



## Austenite Stability of TRIP-Steels

Stoyan PARSHOROV<sup>1</sup>, Peter PETROV<sup>2</sup>, Stefan VALKOV<sup>2</sup>

<sup>1</sup> Institute of Metal Science, Equipment, and Technologies with Hydro- and Aerodynamics Centre “Acad. A. Balevski” at Bulgarian Academy of Sciences, 67 “Shipchenski prohod” St., Sofia 1574, Bulgaria, e-mail: [s\\_parshorov@ims.bas.bg](mailto:s_parshorov@ims.bas.bg)

<sup>2</sup> Institute of Electronics of Bulgarian Academy of Sciences, Sofia, Bulgaria

### Abstract.

The stability of austenite in TRIP-steel was investigated at uniaxial strain deformation. It has been found that by alloying, plastic deformation and aging, using the Shaeffler’s diagram, the phase composition of the solid solution can be controlled and predicted. The relationship between the composition of the solid solution, the micro-structural parameters of austenite and its stability is shown. The studies allow a new understanding of the applicability of TRIP-steel.

**Keywords:** TRIP-steel, plastic deformation, Shaeffler’s diagram, phase composition

## 1. Introduction

The steels of the austenite-martensite class known in publications as “steels of controlled transformation” or the so called TRIP-steels are characterized by plasticity provided by phase transformation as a result of deformation. This plasticity is accompanied by high strength characteristics and impact ductility.

The TRIP-steels have a balanced chemical composition that provides they are austenite after quenching and after certain thermal treatments (aging at high temperatures of the order of 800°C or cooling below room temperature) or after deformation at temperatures of the order of 100-150°C a large part of the austenite transforms into martensite [1-3].

The aim of the present study is to investigate the dependence of the stability of austenite in TRIP-steels from alloying, aging and plastic deformation processes.

## 2. Material and method

The investigations reported in publications show that austenite unstable steels contain carbon plus nitrogen in the range of 0.1-0.7% wt and austenite stabilizing elements, such as manganese above 10%, part of it being possibly replaced by nickel. The additional alloying with ferrite stabilizing elements in definite limits can render a positive effect on the austenite tendency to deformation martensite formation [1-7].

The Institute of Metal Science at the Bulgarian Academy of Sciences has developed and investigated more than 80 alloys with unstable structure.

We subjected to detailed study 12 TRIP-steels of selected compositions meeting certain requirements – after quenching they have austenite phase composition and no more than 5% martensite (with the exception of alloy No. 10 which serves as a comparison) and after deformation to fracture of the samples they have maximum tendency to form deformation martensite of the order of 50-60%, Table 1.

In order to study martensite transformation during tensile deformation a specialized installation is developed, described in details in [8], the registration of the transformation being performed

in magnetometric way. The installation permits to investigate the transformation of austenite in deformation martensite at room temperatures. The specimens are preliminary quenched from temperature of 1100°C in quartz tubes in water. The size of the inherited austenite grain of all alloys is in the limits of 7-8 rating.

For some more characteristic alloys presented in Table 1 X-ray diffraction analyses of the austenite microstructure parameters are made in compliance with a method described in details in [9-11]. It is based on the principle that each microstructure parameter of the martensite introduces its share in the extension of every one of the crystal lattice reflection lines. The relation between the coefficients of Fourier order describing the reflection line and its width as sum effect allows obtaining dependencies connecting in certain way the influence of every microstructure parameter on this width. The major parameters describing austenite microstructure are shown in Table 1.

