doi: 10.18323/2782-4039-2025-2-72-3

Ductility, bending and wrapping ability relationship in wires made of electromagnetically cast ultrafine grained Al–0.5Fe and Al–0.5Fe–0.3Cu alloys

Andrey E. Medvedev*[1,3], PhD (Physics and Mathematics), senior researcher
Olga O. Zhukova[1,4], engineer-researcher
Darya D. Fedotova[1,5], master, 4th category operator
of the Research Laboratory "Metals and Alloys under Extreme Conditions"
Elvira D. Khafizova[1,6], PhD (Physics and Mathematics), senior researcher
Mikhail M. Motkov[2,7], PhD (Engineering), senior researcher
Maxim Yu. Murashkin[1,8], PhD (Engineering), senior researcher
[1]*Ufa University of Science and Technology, Ufa (Russia)*
[2]*Siberian Federal University, Krasnoyarsk (Russia)*

***E-mail:** medvedevandreyrf@gmail.com

[3]ORCID: https://orcid.org/0000-0002-8616-0042
[4]ORCID: https://orcid.org/0000-0002-1879-9389
[5]ORCID: https://orcid.org/0009-0000-7526-8309
[6]ORCID: https://orcid.org/0000-0002-4618-412X
[7]ORCID: https://orcid.org/0009-0007-1272-3993
[8]ORCID: https://orcid.org/0000-0001-9950-0336

Received 20.03.2025 *Revised 10.04.2025* *Accepted 28.04.2025*

Abstract: The research status on such functional properties, as bending capability, wrapping capability and ductility of conductive Al–Fe and Al–Fe–Cu alloys wires is uncertain. Bending and wrapping capability is determined by the industrial standards while no attempts were made to study the relation between them and ductility of the Al alloys wires, paying even less attention to the ultrafine-grained Al-based wires, produced by electromagnetic casting and equal-channel angular pressing. In this study alloys with two different chemical compositions (Al–0.5 wt. % Fe and Al–0.5 wt. % Fe–0.3 wt. % Cu) and two different casting methods (casting into electromagnetic mold and continuous casting and rolling) were used. Part of the wires for the study was prepared by cold drawing (CD), the other part – by the combination of the equal-channel angular pressing by the Conform scheme and cold drawing (ECAP-C+CD) to obtain coarse grained (CG) and ultrafine grained (UFG) structures, respectively. Annealing at 230 °C for 1 h was carried out to evaluate the thermal stability of the wires. It was shown that the correlation between ductility (elongation to failure), number of wraps and number of bends (both before the first crack and before complete failure of the specimen) may differ depending on the deformation value, deformation scheme, and amount of alloying elements of the alloy wire, as well as ability to form solid solutions.

Keywords: Al alloy; Al–Fe; Al–Fe–Cu; electromagnetic casting; continuous casting and rolling; equal-channel angular pressing; cold drawing; elongation to failure; ductility; wire bending; wire wrapping; fracture analysis.

Acknowledgments: The work was supported by the Russian Science Foundation, grant number 20-79-10133, https://rscf.ru/project/20-79-10133/.

The research part of the work was carried out on the equipment of the Core Facility Centre "Nanotech" of Ufa University of Science and Technology.

The authors express their gratitude to Professor V.N. Timofeev (Siberian Federal University) for providing the research material.

For citation: Medvedev A.E., Zhukova O.O., Fedotova D.D., Khafizova E.D., Motkov M.M., Murashkin M.Yu. Ductility, bending and wrapping ability relationship in wires made of electromagnetically cast ultrafine grained Al–0.5Fe and Al–0.5Fe–0.3Cu alloys. *Frontier Materials & Technologies*, 2025, no. 2, pp. 29–38. DOI: 10.18323/2782-4039-2025-2-72-3.

INTRODUCTION

Aluminium and aluminium alloys are among the most widespread materials in different areas of industry. The increased use of the aluminium and its alloys is dictated by their increasing competitiveness with copper alloys. Low cost, high availability, sufficient mechanical strength and electrical conductivity, coupled with high ductility and corrosion resistance ensure the growing presence of these alloys in different areas of industrial complex [1].

Aluminium and its alloys possess a few properties, and their importance and acceptable levels depend on their application. Hence, for electrical wires and cables the electrical conductivity, mechanical strength, and ductility are the most important [2]. Electrical conductivity is the primary factor here since it determines the ability to transfer electrical current, thus the most important property for the electrical wire. Mechanical strength is important in applications that involve any notable value of stress applied to the wire or cable, such as the overhead powerlines. The ductility determines the level of deformation that wire, or cable can endure before cracking or failure, thus meaning how flexible it is for different ways of mount.

Most often research papers only present the ductility of the studied material, which is insufficient for complex evaluation of the material functional properties. It is true that wires and cables used in the electrical industry in most cases are subjected to static load schemes, meaning tensile tests are the fastest way to obtain the experimental data that would be enough for most of the applications. However, in some real-life application cases such parameters, as fatigue [3], number of bends [4], winding capability [5] and fretting resistance [6] do matter. In terms of practical application, every important parameter should be evaluated, since there is no direct correlation of the different properties between each other.

For the overhead powerlines and other applications that withstand cyclic loads, fatigue tests are required. The fatigue tests are expensive and time-consuming, so they are not implemented in cases when the wire or cable has only static loads, or is only deformed once (for example, during mounting). For these cases, the ability to withstand bending and wrapping has higher importance [7].

