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# DEFORMATION FEATURES OF THE CENTRAL LAYERS OF Fe – 3%Si(110)[hkl] ALLOY BY ROLLING WITH A ROLL DIAMETER OF 90 MM

**Abstract.** The article presents the results of studies of the effect of initial crystallographic orientation and deformation modes on rolling texture in the central layer of *Fe – 3%Si(110)[hkl]* single crystals.Several groups of samples of single crystals were rolled under laboratory conditions. The groups of samples were classified according to the final deformation rate, the ideal crystallographic orientation of the rolling plane and deflections of the direction of the ideal orientation plane from the rolling direction. The methodology of the experiment took into account the amount of reduction rate during one rolling. Radiographic method was used to analyze the results of rolling. The obtained data was superimposed on a stereographic projection, and straight pole figures were built. The results of decoding direct pole figures revealed differences in the formation of the texture from the previously obtained results. The research shows the manifestation of the one-component deformation texture in the central layer.

**Keywords:** deformation of single crystals, crystallographic texture, standard crystallographic projection, pole figures, deformation texture.

**Introduction.** The studies of texturing of metals and alloys, as well as their influence on the final properties of semi-finished products and final products, are conducted by specialists of the machine-building complex and scientists from different fields. The examples of these fields are solid-state physics, physical metallurgy, plastic deformation, mathematics.

Nowadays, the main types of textures are represented by axial, conical and rolling textures, classified within the group according to the symmetry.

Theoretical and experimental data in the metal forming, based on the preferred orientation in microplastic deformations, allows us to design new types of textures using special schemes of the external field of influence, based on the symmetry approach.

The design of new types of textures, on a symmetry basis, is aimed at obtaining semi-finished products and products with predetermined physico-mechanical and special properties. As a result, it will lead to the improvement of the operational properties of machines and mechanisms, and increase both technical and economic indicators of the machine-building complex.

**The formulation of the research problem and the physical essence of the process.** The formation of texture during plastic deformation is a consequence of the rotation of crystallographic planes and directions relatively to technological or another special direction. The crystallographic texture, being the main component in the formation of physico-mechanical properties in polycrystalline materials, is determined by the initial texture of the workpiece before processing and its main kinematic and dynamic parameters. One of the ways to optimize the physico-mechanical properties of semi-finished and finished products made of polycrystalline materials can be accomplished by controlling the texturing. The initial crystallographic orientation of the original workpiece must be taken into account.

Thus, the task of the current paper is to determine the effect of the initial *(110)[hkl]* texture of Fe–3%Si single crystals on the deformation texture in the central layers during rolling with different reduction rate.

The difference between rolling deformation of *(110)[hkl]* alloys on the surface and deformation of the central layers is that maximum stress axes rotate continuously around the transverse direction of rolling. As a result, there is a change in the slip systems involved in the deformation process. In case when the single crystal is oriented ideally relative to the (110) plane, there is a symmetric change of slip systems on the opposite surfaces. However, when this orientation is shifted towards the direction of rolling, there is an ambiguous participation of the slip systems in the deformation.

The influence of the initial orientation and deformation modes on the rolling texture of *(110)[hkl]* single crystals with a deflection of 5÷10° from the plane towards the direction of rolling was analyzed on the example of Fe–3%Si alloy.

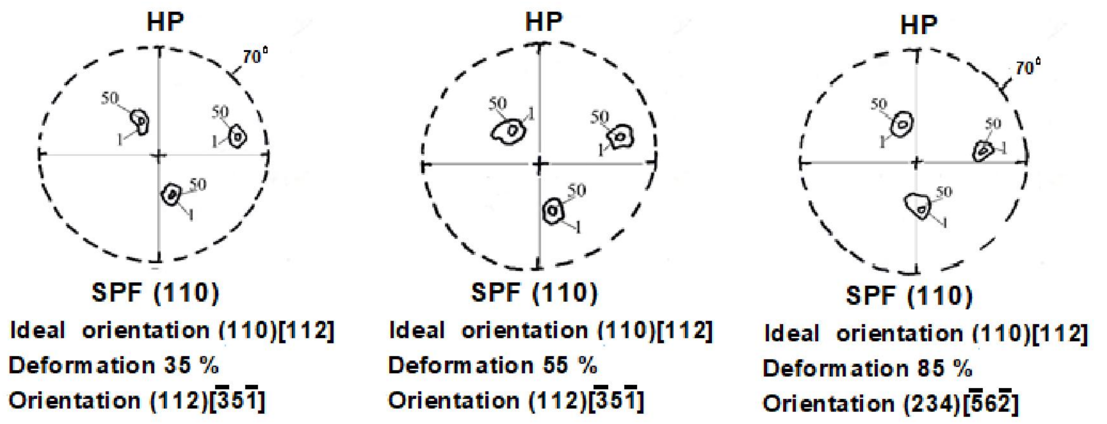
Three types of samples were rolled under laboratory conditions. The first group had $(110)[\bar{1}12]$ and $(110)[\bar{1}11]$ initial ideal orientation, with a deflection of 8 degrees from the plane towards the rolling direction. The second group had $(110)[\bar{3}31]$ and $(110)[\bar{5}51]$ initial ideal orientation, with a deflection of 7 degrees. The third group had $(110)[\bar{5}51]$ initial ideal orientation with a deflection of 5 degrees.

