Abstract: Assembled steel constructions use gusset plates for bonding profile angles into the structure. These structures are often developed into a Computer Aided Design (CAD) environment that is ready for a Product Data Management (PDM) approach.

The article showcases the required steps for transferring data from a CAD environment to a Computer Integrated Manufacturing (CIM) concept for gusset plates.

Key-Words: PDM, CIM for gusset plates

1 Introduction
Product Data Management (PDM) is focused on managing and tracking the creation, change and archive of all information related to a product. The information being stored and managed include engineering data such as computer-aided design (CAD) models, drawings and their associated documents.

Assembled steel structures include profile angles connected with gusset plates. The whole model can be easily developed using CAD drawing procedures but could be very productive if design accelerators are used.

Automatic detailing procedures rises the productivity level and data accuracy transfer level, offering an archive of all drawn parts that could be used as reference for the Quality Management System.

The use of NC (Numeric Controlled) Machines decreases the overall manufacturing duration and costs. NC-Machines are flexible and easy to program, but sometimes they are not fully integrated into a PDM chain.

Some full developed CAD systems from Tekla® and Trimble® [3], AVEVA-BOCAD® [5], [6] offers full integration and represents high-end software products available for manufacturing companies.

This paper shows how CAD/CAM can be introduced in a regular company that produces assembled steel towers for power transportation lines, using a software system that is affordable for many manufacturing companies.

Steel gusset plates are chosen to illustrate how a CAD concept can be transformed into a data flow that is the source for a complete PDM chain.

2 Problem Formulation
The design of gusset plates starts in a CAD environment. Here, a previously validated structure is transformed into an assembly drawing.

The design will lead to a 2D representation of each side of the steel construction. Linear angles with a precise profile are inserted using a draft structure that includes line clusters which model the sides of the steel construction.

The CAD environment is AutoCAD, well known for its drafting capabilities. It’s also an open system for third party applications that enrich the genuine modeling system. The author developed an AutoLISP [10][11]based system of programs that solves the problem of PDM integration form CAD towards CIM [1][9].

2.1 Design specifications

2.1.1 Topology of bolts
The designer develops the gusset plates into a precise knot, formed by several concurrent profile angles.

The topology of the knot restricts the directions of angles, following the geometric data imported from the Finite Element Method (FEM) calculation step. The angles (usually L shape profile with equal wings) connect with a gusset plate through bolts.

One assumes that the assembly holes are on exact position on two or more assembled parts.
The gusset plate will copy the similar patterns from several angles forming a complex part, subject to the PDM approach. The steel structures used for power transportation towers have some prescriptions for the use of bolts. Each bolt dimension becomes a precise image and is drawn as an AutoCAD block. The designer chooses the insertion point, depending on his skills and project restrictions. Each bolt (hole symbol) can be inserted as single unit, without superposing, even if there are holes drilled into a package of steel parts. Each steel plate or angle has a thickness corresponding to the profile or plate that is drawn. The data is stored into the drawing database as extended data that occurs automatically when an angle is inserted or it is asked as value when a new plate is developed. If the profile wings and plates overlap, one can compute the total height of the package in order to determine the required bolt length. Placing bolt symbols will generate a chart of holes which represent the assembly prescriptions for assembly knots. Bolt symbols are much more expressive than circles because, at this scale, differences between diameters are hard to observe. For each gusset plate it must be possible to obtain a chart of the symbols used as holes, according to a Plate Coordinate System.

2.1.2 Bending of gusset plates
Some knots have a 3D disposal and must appear in the construction plan in order to relieve the whole disposal of holes. In these conditions, the gusset plate should have a bending line that separates the two sides which are normally in two concurrent planes. The generated gusset plate stores the bending angle as extended data, in order to be used when the gusset will be redrawn as a separate part.

2.2 Automatic drafting of gusset plates
A specific need is to automatically obtain the representative reference drawing of the steel gusset plate. The author established a set of representation rules. They are the following:

- The gusset plate must have a precise origin of the own coordinate system;
- A preferential direction of the ox axe must be retained as orientation of the gusset;
- The gusset contour must scale to fit into the drawing area on an A4 standard format;
- All the holes will be retained identically as the source holes and must be numbered;
- A table with hole numbers, hole symbols, X and Y coordinates must be provided;
- The bend line must be represented associated with two bend marks as additional holes;
- An additional view for bend profile must be drawn with dimensions that uses the length and height of the bend as control dimensions;
- If the original gusset doesn’t have a mark it must offer the possibility to mark the gusset directly on the representative drawing.