**Table 1. Chemical and phase composition of the investigated alloys**

| Alloy No. | Chemical composition, %wt. |       |      |       |                           | Phase composition |                           |
|-----------|----------------------------|-------|------|-------|---------------------------|-------------------|---------------------------|
|           | C                          | N     | Cr   | Mn    | Other                     | After quenching   | After plastic deformation |
| 1.        | 0.10                       | 0.203 | 9.13 | 10.85 | Si=1.15                   | A                 | A + 50% Md                |
| 2.        | 0.26                       | -     | 9.90 | 10.44 | Si=1.09                   | A                 | A + 49% Md                |
| 3.        | 0.38                       | -     | 4.80 | 11.20 | Si=1.02                   | À                 | A + 56% Ìd                |
| 4.        | 0.29                       | 0.140 | 5.10 | 11.70 | Si=0.93                   | À                 | À + 58% Md                |
| 5.        | 0.30                       | -     | 4.80 | 11.26 | V= 1.54<br>Si=1           | À                 | A + 50% Md                |
| 6.        | 0.21                       | -     | 7.63 | 2.36  | Ni = 7,9<br>Ì=2.3<br>Si=4 | A                 | A + 63%Md                 |
| 7.        | 0.33                       | -     | 5.02 | 11.19 | Ì=1.58<br>Si=1.12         | A                 | A + 52% Md                |
| 8.        | 0.36                       | 0.07  | 9.08 | 12.76 | Ì=2.55<br>Si=1.5          | À                 | À + 54% Md                |
| 9.        | 0.36                       | 0.246 | 4.78 | 13.03 | Si=2.03                   | À                 | À + 55% Md                |
| 10.       | 0.29                       | -     | -    | 11.62 | Si=1.3                    | À +<br>20%Mt      | À + 34% Md                |
| 11.       | 0.036                      | 0.246 | -    | 16.78 | Si=2                      | À                 | À + 50.6% Md              |
| 12.       | 0.073                      | 0.234 | -    | 20.18 | Si=1.75                   | À                 | À + 47.8% Md              |

Designations: A-austenite; Md-deformation martensite; Mt-initial martensite  
D- domain of crystal,  $\epsilon$ - lattice micro-deformation and  $\alpha$ - concentration of stacking faults.

The results of the investigations are shown in Table 2.

**Table 2. Microstructure parameters of the austenite of the investigated alloys**

| N   | Alloy              | Microstructure parameters of the austenite after quenching |                     |               |
|-----|--------------------|--|---------------------|---------------|
|     |                    | $\varepsilon \cdot 10^3$                                   | $\alpha \cdot 10^4$ | Lm. $10^8$ cm |
| 1.  | X10A20CrMn10.10    | 0.30   | 31.5                | 396           |
| 2.  | X30CrMn10.10       | 0.83   | 38.4                | 344           |
| 3.  | X40CrMn5.12        | 1.42   | 46.5                | 275           |
| 4.  | X30A15CrMn5.12     | 0.83   | 58                  | 335           |
| 5.  | X30CrMnV5.12.2     | -  | -                   | -             |
| 6.  | X20CrMnNiMo8.3.8.2 | 0.64   | 62                  | 456           |
| 7.  | X30CrMn5.12        | -  | -                   | -             |
| 8.  | X40CrMnMo5.12.3    | 0.63   | 72                  | 465           |
| 9.  | X40A25CrMn5.13     | -  | -                   | -             |
| 10. | X30Mn12            | 0.36   | 87                  | 489           |
| 11. | X0A25Mn16          | 0.22   | 96                  | 534           |
| 12. | X0A25Mn20          | -  | -                   | -             |

### 3. Experimental Results and Discussion

Fig. 1 shows as an illustration instrumental records of the performed investigations on specimens of some of the alloys, carried out at room temperature. It is also shown the instrumental curve of alloy No 10 in which there is initial martensite as well as that of alloy No.6 after aging. It is seen that the aging of alloys results in austenite stabilizing components removal out of the solid solution and transformation of part of the austenite into martensite. The further deformation of aged austenite shows that it is stabilized and possesses low predisposition towards martensite formation during plastic deformation. Similar stability of austenite, as seen in Fig. 1, is observed also in alloys with present initial martensite, alloy No 10. In this case probably the austenite stability is due to exhausting the points for initiation and growth of deformation martensite.

