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PIPELINE SYSTEMS MODELING IN 3 DIMENSIONS

Summary. In this work a method and a software are presented for the creation of a 3 dimensional (3D) geometric model of pipelines which are found, e.g. in the industrial chemical installations. Apart from the geometric form all data necessary for the creation of global bills of elements and those for a specific fragment of pipelines are stored in the system. Using this model one can create drawings for any view, and for isometric drawings in particular. The system was implemented in Lisp and Pascal. The software is an extension of an AutoCAD system.

1. Introduction

During design of the apparatus with pipeline installations one of the major difficulties is the preparation of a technical drawing where one wants to show, among other things, the pipeline system in 3D [Bole at al.]. Particularly, one has to make drawings for various views in order to present the actual localization of the pipeline. Even a small change in the pipeline construction often involves the necessity of redrawing of large parts of a pipeline system. Because of the pipeline assembly and the preparation of orders for the elements is also indispensable to prepare a list of elements of the whole pipeline as well as separate lists of elements for the separate pipeline fragments. Actually it is also required that the list for the fragment is prepared in the sequence in which elements occurred in these fragments. It speeds up the pipeline assembly and makes it possible to avoid mistakes resulting from erroneous interpretation of the description of the construction.

Automatic creation of different drawings of the pipeline system is made possible for different views. The software generates dynamically various lists of elements (bills of material). The software ensures the logical consistency and geometric correctness of a model of the pipeline systems.

2. Model of pipeline

The creation of the model of the pipeline system is interactive. The user's task is to select the logical connections. The system creates a geometric model and the data base. The geometry of an object is determined in 3D space and the

designer has full 3D model of a pipeline system. The system records of text
and numerical information about the pipeline in the data base. Description of
every element are connected with its counterparts in the geometric model. The
process of creation of a geometric model is semiautomatic. It is the user task
to define the coordinates of the beginning of the pipeline, i.e. coordinates of
points in which the pipelines are connected with the specific devices. The user
also gives the measurements of pipeline elements. In the next step of the
system development the users will only give the pipe lengths whereas the
dimension of the other elements will be taken from data base (catalogues) on
the elements.

A set of schematic graphic symbols (icons) is used for pipeline element
drawing, i.e. valve, elbow etc. Schematic symbols are drawn on a plane, i.e.
they are 2D items. As can be seen from this the geometrical model of a pipeline
system is being created in 3D space whereas the pipeline elements are
represented in a simplified form as flat entities. The set of schematic
symbols is shown in Fig.1. The pipes are represented in the drawing as lines
actually corresponding to the localization of the symmetry axis of the pipes.

The symmetry axis of the element was assumed in the system as the direction
of that element. The axis is represented by means of end point pe of the
element and central point pc. Pc point for the specific types of element was
selected so that it lies on its own axis and on the axis of the element which
will be connected latter on. The location of the pc and pe points for the
selected elements is shown in Fig.2.

As far as logical consistence is concerned the system:
1) supervises that the connecting of the pipeline elements be reasonable, e.g.
makes it possible to join no more than only three other elements to tee;
2) stores information about of the pipeline diameter taken into consideration
(the reduction is occurred) transferring it automatically depending of the
element along the pipeline.

3. Model handling in 3D

Inserting a new element into the pipeline the localization of its end
points pn are determined. In these cases when it is indispensable for the
determination of the new plane (elbow, branch, cross) an icon representing the
considered element of the pipeline is placed on this plane.

For the known points pe, pc, pn one determines the Cartesian coordinate
system OX'Y'Z' (UCS in AutoCAD) in relation to the fundamental Cartesian
coordinate system OXYZ (WCS in AutoCAD). Every coordinate system discussed in
the program is based on the right fingers rule. Localization of the OX'Y'Z'
system is such that the points pe, pc, pn are on OX'Y' plane.