The research on the matter of bending and wrapping capabilities of conductive aluminium alloys is very scarce. The values of these parameters are most often dictated by standards, such as ISO 7801:1984 "Wire. Bending test method" or ISO 7802:2013 "Metallic materials. Wire. Wrapping test". These standards determine the minimal amount of bends or wraps that the material should withstand in order to pass the bar, with no regard to the ductility of the material. However, as it was mentioned in the previous paragraph, the relationship between these parameters is of high interest.

Of particular interest are the alloys with an ultrafine-grained (UFG) structure formed in conductive materials by severe plastic deformation (SPD) methods. These materials usually demonstrate a very favorable "strength – electrical conductivity" combination, but ductility does not always exceed that of analogs produced by conventional methods [8]. In this regard, the study of the behavior of wires with a UFG structure, which have high strength and good electrical conductivity along with acceptable wrapping and bending abilities is very important for assessing their further use to produce conductors with a new level of properties, as well as the suitability of such conductors for installation. According to the results of our recent studies, Al–Fe aluminium alloys with the UFG structure demonstrate a combination of "strength-electrical conductivity-heat resistance" that is not competed by aluminum alloys of other alloying systems as Al–Mg–Si and Al–Zr etc., widely used in the cable industry [9].

The purpose of this study is to establish the relation (or absence of it) between ductility (total elongation to failure), bending and wrapping capabilities of the electrically conductive wires made of Al–Fe and Al–Fe–Cu aluminium alloys in both coarse-grained and ultrafine-grained states.

METHODS

Two different alloys – Al–0.5 wt. % Fe and Al–0.5 wt. % Fe–0.3 wt. % Cu – were picked for the study. These alloys have chemical composition similar to that of commercial 8176 [10] and 8030 alloy [11], respectively. The alloys were produced via casting into electromagnetic mold (electromagnetic casting, EMC) for the purpose of fine chemical composition control and identical casting conditions. For the comparison part of the Al–0.5 wt. % Fe alloy samples were produced via continuous casting and rolling method (CCR), conventionally used for aluminium alloys. The chemical composition of the alloys is presented in Table 1. CCR alloy was chosen as a one to be compared with, since it is produced by the conventional technique, contrary to Al–0.5Fe (EMC) and Al–0.5Fe–0.3Cu (EMCM) alloys, produced via relatively new method of casting into electromagnetic mold. As established by the authors in the course of their previous studies, although the addition of 0.3 % Cu adds mechanical strength and thermal stability to the alloy, it also requires a very careful approach in terms of obtaining and processing, thus the EMC method was applied to it [12].

Table 1. *Chemical composition of alloys of the Al–Fe system, wt. %*
Таблица 1. *Химический состав сплавов системы Al–Fe, вес. %*

Alloy	Alloy designation	Si	Fe	Cu	Σ(Mg, Zn, V)	Al
Al–0.5Fe	EMC	0.04	0.50	0.01	<0.01	Rem
Al–0.5Fe	CCR	0.06	0.48	0.01	<0.20	Rem
Al–0.5Fe–0.3Cu	EMCM	0.02	0.50	0.30	<0.01	Rem

Samples of the alloys studied were subjected to two different deformation treatments: cold drawing (CD) and combination of the equal-channel angular pressing (by the Conform scheme [13]) and cold drawing. The ECAP by the Conform scheme (ECAP-C) includes placing a wire rod of 11 mm in diameter into a pressing channel comprised of a running wheel die with the pressure arranged along working surfaces. Friction resistance forces a wire rod going from a running wheel die into a channel formed by a pressure arrangement and a gauge, coupling at a certain angle ψ with a wheel die. Shear straining occurs at an intersection of these channels (deformation zone). An intersection angle of channels ψ constituted 120° with four processing cycles. A wire rod was rotated around the axis by +90° after each ECAP-C cycle (route B_c), at room temperature (RT). As a result of ECAP-C processing, samples with a cross section of 10×10 mm and a length of at least 100 mm were obtained.

During the CD the samples were subjected to cold deformation on a laboratory drawing machine with a drawing ratio of 13.5 (relative compression ~75 %). As a result of the CD, wire samples with a diameter of 3 mm were obtained. Samples of the original wire rod were also subjected to CD using similar conditions.

Annealing at 230 °C for 1 h was carried out in an atmosphere Nabertherm B180 (Germany) furnace according to the IEC 62641:2023.

JEOL JSM 6940LV (Japan) was used to perform scanning electron microscopy. Additional fracture analysis was conducted in order to provide insight into the fracture behavior of the EMCM alloy.

To obtain statistically reliable results, tensile tests were carried out on three samples for each state on a universal tensile testing machine Instron 5982 (USA) at RT. The strain rate of 100 mm/min (for wire samples after cold drawing according to ASTM A931-96). Based on the test results, the values of elongation to failure (δ) were determined. The tensile tests were carried out on the samples after cold drawing (CD), after ECAP-C and cold drawing (ECAP-C+CD), as well as after annealing.

The bending tests were conducted according to ISO 7801:1984. For each state at least 3 samples were tested. On the special testing rig each sample was tested, and the number of bends until first crack (*C*) and until complete failure (*F*) was recorded.