2.3 CNC Specifications
In order to automatically obtain the programs for cutting and other fabrication procedures, such as punching or marking the steel plates, all specifications about programming the NC Machines were gathered and implemented into a suite of programs that transform the topology of gusset plates into a specific database. The information is obtained directly from the representative drawing of the gusset plate that was automatically released after the selection of a gusset plate from the model space.

This procedure offers a standard representation of the gusset plate, in the form of a checking document and as data source for the PDM chain. The automatic generating of standard part representation and the automatic generating of the NC Program forms a product data chain that will bring a gain in accuracy and rapidity of the whole PDM procedure.

2.4 Automatic generation of BOM
Bill of Materials is a function often used in PDM applications. A table containing information about the components, their material, dimensions and mass must be provided. Steel gusset plates will present into such a table the number of identical plates being automatically computed.

For such reasons, each gusset has a precise code generated automatically as index in the code database. The database is automatically maintained, using filtering features, raid view of coded parts, etc.

3 Problem Solution
The solution is integrated into a CAD Application named TowMaster that forms the core design tool implemented into a CIM concept in Romania developed for SC ELECTROMONTAJ SA. This
company has an integrated CAD/CAM/CAE system for design, manufacturing and construction for electric power lines [2]. The problem of gusset plates was solved as part of the overall effort in programming the PDM system.

3.1 Design facilities

3.1.1 Bolt symbols
The problem was solved using AutoCAD blocks, generated for each bolt size. A side database is used to access the bolt hole dimensions used in calculations and in automatic generation of CNC programs.

![Fig. 1 Bolt symbols used as blocks](image)

There are two distinct bolt specifications used for marking purposes as “M118” and for pointing two marks that can be used to scratch or paint the bending line of the gusset plate, “M115”. Additional similar marks can be added into the program on custom desire.

3.1.2 Grouping commands into a menu
For user friendly purposes, the program has a menu cluster to pick the commands.

![Fig. 2 Command Menu in AutoCAD](image)

3.1.3 Generation of a gusset plate
The main command is designed to generate gusset plates. The contour of the gusset can be used if it was previously drawn as a closed poly-line. A direction line can be used to indicate the own Ox direction. The origin is automatically computed using the gusset contour as the projection of the most left vertex.

If a contour poly-line is not available, the program can compute and draw a rectangle-shaped contour that gathers all the holes and respects the minimum distance from the contour.

![Fig. 3 Generation of a new gusset using a polyline or a computed contour](image)

A code is automatically provided and the thickness of the gusset is asked both being stored as extended data.

3.1.4 Bending gusset facility
A gusset can be “bended” inserting a bend line that will be automatically trimmed at the gusset edges and will store the extended data of the bending angle. Bending angles can be positive or negative, in order to indicate if the bend is upwards or downwards.

![Fig. 4 Bending a gusset plate](image)

3.1.5 Drafting the gusset plates
The gusset detail is different from the original. The data is concentrated in a table where all the holes from the expansion zone of the gusset’s contour are presented.

Generating the representative drawing is automated; the command dialogue asks to select the gusset contour and to indicate a point where the drawing must be inserted. A certain scale factor is computed.
in order to fit the gusset and these dimensions into the drawing area.

**Fig. 5 Generation of a representative gusset drawing**

The detail drawing contains the contour of the gusset, its holes and their order number, their representation origin, the bent profile with the bending control applications and the holes table.

Along with the normal holes, two auxiliary LL holes are calculated and introduced in the profile. These correspond to some hallmarks automatically introduced on the bending line. Certain machines have marking heads with punctures or paint that could also trace these marks, simplifying the line tracing of the bend line.

Along with this information, a code (red) and other data about the material used, „350 x 8 - 250 H2” (lengthXthickness – width quality) are also present. All this information is necessary in making the CNC perforation and gusset marking.

If the hallmark has been omitted during the designing session, it can be added at any time as a „M188“ hole. Another possibility is to use the MARKG command which places it in the drawing. Once the hallmark is applied, it will be taken into consideration when generating the CNC program.

