteria	Flame Cutting	Plasma Cutting
Different wall thickness	Very tolerant	Limited
Maximum wall thickness	Unlimited	Limited to normally 25mm
Cutting speed	Low	High below 20mm wall
Material	mild steel only	Any
Safety	no need for specific protection	Complete protection housing needed against arc noise, arc light, toxic gases in case of air or oxygen use.
Compound cuts	Tolerant	Limited



Fig. 9. Flame Cutting

Slika 9. Rezanje plamenom



Fig. 10. Plasma Cutting

Slika 10. Rezanje plazmom

8. Operator Safety

By all relevant safety standards robot use requires safety means avoiding access of the operator or other shop floor people to the robot working zone during automatic operation. Test or repair work in that zone is allowed at reduced speed only. In case of robotic pipe cutting the working zone covers the full robot travel length (in most cases about 8 m), and therefore the rear side of the cutting machine at least has to be protected by a safety fence with electrically locked access door. Software and hardware stops can be used in addition to reduce the horizontal robot reach. The safest solution is, of course, to build a complete housing around the machine, Fig 11, serving also as protection of the operator against all risks caused by the use of plasma process, see chapter 7 above.

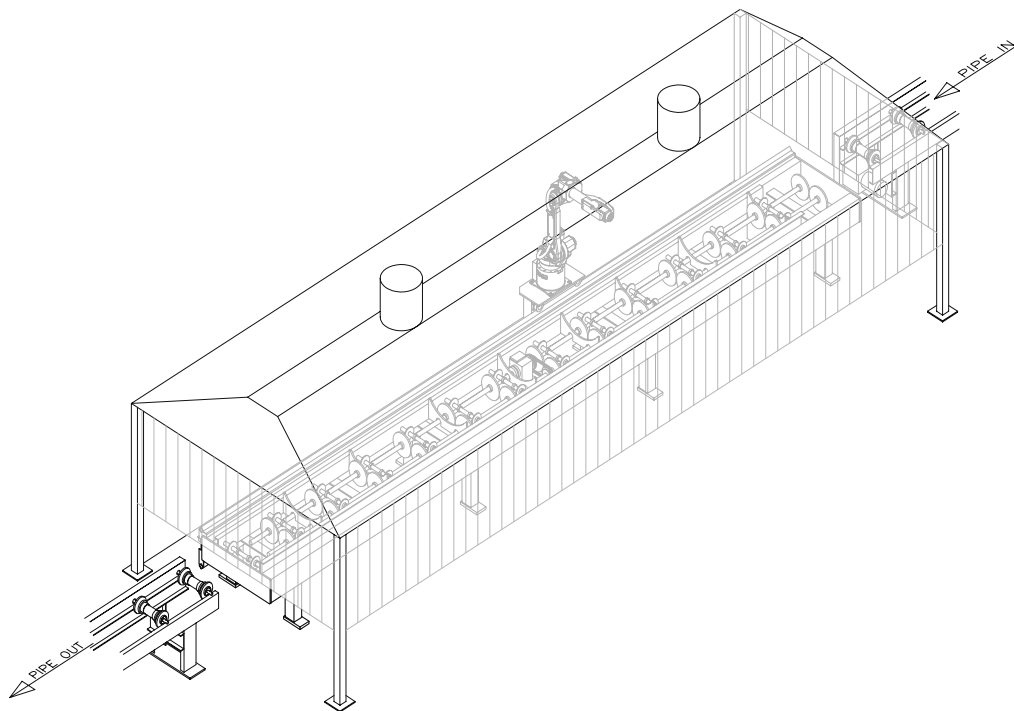


Fig. 11. Safety Housing with Fume Extraction

Slika 11. Sigurnosno kućište s ispuhom dima

Fig.

9. Machine Programming

The BurnPro-R software was especially developed to control the 8 of the robot saddle and hole cutting machine allowing easy programming by the machine operator. A 3D Graphical Visualization of the cut and recipe defined was created for operator verification.

The 8 axis of motion (pipe rotation, longitudinal travel, and all other motions) are coordinated using a standard commercial robot. The mathematical equations for each type of cut are preprogrammed in the PC provided for the operator. The type of cut and other dimensional factors entered by the operator determines the exact cutting trace, cut start location, and torch angles to be used during the selected cut. The control panel provides control of all machine functions. It includes a touch screen display, a joystick, and an array of pushbuttons including E-stop. The display screen is activated by the touch of the operator. The graphical user interface displays illustrations of the various cut selections and of the data required for each cut, *Fig. 12*.