The wrapping tests were conducted according to ISO 7802-2013. The requirements of the GOST 10447-93 were also noted. At least one sample was tested for each state. Wire samples of 3 mm in diameter were tightly wrapped around steel rod of 3 mm in diameter with the rate of no more than 1 s^{-1}. For passing the test each sample should withstand at least 5 turns, where 1 turn is equivalent for the 360° rotation. Different standards have different regulations for the acceptable number of wraps, from 5 (according to GOST 10447-93) up to 16 (according to ISO 7802:2013). Authors have made the conclusion based on the test results, that in case of 5 successful wraps, further wrapping goes unobstructed, until some major microdefect is presented, or the experimenter runs out of testing material. In this study authors took the regulations presented in GOST 10447-93.

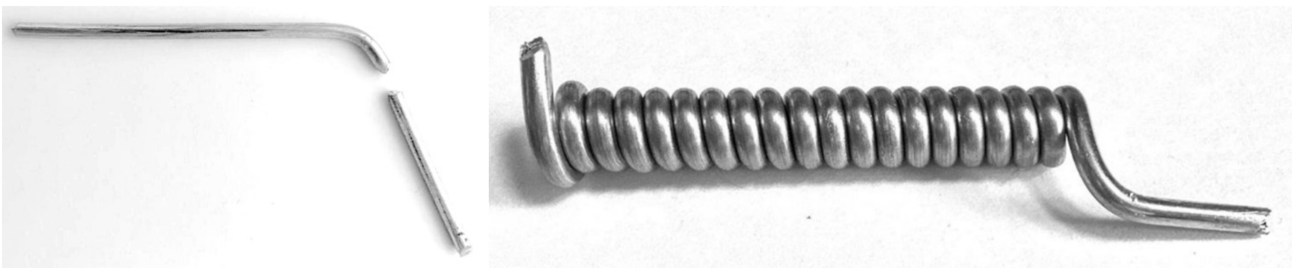
RESULTS

Wrapping, bending and tensile tests assessment

Fig. 1 demonstrates the view of the samples after bending and wrapping tests. It may be noted that the fracture of the bending sample occurs not in the region of the bending, but at the periphery of it. Surface of the samples after both types of tests contains no visible defects.

Table 2 contains the results of the tensile, bending and wrapping tests of all studied materials: EMC, CCR and EMCM. Cold drawing provides the ductility (elongation to failure) of about 5 % on average in all alloys' samples, except for the EMCM alloy, where its average level is 2 %. According to IEC 62641:2023 the minimum elongation to failure of aluminium wires is 1.7 % for the cold-drawn state and 3.5 % for the annealed state. All the alloys studied have passed the 2 % elongation to failure mark. Some of the alloys surpass even the requirements for the annealed wires.

Combined ECAP-C+CD in low-Fe alloy, such as EMC and CCR, results in decreased, relatively to CD, level of ductility. Since these alloys could be considered as technically pure aluminium, they act like one, and an increase in the deformation value leads to the aforementioned results.



a *b*

Fig. 1. *Samples after bending (**a**) and wrapping (**b**) tests.*
Both samples are made of wire of 3 mm diameter
Рис. 1. *Внешний вид образца после испытаний на перегибы (**a**) и навивы (**b**).*
Оба образца изготовлены из проволоки диаметром 3 мм

Table 2. *Results of the wrapping, bending and tensile tests*
Таблица 2. *Результаты испытаний на навивы, перегибы и растяжение*

Alloy	State	Wrapping			Bending		Ductility
		Total number	Meeting requirements of GOST 10447-93	Meeting requirements of ISO 7802:2013	Until the first crack, *C*	Until complete failure, *F*	Elongation to failure, %
EMC	CD	>16	yes	yes	8–9	11–13	4.9±0.4
	CD+230 °C	>16	yes	yes	7–8	12–13	3.8±0.7
	ECAP-C+CD	>16	yes	yes	9	12	2.8±0.2
	ECAP-C+CD+230 °C	>16	yes	yes	7	10–11	2.5±0.3
CCR	CD	>16	yes	yes	8–11	9–15	5.6±0.4
	CD+230 °C	>16	yes	yes	6–11	14–16	3.2±0.5
	ECAP-C+CD	>16	yes	yes	9–10	12–14	2.7±0.2
	ECAP-C+CD+230 °C	>16	yes	yes	8	11–14	2.2±0.7
EMCM	CD	>16	yes	yes	6–9	7–10	2.3±0.4
	CD+230 °C	>16	yes	yes	9	11–13	3.1±0.3
	ECAP-C+CD	0	no	no	1	1	2.7±0.5
	ECAP-C+CD+230 °C	>16	yes	yes	10–12	14–30	7.2±3.7

The most notable difference between CD and ECAP-C+CD is observed in the EMCM sample. The introduction of the ECAP-C stage significantly increases the elongation to failure, but at a level that lies within the error value. Still, the total elongation to failure of the EMCM samples is higher than 2 %, which is considered to be sufficient for practical applications according to IEC 62641:2023. In EMC and CCR alloys, contrary to the EMCM, the annealing at 230 °C after CD and ECAP-C+CD results in a small, but notable decrease in ductility.