As far as the geometric correctness is concerned the system automatically
establishes this location of the elements joined to the pipeline on the basis
of geometrical data about the elements which is being joined and the data about
the already existing elements in the system. One takes into consideration the
exception from the role described above for bent pipes. In practice an actually
bent pipe may be meant here as well as such a case when due to imprecise data
on the elements. In order to connect the two already existing elements one has
to bend the pipe to a minimum. In practice this bend may be so small that
during the assembly bending is not necessary, however in the pipeline model the
pipe is represented as a bent one. A bent pipe is represented as a line
connecting the joining points of the elements combined. On this line are placed
either one or two crosses depending on the number of the required bends. The
location of these lines in the model may differ distinctly as compared to the
actual location of the bent pipe. Pc, pe, pn points are determined on the basis
of the actual location of these elements which ensures correctness.

The simplified function quoted below in AutoLisp is based on points pc, pe,
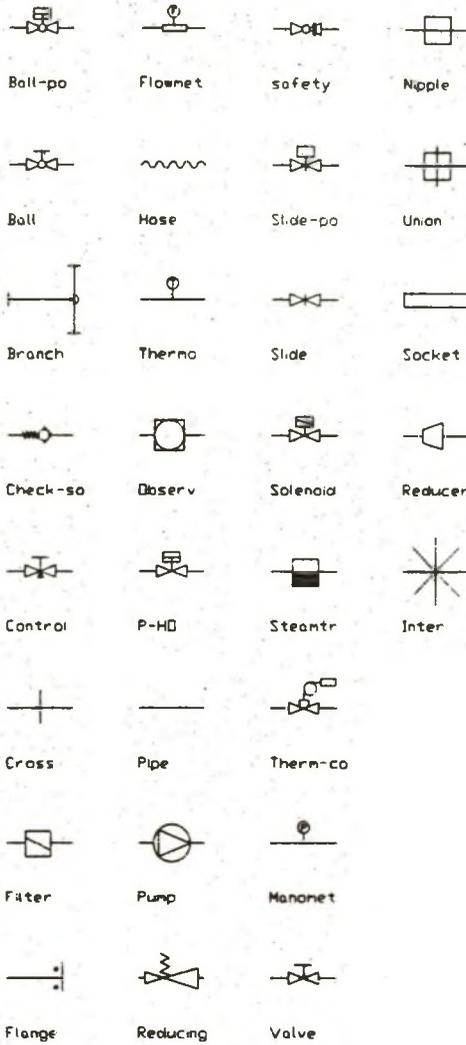pn and determines the coordinate system OX'Y'Z'.

