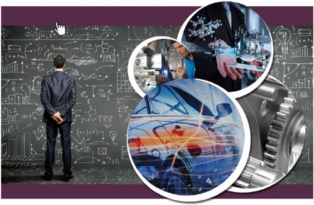
IMSMATEC

4. International Conference on Materials Science, Mechanical and Automotive Engineerings and Technology (IMSMATEC'21)

26-28/05/2021



NEVŞEHİR HACI BEKTAŞ VELİ ÜNİVERSİTESİ
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PREFACE

The conference, organized by Nevşehir Hacı Bektaş Veli University, was held between 28-30 May 2021 with video conferencing method, with our valuable participants, successfully and efficiently. First of all thank you for your interest. IMSMATEC 2021 aims to present current research in the field of Materials Engineering. Mechanical Engineering and Automotive Engineering for scientists, academics, engineers and universities, technologists, entrepreneurs and policy makers from all over the world. Thus, IMSMATEC 2021 provides opportunities for delegates to share new ideas and practical experiences face-to-face, establish business or research associations and find global partners for future collaboration. endeavor to make this event happen. We would like to thank BC TECH, of IMSMATEC21 as their names and company logos indicate. We also express our gratitude to the Honor Committee, Scientific Committee, Organization Committee, Secretarial Aid and Students for their efforts to make the event successful. Finally, we thank academics, practitioners, and experts who participated in IMSMATEC'21 to share their information. Hope to see you all at the next International Symposium…

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INVITED SPEAKER

Prof. Dr. Mohamed KCHAOU

University of SFAX

TUNUSIA

Prof. Dr. Behçet GÜLENÇ

Gazi University

TURKEY

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IMSMATEC’21 VİDEOKONFERANS PROGRAM