Samples were rolled on the laboratory rolling mill DUO-90 with the rolls diameter of 90 mm, at room temperature. The rolling was carried out without grease lubricant. The guides were used to prevent the rotation of samples. The cross-section of the original samples was 0,48×15,0 mm.

The formation of the rolling texture of the central layers of the first group had a similar character with the one described in the earlier papers [1÷7, 11÷13]. The main difference of the obtained results from the previous studies is that the orientation of the "group 1" deformed single crystals is single-component. Figures 1, 2 show {110} pole figures taken from the central layers of the Fe – 3%Si alloy of the specified group, rolled with reduction rate of 35%, 55% and 85%.

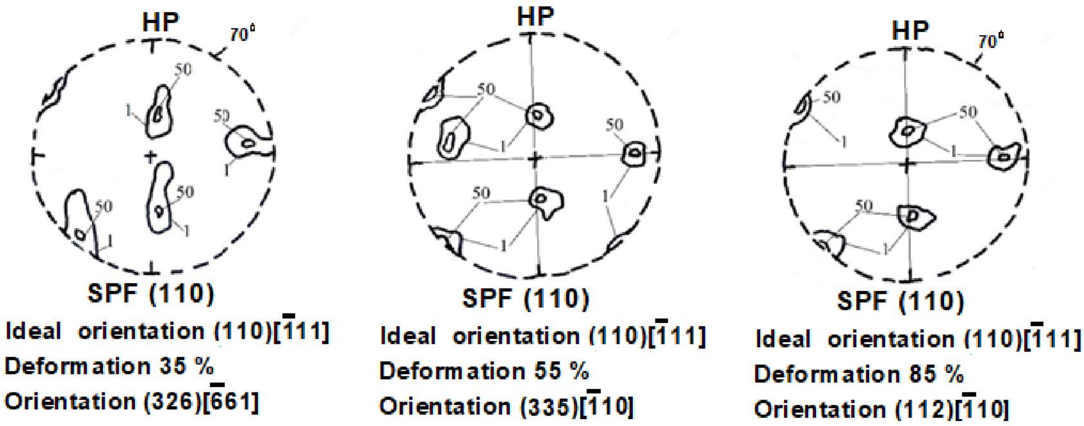
The analysis shows that *(110)[hkl]* orientation of Fe-3%Si alloy is one-component. The samples with $\mathbf{(110)[\bar{1}12]}$ ideal orientation, at a reduction rate of 35% have orientation close to $\mathbf{(112)[\bar{3}5\bar{1}]}$ (Figure 1,a); the samples with $\mathbf{(110)[\bar{1}11]}$ ideal orientation have the orientation close to $\mathbf{(326)[\bar{6}61]}$ (figure 2,a). The latter sample also has dispersion around transverse rolling direction. The further increase of deformation rate reduces dispersion and almost does not change the orientation (figure 1b, figure 2b).

The sample with $\mathbf{(110)[\bar{1}12]}$ ideal orientation, at a reduction rate of 85%, has orientation of the plane between (112) and (111); at the same time it is slightly shifted counterclockwise from the $\mathbf{[\bar{1}10]}$ axis and can be recorded as $\mathbf{(234)[\bar{5}6\bar{2}]}$ (figure 1, c). When the sample with $\mathbf{(110)[\bar{1}11]}$ ideal orientation is deformed at a reduction rate of 85%, $\mathbf{(112)[\bar{1}10]}$ orientation is one-component (figure 2, c).




