NEW GENERATION CONTACT SHOES INFLUENCE ON THE PROCESS

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1. INTRODUCTION

Our study is focused on the sub-assembly contact shoes, pressure rings and pressure bellows. We were keen to mainly study

1. The contact shoe design
2. The most efficient pressure to ensure an optimal electrical contact between the contact pad itself and the casing
3. The contact shoe cooling circuit in view to provide to the shoe the best mechanical and electrical characteristics in order to bring to the users of COFOR® components a new standard in process setting technical solutions.

A finite elements simulation, combined with a thermal and structural studies were used.

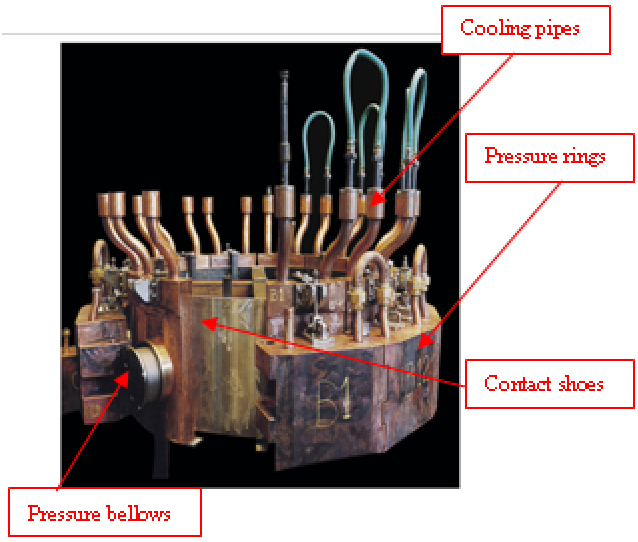


Figure 1: Electrode sub-assembly

Our presentation which follows is dedicated exclusively on the influence of the contact shoe cooling system on the process through a thermal and structural analysis.

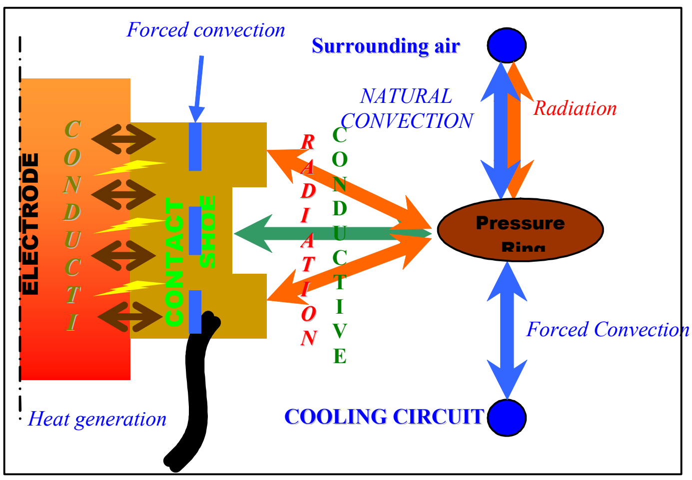
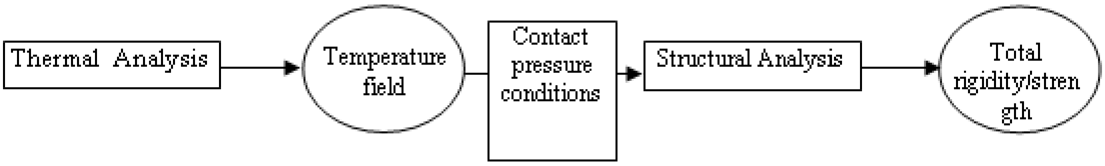


Figure 2: Temperature exchange diagram

The overall rigidity of the new design contact shoe is based on the combination of thermal strength and structural strength mutual influences.



2. STUDY

Study was performed by comparison among major existing system made of plain copper contact shoe with a U shape cooling line, such as the one as per figure 3 , and various shapes such as the one as per figure 4.