28 MAY/ 28 MAYIS 2021

09:30	**OPENING CEROMONY/AÇILIŞ TÖRENİ HALL OPENING / AÇILIŞ SALONU**
	İstiklal Marşı ve Saygı Duruşu/ National Anthem and Stance of Respect
	Sempozyum Başkanı Doç. Dr. Cemal ÇARBOĞA’nın Konuşması/ President of the Symposium Assoc. Prof. Dr. Speech by Cemal ÇARBOĞA
	Mühendislik /Mimarlık Fakültesi Dekanı Prof. Dr. Aslıhan KARATEPE’ nin Konuşması/ Dean, Faculty of Engineering / Architecture Dr. Speech of Aslıhan KARATEPE
	Nevşehir Hacı Bektaş Veli Üniversitesi Rektör Yardımcısı Prof. Dr. Serkan ŞAHİNKAYA’nın Konuşması/Nevşehir Hacı Bektaş Veli University Vice Rector Prof. Dr. Serkan ŞAHİNKAYA's Speech
Session Chairman /Oturum Başkanı: Prof. Dr. Recai KUŞ HALL OPENING / AÇILIŞ SALONU	
10:00-10:15	**INVITED SPEAKER:** Prof. Dr. Behçet GÜLENÇ/ QUALITY AND CONTROL IN WELDED STEEL STRUCTURES
10:15-10:30	**INVITED SPEAKER:** Prof. Dr. Jamal FAJOUI / THERMO-VISCOELASTIC MODELING OF PVC FOAM BASED ON DMA TEST
10:30-10:45	**INVITED SPEAKER:** Prof. Dr .Igor Alex VAKULENKO/ INFLUENCE FERRITE GRAIN SIZE ON THE DEVELOPMENT OF DISCONTINUOUS FLOW AT LOW CARBON STEEL
10:45-11:00	**INVITED SPEAKER:** Prof. Dr. Mohamed KCHAOU / INNOVATIVE METHODS FOR OILY WASTEWATER TREATMENTS
Session Chairman /Oturum Başkanı: Prof. Dr. Yavuz SUN HALL 1 / SALON 1	
11:00-11:15	**SYNTHESIS OF POLYETHYLENE IMINE (PEI) FUNCTIONALIZED IRON OXIDE NANOPARTICLES BY CONTINUOUS FLOW METHOD** Nevzat Akkurt, Cem Levent Altan, Mehmet Fahri Saraç
11:15-11:30	**INVESTIGATION OF THE EFFECTS OF ADDITIVES AND RUBBER TYPE ON VULCANIZATION AND MECHANICAL PROPERTIES IN SPECIAL MIXING RATIOS RUBBERS USED IN AGRICULTURE TYRE TREAD COMPOUNDS** Furkan Çeltik, Enes Kılıç,Ekrem Altuncu
11:30-11:45	**THE EFFECTS OF NEODYMIUM-CATALYZED BUTADIENE RUBBER AND PROCESS AIDS ON DIE SWELL AND PROCESSABILITY PROPERTIES WHILE EXTRUSION OF HEAVY DUTY VEHICLE TIRES** Enes Kılıç, Furkan Çeltik, Ekrem Altuncu
11:45-12:00	**SIDE DOOR ARCHITECTURES IN PASSENGER CARS** Kenan Sert
Session Chairman /Oturum Başkanı: Assoc. Prof. Dr. Bülent AYDEMİR HALL 2 / SALON 2	
11:00-11:15	**TRIBOLOGICAL BEHAVIOR OF SEVERELY DEFORMED COPPER ALLOY AT ELEVATED TEMPERATURE** Muhammet DEMİRTAŞ
11:15-11:30	**EFFECT OF DIFFERENT VOLTAGES ON THE MORPHOLOGICAL AND STRUCTURAL PROPERTIES OF ZNO NANOWIRES** Ahmet Emrecan Öksüz, Metin Yurddaşkal, Tuncay Dikici
11:30-11:45	**PREPARATION AND CHARACTERIZATION OF EMULSION-TEMPLATED POROUS FOAMS CONTAINING ALUMINUM-SILICATE NANOPARTICLES AS A SUPPORT MATERIAL FOR SHAPE-STABILIZED PHASE CHANGE MATERIALS** Sena BAYRAM, Hatice Hande MERT
11:45-12:00	**USING SURFACE MODIFIED PUMICE FOR THE PREPARATION OF POLYHIPE MATERIALS** Ali Eslek, Emine Hilal Mert, Hatice Hande Mert, M. Selçuk Mert
Session Chairman /Oturum Başkanı:Assist. Prof. Dr. Kubilay KARACİF HALL 3 / SALON 3	
11:00-11:15	**FRICTION DRILLING METHOD AND ITS APPLICATION AREAS** Melahat AKA, Oğuz ERDEM
11:15-11:30	**HARDNESS AND ADHESION PROPERTIES OF PVD- (TI, CR, NB)-HBN** Yaşar SERT, Mustafa YEŞILYURT, Osman GÜNAYDIN, Tevfik KÜÇÜKÖMEROĞLU, Levent Taylan EMİR, Gökhan GÜLTEN
11:30-11:45	**ROOT CAUSES AND SOLUTION OF HOLES AND LEAKAGE PROBLEM OCCURED IN PET BOTTLE PRODUCTION** Mustafa Timur, Halil Kılıç

Influence Ferrite Grain Size on the Development of Discontinuous Flow at Low Carbon Steel

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Abstract

On example of low-carbon steel, it is shown that development of strain hardening processes, starting from the moment initiation of plastic deformation, determines nature behavior of the metal at all subsequent stages of loading. The conditions formation of deformation bands and reasons for the disappearance of intermittent yield section on the deformation curves are considered. The use of the dependence characteristics of strain hardening on the size ferrite grain made it possible to explain evolution structure of low-carbon steel at region of intermittent flow.

Keywords: Steel, ferrite, grain size, strain hardening

1. Introduction

The strength properties of most metallic materials near the grain boundaries of the matrix are of approximately the same order of magnitude as compared to the perfect crystalline structure [1]. On other hand, dependence of the result stress on activation a certain dislocation slip system and structure of the grain boundary itself indicate the development of complex structural changes upon its overcoming . On this basis, for single-phase alloys, the grain size (d) is considered to be the main structural element that determines the conditions for the initiation and propagation of deformation [2,3]. For low carbon steels, this characteristic is the grain size of ferrite [4].

