

EXCEL IMPLEMENTATION OF SCHAEFFLER AND DELONG DIAGRAMS

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Abstract: This paper presents the Schaeffler and Delong diagrams implemented into spreadsheet software (ex. Excel) and how to use them. The diagrams have the advantage that they are automates, resulting the graphic representation in real time, depending on the input dates. Also, the diagrams keep in mind that chemical compositions of the base and weld metals shows tolerances for percentages of alloying elements, for example: %Cr=14-16%; %C=0.05-0.08% etc. In this case, on the diagrams for the areas represented by the chemical composition of base and weld metals and welded seam are not longer points, but areas (rectangles) close more and eloquent against reality. Thus, by their sizes and positions, these rectangles provides data not only on the probable structure, but on possible changes of the structure if encroach more areas, due to tolerances in the chemical composition of weld and base metals, respectively base metals participation coefficient to the welded seam.

1. PAPER OBJECT

The paper object is presentation of the Schaeffler and Delong diagrams implemented into spreadsheet software (Excel) considering all theoretical hypotheses. It was practically made the two automated diagrams and by introducing the input dates (chemical composition of base and weld metals and welding process that gives us the dilution) are calculated and automated plotting, through rectangles, the chromium equivalent (minim and maxim) and nickel equivalent (minim and maxim) representing the base metals structures, respectively is plotting the possible welded seam structure.

2. THEORETICAL BACKGROUNG ABOUT SCHAEFFLER AND DELONG DIAGRAMS

Depending on the effect of alloying elements for steel, they can be divided into:

- austenitic or gamma elements which increase austenitic field: nickel, carbon, manganese, copper, nitrogen;
- ferritic or alpha elements, which decrease the field of austenitic and increasing ferritic field: chromium, molybdenum, silicon, aluminium, tungsten, titanium, niobium, vanadium.

With Schaeffler diagram is possible to determine the chemical composition and structure of welded seam.

An appreciation of alloy steel structures after rapid cooling from temperatures of approx. 900°C may be made with Schaeffler diagram (Anghel, 1995), shown in figure 1.

Action alloying elements on the structure is determined by Cr_{ech} and Ni_{ech} sizes.

Chromium equivalent is the amount of chromium content and the content of other alpha elements (in some factors) representing their influence comparable to that of chromium.

$$Cr_{ech} = \%C + \%Mo + 1,5 \cdot Si + 0,5 \cdot Nb \quad (1)$$

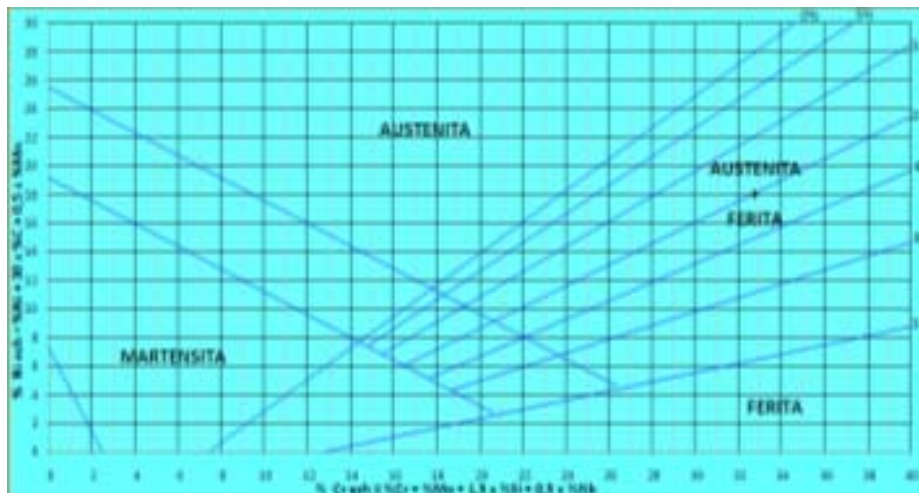


Figure 1 Schaeffler diagram

Nickel equivalent is the amount of nickel content and the content of other gamma elements (in some factors) representing their influence comparable to that of nickel.

$$Ni_{ech} = \%Ni + 30 \cdot \%C + 30 \cdot \%N + 0,5 \cdot Mn \quad (2)$$

In these relations, the contents of considered alloying elements are given in percents.