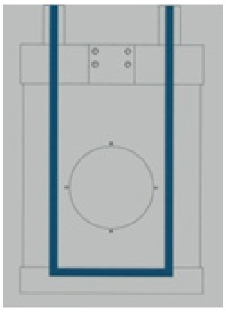


Figure 3: U shape cooling circuit

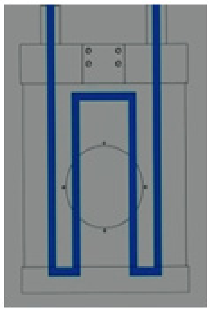


Figure 4: other shape cooling circuit

2.1 Thermal Analysis in the Contact Shoes

The contact shoe transfers its own heating flux through its closed environment, such as the electrode casing, its own cooling circuit and the components in contact with it (pressure ring, pressure bellows, bus bars).

The hereunder temperatures profiles have been derived experimentally using a finite elements method by means of thermal scan software (SOLID WORKS, thermal module and ANSYS. These software are well known and very much used by worldwide firms for their temperature phenomena's experimentation)

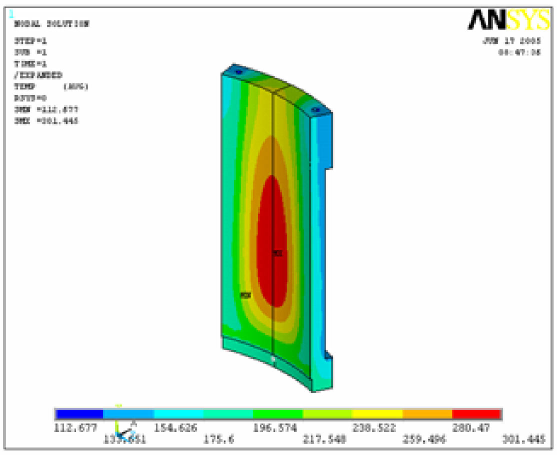


Figure 5 : Temperature distribution with U shape cooling circuit

Blue ⇨ 112.7 °C
Yellow ⇨ 238.5 °C
Red ⇨ 301.5 °C

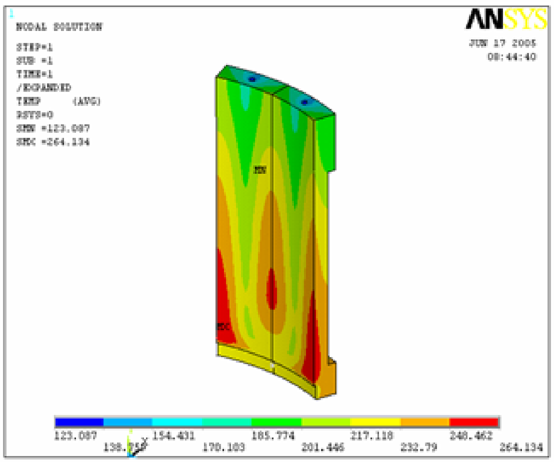


Figure 6 : Temperature distribution with W shape cooling circuit

Green ⇨ 185.8 °C
Yellow ⇨ 217.1 °C
Red ⇨ 264.1 °C

1. On traditional contact shoes using U shape cooling line, we note a hot area (301.5 °C) in the center of the contact shoe (figure 5)
2. With various circuits layouts, we noticed different thermal heterogeneity in temperature (eg figure 6)

This confirms the observations with the current traditional furnace design, saying that the plate centre is the hottest area (approximately 280°C in stabilised operation) due to a lack of cooling. Unfortunately, it is exactly where the pressure is applied (Remind : the first copper temperature granular distortion : 140°C).

