Dimensional Consistency of Powder Components

by Olle Thornblad
Höganäs AB, Sweden

Keywords

- Dimensional tolerance
- Iron-Copper-Carbon
- Distaloy

Abstract

The dimensional tolerance is a very important factor for manufacturing of powder components. It is essential to consider this point already as the first step of the calculation/quotation process. By choosing a composition of the mix that is designed to be the least sensitive to segregation in handling of the powder as well as variations in pressing and sintering, a lot of worry can be avoided at the end of the process. Also small modifications of the production line give large effects on the stability of the end product and important cost savings.

Introduction

In modern powder metallurgy the demands for closer tolerances and lower cost are normal. By the use of systematic computer software and statistical evaluations it is possible to predict achievable tolerances in the production of a component. This paper is presenting an evaluation in the iron-copper-carbon system. Concentrating on the compositions in the MPIF Standard 35, FC-0205-40 (Fe-1.5-3.9% Cu, 0.3-0.6% C) and FC-0208-50 (Fe- 1.5-3.9% Cu, 0.6-0.9% C) that represents a fairly narrow sector of materials used in Powder Metallurgy. Nevertheless, they represent a large volume of the world's usage of PM components and many new components in these classes of material are still developed and introduced to the end users.

The aim of the presentation is to show by what means it is possible to reduce the variations in size and simultaneously reduce the cost of the powder mix. Unfortunately, this is only possible when designing a tool for a new component or when a new tool has to be produced for an existing component, as the dimensional change during sintering will be affected.
Two production cases are presented, showing that it is possible to reduce the size variations from 200 microns down to 35 microns for a 50 mm component only by changing the composition of copper and carbon in the powder mix and by using a copper, diffusion bonded to the iron powder.

Execution

The basic works were carried out using the Design of Experiments-technique in order to reduce the amount of tests to a manageable number. The test program covered the range of iron-copper-carbon between 1.5-3.9% of copper content and 0.3-0.9% of combined carbon content. AHC100.29 was used as base powder. All the values presented in the graphs are analysed or measured after sintering. The dimensional change is between the green and the as-sintered size.

In Fig. 1, the effect of the copper and carbon content on the dimensional change (DC in %) during sintering is shown as well as the influence on the mechanical properties after sintering. It is evident that by reducing the copper (Cu) content and increasing the combined carbon (C-C) content the area of permissible variations in chemical analysis is increasing in the graph presenting the dimensional change (DC). The tensile strength (Rm in MPa), yield strength ($Rp_{0.2}$ in MPa) and hardness measured as HV10 (HV) is affected in an almost proportional way by the Cu-C ratio.

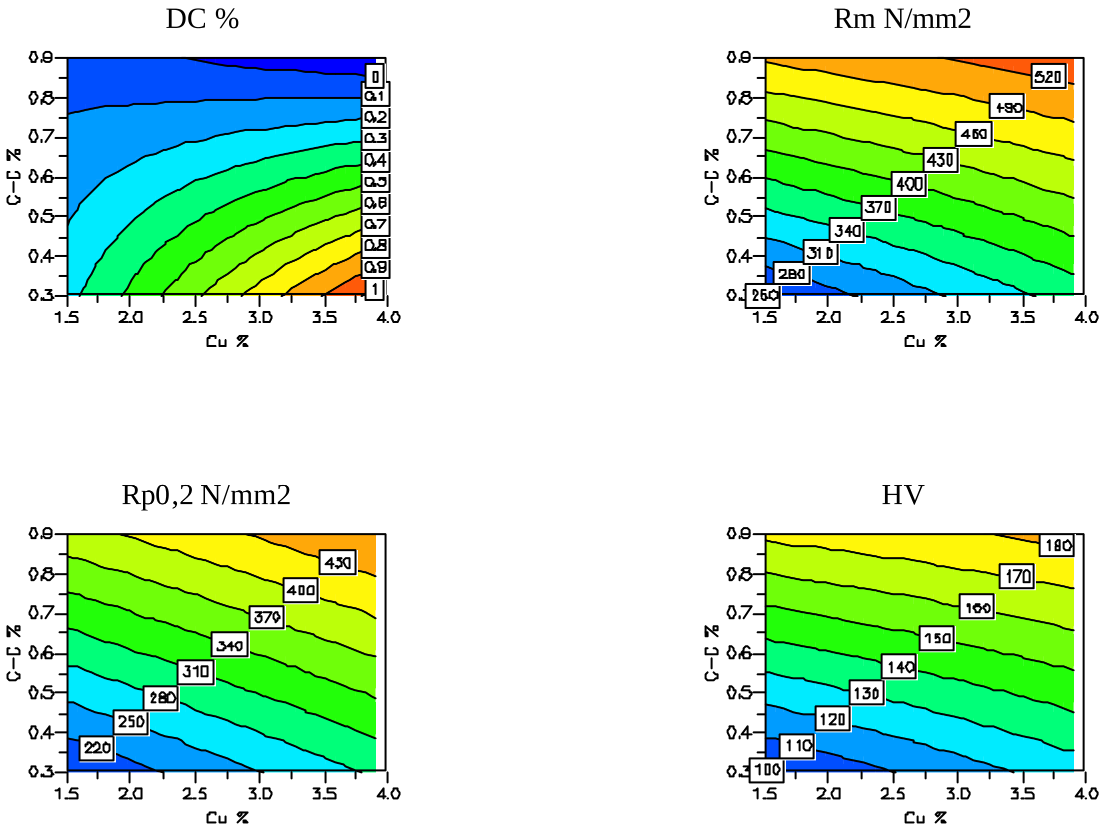


Fig 1. Dimensional change and mechanical properties of the Fe-Cu-C system. (Also shown as Appendix A).

In Fig. 2, it is shown that a scatter in sintering temperature, sintering time and density level have very little influence on the dimensional change within the whole range of copper and carbon content. This makes it possible to concentrate the efforts to diminish the dimensional variations to the ratio of copper-carbon and type of copper used in the powder mix.

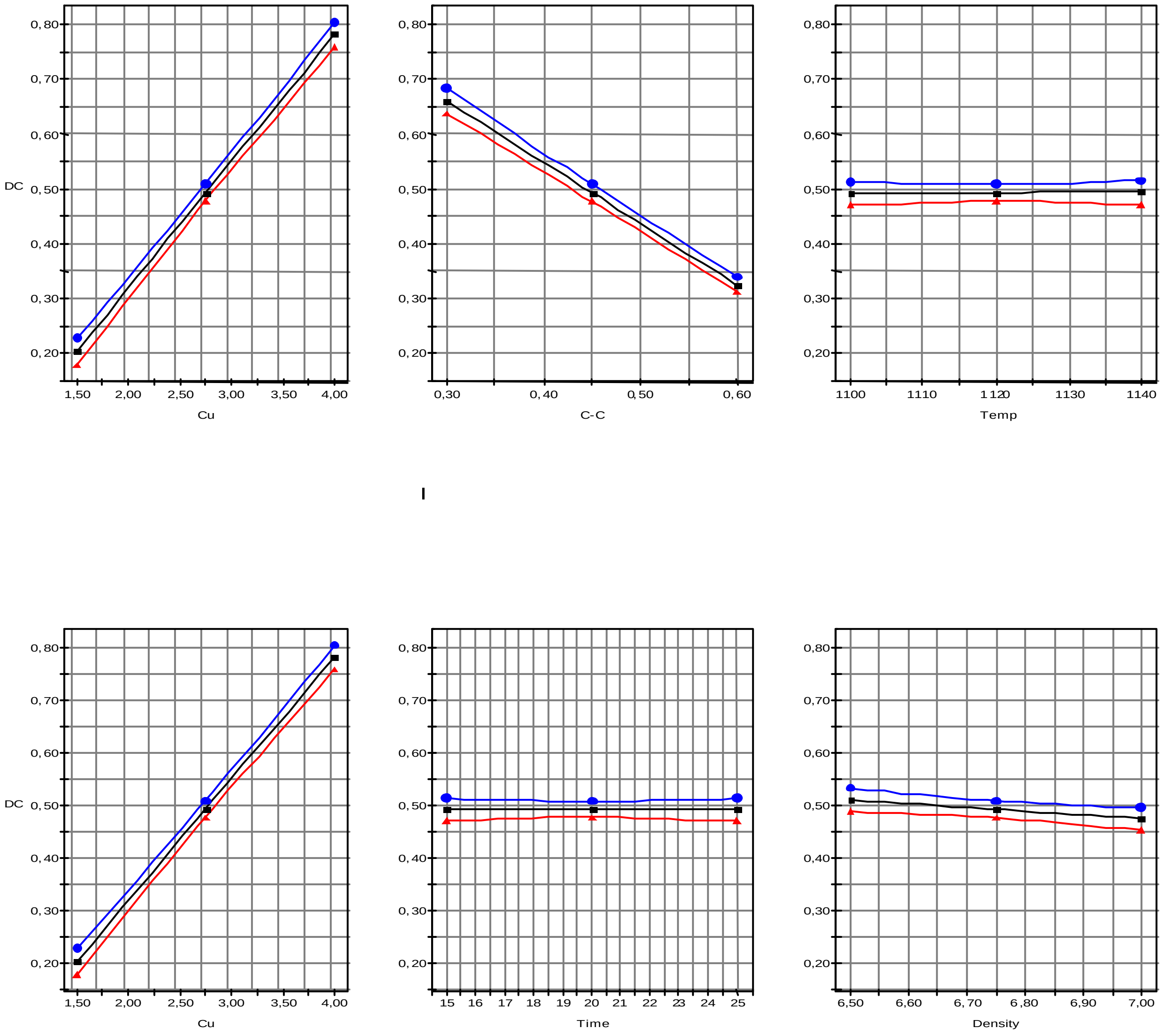


Fig 2. Prediction plots showing the influence of various parameters on the dimensional change during sintering.

The appearance of the graphs in Fig. 3 and 4 for both systems, FC-0205 and FC-0208, makes it obvious that there is a great deal to benefit from by adjusting the ratio copper/carbon to lowest possible value, i.e. decrease the copper content and increase the carbon content.

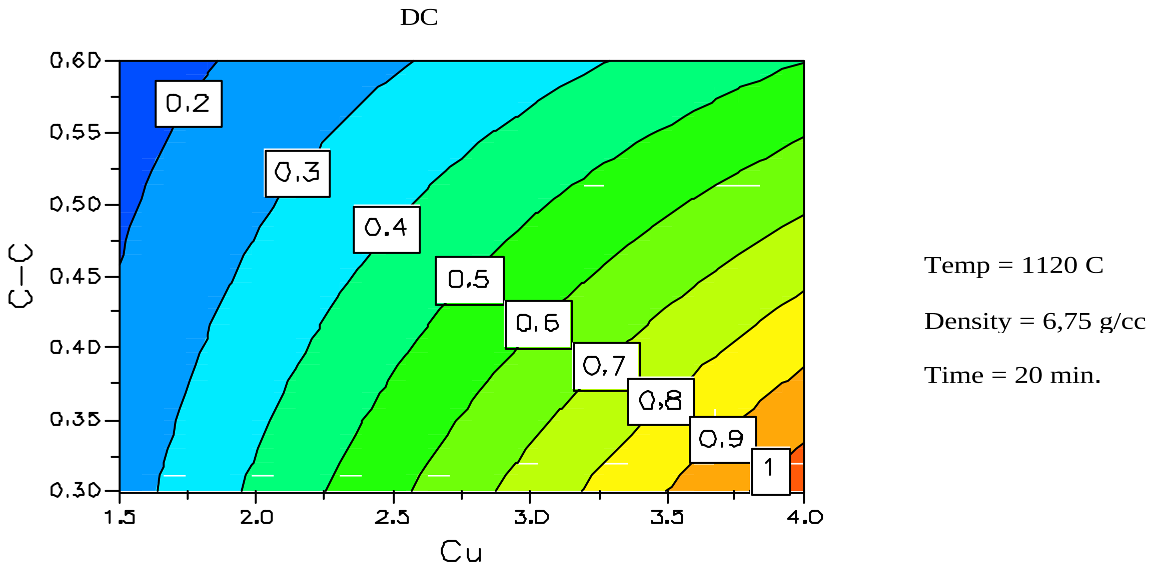


Fig. 3. Dimensional change as a function of copper and carbon content in FC-0205

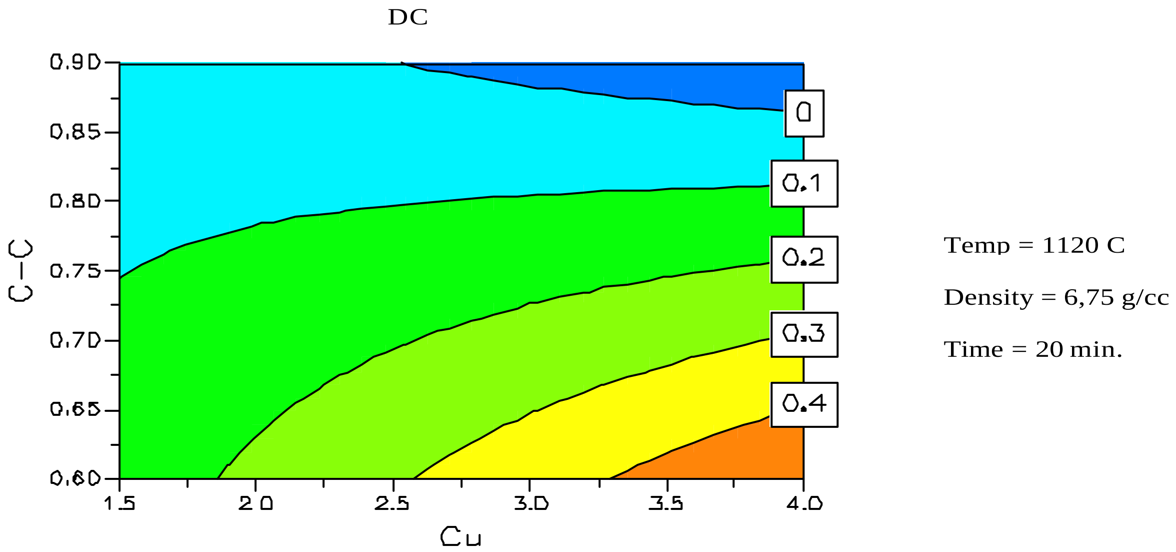


Fig. 4. Dimensional change as a function of copper and carbon content in FC-0208

In two practical cases it is shown that the dimensional variations can be substantially improved. In the first case 3.45% Cu (-75 micron Cu powder) and 0.40 % C was used. The fine Cu powder is segregating very easily during handling of the powder mix.
Fig. 5 shows the analysed copper and carbon contents and the dimensions measured on sintered components. It represents several production campaigns during a long period with many batches of powder. The total variation is about 200 microns on a component size of 50 mm, which corresponds to IT 12 (international tolerance class).

Fig. 6 shows that a change of the composition to 1.75 % Cu and 0.75 % C, i.e. changing from FC-0205 to FC-0208, and by using Distaloy Cu (copper diffusion-alloyed to iron powder) instead of fine copper powder, it was possible to reduce the variations to 35 microns sintered under similar conditions. This corresponds to IT 8.

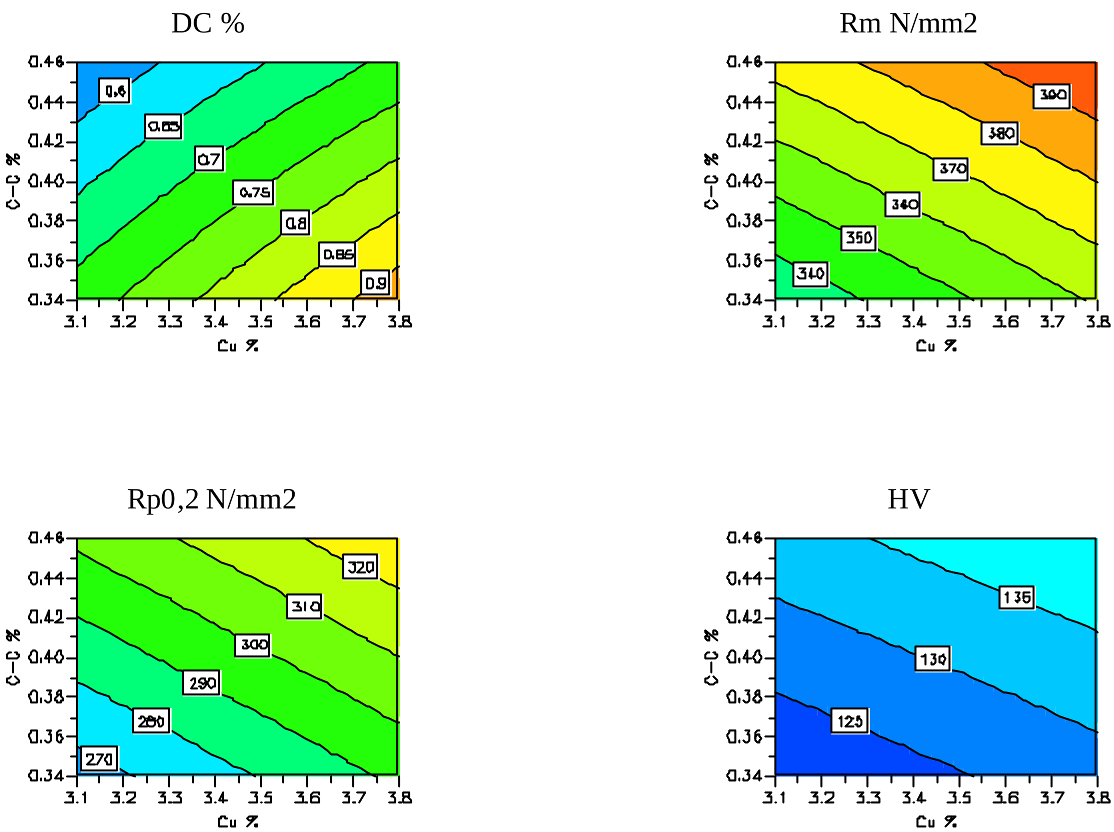


Fig. 5. Dimensional change measured at production lots of components with a nominal content of 3.45% Cu and 0.40% C and the corresponding mechanical properties. (Also shown as Appendix B).

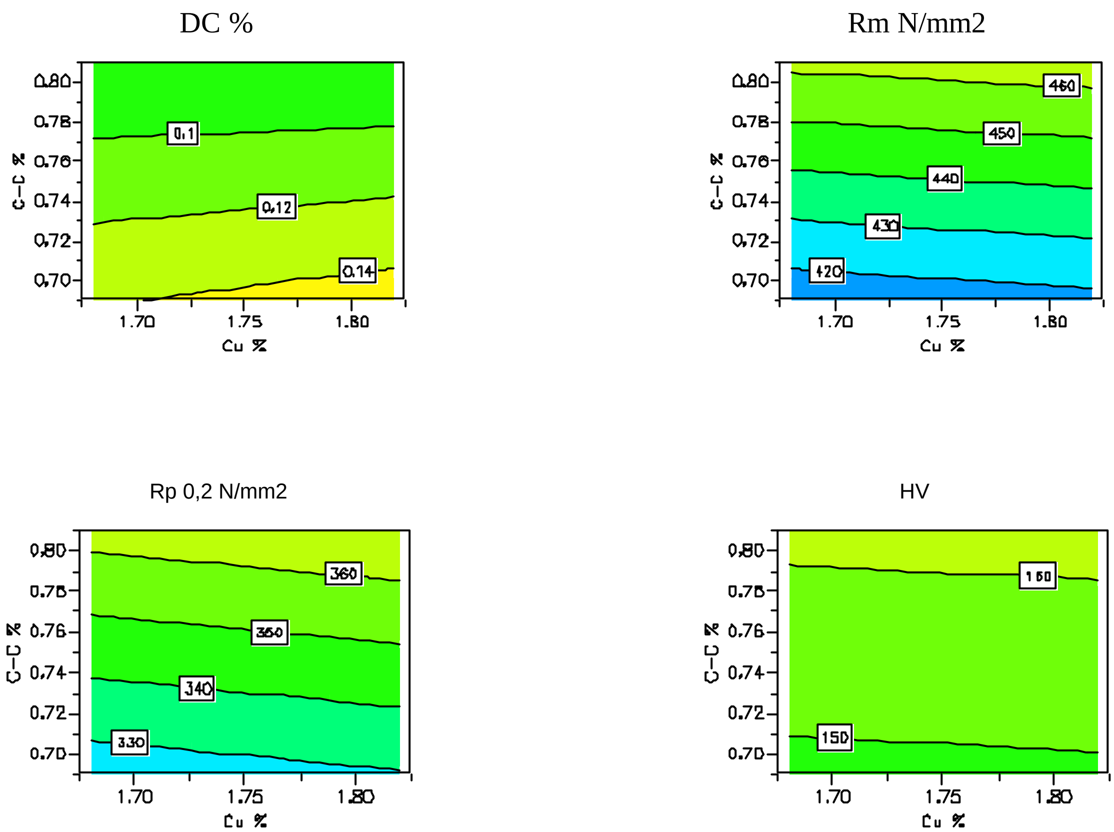


Fig. 6. Dimensional change measured at production lots of components with a nominal content of 1.75% Cu and 0.75% C and the corresponding mechanical properties. (Also shown as Appendix C).

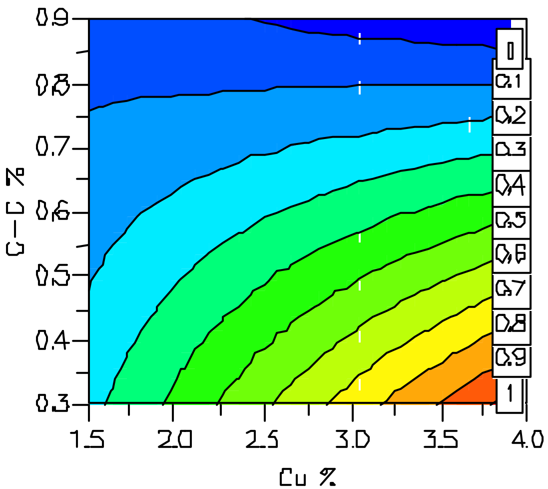
Appendix D. is showing the microstructures of four different compositions from which it is evident that at higher levels, within the chosen system of Cu and carbon, the material contains a minor percentage of a Cu-rich phase after normal sintering conditions.

Conclusions

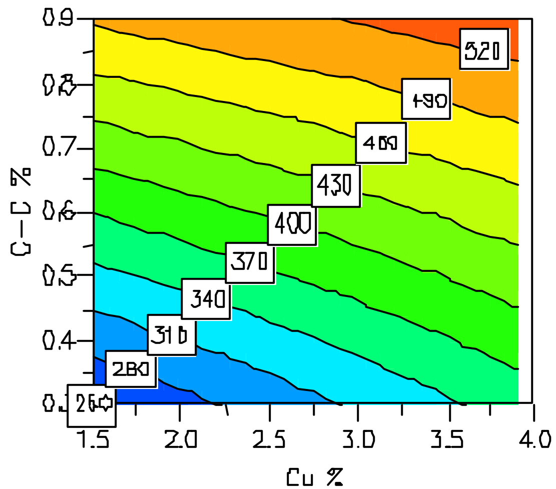
In the investigations presented, the possibility is shown to substantially improve the dimensional tolerances of iron-copper-carbon components by optimising the composition of the powder mix in terms of copper/carbon ratio as well as using additives that do not easily segregate.

Appendix A. Dimensional change and mechanical properties of the Fe-Cu-C system.

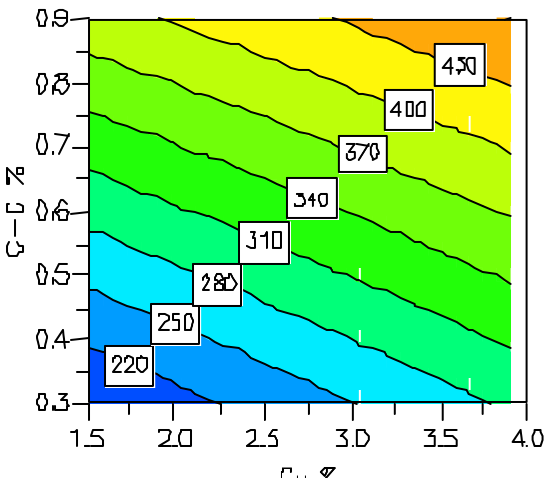
DC %



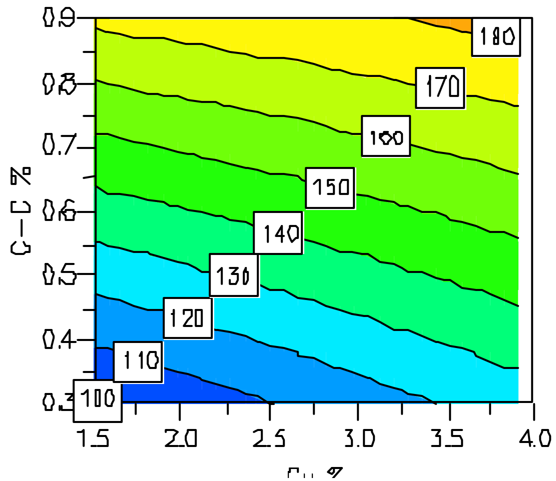
Rm N/mm2



Rp0,2 N/mm2

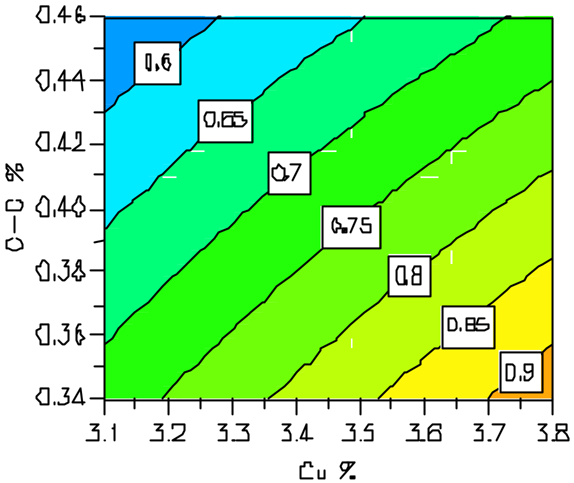


HV

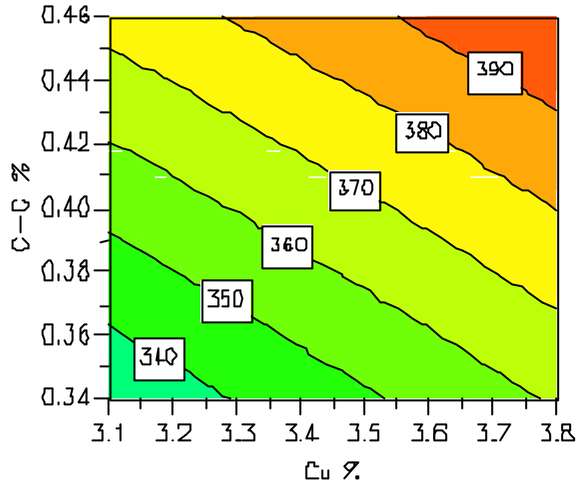


Appendix B. Dimensional change measured at production lots of components with a nominal content of 3.45% Cu and 0.40% C and the corresponding mechanical properties.

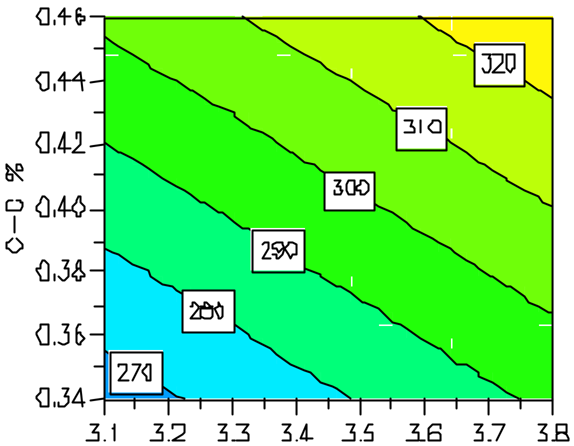
DC %



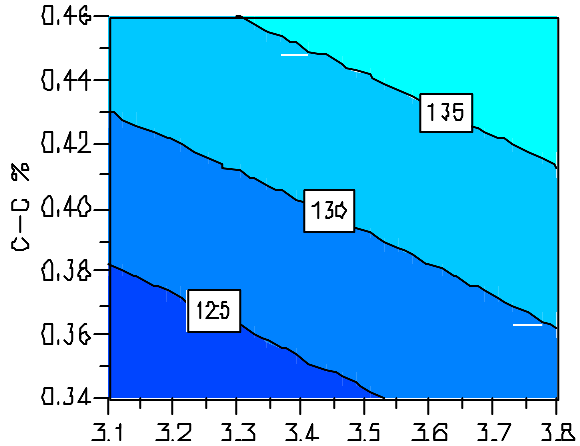
Rm N/mm2



Rp0,2 N/mm2

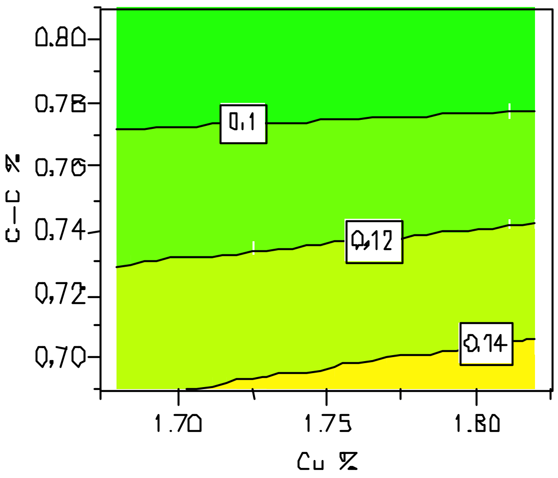


HV

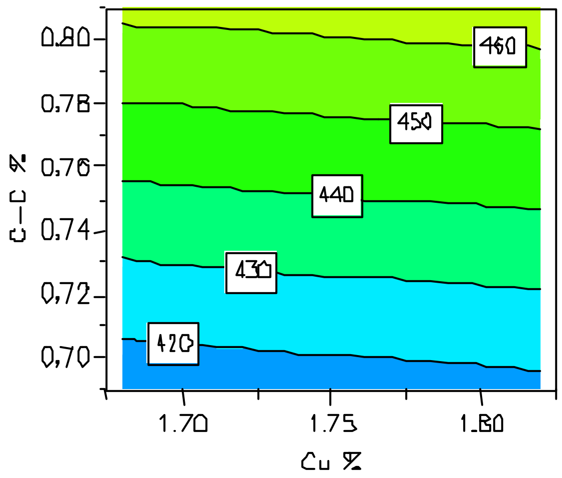


Appendix C. Dimensional change measured at production lots of components with a nominal content of 1.75% Cu and 0.75% C and the corresponding mechanical properties.

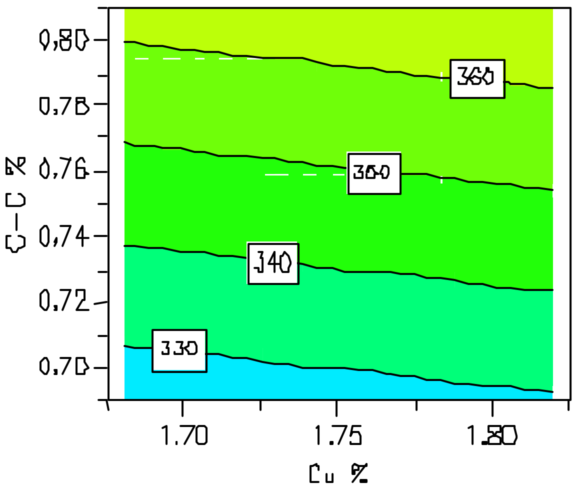
DC %



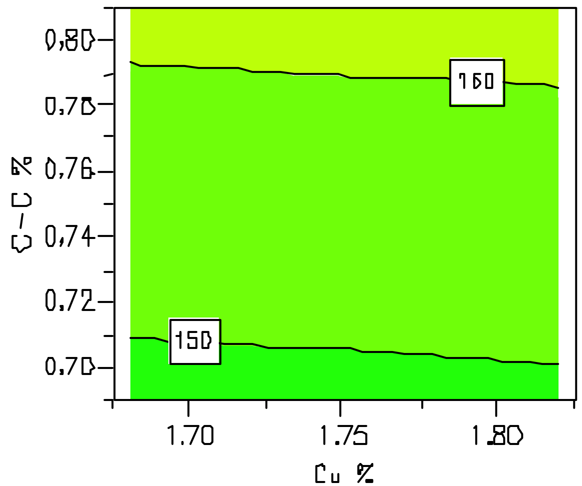
Rm N/mm2



Rp 0,2 N/mm2



HV



Appendix D