*a)* *b)* *c)*

Figure 1 – Straight pole figures (110) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial $\mathbf{(110)[\bar{1}12]}$ ideal orientation,; the reduction rate of a) – 35%; b) – 55%; c) – 85%




*a)* *b)* *c)*

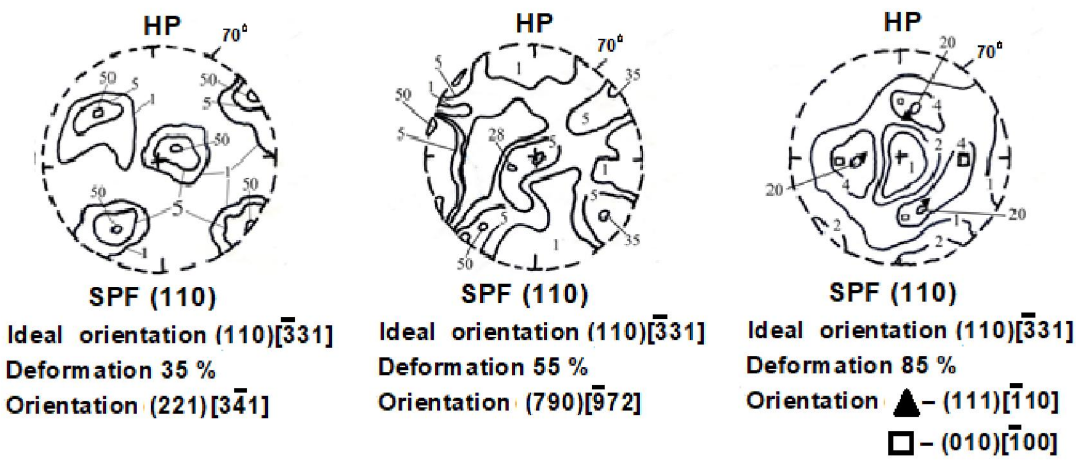
Figure 2 – Straight pole figures(**110**) of the central layers of the samples (a, b, c) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[$\bar{\mathbf{1}}$**11**] ideal orientation,; the reduction rate of a) – 35%; b) – 55%; c) – 85%

The formation of $(110)[hkl]$ rolling texture of central layers of $Fe - 3\%\,Si$ alloy (groups 2 and 3), deflected along $(110)$ plane towards the rolling direction of 7 and 5 degrees respectively, in general has a similar character with the one described in the earlier papers. Depending on the rolling conditions and initial orientation, it differs by the dispersion of orientations and the presence of the other weak components [8÷10, 14÷21].

The results of the radiographic analysis of the rolling groups 2 and 3 are presented in figures 3–5. The analysis of pole figures was carried out similarly to the first group. The data is presented in the table below.

Thus, in the process of formation of (110)[hkl] rolling texture of the central layers of Fe – 3%Si alloy with the deflection of 8 degrees from (110) plane towards the rolling direction, the following results were obtained. In all cases, the orientation appeared to be one-component, close to (112); in the case of [$\bar{\mathbf{1}}$**12**] reference direction, it is close to $[5\bar{6}\bar{2}]$ direction; in the case of [$\bar{\mathbf{1}}$**11**] reference direction, it is close to $[\bar{1}10]$ direction.

The analysis of texturing during the rolling process of single crystals of groups 2 and 3 showed that there is a similarity in texture formation. The main orientation in all the cases is $(111)[\bar{1}10]$, i.e. the single crystal rotates around $[\bar{1}10]$ crystallographic direction, close to the direction of rolling.




*a)* *b)* *c)*

Figure 3 – Straight pole figures(**110**) of the central layers of the samples (a, b, c) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[$\bar{\mathbf{3}}$**31**] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%