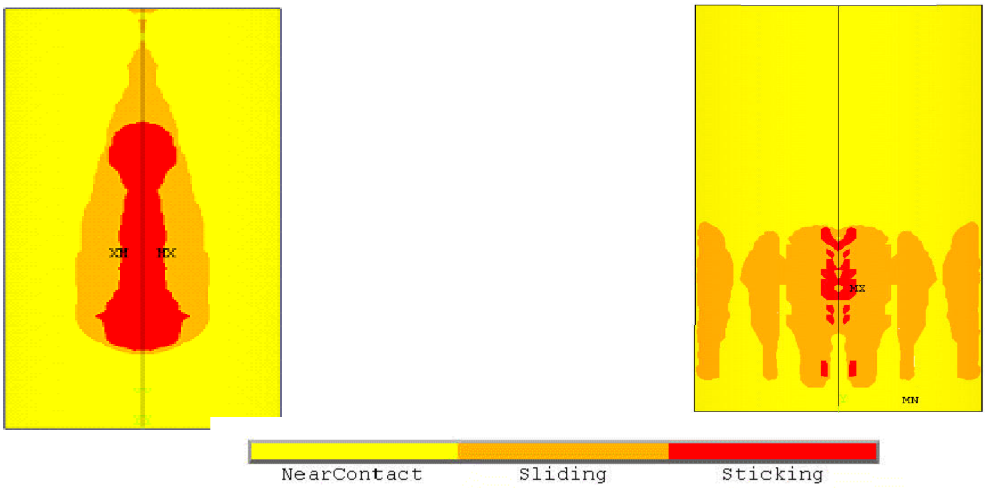


Figure 7: One U shape cooling line
Location at the middle of the shoe depth
Under pressure from the pressure bellow : 25 bars

Figure 8: 5 cooling lines evenly shared
Location at the middle of the shoe depth
Under pressure from the pressure bellow : 25 bars

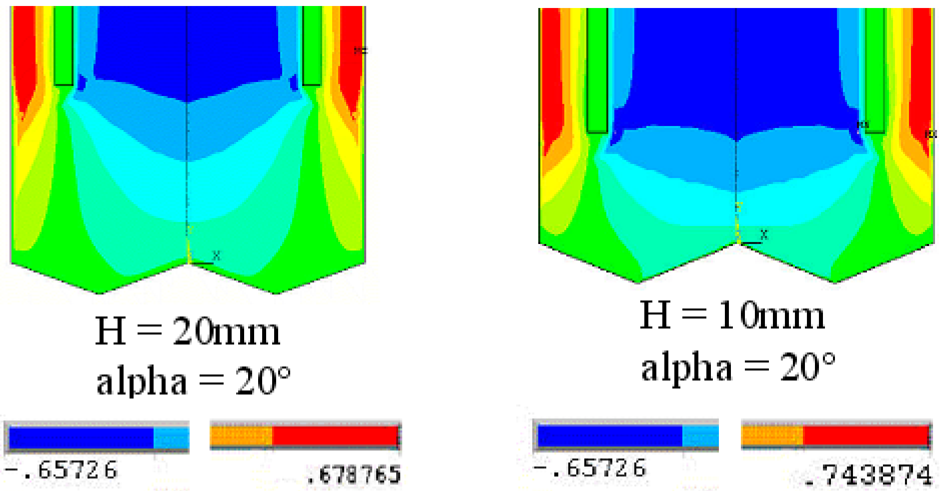
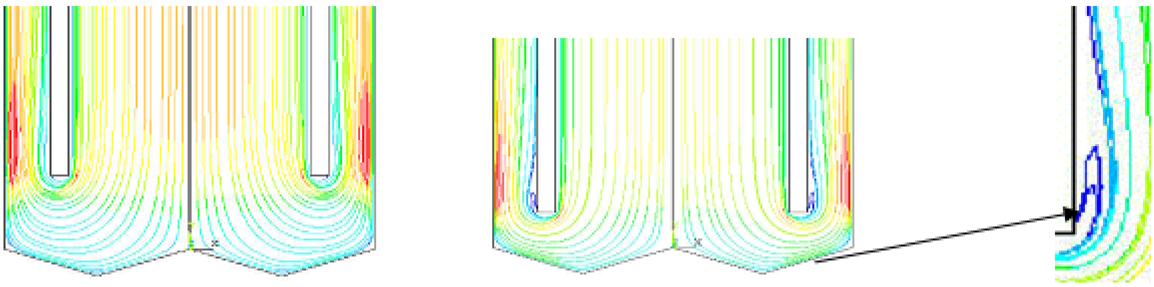