The theoretical calculations involved the dilution of the materials, which largely depends on the used welding process.

Dilution is the proportion of the base metals with participates by melting to form the molten welded seam. Using figure 2 dilution can be expressed as:

$$d\% = \frac{S_A + S_B}{S_A + S_B + S_{MA}} \cdot 100\% \quad (3)$$

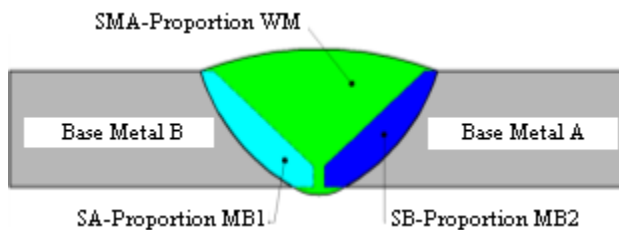


Figure 2 Welding dilution

To the limits, if $S_A + S_B = 0$, that is base metals are not melted, we have $d = 0\%$. It is the case of brazing and weld-brazing, processes in which the weld metal melts at a temperature below the melting temperature of the base metals. At the other limit, $S_{MA} = 0$, that is weld metal is not used, we have $d = 100\%$ maximum dilution. It is the case of welding process in which not use the weld metal.

For current welding processes such dilution ranges:

Table 1 Dilution for different welding processes

Welding process	Dilution
Weld-brazing	0 %
WIG (TIG) welding	15 – 30 %
Welding with coated electrodes	25 – 45 %
MIG / MAG welding	60 %
Fluxshielded arc welding	20 – 40 %
Welding without filler metal	100 %

In the Schaeffler diagram are marked in the common areas in which are placed the main types of stainless steel (Anghel, 1995):

- resistant stainless steel or austenitic (A)
- ferritic stainless steel (F)
- martensitic stainless steel (M)
- duplex stainless steel (F +, M + F, A + M, etc.).

In addition to assessing the approximate crystalline structure of high-alloy steel welds knowing its chemical composition, Schaeffler diagram allows a simplified and suggestive main specific problems which issues at welding of alloy steels. These problems, which can occur, are:

- embrittlement due to hydrogen, cold cracking;
- hot cracking;
- significant increase of grain
- embrittlement by forming σ phase.

Working mode with Schaeffler diagram (figure 3):

1. we calculate the Cr_{ech} and Ni_{ech} for base and weld metals and plotting these points on the diagrams, respectively points A and B for base metals and point E for weld metal;
2. on the segment AB we plot the point D, starting from point B, depending on the participation of the two metals to forming the welding seam;
3. on the segment EC we plot the point C, starting from point E, which represent the welding seam structure, also depending on the participation of weld metals to the welding seam.

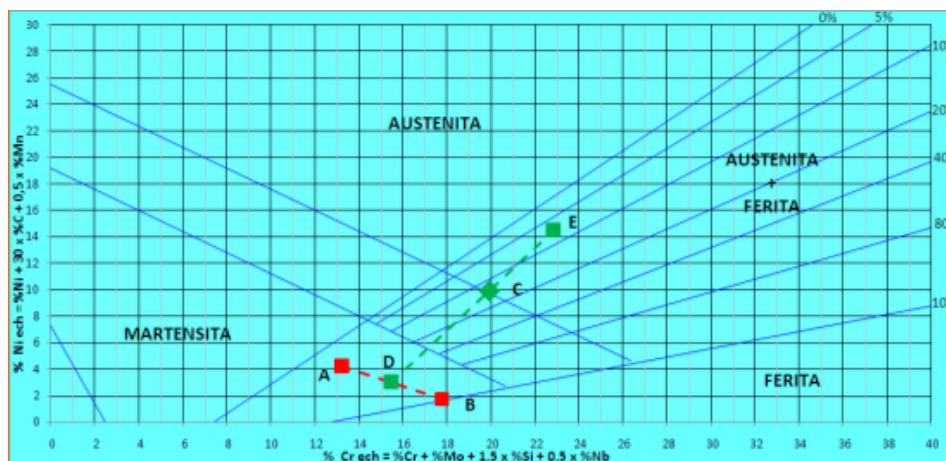


Figure 3 Working mode with Schaeffler diagram

In case of fluxshielded arc welding, the chemical composition of welded on metal is influenced by the addition of welding wire and flux activity.