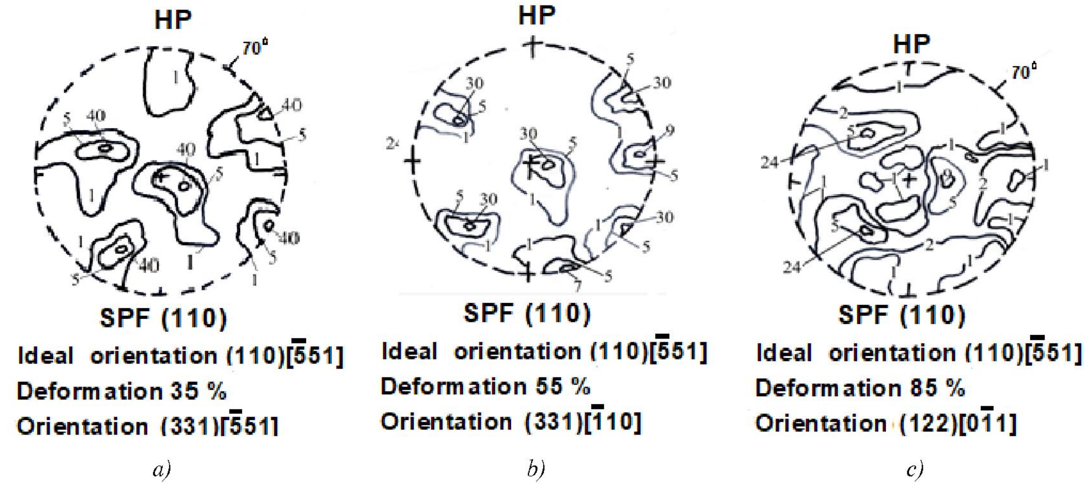



Figure 4 – Straight pole figures(**110**) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[**5̄51**] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%

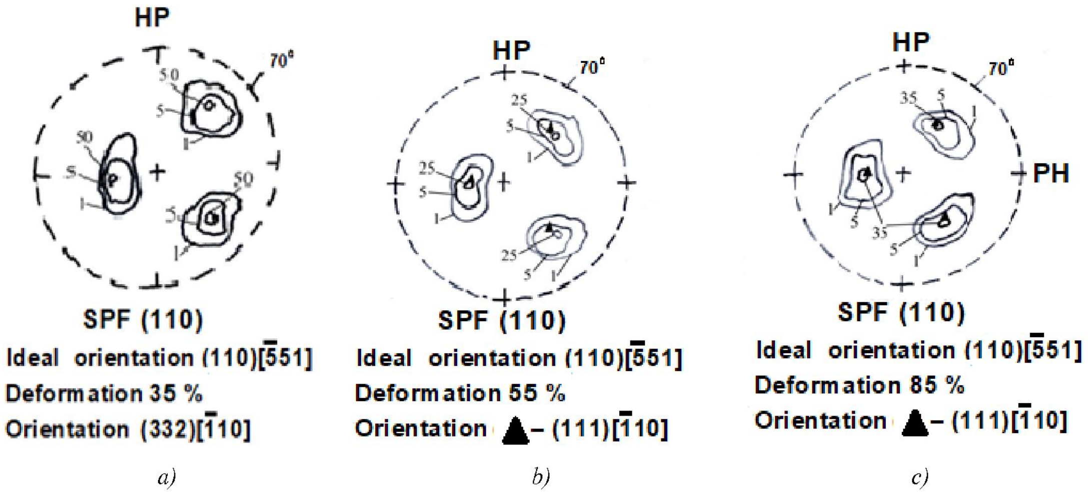



Figure 5 – Straight pole figures(**110**) of the central layers of the samples (*a*, *b*, *c*) of Fe – 3%Si(110)[hkl] cold rolled alloy with the initial (**110**)[**5̄51**] ideal orientation; the reduction rate of a) – 35%; b) – 55%; c) – 85%

Radiographic analysis of the rolling groups 1-3 of Fe – 3%Si alloy

| Group | Figure | Ideal orientation | Deflection from (110) plane [degrees] | Orientation after deformation: | | |
|---|---|---|---|---|---|---|
| | | | | 35% | 55% | 85% |
| | | | | Preliminary | Intermediate | Final orientation |
| 1 | 1 | $(110)[\bar{1}12]$ | 8 | $(112)[\bar{3}5\bar{1}]$ | $(112)[\bar{3}5\bar{1}]$ | $(234)[\bar{5}6\bar{2}]$ |
| | 2 | $(110)[\bar{1}11]$ | 8 | $(326)[\bar{6}61]$ | $(335)[\bar{1}10]$ | $(112)[\bar{1}10]$ |
| 2 | 3 | $(110)[\bar{3}31]$ | 7 | $(221)[3\bar{4}1]$ | $(790)[\bar{9}72]$ | $(111)[\bar{1}10]$<br>(0 [illegible] 0)$[\bar{1}00]$ |
| | 4 | $(110)[\bar{5}51]$ | 7 | $(331)[\bar{5}51]$ | $(331)[\bar{1}10]$ | $(122)[0\bar{1}1]$ |
| 3 | 5 | $(110)[\bar{5}51]$ | 5 | $(332)[\bar{1}10]$ | $(111)[\bar{1}10]$ | $(111)[\bar{1}10]$ |