Figure 9: Influence of the Height



H = 10 mm – α = 20°

NB : for small H (< 5 mm, occurs a re-circulation)

Figure 10: Influence of the Height

We conclude therefore that :

– whatever the used layout we record a temperature distribution of 112.7 °C to 301.5 °C as per our thermal scan program.
– we claim through the simulation that : “the calories are mainly evacuated by the water cooling circuit”

2.2 *Structural Analysis*

After the structural analysis simulation, the evolution of the contact area between the contact shoe and the casing, simultaneously with the elevation of the temperature in the contact shoe, leads to a contact shoe distortion in different directions. Therefore :

– we note a contact area shrinkage after several hours only.
– All what has been previously written has a direct influence on the electrical energy consumption.

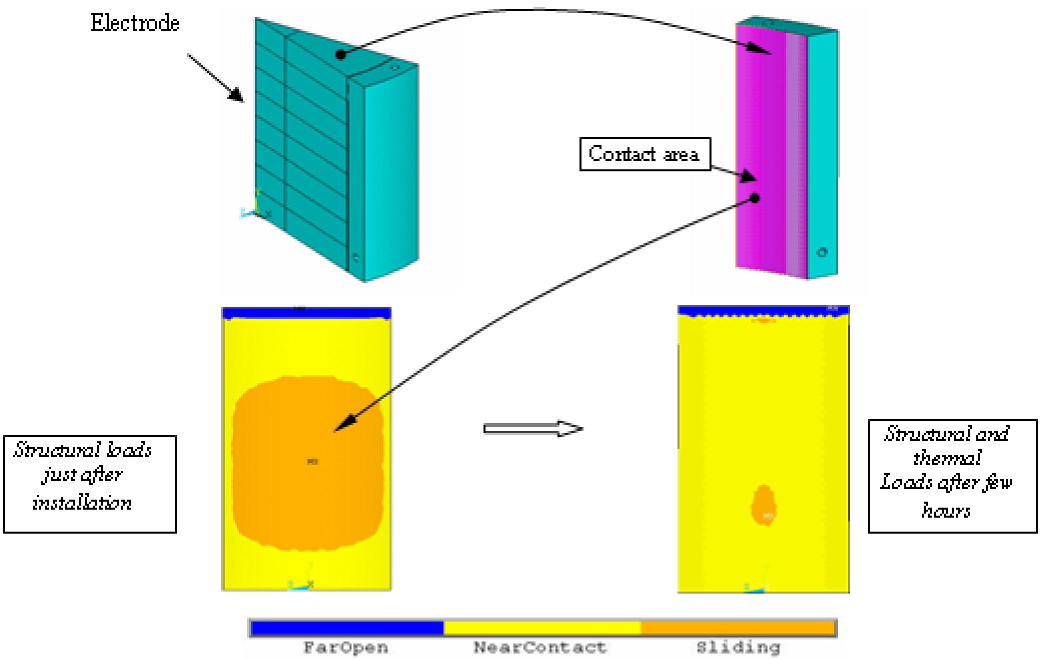


Figure 11: Contact area

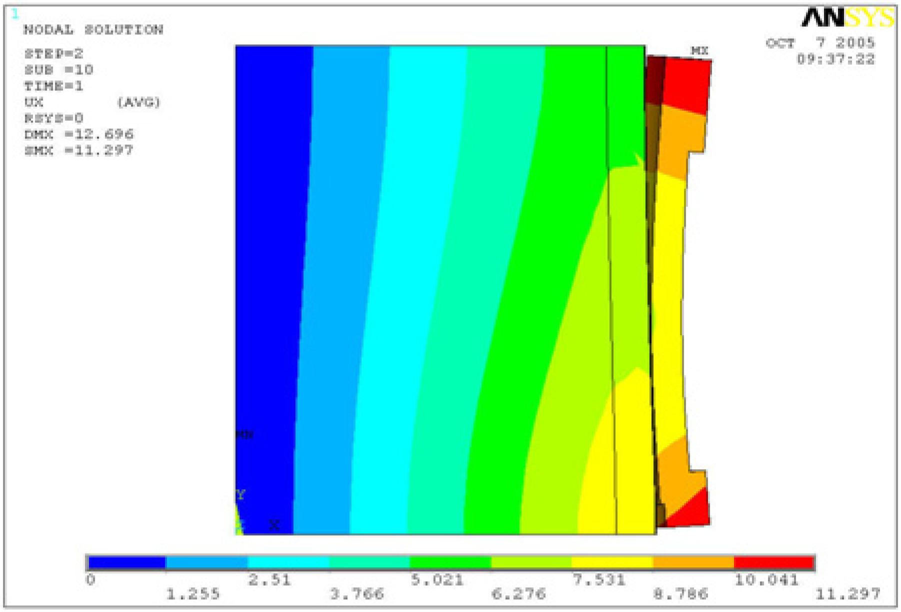


Figure 12: Radial distortion area (amplified scale)

2.3 Conclusion of the Study

Our study demonstrates that the weak point of the existing systems is the contact shoe bending deformation, and consequently the bad current transmission from the contact shoes surface to the electrode surface.

The result of this preliminary study showed us the necessity to avoid such deformation in working at two levels:

- to get a more uniform temperature distribution introducing a new cooling circuit design
- to reinforce the contact shoe sections at critical areas, what will also create further benefits for the life span of the product

3. INTRODUCTION OF THE COFOR® CONTACT SHOE WITHOUT WELDING

Our study, as discussed above, has definitely oriented our research for new contact plate design towards a multi-channel cooling circuit.

After having simulated several possibilities, our final choice was for the following design as per Figure 13.

3.1 Benefits Comming from the Multi-channel Cooling Circuit

3.1.1 Location and geographical sharing of this new cooling circuit

- Tested by simulation in comparison with the traditional design
- Displays an outstanding temperature distribution homogeneity in the plate as showed as per Figure 14.