Table 2 contains, in addition to ductility data, results of the wrapping tests of the studied alloys. The only exception for the successful wrapping tests passage (the minimum amount of wraps is 5 according to the GOST 10447-93) was demonstrated by the EMCM alloy in the ECAP-C+CD state. Not a single wrap was possible to make since the wire was fracturing upon wrapping. In the CD state, however, the wire made of EMCM alloy demonstrated the sufficient number of wraps. Although elongation to failure of the EMCM alloy sample in the ECAP-C+CD state is relatively high, it has no direct correlation with the wrapping ability. The EMCM alloy in ECAP-C+CD state after annealing does pass the wrapping test. However, the first wraps were partially cracked, and only after a couple of wraps did the test continue smoothly.

Table 2 shows the number of bends before the first crack (C) and before complete failure (F). The values related to the elongation to failure of these wires are also given. It is more reasonable to assess the ability of the wire to bends by the number of bends C, and not F – if the spread of C values is insignificant, then the spread of parameter F can reach several tens of units, especially in the annealed state.

Most of the wires in the studied states meet this criterion, except for EMCM alloy in the ECAP-C+CD state – the wire in this state is so brittle that it fails already at the first bend on each of the studied samples.

With the increase of the parameters C and F, in most cases the parameter δ (ductility) also increases, especially in the annealed states. However, this correlation is not straightforward. The most striking illustration is the ECAP-C+CD state of the EMCM alloy – despite the acceptable level of δ of 2.7±0.5 %, the wire in this state does not withstand even one bend. At the same time, the EMCM wire in the CD state, characterized by similar values of δ (2.3±0.4%), not only surpasses the ECAP-C+CD state in the parameters C and F, but also successfully meets the requirements of ISO 7801:1984 and IEC 62641:2023.

Fracture analysis of the EMC and EMCM alloys

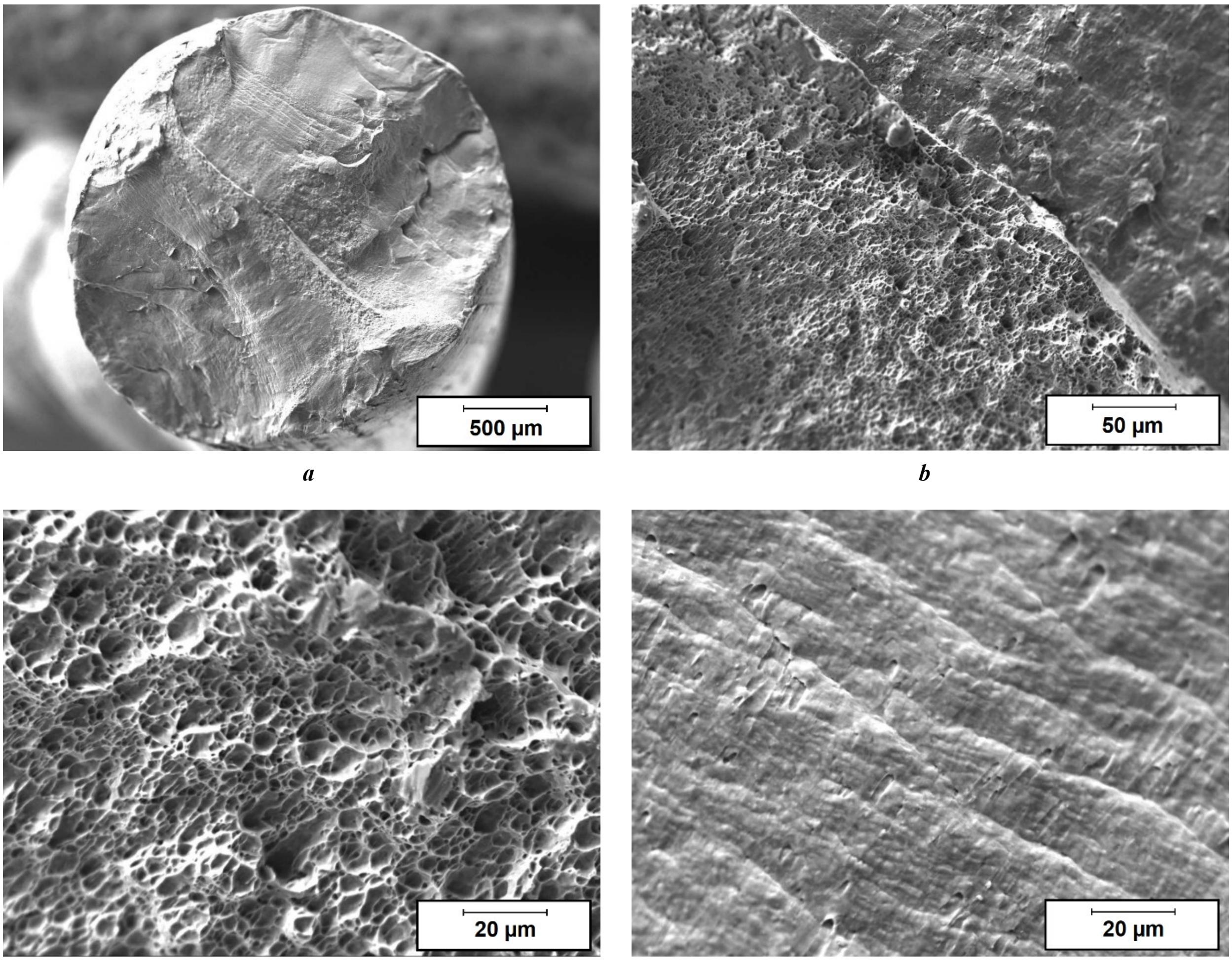
The fracture surface of the EMC alloy in the CD state (Fig. 2) has clearly a ductile nature. Surface has a break line across the fracture surface (Fig. 2 a, b). On one side of the break line there are round dimples, characteristic for the ductile fracture (Fig. 2 c), on the other – lamellar patterns (Fig. 2 d). These patterns formed as a result of compression of the parts of the sample during the last cycles of the bending test, when the crack has already formed and developed, and parts of the sample were freely moving against each other.