In order to have general criteria of comparability for the individual TRIP-steels compositions we have used the well-known Schaeffler's diagram [12]. The diagram compares the austenitic stabilizing and austenitic stabilizing role of each element to those of chromium and nickel with a corresponding coefficient, e.g. chromium and nickel equivalents. Fig. 2 shows Schaeffler's diagram with written in it values of the equivalents for the considered by us 11 alloys (without these of alloy 10).

It is seen that after quenching all of them enter the two phase zone of the diagram – austenite and martensite. The analysis of the locations both of the chromium free alloys and of those additionally alloyed with molybdenum shows that the application of Schaeffler's dependencies to TRIP-alloys requires further definition of some coefficients. In compliance with our concept the coefficient of molybdenum ferrite stabilizing ability can be accepted to be 0.6 instead of 1. It could be said in analogy that the manganese austenite stabilizing ability is higher than that in the diagram and the coefficient in front of this element can be accepted to be of the order of 0.8 instead 0.5.

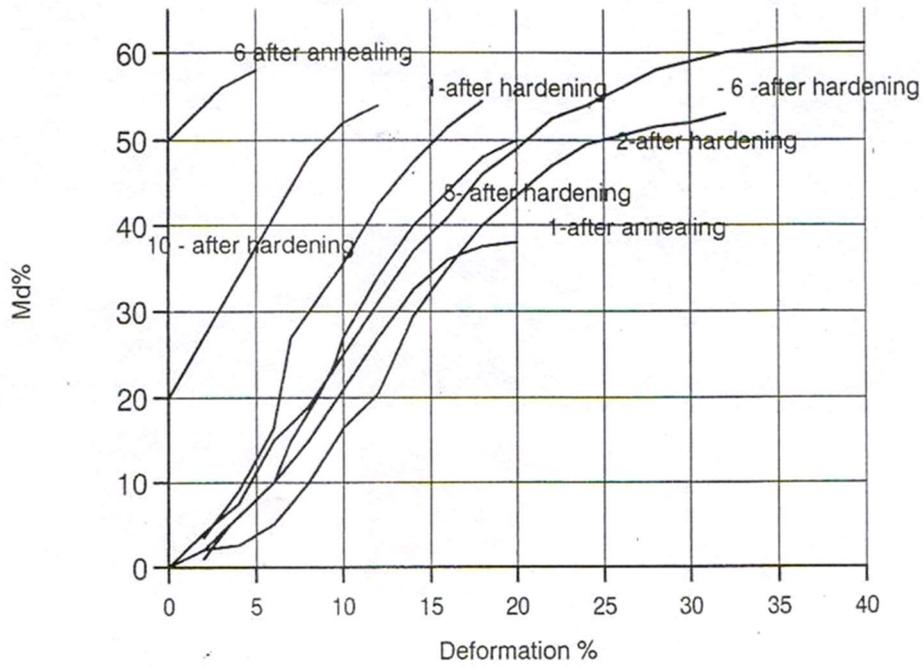


Fig.1. Dependence of the deformation martensite quantity on the deformation rate

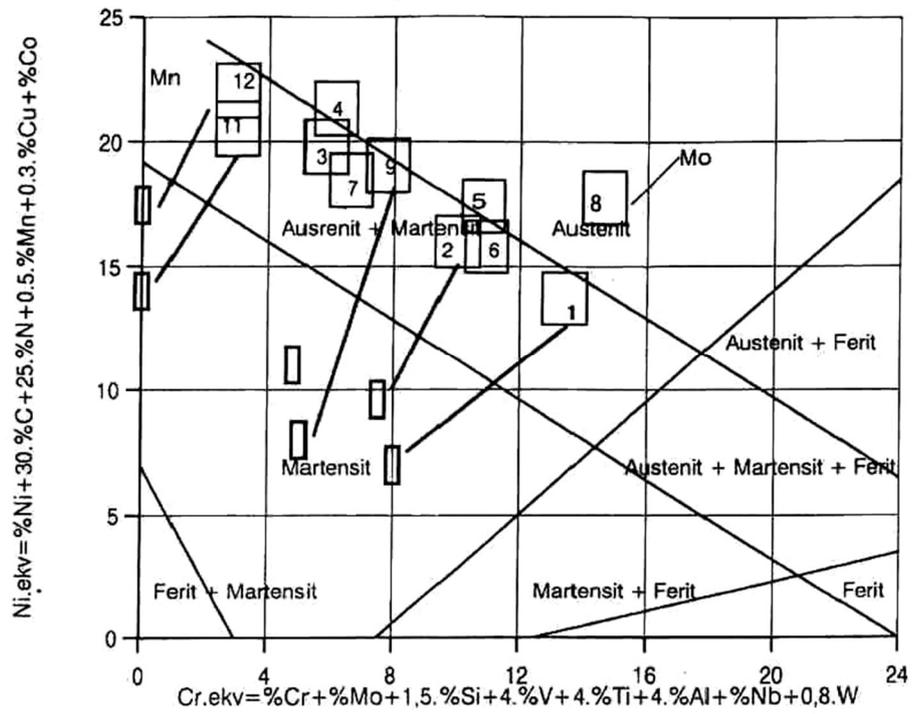


Fig. 2. Schaeffler's diagram applied to the studied TRIP-compositions

## Conclusion

The results and Schaeffler's diagram presented could be a basis for developing new TRIP-steel compositions where the influence of every element is taken into account. Resulting of it some more important practical conclusions follow:

- Manganese and nitrogen are elements that favour the formation of deformation martensite. This is related to the lower energy and higher concentration of stacking faults in the solid solution containing these elements, Table 1. In these alloys a decrease of micro-deformations and increase the lengths of crystal domain is observed which favours the movement of the partial dislocations enclosing the stacking faults that are major bearers of nucleation and deformation martensite.
- Chromium, despite being a ferrite-stabilizing element, favours the deformation martensite formation associated with the reduction of the critical germ of the martensite.