The difference between the results concerning the analysis of alloys of groups 3 and 2 is the following: in the first case, a one-component $(111)[\bar{1}10]$ orientation is formed, while in the second case almost always there is another weak orientation. It must be noted, that a one-component $(111)[\bar{1}10]$ orientation is formed in the case of a small reduction rate during one rolling, whereas an increase in reduction leads to a two-component orientation.

**Conclusions.** In the process of studies of *rolling texture in the central layer of* Fe – 3%Si(110)[hkl] alloy, there were discovered some differences in the formation of the texture from those described earlier in the scientific and technical literature. It was established that during the rolling of Fe – 3%Si alloy along (110) plane deflected from the rolling plane around the transverse rolling direction, a single-component deformation texture is formed in the central layers, due to the action of symmetric slip systems.

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**ДИАМЕТРІ 90 ММ БІЛІКТЕРМЕН ПРОКАТТАУ КЕЗІНДЕ Fe – 3%Si(110)[hkl] ҚОРЫТПАСЫНЫҢ ОРТАША ҚАБАТТАРЫНЫҢ ДЕФОРМАЦИЯЛАНУ ӨЗГЕШЕЛІІКТЕРІ**

**Аннотация.** Мақалада бастапқы кристаллографиялық бағдарлау мен деформациялау тәртіптерінің Fe – 3%Si(110)[hkl] қорытпасы монокристалдарының орташа қабатындағы илемдеу текстурасына әсерін зерттеу нәтижелері ұсынылады. Монокристалдар сынамаларының топтары зертханада илемденді. Сынамалар топтары деформациясының соңғы мөлшері бойынша, илемдеу жазықтығында жататын идеал кристаллографиялық бағдарлау бойынша және идеал бағдарлаудың жазықтығы бағытының илемдеу бағытынан ауытқуы бойынша жіктелді. Және де эксперимент жүргізу әдістемесімен бір өңдеу кезіндегі қысылу шамасы ескерілді. Илемдеу нәтижелерін зерттеу үшін рентгенграфиялық әдіс пайдаланды. Рентгенграфиялық зерттеудің нәтижелерін стереографиялық проекцияға салып тіке полюстэк фигуралар құралды. Тіке полюстік фигуралар талдау арқасында текстура қалыптасуының бұрын алынған нәтижелерден ауытқулары айқындалды. Сол ауытқулар мәні болып орташа қабатта деформацияның бір компонентті текстурасының пайда болуы табылады.

**Түйін сөздер:** монокристалдар деформациясы, кристаллографиялық текстура, стандарттық кристаллографиялық проекциялары, полюстік фигуралар, деформацияның текстуралары.

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**ОСОБЕННОСТИ ДЕФОРМАЦИИ СРЕДНИХ СЛОЕВ СПЛАВА Fe – 3%Si(110)[hkl] ПРОКАТКОЙ С ДИАМЕТРОМ ВАЛКОВ 90 ММ**

**Аннотация.** В статье предложены результаты исследования влияния исходной кристаллографической ориентировки и режимов деформации на текстуру прокатки в центральном слое монокристаллов сплава Fe – 3%Si(110)[hkl]. В лабораторных условиях были прокатаны группы образцов монокристаллов. Группы образцов были классифицированы по конечной величине деформации, по идеальной кристаллографической ориентировке, лежащей в плоскости прокатки, и по отклонениям направления плоскости идеальной ориентировки от направления прокатки. Методикой проведения эксперимента учитывалось также и величина обжатия за один подкат. Для исследования результатов прокатки был применен рентгенографический метод. Данные рентгенографического исследования накладывали на стереографическую проекцию и строили прямые полюсные фигуры. Результаты расшифровки прямых полюсных фигур выявили отличия в формировании текстуры от ранее полученных результатов. Эти отличия заключаются в проявлении в центральном слое однокомпонентной текстуры деформации.

**Ключевые слова:** деформация монокристаллов, кристаллографическая текстура, стандартные кристаллографические проекции, полюсные фигуры, текстуры деформации.

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