Fig. 1. Set of schematic symbols for pipeline elements

Ball-po   Flowmet   safety   Nipple

Ball   Hose   Slide-po   Union

Branch   Thermo   Slide   Socket

Check-so   Observ   Solenoid   Reducer

Control   P-HD   Steamtr   Inter

Cross   Pipe   Therm-co

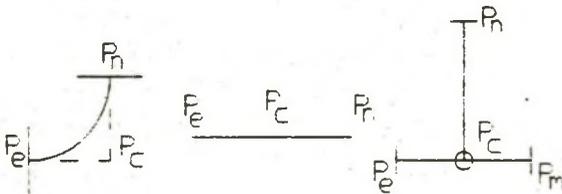Filter   Pump   Manomet

Flange   Reducing   Valve

Fig. 2. Characteristic points of some selected elements

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(defun new_ucs(pe pc pn / e ap )
  (command "ucs" "w")  (command "ucs" "3" pc pe "")  (setq e (transf pn 0 1))
  (setq e (transf (list 0 (cadr e) (caddr e)) 1 0))  (setq ap (transf pe 0 1))
  (setq ap (transf (list (- 0 (car ap)) (cadr ap) (caddr ap)) 1 0))
  (command "ucs" "w")  (command "ucs" "3" pc ap "")  (setq pom (transf e 0 1))
  (if (and (= 0 (cadr pom)) (= 0 (caddr pom)))
      (setq e (transf (list 0 1 0) 1 0)) )
  (command "ucs" "w")  (command "ucs" "3" pc ap e)  )
```

The function 'new_ucs' applies two basic operations. The first one is the
determination of the coordinate system by means of the UCS command (AutoCAD
system). The second function 'transf' transforms the coordinates of the point
from the OX'Y'Z' system to the OXYZ system and back again. The first parameter
of this function are coordinates of this point and the second number 1 or 0.
The number 1 signifies transforming from the basic coordinates system OXYZ to
OX'Y'Z' and 0 back again.

4. Characteristic of pipeline elements

   Elements found in the picture of pipeline are divided into 2 groups: visible
and invisible ones. Visible elements are represented in the drawing by means of
symbols and can be connected at least with two other elements (most often:
antecedent, consequent) - see Fig.1 and Tab.1.
   In the case under consideration only a cross has 4 connection and only a
branch has 3 connections. Visible elements may be labelled with an identifier
and in such case the element is treated as a marker used in dividing the
pipeline system into fragments.
   Invisible elements are added to the drawings by the user, i.e. they are
represented in the data base of the drawings. These elements are not displayed
but they are taken into account in the preparation of the bill of elements.
The user may join the invisible element with the visible one existing in the
drawing. It was assumed that one invisible element may be associated with
(subordinated to) one visible element. The deletion of the visible element
results in the deletion of the invisible element associated with it.
   When modeling pipeline in 3D one can use bent pipes. Such pipes are inserted
between two indicated element of a pipeline. The situation which requires
either single or double bend is automatically recognized. Bent pipes are
represented in the model by means of line with one cross to symbolized a single
bend and lines with two crosses which corresponds to a double bend. In both
cases the beginnings and ends of pipes are precisely represented.
   The set of typical elements was extended with an object for determining
places in the machine where the pipeline are either to begin or to end. Since
these elements play a role of interface between the machine and pipeline they
were call in brief 'inter'. Object of the inter type are not included in the
bill of elements. Using inter elements is not obligatory and it has been
introduced to facilitate localization of the beginnings of pipelines especially
in these part of the machine which is not submitted to frequent changes.

5. Operating rules

   The main manner of preparing a drawing of pipeline system is to select its
visible elements in the sequence in which these elements occurred in the
pipeline. Invisible elements are inserted by pointing to the visible ones with