To avoid any problems that may appear to welding, the welded seam structure should be in the ideal area (austenitic area with 5 to 10% ferrite and a $Cr_{ech} < 25$).

The Schaeffler diagram can appreciate and ferrite content in cases where welded seam is on the diagram in the austenitic-ferritic area. In case from figure 3, point C corresponds to an austenitic-ferritic area about 12-14% ferrite.

For a more precise calculation of the ferrite content was made another diagram, which linked the chemical composition and ferrite content, respectively DeLong diagram, first published in 1956 (figure 4) (Candea, 1998).

It recognizes the importance of the element nitrogen, as a strong austenitic element and added this item to Ni equivalent, with a multiplier of 30. Because of lower division and a larger scale, this diagram improved calculation accuracy for a range of ferrite stainless steel.

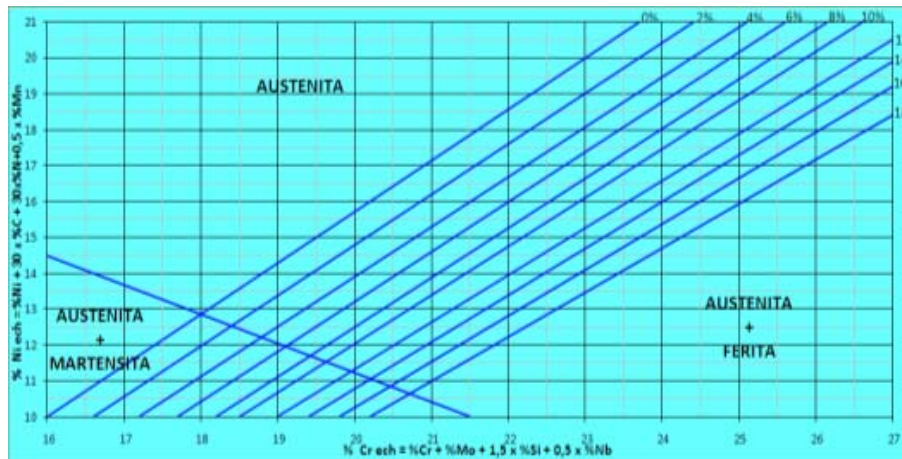


Figure 4 DeLong Diagram

The working mode is identical with the shown to the Schaeffler diagram (figure 5).

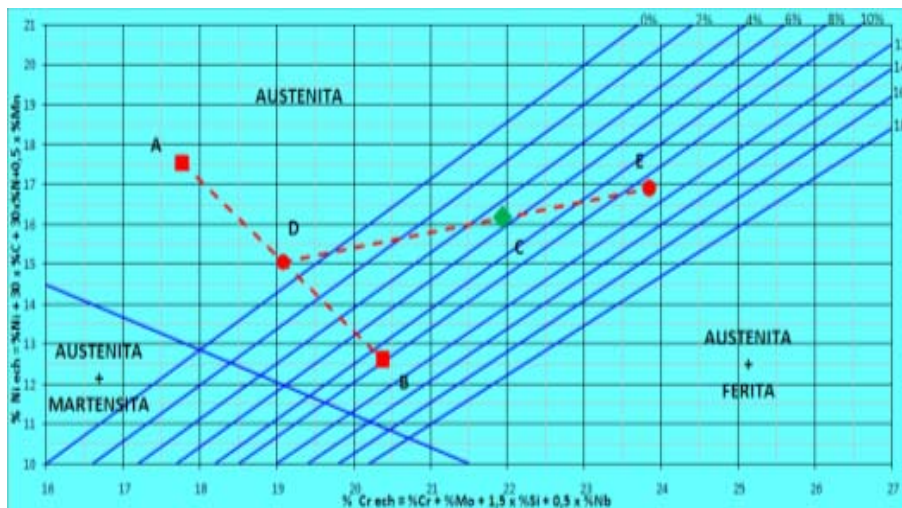


Figure 5 Working mode with DeLong diagram

IMPORTANT NOTICE:

If working mode above mentioned is used with DeLong and Schaeffler diagrams, is obtained on these **a point** for welded seam, which is not according with reality.