The fracture surfaces of the EMCM alloy in a CD state, as well as EMC alloy in the ECAP-C+CD state are similar in nature (which is expected given these states have similar F value (Table 2), thus they are not presented in the study.

The bending sample of the EMCM alloy after ECAP-C and CD, however, has different fracture behavior, images of which are presented in Fig. 3. The sample was barely able to withstand one bend (Table 2), cracking during it and completely fracturing upon the second bend. Three areas of the fracture surface (Fig. 3 a) correspond to the first crack (1), fracture area (2) and the break area (3). Judging from the number of bends one would expect the fragile nature of the fracture, but the fracture analysis indicates the opposite – the fracture surface consists of dimples (Fig. 3 c, d), although they much shallower than that of the other samples (Fig. 2). Process, similar to one in cold-drawn EMC alloy sample (Fig. 2 d), occurs in the fracture area – two parts of the sample compressed against each other, crumpling and smoothing the dimpled surface (Fig. 3 d).

DISCUSSION

The research literature on the subject is very scarce, making this study somewhat unique. The general requirements for the wires are given in standards (ISO 7801:1984, IEC 62641:2023, ISO 7802-2013, GOST 10447-93), but they operate independently, having no connections with each other. However, it would be useful to find out if there



a ***b*** ***c*** ***d***

Fig. 2. *Fracture surface of the bending tests sample of the EMC alloy in the CD state, SEM:*
a *– overview of the fracture surface;*
b *– the border between the last and second-to-last fracture areas;*
c *– magnified image of the actual fracture surface, dimples are visible;*
d *– magnified image of the second-to-last fracture surface, dimples are smoothened by the smashing of the parts of the bending sample*
Рис. 2. *Поверхность излома образца из сплава ЭМК в состоянии ХВ после испытаний на перегибы, СЭМ:*
a *– обзор поверхности излома;*
b *– граница между последней и предпоследней зонами излома;*
c *– увеличенное изображение фактической поверхности излома, видны ямки;*
d *– увеличенное изображение предпоследней поверхности излома, ямки сглажены за счет сминания частей образца*

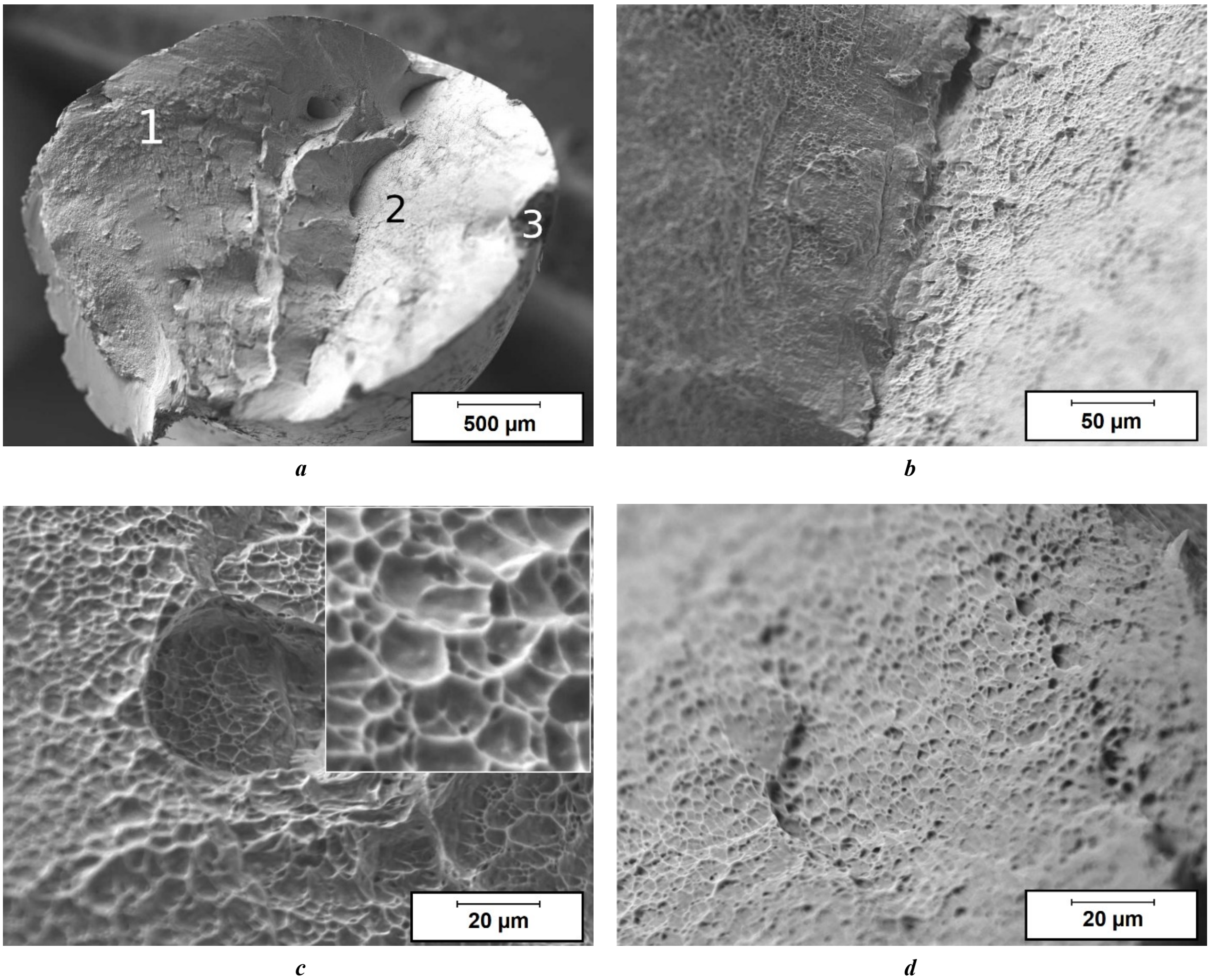
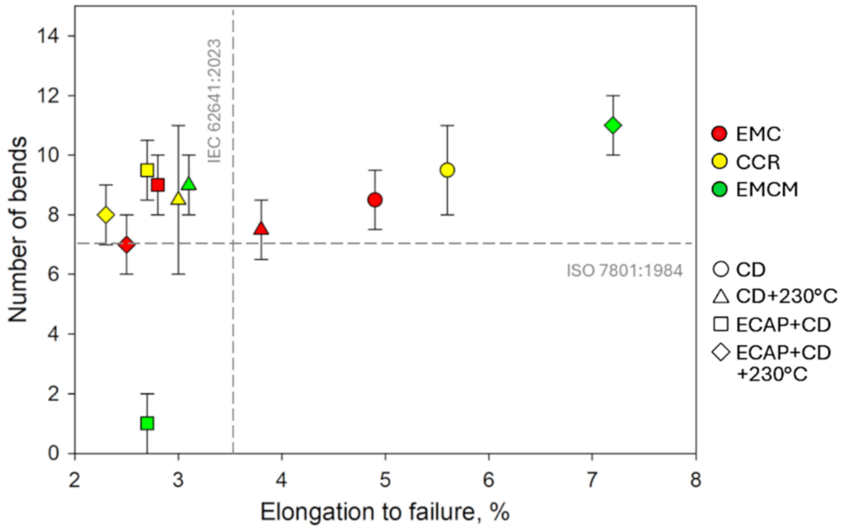