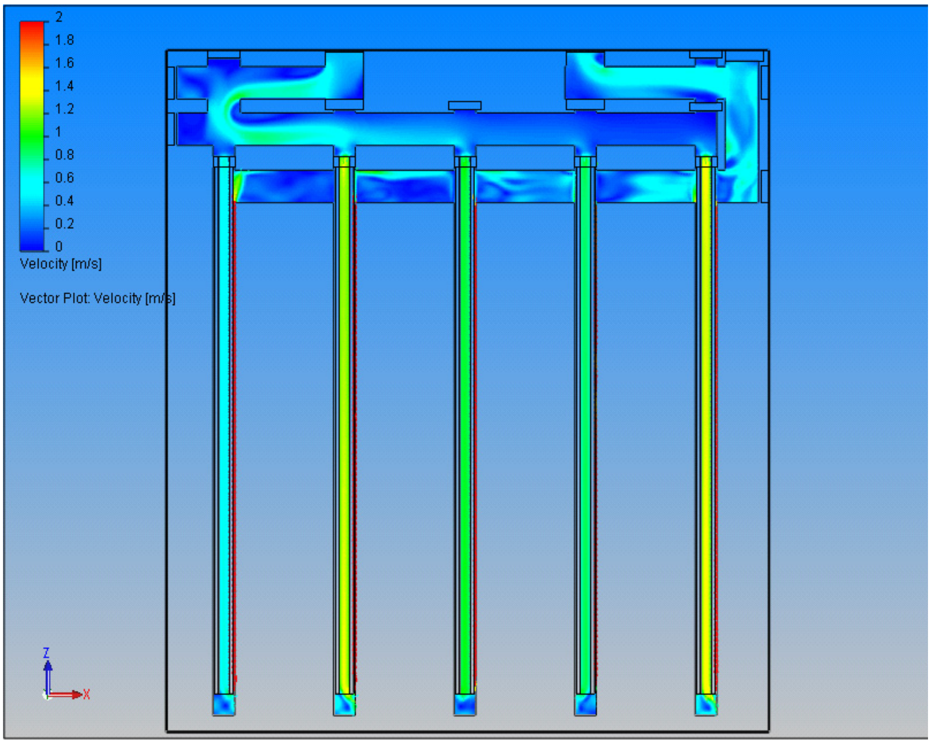


Figure 13: Multi channel cooling circuit

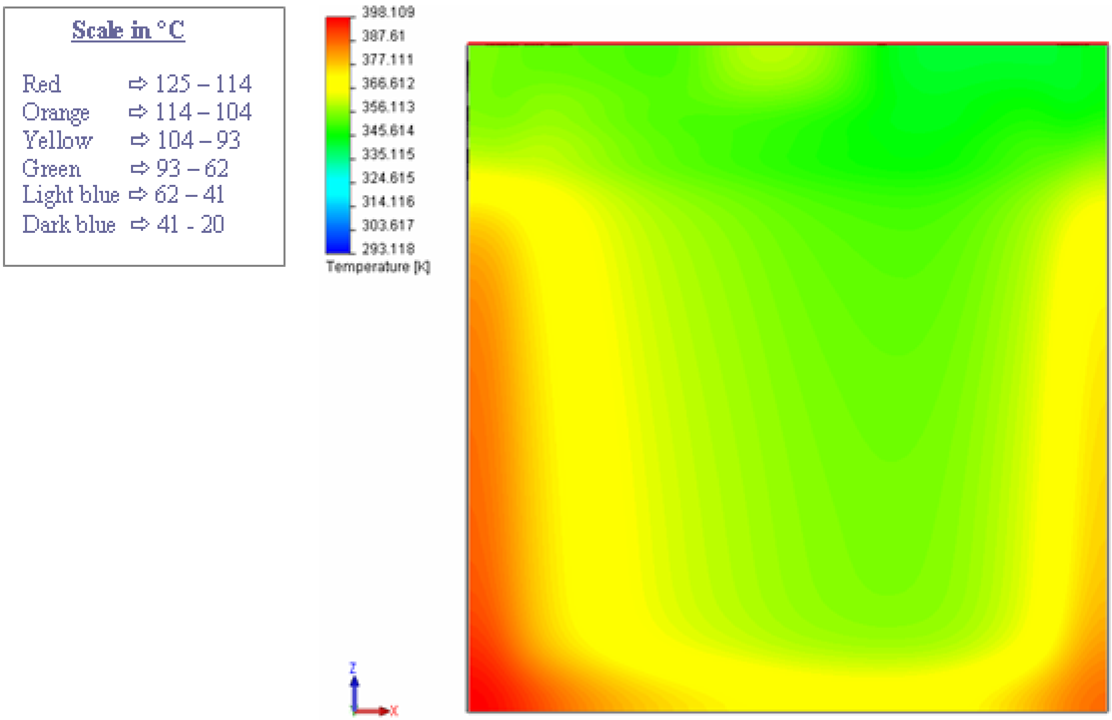


Figure 14: Multi channels cooling circuit - Temperature distribution

- Suppress the hot points, then the local material resistance increases, then it favours the current circulation from the
- plate to the casing.

In presence of an heterogeneous temperature distribution we check an heterogeneous current circulation from the plate to the casing, **following conduction lines harmful to an homogeneous electrode baking**.

- Allow for less plate distortion due to the inherent rigidity of the patented COFOR® based on the patented high strength COMETVA forging process
- Decrease the electrical resistance, providing then a better energy utilisation. The simulation with the COFOR® contacts shoes showed a substantial reduction in the amount of Joule losses.
- Gives the possibility to adjust the water flow to :
  - either increase the plate temperature in the hypothesis where the baking area is located at a too low level on the copper plate, to bring the baking zone to a higher level as necessary or as required ;
  - or decrease the plate temperature in the reverse hypothesis to bring down the baking zone as required.

This new approach allows our COFOR® clients to "manage" the water temperature to such a degree that the effect of a "heat sink" on to the electrode can be managed to reduce electrode breaks due to thermal chock, especially shortly after maintenance period. This application may also well be managed between winter and summer.

On the basis of the above listed advantages, we are convinced to offer to our clients a major improvement on this important component, to the benefit of the process in itself as well as to the cost savings in energy.

3.1.2 Suppression of the welded plugs at the bottom part

Copper is well known and recommended for its excellent thermal and electrical conductivity.