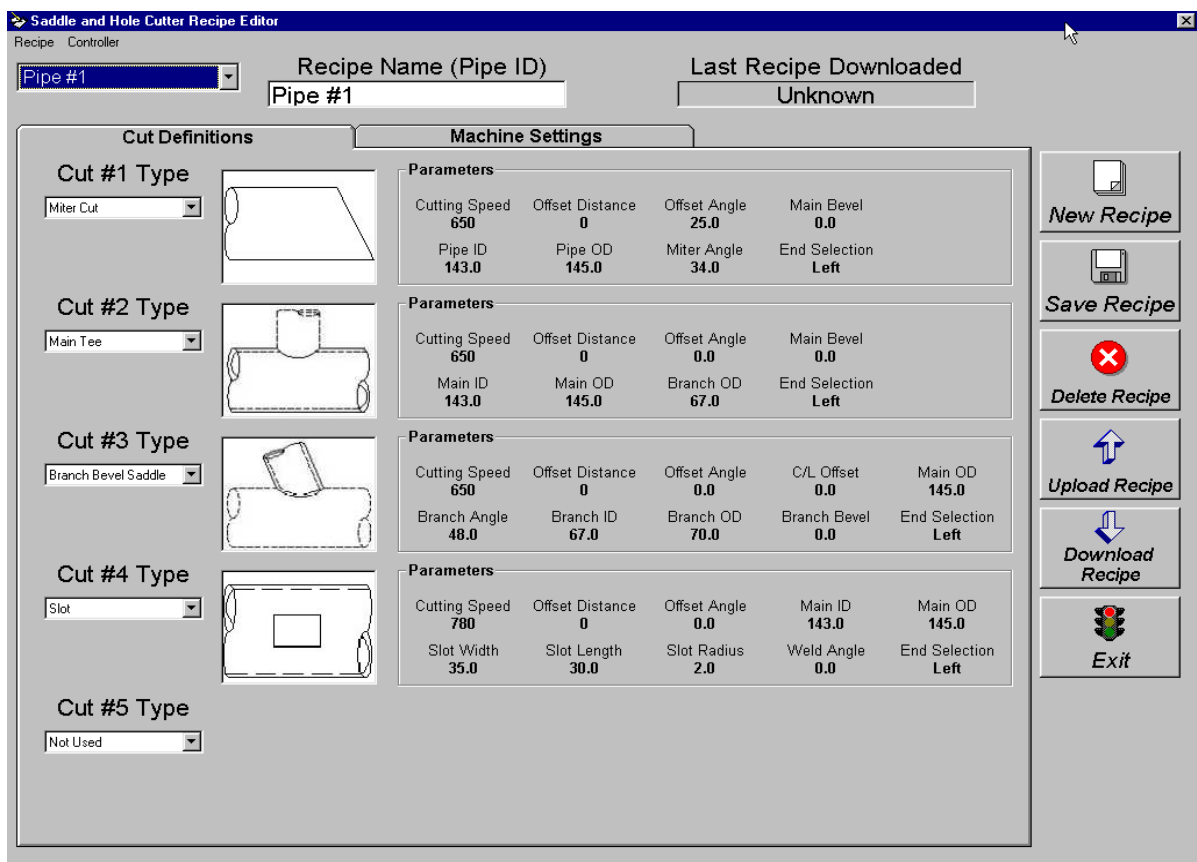


Fig. 12. Graphical User Interface

Slika 12. Grafičko korisničko sučelje

The operator quickly and easily enters the data required for each cut, *Fig. 13*.

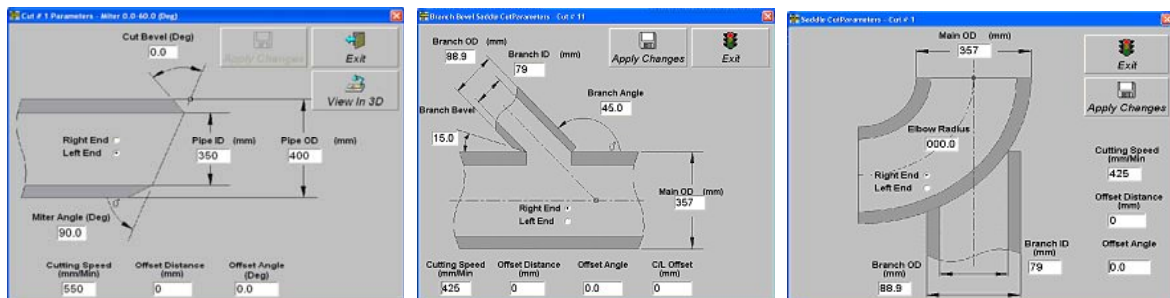


Fig. 13. Typical Cut Parameter Interface

Slika 13. Tipično sučelje parametara reza

The operator can program up to 20 cuts at a time, all using a common starting (index) point. Once a recipe had been defined, the operator can display a 3D graphical representation for visual inspection, *Fig. 14*.