Fig. 3. *Fracture surface of the bending tests sample of the EMCM alloy in the ECAP-C+CD state, SEM:*
a *– fracture surface overview, where 1 – first crack zone, 2 – fracture area zone, 3 – break area zone;*
b *– border between zones 1 and 2;*
c *– the enlarged section of zone 1, as well as even further magnified image of the surface, illustrating the ductile nature of the fracture;*
d *– the enlarged section of the zone 2, it demonstrates smaller, relatively to zone 1, size of the fracture dimples*
Рис. 3. *Поверхность излома образца сплава ЭМКМ в состоянии РКУП-К+ХВ после испытаний на перегибы, СЭМ:*
a *– общий вид поверхности разрушения, где 1 – зона первой трещины, 2 – зона разрушения, 3 – зона отрыва;*
b *– граница между зонами 1 и 2;*
c *– увеличенный участок зоны 1, а также еще более увеличенное изображение поверхности, иллюстрирующее вязкий характер разрушения;*
d *– увеличенный участок зоны 2, на нем видны меньшие относительно зоны 1 размеры ямок*

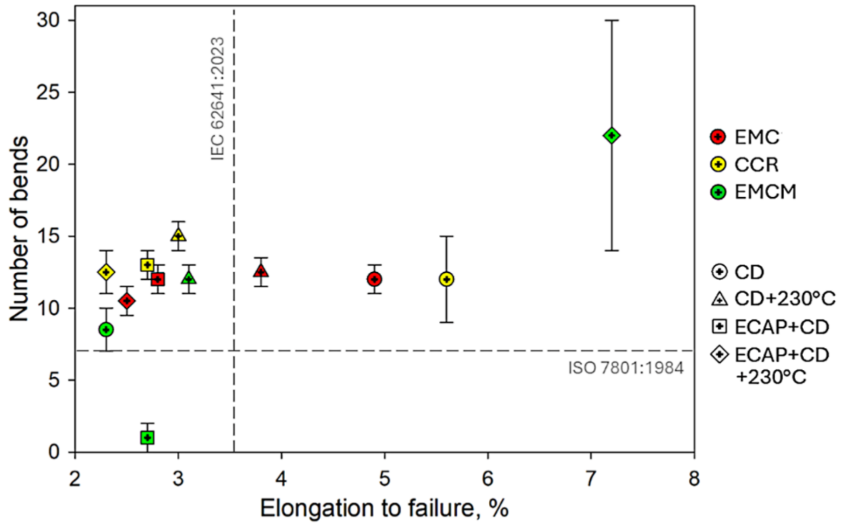
is a correlation between ductility, bending and wrapping capabilities, since it would allow us to predict the behaviorof aluminium materials with higher precision. Thus, the further discussion will be based on the aforementioned standards. The results of tests (Table 2) were visualized in a point plots, presented in Fig. 4.