These major benefits are turned in drawbacks as soon as you want to weld plugs.

We need to heat the entire piece, then :

- very tough working conditions
- deposit of a copper oxide layer inside the cooling circuit which creates a natural thermal barrier
- that is traditionally the weakest area of the contact shoes due to the differential expansion coefficient between the contact shoe itself, the plug and the welding which provokes cracks and then water leakage.

Our new contact shoes without welding are endowed with very clean, bright and polished cooling circuits which improves drastically the calories absorption and then allows reducing considerably the water circulation quantity.

Furthermore, this COFOR® design makes use of an ultra strong copper material patented by COMETVA SA with a 320 MPA yield stress. This outstanding characteristic provides a better geometrical layout and subsequent resistance to deformation of our COFOR® contact shoe. That allows us to work on the optimisation of the pressure to be applied on the contact plate to favour the current circulation on the one hand and to limit a casing deformation on the other hand.

These two parameters have a major influence on the electrode slipping and then on the electrode breakage risk which is linked to the baking isotherm location heights between the contact shoes and to the heterogeneity of the baked electrode (local pockets of gas).

All these benefits provide to the customer :

- a more accurate control and management of the baking
- less Joule losses
- less water circulation
- an improved reliability of the casing and contact shoe interface

3.1.3 Less water utilised

- More efficient cooling with less water flow losses in comparison with traditional cooling circuits.

We need usually 5 to 7 m^3 / h water flow with the traditional U shape cooling line.

With the COFOR® contact shoe we need approximately 3 m^3 / h for the same power of furnace, that means 50% water circulation savings.

3.2 – Contact Shoe Design

We worked on the design of this brand new contact shoe, not only at the cooling circuit and water flow level but also at the level of its overall design with the following goals :

- to decrease drastically any distortion
- to give adequate masses in order to be compatible with the functional temperature request, this later being a combination of the process temperature need and the Joule effect coming from the current flow.

We focused specifically our design study on the bottom end which is critical as far as the pressure sharing and reliability are concerned.

Different ways were investigated such as the one as per figure 15.

For instance, our design allows delaying considerably the cooling circuit damaging when blows occur.

We may even improve this outstanding feature in applying our CERMET® coating at the bottom end (Figure 16).

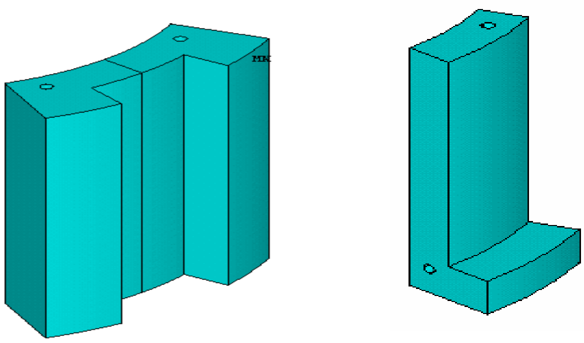


Figure 15: Contact shoes design

Contact Shoe with CERMET Coating

Figure 16

3.3 Conclusion

To summarise your benefit in choosing the COFOR® contact shoes without welding :

- Cost saving in energy
- Furnace yield in the neighbourhood of 99,8 %, linked to the contact shoes
- 100% availability of your furnace, linked to the contact shoes

– Money saving in buying less spares
– Reduced water circulation
– Baking zone management due to the possibility to have control of water temperature through the contact shoes
– Reduction of electrode breaks after maintenance intervals.

4. ADDENDUM

Apart from our current core business focused on designing and producing high quality patented pure forged copper contact shoes and pressure rings, we assigned to COMETVA SA the following mission :

– To be involved in the design of the complete circuit from the transformer output until the electrode, in order to offer to our clients innovative and cost effective solutions for any single component in this loop.
– To study the most adapted materials, taking into account the thermal constraints and the required electrical conductivity.
– To reduce the resistance of every electrical interface in this loop.
– To study and offer to our clients low temperature metals, already tested, which are excellent conductors and which allow to reduce the electrical loop length.