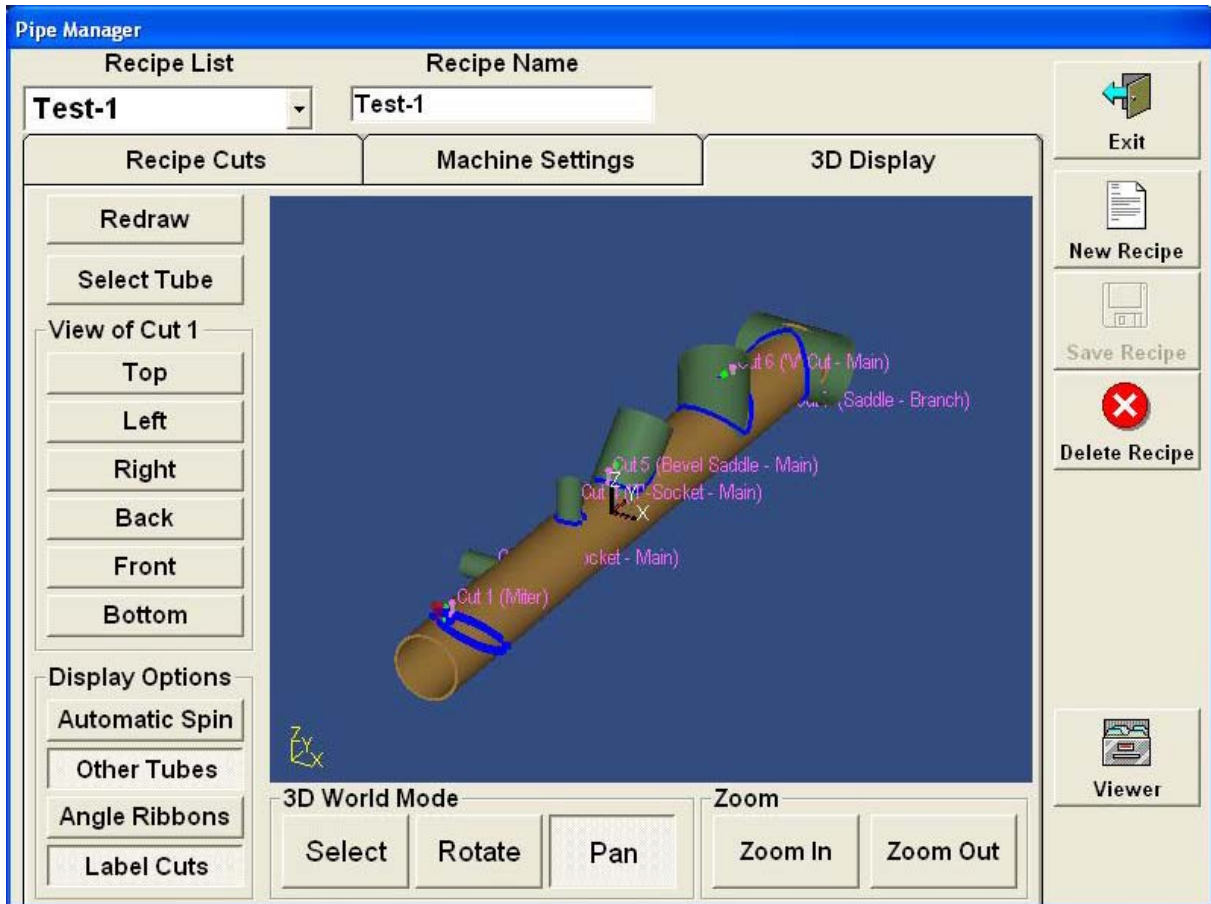


Fig. 14. 3D Graphical Display

Slika 14. 3D grafički prikaz

10. CAD/CAM Operation

The BurnPro-R software is designed to allow an operator to input pipe cuts and recipes into the computer by the same method used at the machine. The operator can download the recipes by file name (pipe identification) to the saddle and hole cutting machine. The computer can archive files from the saddle and hole cutter for future use. The computer can store thousands of recipes that can be catalogued and sorted by designation. Each recipe can contain up to 20 different cuts. All cuts within a recipe are indexed to a common reference point on the pipe. Additional recipes can be indexed to that same point.

The software can be configured to download data from an external CAD-system if data is presented in an acceptable format.