Fig. 4 shows notable correlation between bending (and wrapping) and tensile tests. The *C* value (Fig. 4 a) demonstrates a certain trend of increasing with the increase of the sample's ductility. Increased ductility of the sample provides the means for the material to accumulate higher amount of deformation thus increasing the deformation that the sample can withstand until the first crack. However, in the area of relatively low ductility (below 3 %), the *C* values of the studied alloys almost merge, showing little to no difference. It should be noted that the *F* value in most cases has higher error value, showing that the accumulation of the deformation during the bending tests goes uneven (Fig. 4 b). It also means that the surface defects have a greater role in *F* value compared to *C* value. The dependance of the *F* value from the ductility is notable, contrary to *C*, in the area of lower ductility (below 3 %), where increase in elongation to failure correlates with the increase of *F* value. In the area of higher ductility, however, such correlation cannot be observed.

The tests, applied to materials studied represent three types of static stresses to which materials can be subjected: tensile, compressive, and shear. The tensile tests involve only tensile stress, while bending tests involve both tensile and compressive stress, simultaneously occurring in the contrary areas of the sample [14]. During the bending and wrapping tests failure usually occurs because the ultimate



a



b

Fig. 4. *Number-of-bends and to elongation-to-failure plot:*
a *– until the first crack, C;* ***b*** *– until complete failure, F.*
Red markers – EMC state, yellow markers – CCR state, green markers – EMCM state.
Circle markers – alloys in CD state, triangle markers – alloys in CD and annealing at 230 °C for 1 h state,
square markers – alloys in ECAP-C+CD state, diamond markers – alloys in ECAP-C+CD and annealing at 230 °C for 1 h state
[The error bars show the error values in multiple samples within one state. Gray dotted lines show the thresholds according to IEC 62641:2023 and ISO 7801-1984]
Рис. 4. *Соотношение количества перегибов и величины удлинения до разрушения:*
a *– до первой трещины, Т;* ***b*** *– до полного разрушения, Р.*
Красные маркеры – состояние ЭМК, желтые маркеры – состояние НЛиП, зеленые маркеры – состояние ЭМКМ.
Круглые маркеры – сплавы в состоянии ХВ, треугольные маркеры – сплавы в состоянии ХВ после отжига при 230 °С в течение 1 ч, квадратные маркеры – сплавы в состоянии РКУП-К+ХВ,
ромбовидные маркеры – сплавы в состоянии РКУП-К+ХВ после отжига при 230 °С в течение 1 ч
[Планки погрешностей показывают значения в нескольких образцах в пределах одного состояния. Серые пунктирные линии показывают пороговые значения согласно IEC 62641:2023 и ISO 7801-1984]

tensile strength of the outer areas of the specimen has been exceeded. This results in cleavage, or a first crack *C*, in which separation rather than slip occurs along certain crystallographic planes [15].

Thus, there is a difference in the loading schemes (simple vs complex) and even loading type (dynamic vs static) of bending (and wrapping) and tensile tests. This drastic difference doesn’t allow to analytically evaluate the relationship between them, meaning that for the complex assessment of the wires behavior all three tests should be made, making the established correlation strictly experimental.

Despite the noted correlation, a certain anomaly was detected, and it is the behavior of the EMCM alloy. It may be noted that the majority of the specimens meet the requirements of minimum number of bends, equal to 7 (according to ISO 7801:1984) (Fig. 4), with one exception, being EMCM alloy in ECAP-C+CD state. Interestingly, none of the EMC or CCR samples demonstrated such low *C* and *F* values, even in the ECAP-C+CD state (Table 2). It should be noted that the EMCM sample in the ECAP-C+CD state have also failed to meet the wrapping criteria (Table 2).

It would appear that EMCM alloy in the UFG state (provided by the combined ECAP-C and CD treatments) accumulates deformation much quicker than the other studied materials and states. Since the fracture of the EMCM sample is not fragile, the reason why the samples of the EMCM alloy accumulate significantly higher amount of structural defects lays within their chemical composition: EMCM alloy contains Cu, capable of forming solid solution, clusters, intermetallic particles and grain boundaries segregations. The Cu ions in the EMCM alloy find their way into solid solution and/or grain boundary segregation (similar to one observed in Cu-containing aluminium alloy under similar treatment) during the deformation. In the [16] it was demonstrated that similar deformation treatment can force Cu atoms into grain boundaries, leading to formation of the nano-sized Al_xCu_y precipitates and significantly reducing the ductile properties of the material. Similar effect was also observed in Al alloys with insoluble alloying elements, such as Fe [17]. Though the exact nature of this occurrence is unknown, it is observed regularly. In the [9] it was shown that combined ECAP-C+CD forms in EMCM alloy structural features, that are not presented in the same alloy in CD state.

Thus, the detected discrepancy between the number of bends and the level of ductility of wire samples during the tensile tests made of the EMCM alloy of the Al–Fe system, additionally alloyed with copper, is most likely due to the migration of the Cu ions into the grain boundary regions. This effect can also explain the distinctive inability of the EMCM alloy wire in ECAP-C+CD state withstand the wraps.

CONCLUSIONS

In this study the analysis of the ductility, bending and wrapping ability of the wires made of Al–Fe and Al–Fe–Cu systems alloys in CD and ECAP-C+CD states were analyzed.