In fact, base and weld metals, for chemical compositions shows tolerance for percentages of alloying elements, ex. Cr = 14-16%, C = 0.05-0.08%, etc. (Candea, 1998).

In this case, on the diagrams for the areas represented by the chemical composition of base and weld metal and welded seam **are not longer points, but areas** (rectangles).

It is more precisely to determine for each one the **Crech** and **Niech minimum** respectively **Crech** and **Niech maximum** and represent on the diagrams of these areas in the form of rectangles.

Thus, by their sizes and positions, these rectangles provides data not only on the probable structure, but **on possible changes of the structure if encroach more areas**, due to tolerances in the chemical composition of weld and base metals, respectively base metal participation coefficient to the welded seam (Candea, 1998).

Otherwise, this aspect is introduced as new in design software, to other programs designed until now.

3. IMPLEMENTATION OF THE DIAGRAMS INTO SPREADSHEET SOFTWARE (EXCEL)

The practical implementation of the diagrams involved exact knowledge of lines positions in these diagrams and their graphic representation as such.

Practical implementation can be done using the representation through by points for areas of base and weld metals and welded seam (Patrick), as well as using representation through by regions (rectangles) for them.

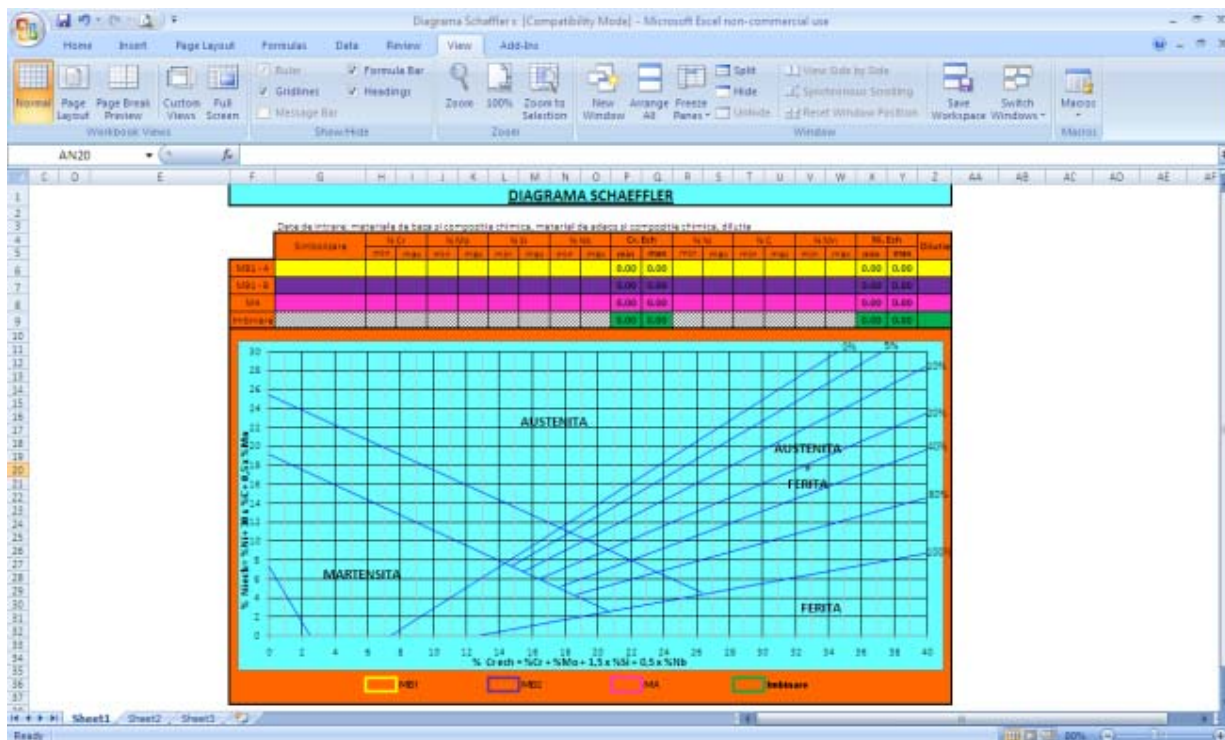


Figure 6 Practical implementation of the Schaeffler diagram

It is considered that the second method is more accurate, as such has been implemented in practice, but on the diagrams is presented graphically through by points the average of chemical compositions, both base and addition materials and welded seam.

