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## PHYSICS OF STRENGTH AND PLASTICITY

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# About Al–Si Alloys Structure Features and Ductility and Strength Increasing After Deformation Heat Processing

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A technique of deformation heat processing for Al–Si based alloys is proposed which can significantly increase their both ductility and strength and also reveals additional reserves for their strength and hardness increasing through cold work hardening. The method includes serial of small hot plastic deformations with intermediate cooling and short annealing. This makes the silicon inclusion rather small with shape close to spherical, which leads to the ductility increasing. Then a work hardening processing could be performed for the material. Finally, both ductility and strength appear higher than in the initial cast state.

**Key words:** Al–Si alloys, deformation heat processing, mechanical properties, silicon inclusions, microstructure.

Запропоновано спосіб деформаційно-термічного оброблення стопів системи Al–Si, що дає можливість значно підвищити одночасно їх пластичність та міцність, а також відкриває додаткові можливості підвищення їх міцности та твердости за рахунок деформаційного зміцнення. Метода включає серію малих гарячих пластичних деформацій з проміжним охолодженням і короткочасними відпалами. Це дає можливість одержати досить дрібні включення кремнію форми близької до сферичної, що і приводить до збільшення пластичности та міцности. Потім для матеріялу може бути виконана холодна деформація для додаткового зміцнення. В результаті і пластичність, і міцність виявляються значно вищими, ніж у вихідному литому стані.

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**Ключові слова:** Al–Si стопи, деформаційно-термічне оброблення, механічні властивості, включення кремнію, мікроструктура.

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## 1. INTRODUCTION

Low ductility is a well-known peculiarity of Al–Si alloys (silumins). Despite of their indisputable advantages as low density, good corrosion behaviour, decent strength properties at relatively low cost their low plasticity restricts their implementation areas and made for them bad reputation of a material for low quality products. Being an eutectic alloy type with quite low (comparing with some other Al alloys) foundry shrinkage silumins are widely used for cast products. Special casting techniques and modifiers could increase the material strength and/or ductility. However, in spite even seeming at a first glace significant growth of ductility, it indeed remains rather low, which does not really make the material able to plastic deformation processing. Here we have some examples. In work [1] it was declared on 1.5 times of ductility increasing for alloy AK9M2. Actually, its values grew from 1.2 to 1.8% . In work [2] the observed change of relative extension was from 0.5...0.7% to 0.9...1.1% for AK8M3 alloy.

Most of the studies of Al–Si alloys properties improvement are focused on the cast state [3–5] which is not surprising, because they are used primary for cast products. However, brittle at normal temperature Al–Si alloys could be affected to a hot deformation processing that has mentioned even in [6]. As known, plastic deformation has an effect on the material structure. The main idea here is to crush silicon inclusions, which are the main cause of these alloys brittleness, at the temperature where the material is plastic enough.

Despite the idea is time after time appeared since 30's of XX century this technique still not become widely spread. However, in recent years is observed an increasing of interest to it. A method of Al–Si alloys deformation heat processing by forging was presented in [7]. The proposed technique consists of the following sequence: annealing at 500 ± 10°C for 2 hours, hot deformation by forging at a temperature of 510–550°C (beginning of forging) to 350–400°C (end of forging); an optional intermediate annealing at 510–550°C, a final post-deformation annealing at 520 ± 10°C for 2 hours. This method leads to the formation of polygonal inclusions of silicon fairly evenly distributed in the structure. It allows to increase the plasticity values of the material to $\delta = 4–16\%$ (depending on silicon content). Increasing of the strength is up to 15–75% compared with the cast state, but only for alloys with high silicon content (20–30% ), the simultaneous increase in ductility for which is insignificant.

Another example of recently published research of Al–Si alloys forging technique is [8]. There the casted samples were forged at 300°C with deformation degree of 15%, 25%, and 35%. Then the samples were annealed at 535°C for 5 h, followed by aging at 170°C for 2 h. In the structure were obtained close to spherical shape silicon inclusions with various sizes (actually, about 2–5 μm, according to the given photos of the structure). At the most deformed samples they reached relative extension values up to 12%.

There also exist several others studies on this topic. This proffers that Al–Si alloys could be effectively affected to plastic deformation, which leads to shredding and spheroidization of silicon inclusions and ductility increasing. Nevertheless, attempts to reproduce Al–Si forging techniques do not always succeed. The practice shows, that the samples of such alloys could be prone to cracking even during hot deformation. So, statements about the super plasticity of such alloys at temperatures higher than 430°C, like in [6], look somewhat overpriced.