2. Material and research methods

The material for the study was low-carbon steels with a carbon content of 0.06 - 0.07% C. Various ferrite grain sizes were obtained as a result of various thermal and thermo mechanical treatments (quenching for martensite and tempering at 650°C; normalization; isothermal decomposition at temperatures of 500 - 550°C, plastic deformation by drawing by 30-90% and annealing at 650°C). The strain hardening characteristics were determined from analysis of the logarithmic tensile curves. The structure of the steels was investigated using light microscopy. The ferrite grain size was determined using quantitative metallographic techniques [4].

3. Results

3.1. Determination of strain hardening.

In the process of plastic deformation metal material, the interaction of moving dislocations with defects crystal structure is accompanied by deceleration, up to their complete stop. To resume plastic flow, it is necessary to unblock dislocations, which becomes possible only due to an increase at resulting stress. The observed phenomenon of deforming force growth called the strain hardening [5]. To assess the effect of strain hardening developed a variety of techniques based on the analysis of strain curves [5,6]. These curves represent locus by points of ratio between degree of plastic deformation (ε) and effective stress (σ). In appearance, the deformation curves of metallic materials are divided into two types: with a section of intermittent flow (Fig. 1a) and without it (Fig.1b). At sector of the *A-C* curve, propagation of plastic flow is extremely heterogeneous.

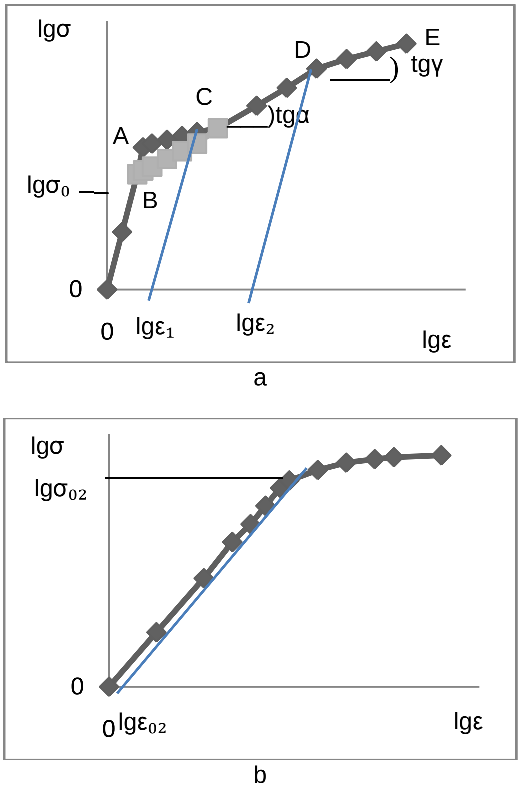
The deformation is provided to the expansion (growth) of the deformation bands, which at literature are called the Luders bands [7]. Degree of deformation on such band in absolute values coincides with the length of yield sector (*AC*). In units of ε, such a deformation is called the Luders deformation (ε_L). Deformation at sector *AC* ends when the entire working part of the sample is deformed by an amount of ε_L. At case of the second type yield, the deformation curve has no section of discontinuous flow. Various analytical dependencies are used to describe the patterns of change in deformation curves. One of them is the Ludwik ratio [8]:

$$\sigma = \sigma_0 + K \cdot \varepsilon^m , \qquad (1)$$

where σ_0 - stress of irreversible motion of dislocations, K-constant, m- exponent. To determined σ_0, m depending on the ratio used, the deformation curve is plotted in logarithmic coordinates (Fig. 1a). The value of σ_0, is determined as a result extrapolation area of uniform strain hardening (*CD*) to zero plastic deformation (sector *BC* Fig. 1a) [9]. After transformations (1) we get:

$$\frac{d\sigma}{d\varepsilon} = \frac{m(\sigma - \sigma_0}{\varepsilon} \qquad (2)$$

Taking into account that dσ/dε is a measure of the increment σ from ε, this characteristic is called the rate of strain hardening [4.10]. The comparative nature of the change dσ/dε from ε and increase dislocation density (Δρ) at strain hardening of curve deformation showed performance of the relation [2,4]:



a

b

Fig.1. The curve of deformation at logarithmic coordinates with a region of discontinuous flow (A-C) (a) and without of that sector (b).

$$\frac{d\sigma}{d\varepsilon} = f(\Delta\rho) \qquad (3)$$

Thus, proportion to the heterogeneous yield area of length (ε_L), the metal has a certain accumulated dislocation density. The larger ε_L, the higher should be number of dislocations on system at the time onset of Consequently, with an increase in ε_L, the metal should have reduced characteristics of strain hardening. The fulfillment of the ratio between ε_L and m (Fig. 2) confirms the developed dislocation substructure.

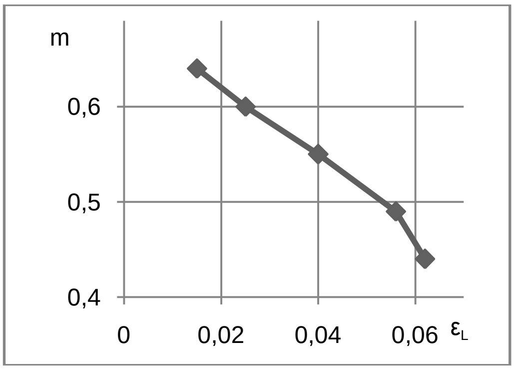


Fig.2. Effect of Luders strain (ε_L) on the exponent m. deformation at homogeneous strain hardening.

3.2. Influence ferrite grain size on strain hardening at region interrupted deformation.

Based on the analysis of deformation curves low-carbon steels (Fig. 1.a), the values σ_0 and yield stress (σ_Y) on the ferrite grain size (Fig. 3) obeys the relation [11,12]:

$$\sigma_Y = \sigma_i + k_Y d^{-0,5} \qquad (4$$

Where σ_i - is some initial stress, k_Y - is the slope coefficient. Depending on the loading conditions and investigated processes of plastic deformation, the value of σ_i is quite often identified with the friction stress crystal lattice [9], with the increase stress due to the presence impurity atoms at alloy [9], crystal lattice defects from embedded atoms [2], flow stress, the yield point of a single crystal [4]. The value k_Y characterizes the stress intensity from accumulation dislocations at slip plane near grain boundary [11].

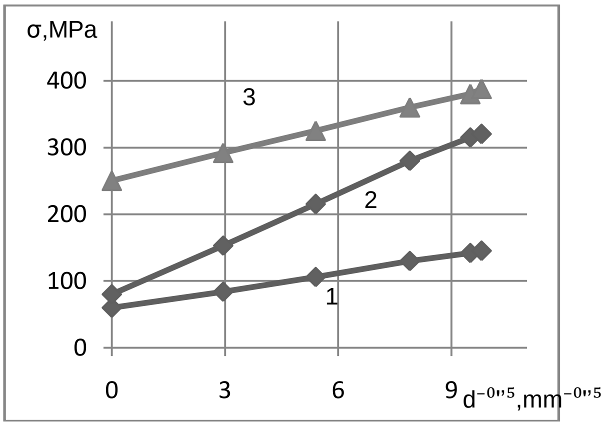


Fig.3. Influence of ferrite grain size by ratios (4), for σ_0, (1), yield of stress (2) and ultimate strength (3) of low-carbon steel with 0.06% carbon.

Detailed studies of changes at dislocation structure on the grain size of low-carbon steel ferrite made it possible to determine - the dislocation density at the beginning plastic flow is inversely proportional to the size of ferrite grain::

$$\rho \approx \frac{1}{d} \qquad (5)$$

The use of relation (5) makes it possible to assess the role of strain hardening processes at the stages of nucleation and propagation of deformation bands. Indeed, as shown in [13], deformation into the front of Luders band with a width of λ varies from ε=0 to ε_L (Fig. 4). Considering that a certain amount "*a*" of grains is laid along the length, gradient of deformation by the front of strain band will be:

$$\frac{d\varepsilon}{d\lambda} = \frac{\varepsilon_L}{a \cdot d}, \qquad (6)$$

In essence, the value of dσ/dε should depend not only on the initial dislocation density, but also on the magnitude of its increment during formation of the deformation band. According to the Orowan relation [9], the local strain rate (ε*) is generally estimated as follows:

$$\varepsilon^* = \rho_m \cdot b \cdot k \cdot v \qquad (7)$$

where ρ_m is the density of mobile dislocations, *b* is the Burgers vector, k is the geometric factor, which is equal up to 1, and v is the velocity of dislocation movement. Compared with (7), ε* can be represented in terms of dσ/dε for the front of deformation band:

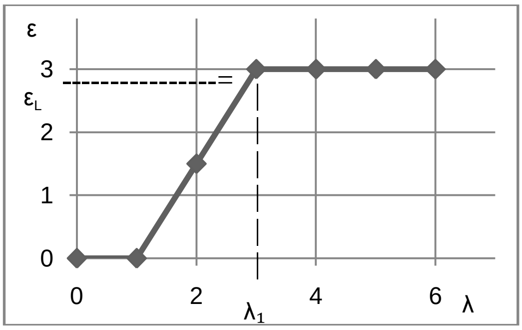


Fig.4. Diagram distribution magnitude of plastic deformation into by front of Luders band (ε_L is the Luders deformation, λ is the width of band front in units of grain size).

$$\varepsilon^* = v_L \cdot \frac{d\varepsilon}{d\lambda} \qquad (8)$$

Where v_L is the speed of movement front deformation of the band. Assuming that v_L cannot greater than v, for the initial conditions propagation of plastic deformation, the following relation should be satisfied:

$$v = v_L \qquad (9)$$

Equating (7) and (8) with each other, taking into account (6), finally obtain that for the formation of a deformation band of ε_L in steel with a ferrite grain size, the required density of mobile dislocations [13] :

$$\rho_m = \frac{\varepsilon_L}{a \cdot b \cdot d}, \qquad (10)$$

where *a* is the number ferrite grains that fit on width front of the deformation band. It was found experimentally [13] that the quantity *a* is actually a variable characteristic. Depends on the size of ferrite grain and can range from one to several *d*. The maximum value of *a* does not exceed 3. On this basis, one should take into account the existence of a certain gradient density of dislocations at transition from the peripheral sections front of the deformation band to the volumes of metal that have already undergone Luders deformation. After combining relations (2), (3), and (10) obtained a relation that allows us to estimate effect of the ferrite grain size on dσ/dε:

$$\frac{d\sigma}{d\varepsilon} = \frac{m \cdot k_Y^1}{a \cdot b \cdot {}_m \cdot d^{1,5}} \qquad (11)$$

From the analysis of relation (11) it follows that after appearance a first signs of plastic deformation, the rate of strain hardening is inversely proportional to the size ferrite grain of low-carbon steel and density of mobile dislocations to maintain conditions for the propagation plastic flow. Thus, with an increase at grain size, the required density of mobile dislocations for plastic deformation of the metal will decrease. After substituted experimental values m, k, d and dσ/dε in (11), the ρ_m were calculated. Comparative analysis with the known data showed a fairly good agreement (Fig.5b). With an increase at ferrite grain size, the required density of mobile dislocations to maintain plastic flow on yield area decreases. On this basis, the accumulated density of dislocations by metal at moment beginning region of uniform strain hardening also decreases. In contrast, a decrease at ferrite grain size is accompanied by an increase by total dislocation density at onset of deformation on region of homogeneous strain hardening. Moreover, taking into account existence limiting value of the dislocation density, after which fracture occurs of metal [2,9], low-carbon steel will be have a lower plasticity reserve until formation of the first sub- or micro cracks. On other hand, as the grain size ferrite of low carbon steel increases, Luders strain decreases. Considering that for steels intended for deep drawing, presence of ε_L is a rejection indicator, let us consider conditions for disappearance of the discontinuous flow section on the deformation curve. The yield stress (σ_Y) and σ_0 of low carbon steel obey same

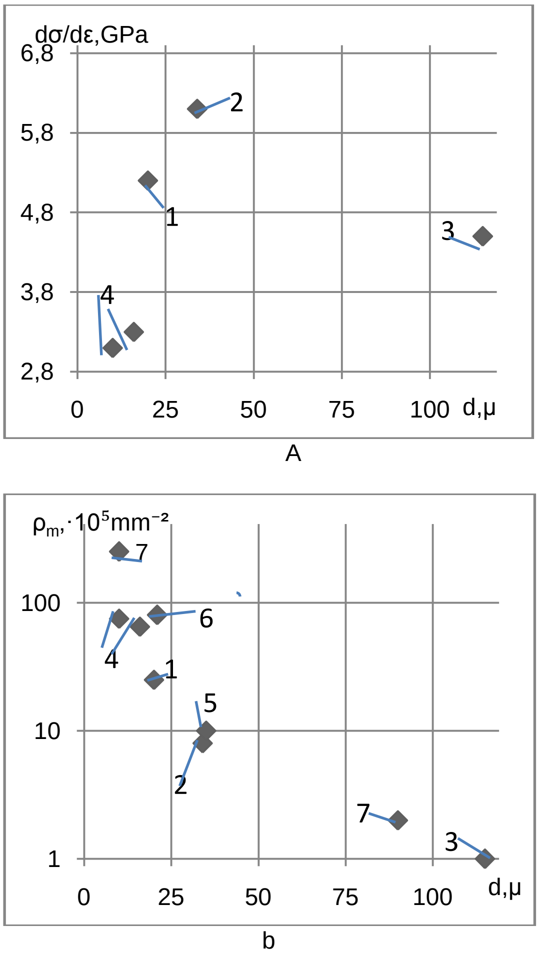


Fig. 5. The effect grain size ferrite of low-carbon steel on the rate of strain hardening (a) and density of mobile dislocations required for the formation of deformation bands (b). Structure state of steel with 0,06%C after patenting (1), normalization (2), quenching and tempering 680°C (3), patenting, deformation 75–90% and annealing 680°C (4), [14] - (5), [15] - (6), [16] - (7)

dependence on the grain size of ferrite (4) (Fig. 3). With an increase grain size of ferrite, at stresses of order of σ_0, to maintain conditions for the propagation of plastic deformation, required density of mobile dislocations will proportionally decrease (Fig. 5b). This position is confirmed by the observed dependences Fig. 5a and $\varepsilon_L \sim f(d)$ (Fig. 6). Moreover, formal plotting of experimental data ε_L against corresponding values of the strain hardening rate, for example, for ε=0,05 indicates existence of an unambiguous inversely proportional relationship between them (Fig. 7). Thus, by increasing the ferrite grain size, it is possible to achieve such a structural state at metal that there will be no section of intermittent flow on the deformation curve. From the analysis of Fig.3 it follows that with an increase at grain size ferrite of low-carbon steel, the rate of decrease at yield stress significantly exceeds the analogous characteristic for σ_0:

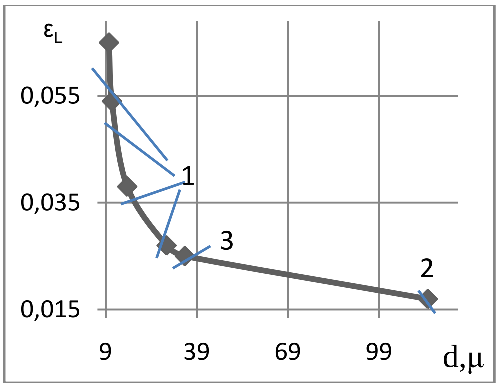


Fig.6. The influence grain size ferrite of steel with 0.06% C on ε_L. For structural states of steel: (1) - isothermal transformation at a temperature of 550°C, deformation by drawing by 25–90% and annealing at 680°C, 1 h; (2) - quenching for martensite and tempering at 680°C, 1 h; (3) - normalization.

$$\frac{d\sigma_Y}{dd} > \frac{d\sigma_0}{dd} \qquad (12)$$

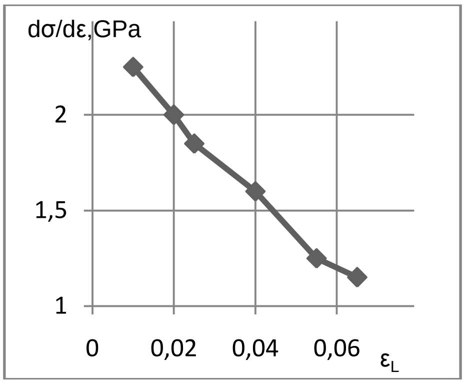


Fig.7 Mutual variation of dσ/dε and ε_L.