- The increase of chromium in these alloys to 10% by weight slightly affects their tendency to deformation martensite formation.
- Molybdenum has a favourably affect on deformation martensite formation as it improves the plastic properties of alloys and eases the growth processes of martensite nucleation.
- Vanadium is a strong carbide and nitride forming element and the formation of difficult to dissolve nitrides and carbides results on the one hand in removal of inclusion atoms from the solid solution and austenite destabilization and on the other hand it refines the austenite grain which increases the stacking faults energy and austenite stabilization. In this connection alloying with certain quantities of vanadium should be well balanced.

Schaeffler's diagram is valid at condition that the alloys are quenched from sufficiently high temperature and the alloying elements are in the solid solution. Any cause related to removal of the alloying elements from the solid solution strongly affects its stability. In that sense, the diagram shows that depending on the quenching temperature, solubility of the alloying elements in the austenite, the energy of respective carbides and nitrides formation, different quantities of alloying elements can be fixed in the solid solution and they will determine its stability. Therefore, the temperature cross-sections of the triple diagrams of Fe-Me-C condition at quenching temperatures typical for austenite steels at 1000-1100°C should be used as subsidiary diagrams [13].

Me designates the various carbide forming elements. It is obvious from the triple Fe-Me-C systems that the whole quantity of alloying elements determined by the concentration limits shown above, in which the TRIP-steels are defined, can dissolve in the austenite at these temperatures.

As the alloying of the austenite determines its stability then by the aging processes its phase composition and properties could be affected. That is verified by the presented deformation dependence of aged specimen martensite, Fig. 1, and our published investigations of carbide and carbonitride phase analyses of these and similar alloys [14]

The results showed that austenitic aging altered the stability of austenite at deformation – fig. 1, as it reduced the amount of carbide forming elements in the solid solution.

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