which they are associated.
   The user can assign a special marker to each visible element of the
pipeline. These markers appear in bills of elements to distinguish the
fragments of pipeline. The user can order the system to prepare a list of
elements belonging to the selected fragment of pipeline as well. The fragment
is determined by selecting two markers.

Table 1. List of selected element types and element attributes
('+' attribute present; '-' attribute absent)

ATTRIBUTE		TYPE OF ELEMENT					
Meaning	Name	pipe	elbow	redu-cer	branch	cross	part 2e
type name	type	+	+	+	+	+	+
subtype name	subtype	-	+	+	+	+	+
number	number	+	+	+	+	+	+
part index	index	+	+	+	+	+	+
pointer no 1	con1	+	+	+	+	+	+
pointer no 2	con2	+	+	+	+	+	+
pointer no 3	con3	-	-	-	+	+	-
pointer no 4	con4	-	-	-	-	+	-
diameter no 1	fi1	+	+	+	+	+	+
diameter no 2	fi2	-	-	+	+	+	-
diameter no 3	fi3	-	-	-	+	+	-
diameter no 4	fi4	-	-	-	-	+	-
pointer to hide	hide	+	+	+	+	+	+
angle	ang	-	+	-	+	-	-
length	len	+	-	-	-	-	-
marker	letter	-	-	-	-	-	-
additio-nal data	comment	+	+	+	+	+	+

In the process of the pipeline drawing 3 main operations are developed:
point   - determines the start/end point of a pipeline element;
join   - joins the new element of the pipeline to anexisting one;
continue - creates the sequence of pipeline elements.

Procedures have been developed for two basic ways of determination of a sequence of pipeline elements. The first way consists in selecting elements one after another together with giving an exact localization. The second way consists in giving two points which are to be connected with two pipes and one elbow. In this case the elbow angle has to be given. The task of a calculation pipe lengths and an exact localization of an elbow is performed automatically.

In the conversation the engineer uses terms such as: parallel to X axis, parallel to Y axis, parallel to Z axis. The direction may also be determined by giving coordinates of two points. Obviously, an optional localization of a pipe in 3D is available but then it is indispensable to give either both ending points or the increments of a pipe in 3 directions when one point is known. In case of elements which change the direction of the pipeline, i.e. elbows, branches (tees), crosses and bends the user determines the changes of direction in relation to the direction of the element proceeding it.

The more important assumptions made are as follows:
1) the user determines the diameter of the pipe either at the start point of the pipeline or when the reducer is inserted; in other cases the diameter of (a) connected element(s) is assumed;
2) the decision of inserting any marker belongs to the user but each branch, cross and pipeline end element have to have one marker; the marker consists of no more than two symbols (letter or letter+letter or letter+digit).
3) the length of the pipe equals the distance between the elements connected with this pipe; the length of the threads and the other parts of pipeline elements which go one into another are not represented in the system;
4) the set of elbows consists of a limited subset of typical elbows, i.e. 30^{o}, 45^{o}, 60^{o}, 90^{o};
5) the user can obtain the isometric presentation of any drawing by selecting among predefined isometric views.

The following commands are provided:
PIPE - creation of a sequence of pipeline elements;
DELPI - deletion of an indicated element;
ADDMARK - association of a marker to a pipeline element;
DELMARK - removal of a marker;
ADDHIDE - association of an invisible element;
DELHIDE - removal of an invisible element;
BILL - generating a bill of elements;
ALARM - finding of the pipeline crosses;

The scope of application of the ALARM command is limited to only checking the crosses of the pipes. The other types of pipeline elements are not taken into account in finding the crosses.