In the table from the top of page will bring the chemical composition of metals A and B (base metals) (for which automatically calculates the minimum and maximum Cr_{ech} and Ni_{ech}) respectively their dilution.

It also introduces the chemical composition of weld metal and automatically calculates Cr_{ech} and Ni_{ech} minimum and maximum, respectively the rate at which participate to forming the welded seam, depending on dilutions of the two base metals, so the proportions of three to be 100%.

Entering and modifying of input dates involves real-time modification of graphical representation.

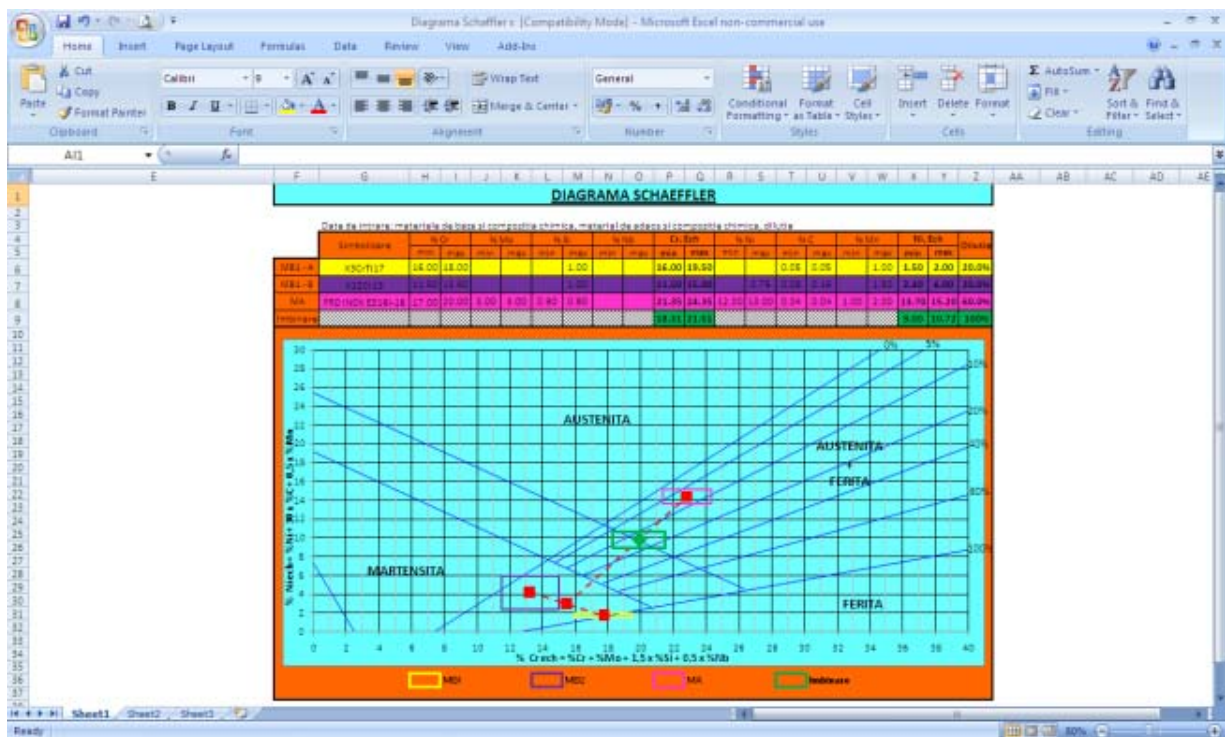


Figure 7 Using the Schaeffler diagram

Similarly, was made practically the DeLong diagram, working mode being identical to that described above to the Schaeffler diagram.

Verification of diagrams implementation was done by experiments, by combining several situations that may arise in practice, the point representing the welded seam structure must being in the area marked with green on the diagram.

For the cases represented on the figure 10 has increased the area of interest for easier observation.

