# 1. TRANSFORMATION PRODUCTS OF AUSTENITE

## Classification of chapters:

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   1.4. Physical engineering characteristics of granular bainite and conditions of M/A constituent formation
      1.4.1. Control of GB formation

## Summarization of capture terms and questions

## Literature

| Time necessary for study | 500 minutes |
Aim: After studying of this capture:

- you gain view about basic product types of phase austenite transformation;
- you will understand the differences among individual austenite phase transformation products;
- you will aware how individual austenite phase transformation products can influence mechanical properties of steels;
- you gain information about possibilities of austenite transformation control on individual products and will be able to apply acquire knowledge in praxis;
- you gain information about basic austenite transformation product utilization in praxis;

Lecture

1. TRANSFORMATION PRODUCTS OF AUSTENITE

1.1. Basic information about austenite and its phase transformation products

1.1.1. What is austenite?

Austenite ($\gamma$) is oversaturated solid solution of carbon in $\gamma$-iron. It crystallizes in FCC crystallographic system and is part of Fe both in steel and in alloys. Its occurrence is in binary system of Fe-C (C in form of Fe$_3$C and/or graphite).

1.1.2. IRA and ARA transformation diagrams

IRA (isothermal austenite transformation) and ARA (an-isothermal austenite transformation) diagrams serve to description of hypothetic austenite ($\gamma$) behaviour and give us information about temperature and their influence on transformation run. IRA diagrams
are responsible for isothermal austenite transformation (temperature and time are the principal units for transformation) and **ARA diagrams** for austenite transformation under an-isothermal conditions (under different cooling rates – temperature don’t play a role). Phase transformations represent qualitative changes in atomic arrangement of individual phases of thermodynamic system. Through of outer condition changes, system of thermodynamic balance is disrupted.

### 1.1.3. Basic dividing of products of austenite phase transformation

Phase transformations $\gamma$ can be divided to two basic variants from point of view of realized atomic mechanisms.

**a) reconstructive** phase transformation, which is connected with infringing of all atomic bands and with new bands formation. The main mechanism is diffusion;

**b) displacive** phase transformation witch is connected with infringing of original arrangement in matrix and with a formation of a new type of crystallographic structure. This is realized at temperatures, when diffusion of atoms is not able to be divided and the new phase is in a form of laths and/or plates formed by displacive (shear) mechanism. Summarisation of all products gives **Fig. 1.1**.

![Diagram](image)

**Fig. 1.1 Basic transformation characteristics of the Fe$_\gamma$ transformation (N represents nucleation and G growth)**
1.1.4. Comparison of nucleation potentials of studied austenite transformation processes

Scheme of nucleation potentials with positions of nucleation of austenite transformation types shows Fig. 1.2.

a) bainite (B)
b) Widmanstätten’s ferrite (WF)
c) acicular ferrite (AF)
d) allotriomorphic ferrite (ATF)
e) idiomorphic ferrite (IDF).

ATF is preferentially initiated on un-metal inclusions being often on the γ grain boundaries, while AF is formed intra-granularly on un-ferrous particles (inclusions or precipitates) with nucleable capacity. From it follows the un-ferrous inclusions on the austenite grain boundaries participate in preferential ATF initiation.

Nucleable conditions for displacive phase transformation products, consequently WF, B, resp. AF formation, influence their morphology first of all. Displacive mechanism of their formation is not different in the basis, their different nucleation conditions lead either to bainite packets formation or to chaotically arranged AF laths (packets).
Material with lower density of nucleable non-ferrous inclusions will be preferentially transformed to B, because relative frequency of nucleable boundaries of austenite grains is higher (provided that “conventional” austenite grain size).

In the case of coarser austenite grain size (represents lower surfaces) and at given density (higher than in previous case) of nucleable non-ferrous inclusions, the AF initiation is partially stimulated to the exclusion of B formation.

1.2. **Reconstructive products of austenite phase transformation**

Reconstructive phase transformation products are connected with diffusion processes. Atomic bands are disrupted and new ones are formed. To this group need:

- **Allotriomorphic ferrite (ATF)**
- **Idiomorphic ferrite (IDF)**
- **Massive ferrite (F)**.

1.2.1. **Allotriomorphic ferrite (ATF)**

Allotriomorphic ferrite (ATF) – is formed close under austenite transformation temperature to ferrite and is subordinated to diffusion. It is formed inter-granularly, hence on the neighbouring austenite grain boundaries and is growing along these. It shows lenticular form – see Fig. 1.2. Individual ATF grains meets one other simply, can connect together and so continual net along austenite grains can be formed: Allotriomorphic ferrite (ATF) can be divided to:

- **active**
- **in-active**

![Fig. 1.3 ATF – austenite interface a) active; b) in-active](image)
**Active ATF** is characterised like ferrite, which is able further to develop products of follow-up phase transformation (WF and B) under corresponded temperature conditions. **Inert** ferrite is inter-granularly formed one, which further phase transformation is restricted at austenite interface due to higher carbon content at the $\gamma$-ATF interface. That defends further development of follow-up the $\gamma$ phase transformation to WF and/or B. Figures 1.3a, b show microstructures examples corresponding above described ATF and austenit interface.

### 1.2.2. Idiomorphic ferrite (IDF)

Idiomorphic ferrite (IDF) is nucleated at temperature approximately 50 °C under the ATF formation temperature. It is formed by reconstructive phase transformation and mechanism is subordinated to diffusion processes. Idiomorphic ferrite (IDF) is formed **intra-granularly**, hence inside of austenite gain, on the same particles like the AF – Fig. 1.2.

![Fig. 1.4 Image of massive ferrite](image)

### 1.2.3. Massive ferrit (MF)

Massive ferrite (MF) is other product of **reconstructive** phase transformation of austenite, being subordinated to diffusion mechanism. Ferrite is finely distributed being usually formed at higher temperatures and at low cooling rate in volume of austenite grain. It has usually coarser morphology (coarser grain). This is given by higher formation temperature. It has not nucleated on the austenite grain boundary and inclusions. It can be formed in place with higher dislocation density, generally in place with higher energetic potential. It is also called block ferrite – see Fig. 1.4.