In this work we tried to develop a technique of Al–Si alloys deformation heat treatment that significantly increases their ductility and reveals the additional resources for their work hardening. Moreover, it should reduce the likelihood of the material brittle fracture, especially during the first deformation stages, when the plasticity is still not high enough. Some attention is also given to the initial cast structure of the material affected to such processing.

## 2. RESEARCH MATERIAL AND METHODOLOGY

The chemical composition of the studied material is given in Table 1.

Material for some of the samples was modified using a NaCl + KCl surface flux before the casting. Composition of the flux was ~45% of NaCl and 55% of KCl that has an eutectic melting point at about 660°C, which is close to aluminium melting temperature. This might give an addition of some thousandth's parts of Na and K.

Another cast structure modification type studied here was treatment of the melt through adding of ~0.5 g/kg of $AgNO_3$ in a melting capsule of Al. It was supposed that owing to its thermal decomposition and reaction with Al disperse particles of silver might be obtained which could be substrates during the aluminium crystals nucleation at the beginning of the alloy solidification. Also, a 'stormy' reaction may give the melt additional mixing.

**TABLE 1.** Chemical composition of the studied material (in % wt.).

| Al | Si | Mn | Mg | Cu | Fe |
|---|---|---|---|---|---|
| Base | 6.8–7.1 | 0.1–0.2 | 0.05–0.1 | 0.3–0.5 | 0.5–0.8 |

Others samples were not modified in these ways.

Some samples were additionally alloyed with about 2% of Cu and 1% of Ag, also they had an increased amount of Mn up to 0.7%. This was made to study the features of an additional effect of disperse and solid solution hardening in comparison with the effects of strength growth obtained through the deformation heat processing.

The specimens were casted into a clay mould two at once. Each cast sample had its own funnel in the mould to fascinate air exit during the casting. A schematic sketch of the mould is given on Fig. 1. The metal casting temperature was about 700–750°C.

Casted samples were separated from solidified funnels and their surface layer was deleted by mechanical processing. Thus, their dimensions become about 8.5×8.5×40.0 mm.

Obtained in this way cast specimens were objected to deformation heat treatment. In general, its technique consisted in the following operations:

– heating to the temperature from 490 to 540°C;

– hot deformation by forging elongation from the heating temperature to ~400 – 430°C. Its degree varied from 3–4% to 18–20%;

– cooling to 40–60°C or even to the home temperature;

– next heating to 490–540°C with keeping in a furnace 10–15 min and following hot deformation.

The described heating deformation and cooling cycles proceeded until the desired resulting deformation degree was obtained.

Here were studied resulting deformations degrees from 25 to 70%.

After the serial of the hot deformations some of the samples were objected to the cold deformation for work hardening.

The obtained samples both as cast and after different regimes of deformation heat treatment were subjected to a technological upsetting test. The test consisted in pressing of a piece of the sample with initial

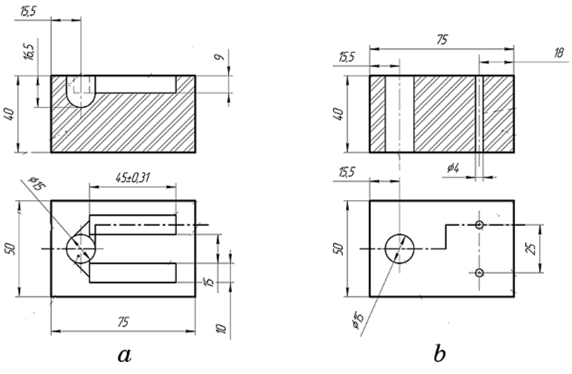


**Fig. 1.** A schematic sketch of the used mould: bottom half (*a*); top half (*b*).

height of 8 mm until visible cracks occurred. The ratio between the initial height and obtained after the critical upsetting (when crack appear) was estimated for each sample.

Tensile tests were performed to estimate the standard mechanical properties of the material: ultimate tensile strength, yield strength, relative extension, and constriction ratio.

Microstructure of the samples was studied through the optical microscopy with magnification ×40, ×100, and ×1000. To revile the microstructure etching was performed at KOH 7% solution with temperature 60–70°C. For more contrast view of the silicon inclusions an additional etching at 2% solution of $AgNO_3$ was performed for some of the samples.