1. For the first time the wires made of Al–0.5 wt. % Fe and Al–0.5 wt. % Fe–0.3 wt. % Cu aluminium alloy, produced using severe plastic deformation methods, subjected to bending and wrapping of tests, were studied. The correspondence of ductility and ability to bend/wrap was established.

2. It was demonstrated that for the low-alloyed aluminium alloys, such as Al–0.5 Fe, the ductility will correlate with the deformation value. In the alloys of higher alloying elements concentration, the chemical composition will have the major role in determining ductile properties. Alloys with soluble elements, such as Cu, will demonstrate the decrease of ductility and maximum number of bends and wraps upon increasing the deformation value.

3. The samples studied demonstrated correlative increase in elongation to failure and maximum number of bends (until the first crack in the high-ductility area and until complete failure in the low-ductility area), thus it is important to study each characteristic of the material separately, considering the potential application of the produced wires.

4. The presence of the Cu in Al–Fe alloys accelerates the deformation build-up, causing faster failure of the samples in bending and wrapping tests, especially after deformation treatment including ECAP-C. However, thermal treatment allows this effect to diminish.

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Соотношение пластичности, способности к перегибам и навивам проволок из ультрамелкозернистых сплавов Al–0,5Fe и Al–0,5Fe–0,3Cu, полученных литьем в электромагнитный кристаллизатор

Медведев Андрей Евгеньевич*[1,3], кандидат физико-математических наук, старший научный сотрудник
Жукова Ольга Олеговна[1,4], инженер-исследователь
Федотова Дарья Дмитриевна[1,5], магистр , оператор 4-го разряда
НИЛ «Металлы и сплавы при экстремальных воздействиях»
Хафизова Эльвира Динифовна[1,6], кандидат физико-математических наук, старший научный сотрудник
Мотков Михаил Михайлович[2,7], кандидат технических наук, старший научный сотрудник
Мурашкин Максим Юрьевич[1,8], кандидат технических наук, старший научный сотрудник
[1]*Уфимский университет науки и технологий, Уфа (Россия)*
[2]*Сибирский федеральный университет, Красноярск (Россия)*

***E-mail:** medvedevandreyrf@gmail.com

[3]ORCID: https://orcid.org/0000-0002-8616-0042
[4]ORCID: https://orcid.org/0000-0002-1879-9389
[5]ORCID: https://orcid.org/0009-0000-7526-8309
[6]ORCID: https://orcid.org/0000-0002-4618-412X
[7]ORCID: https://orcid.org/0009-0007-1272-3993
[8]ORCID: https://orcid.org/0000-0001-9950-0336

Поступила в редакцию 20.03.2025 *Пересмотрена 10.04.2025* *Принята к публикации 28.04.2025*

Аннотация: В исследованиях таких функциональных свойств сплавов Al–Fe и Al–Fe–Cu, как способность к перегибам и навивам, а также пластичность проводов из этих сплавов, имеет место значительная степень неопределенности. Способность к перегибам и навивам определяется промышленными стандартами, однако попыток изучить связь между ними и пластичностью проводов из алюминиевых сплавов не предпринималось. Еще меньше внимания уделено проводам с ультрамелкозернистой структурой на основе алюминия, полученным электромагнитным литьем и равноканальным угловым прессованием. В данном исследовании использовались сплавы с двумя различными химическими составами (Al–0,5 вес. % Fe и Al–0,5 вес. % Fe–0,3 вес. % Cu) и двумя различными способами литья (литье в электромагнитный кристаллизатор и непрерывное литье и прокатка). Часть проводов для исследования была изготовлена методом холодного волочения (ХВ), другая – комбинацией равноканального углового прессования по схеме «Конформ» и холодного волочения (РКУП-К+ХВ) для получения крупнозернистой и ультрамелкозернистой структур соответственно. Для оценки термической стабильности проволок проводили отжиг при температуре 230 °С в течение 1 ч. Показано, что соотношение между пластичностью (удлинением до разрушения), числом навивов и числом перегибов (как до первой трещины, так и до полного разрушения образца) может различаться в зависимости от схемы деформации, типа и количества легирующих элементов в сплаве, а также способности образовывать твердые растворы.

Ключевые слова: алюминиевый сплав; Al–Fe; Al–Fe–Cu; электромагнитное литье; непрерывное литье и прокатка; равноканальное угловое прессование; холодное волочение; удлинение до разрушения; пластичность; технологические перегибы; технологические навивы; фрактографический анализ.

Благодарности: Работа выполнена за счет гранта Российского научного фонда № 20-79-10133, https://rscf.ru/project/20-79-10133/.

Исследовательская часть работы выполнена на оборудовании ЦКП «Нанотех» Уфимского университета науки и технологий.

Авторы выражают благодарность профессору В.Н. Тимофееву (Сибирский федеральный университет) за предоставленный материал исследования.

Для цитирования: Медведев А.Е., Жукова О.О., Федотова Д.Д., Хафизова Э.Д., Мотков М.М., Мурашкин М.Ю. Соотношение пластичности, способности к перегибам и навивам проволок из ультрамелкозернистых сплавов Al–0,5Fe и Al–0,5Fe–0,3Cu, полученных литьем в электромагнитный кристаллизатор // Frontier Materials & Technologies. 2025. № 2. С. 29–38. DOI: 10.18323/2782-4039-2025-2-72-3.