**Fig. 6 Detail on the representative gusset drawing**

### 3.3 NC programming of gusset plates

The geometrical elements of the representative drawing of the gusset have been described previously. If the gusset’s mark is missing, the CNC will be generated without it, therefore incomplete. The hallmark can be completed into the execution drawing using the MARKG comand - through which the A4 format’s contour is selected and it’s position is set in the field marked by the plate’s contour. The processing table will be completed with a new line which marks the hallmark’s position. If the hallmark has been previously added in the pieces’s assembly field, it is not recognised even if it is inserted in the processing table. By marking with MARKG a hallmark can be added and the program will be generated.

Marking is, therefore, an operation which is linked with execution details and it needn’t be done in the assembly, except if we wish the mark will not be covered by the other holes.

File CNC: MASTER-9018.fnc

```cnc
[[MAT]]
[[PCS]]
[HEAD] C:RRR D:444 N:MASTER-9018
M:OL52 CP:P P:356X158X8
LP356 SA158 TA8
Q11 SCA101
[HOL] TS11 DC31.5 X301 Y45
TS11 DC19.5 X329 Y130
TS11 DC31.5 X79.5 Y51.5
TS11 DC19.5 X27 Y130
TS11 DC19.5 X212.5 Y130.5
[MARK] X105 Y118
```

Codes for different NC machine types can be added by the author. If is submitted information about the used language and few test parts with expalantions, it may be generated a postprocessor or an automatic translation program from Fenice-Mitrol language.
3.4 BOM and coding facility
When a gusset plate is generated, a code is automatically associated following the already given codes. The code has a prefix that shows the group, the assembly name, and a number as index.
When a gusset plate is copied, the code remains the same but the designer can modify the copied gusset as the design needs and must afterwards to give to the modified gusset a new code.
All codes database is automatically maintained avoiding coding mistakes.
When a Bill of Materials (BOM) is ready to be generated, the command dialogue will ask the designer to establish the repetition of each selected panel that conducts to the computing of identical parts. This action must be carefully mastered by the designer.
The results are presented into a table that contains the BOM information as follows:

<table>
<thead>
<tr>
<th>Tip/Type</th>
<th>COD/Code</th>
<th>Material</th>
<th>Calitate/Quality</th>
<th>Lungime/Length</th>
<th>Bucati/Units</th>
<th>Masa_tot/Whole mass</th>
<th>Aria_tot/Whole area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bara/Bar</td>
<td>MASTER-9023</td>
<td>L120x10</td>
<td>OL37</td>
<td>1212</td>
<td>5</td>
<td>110.297</td>
<td></td>
</tr>
<tr>
<td>Bara/Bar</td>
<td>MASTER-9024</td>
<td>L120x15</td>
<td>OL37</td>
<td>169</td>
<td>5</td>
<td>118.221</td>
<td></td>
</tr>
<tr>
<td>Bara/Bar</td>
<td>MASTER-9025</td>
<td>L200x16</td>
<td>OL37</td>
<td>889</td>
<td>5</td>
<td>118.221</td>
<td></td>
</tr>
<tr>
<td>Gluzie/Sheet</td>
<td>MASTER-9026</td>
<td>631x8</td>
<td>OL37</td>
<td>800</td>
<td>5</td>
<td>83.488</td>
<td>9.448</td>
</tr>
<tr>
<td>Total</td>
<td>mass</td>
<td>profile</td>
<td>406.942</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8 BOM Table detail
The BOM information can be exported into a .csv file as neutral database format that can be easily read in MSExcel or in MSAccess.

4 Conclusion
Product Data Management for steel gusset plates forms a translation chain for geometrical topological information into a digital database, stores and retrieves directly from drawing database information about the used material and his thickness and provides traceable trusty information for the whole costs calculation effort.
Generation of cost sheets and material supply provisional can be easily made from the BOM that the program delivers.
Automated programming saves costs and assures the integral accuracy of the digital content.
The CIM concept was tailored on the manufacturer’s specifications and was successfully implemented and tested.
The use of AutoCAD or related DWG based CAD Products shows an interesting direction in order to decrease the operational costs and to use standard CAD skills for an impressive productivity growth.
Future research directions are towards a full PDM integration using a module for NC Cutting features for oxy-cut or plasma-cut machines, combined with a 2D nesting program.

References: