# Modeling of properties and phase transformations at high temperatures of 2.25Cr-1Mo steels

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*The aim of this work was to analyse the values of thermo-physical and thermo-dependent mechanical properties and diagrams necessary at high temperatures for the simulation of a welding process of 2.25Cr-1Mo steels based on the compositions provided in the specialised literature.*[b]

Welding is one of the most widely used joining methods for fastening elements. Simulation of welding processes is widely accepted as an important tool for the analysis of the evolution and interrelation of temperature, stress and strain fields in welded structures, as well as the evolution of the microstructure and distortion present. One of the complications that exist in welding simulation is that the necessary thermo-physical and thermo-dependent mechanical properties have been determined for a small number of specific alloys. On the other hand, the information is sometimes incomplete as not all the required properties are measured and generally scattered information from various sources is used to build up a database of the alloy used. In addition, this scattered information differs from one author to another. The main objective of the present work is to analyse the values of thermo-physical and thermo-dependent mechanical properties and diagrams necessary at high temperatures for the simulation of a welding process of 2.25Cr-1Mo steels based on the compositions given in the specialised literature.

## Materials and Methods

The samples of compositions used (SC) during the study, all with nominal designation 2.25Cr-1Mo, are presented. The method used to obtain the thermo-physical and thermo-dependent mechanical properties was that of modelling using software that allows this type of study to be carried out depending on the composition of the material. The models by means of which the aforementioned properties and diagrams were obtained are also presented. See Table 1

| S | C | Mn | P | S | Si | Cr |
|---|---|---|---|---|---|---|
| C1 | 0.15 | 0.6 | 0,03 | 0,03 | 0,5 | 2,6 |
| C2 | 0,050 | 0,3 | 0,03 | 0,03 | 0,5 | 1,9 |
| C3 | 0,102 | 0,433 | 0,014 | 0,0048 | 0,31 | 2.09 |
| C4 | 0,1176 | 0,4 | 0.015 | 0.0136 | 0.31 | 2.50 |

| S | Mo | Cu | Al | Ni | V |
|---|---|---|---|---|---|
| C1 | 1,13 | x | x | x | x |
| C2 | 0,87 | x | x | x | x |
| C3 | 0,93 | 0,12 | 0,02 | 0,03 | 0,011 |
| C4 | 1.12 | x | x | x | x |

Table 1: Compositions of 2.25Cr-1Mo steel (wt %) studied.

## Results and Discussion

The presence of ferrite at room temperature, its transformation into austenite and the carbides present are consistent with experimental reference results (Dèpinoy et al. [2]). Carbide M23C6 was found to dissolve in the intercritical temperature range (except for C2) with C1 being the composition that gives the best approximations. In contrast, M6C stabilises, for C1, C2, C3 and C4, at a temperature of 722°C, 730°C, 750°C and 660°C. The observed difference is due to the variation in the concentrations of the compositional chemical elements in each of the compositions studied. See Fig. 1.

The MnS particles were present in small concentrations, although they are higher and stabilise at higher temperatures than those described in the literature, except for C3, which stabilises at 1250°C. Although this behaviour of MnS is reported for steels such as the one studied, no work has been found so far that shows a similar behaviour for the compositions analysed in this study.

Figure 2 shows that the TTT diagrams obtained present a similar and coherent behaviour to those presented in the specialised literature. The differences are due both to the chemical composition and to the different austenitisation processes used, where these determine the grain size of the material, there being a strong dependence in obtaining these TTT diagrams with respect to the grain size.

The specific heat increases up to temperatures around 720°C, coinciding with the decrease of carbide type M6C. From 720 to 880°C it starts to decrease. There is a zone where the decrease is very small and appears to be practically constant. This is due to the transformation from ferrite to austenite between 800°C, when the first austenite grains begin to appear, and 860°C, when all the ferrite became austenite.

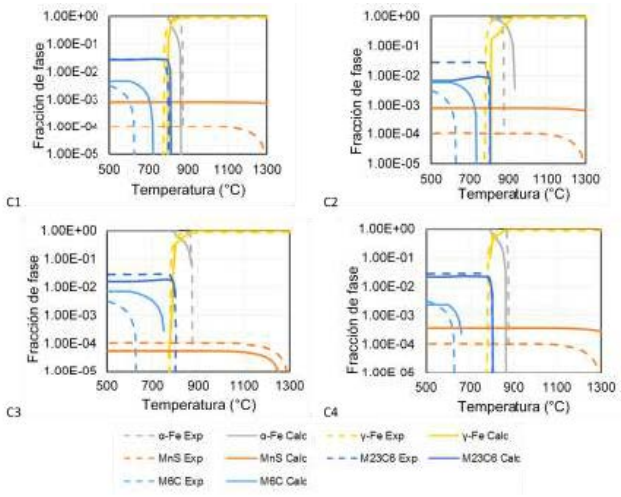


Figure 1: Comparison of the phase equilibrium diagrams obtained (solid lines) and those presented by Dépinoy et al. [2](dashed lines).

From this point onwards, the decrease in specific heat values is more noticeable. From 880°C onwards, its behaviour changes again and it starts to rise since the phase present is already austenite, with the presence of MnS.

As for thermal conductivity, the values obtained for the four compositions shown that at temperatures above 820°C contrasts with the values reported by the specialized literature. This is due to the difference between the chemical compositions and the heat treatment of the steels studied (including those reported by the reference). On the other hand, figure 4b shows which groups show significant differences. From 300°C to 820°C, a decrease in thermal conductivity as a function of temperature is observed. Coinciding with AC3, after 820°C there is a tendency for this property to increase.

The obtained behaviour of the density tends to decrease with increasing temperature and up to 800°C is similar to that suggested by the reference literature. The differences at temperatures above 800°C are a consequence of the variability of the chemical composition and the austenitisation heat treatment to which the steels were subjected. The observed jump coincides with the temperature range in which the ferritic-austenitic transformation of the material occurs and with the presence of M23C6 carbide.

In the case of thermal expansion, from 800°C the thermal expansion decreases due to the transformation of ferrite into austenite. From 870°C to 1430°C it rises linearly due to the completed transformation and the dissolution of carbides in the austenite. From 1430 ºC the dissolved carbides start to diffuse until 1530°C where the austenite can be considered homogeneous.

In all cases, it can be seen that Young's modulus decreases with increasing temperature. It can be seen that there are differences between the behaviours suggested by the literature consulted. The behaviours obtained in the present work by means of the modelling

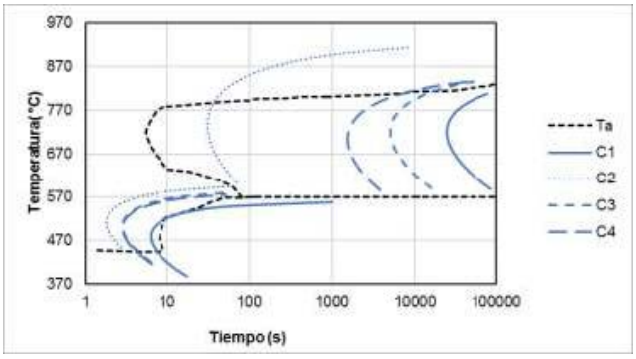


Figure 2: TTT diagrams for steels with denomination 2.25Cr-1Mo compared with those presented by Tsai et al. [3]

differ graphically from those presented in the works already referred to. This is more evident at temperatures above 820°C. A tendency for the Poisson's coefficient to increase with increasing temperature was found, which is in line with results from the literature.

## Conclusions

The thermo-dependent properties and the high temperature diagrams necessary for the simulation of a welding process of a 2.25Cr-1Mo steel obtained by modelling are in correspondence with those reported in the specialised literature. The austenitisation treatment, the chemical composition and the carbides present significantly influence the behaviour of the thermo-dependent properties and diagrams obtained in the present work. The thermo-dependent behaviour at high temperatures of the thermo-physical and mechanical properties and phases described in the simulation of a welding process of a 2.25Cr-1Mo steel must be taken into account.

## Notes

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## References

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