The user can perform all commands of the AutoCAD system together with special commands for pipeline drawing.

6. Pipeline drawings

Using the software for pipeline drawing an ordinary DWG file is created. The drawing consists of blocks and layers. Fragments of the pipeline system of one machine can be located on different layers. The set of these layers can be predefined and connected with the set of types of pipelines. For each type of a pipeline a subset of 4 layers is established. These layers contain:
-visible pipeline elements ("-pipeline");
-isometric lines supporting 3D presentation of the pipe directions ("-isoline");
-attributes with the data associated with each pipeline element ("-database");
-markers subordinated to the visible pipeline elements (" -marker")
In the drawing some additional layers are established as well, among others:
"isonet" - isometric net of lines;"invisible"- invisible pipeline elements;
"inter" - contains elements of 'inter' type
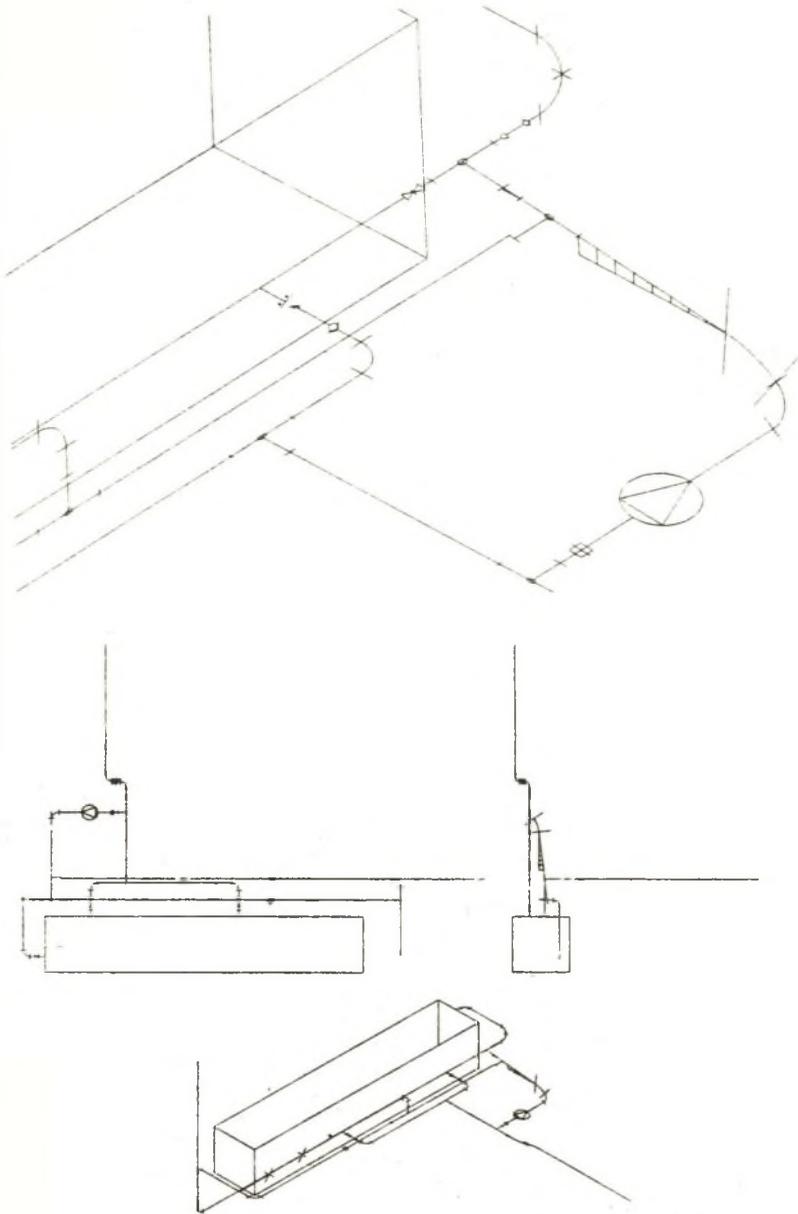Exemplary drawings of a pipeline system are given in Fig. 3.

Fig. 3. Exemplary drawings

7. Bill of elements

For the generation of bills of elements a special program in Turbo-Pascal and associated command BILL are developed. For the current drawing an AutoLisp function and the program make it possible to generate the following reports: (1) bill of elements in a form of a list emphasizing the division of a pipeline into fragments by means of the markers; (2) bill of elements for an indicated fragment of a pipeline; (3) the total bill of all the elements found in the drawing; (4) the total bill of all the elements found in an indicated fragment of a drawing.

8. Projects for the future

The system which is to be developed in the second stage should support the process of conceiving pipelines - not only making drawings. The system should in semiautomatic way form the connection of elements and than a significant speed up of the design process and an optimization of pipeline system can be obtained.

It is also necessary to use within the software a set of practical rules of designing pipeline. These rules will be combined with a mathematical description of the construction. The described software is a starting point for an expert system development for pipeline designing and drawing.

REFERENCES

[1] Bohle D., Jakobs G., Hänisch K., Kalbitz H.: Rechnerunterstützte Konstruktion von Chemieanlagen im 3D-Raum. Konstruktion 33, 1981, H.7, S.263-268

KONSTRUKTIONS MODELLIERUNG VON CHEMIEANLAGEN IM 3D - RAUM

Zusammenfassung

In der vorliegenden Arbeit wurde die Methode und die Software für die Bildung der geometrischen 3D - Modelle der Rohrleitungssysteme, die in den hölzernen Industrieanlagen austreten, vorgestellt. Das System behält, neben der räumlichen Struktur, auch alle unbedingten Daten, um die Elementenliste zu bilden. Wenn man mit dem Modell arbeitet, kann man die Zeichnungen für die beliebige Ansicht (vor allen die isometrische Zeichnung) anfertigen. Das System wurde in der Sprache Auto-Lisp und Pascal geschrieben. Die Software ist die Erweiterung des AutoCAD Systems.

MODELOWANIE SYSTEMÓW RUROCIĄGÓW W PRZESTRZENI TRÓJWYMIAROWEJ

Streszczenie

W pracy przedstawiono metodę oraz oprogramowanie do tworzenia trójwymiarowych (3D) geometrycznych modeli systemów rurociągów występujących np. w przemysłowych instalacjach chemicznych. W systemie pamiętane są, obok struktur przestrzennych, także wszystkie niezbędne dane do tworzenia wykazów elementów. Korzystając z modelu można automatycznie uzyskiwać rysunki dla dowolnego widoku, w szczególności rysunki izometryczne. System napisano w językach Auto-Lisp i Pascal. Oprogramowanie jest rozszerzeniem systemu AutoCAD.