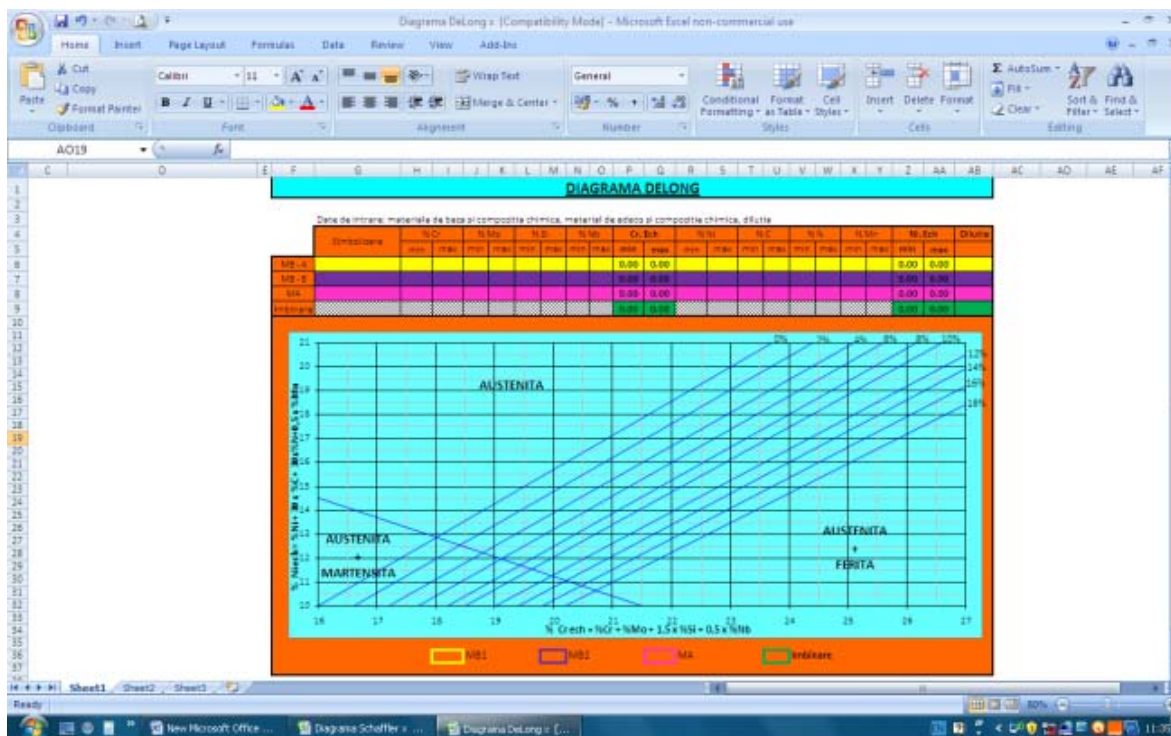


Figure 8 Practical implementation of the DeLong diagram

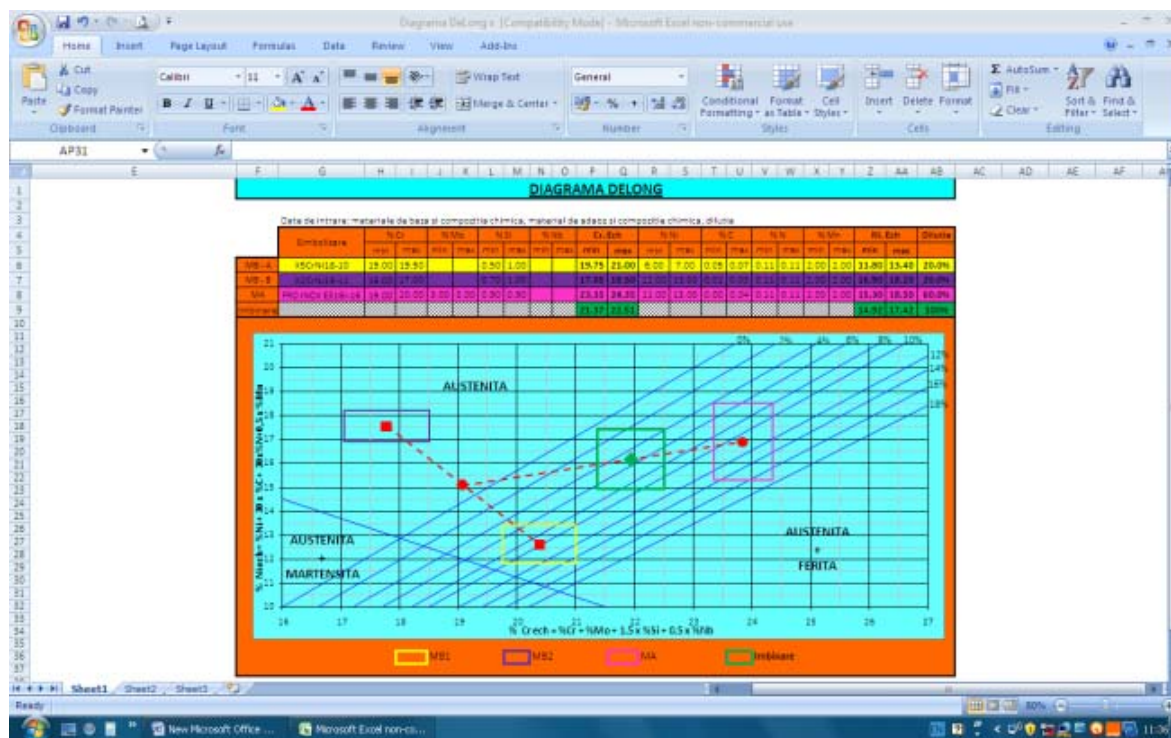


Figure 9 Using the DeLong diagram

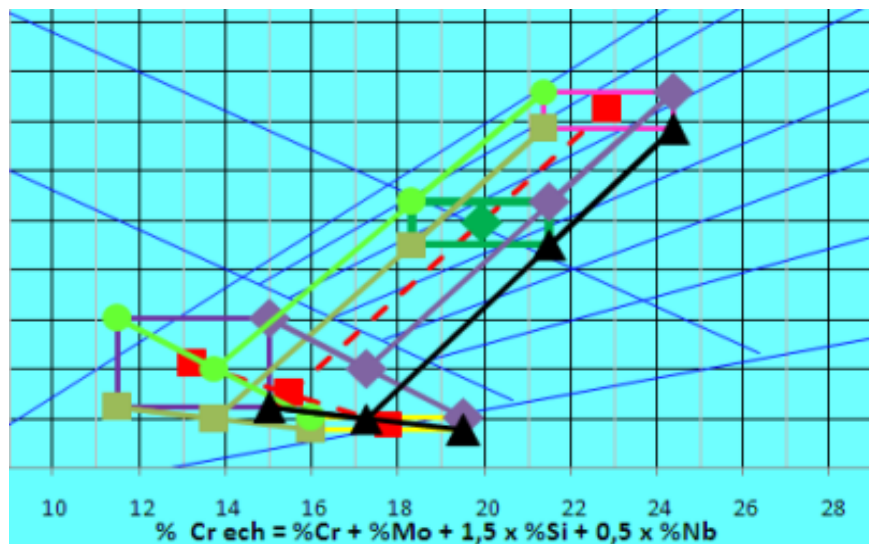


Figure 10 Schaeffler diagram implementation verification

We can observe that for all studied cases (5 in total) the welded seam structure is always falls within the area represented by a green rectangle, what verification the diagram implementation. Similarly, you can check the DeLong diagram implementation. For details about how to make and use these diagrams, please send an email to costy.ceorapin@gmail.com.

4. CONCLUSIONS

By implementing the Schaeffler and DeLong diagrams into a spreadsheet software is achieved an automatically and in real time representation of welded seam structure as an area (not a point) which gives information on welded seam structure after welding and, if is the case, about the content of ferrite.

The diagrams can be used successfully to choosing the weld metals for alloy steels welding and due to graphic representation as an areas and not as points we can appreciate the welded seam structure and if encroach more areas on the diagrams. We can obtain in this case weld with good characteristics.

5. FUTURE DEVELOPMENTS

To ease the working mode with these diagrams will be achieved and give a data base with base metals that are suitable for using these diagrams and a database of weld metals produced in present.

This would mean that the input dates be done automatically by selecting the base metal and weld metal from the databases created.

Also, these databases can then be completed with new metals (base and weld metals) which will probably produce in the future.

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