It can be assumed with some certainty that the larger ferrite grain size, the lower deformation (position point *D*, Fig. 1a) of formation of dislocation structure with a certain periodicity. Indeed, as follows from the analysis deformation curves of low-carbon steel, increase at ferrite grain size is accompanied not only by a decrease in ε_L, but also by a progressive decrease deformation on curve separating the sections (point *D*, Fig.1a). As a result extrapolation of dependences (Fig.8) in the direction of increasing grain size of ferrite, a moment when the indicated ratios intersect the abscissa axis (ε_L and $\varepsilon_n \to 0$) corresponds approximately to the value d near 700μ. It follows from that when the ferrite grain size of low-carbon steel is more than 700μ it is rather difficult to form a deformation band capable of growing, as for fine-grained structures. One of probable reasons is the difficulty in maintaining a certain gradient in distribution of dislocations by a front of the deformation band. Formally, it can be assumed that at case extremely low values of ε_n, increase at probability decomposition of uniform distribution dislocations violates conditions formation of a certain gradient of dislocations as a result, it is impossible to form a nucleus of a deformation band capable of growth. A detailed analysis of the microstructure given in [7] and results obtained confirm the above provisions. From the analysis of structure, it was found that at d from 40 to 250 μ, the usual picture formation of deformation bands is observed. Starting from a grain size of 250 μ, process of formation and growth deformation bands has a slightly different character. Indeed, as follows from the analysis of microstructure, in individual grains with a size of 250 μ, areas with an uneven deformation distribution are already observed [7]. In samples with a grain size of 1000 μ it is rather difficult to identify individual deformation bands. According to general concepts, at case, deformation appears to occur simultaneously in entire volume of the metal. Consequently, in low-carbon steels with an increase at ferrite grain size, the observed decrease required density of mobile dislocations for the formation of front of deformation band leads to decrease ε_L. Simultaneously with this, there is decrease in the deformation of appearance dislocation cellular structure. After the ferrite grain size reaches more than several hundred microns, conditions for the formation of a certain gradient in distribution of dislocations over the width of the deformation band front are violated. As a result, the formation of a section of discontinuous yield on the deformation curve is not observed.

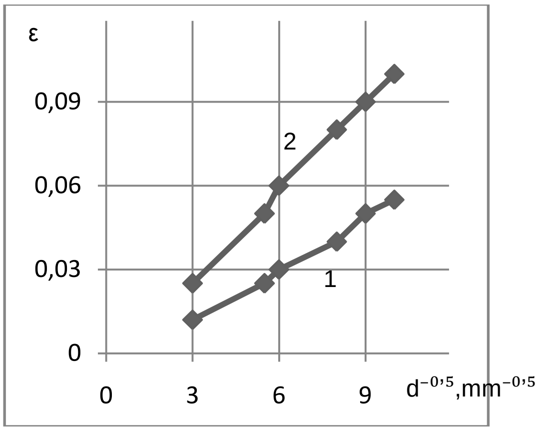


Fig.8. Effect a ferrite grain size of low-carbon steel on ε_L (1) and ε_n (2).

4. Conclusion.

Analysis development of strain hardening processes in the area appearance first signs of plastic deformation is used to explain the phenomenon of intermittent flow in steel. One of the reasons for the disappearance section of discontinuous deformation on the tension curve is the violation conditions for the formation a certain gradient in distribution of dislocations into at front of the deformation band. Proportional to size of the ferrite grain, increase at strain hardening characteristics indicates not only an increase density of mobile dislocations, but also an increase probability of violations in a certain distribution of dislocations. The results obtained can be useful in determining optimal structural state of low-carbon steel intended for cold deformation.

5. References

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