## 3. RESEARCH RESULTS AND DISCUSSION

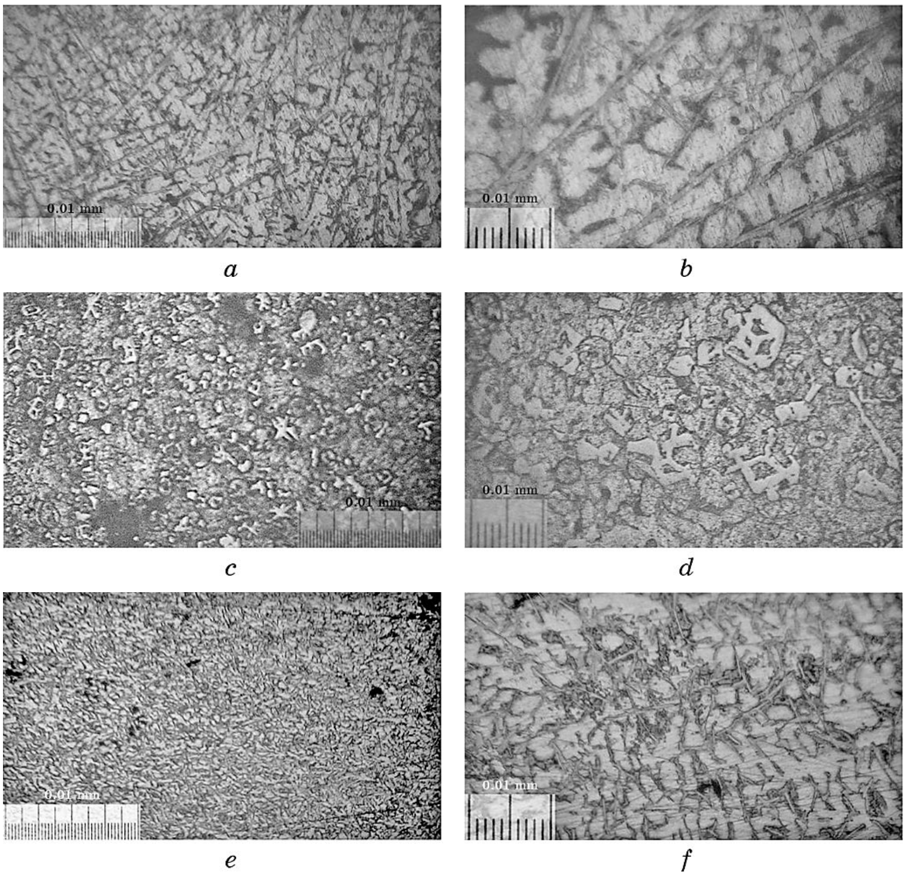
The microstructure study for the cast samples showed a significant influence of K, Na additions, as it supposed to be. An effect of $AgNO_3$ adding was also observed. Figure 2 shows a comparison of the as cast structure.

From the given microstructure illustrations it is clearly seen that K, Na additions qualitatively change the shape of the silicon inclusions making them polyhedral or even ‘skeleton shape’. The inclusions remain rather large, about 30–100 μm. $AgNO_3$ addition does not as much qualitatively change the silicon inclusions shape—we still can see ‘needles’. However, they become significantly smaller and more ramified. The main effect $AgNO_3$ addition makes on the cast dendrite structure that become denser and disperse.

Numerically it could be said, that dendrite structure density (dendrites per mm$^2$) in not modified material was $228 \pm 63$ mm$^{-2}$ and in modified one it become $848 \pm 291$ mm$^{-2}$.

But the more important interest of this research is the structure behaviour after the proposed deformation heat treatment. Unexpected was the fact that K, Na modified samples appear the most ‘naughty’ during the hot forging. They became soft but brittle and crumbled under the strikes. Such behaviour was observed mostly at heating to 530–560°C for hot forging. Decreasing the forging beginning temperature to 490–510°C allowed partially eliminate this drawback. The observed fracture is likely be caused by so called hot fragility that may occur at Al based alloys with Na and K impurities, which was made deliberately here. According to [6] even less than 0.01% of Na or K is enough.

As experiments have shown, even hot deformation could cause cracks appearing and brittle fracture of Al–Si alloys. So, one of the main tasks was working out of a deformation regime such materials could withstand without fracture, taking into account the facts that the specimens



*a* *b*

*c* *d*

*e* *f*

**Fig. 2.** Cast microstructure of the studies Al–Si alloy samples with different types of modification: *a*—no modification, ×40; *b*—no modification, ×100; *c*—NaCl + KCl flux treatment, ×40; *d*—NaCl + KCl flux treatment, ×100; *e*—$AgNO_3$ treatment, ×40; *f*—$AgNO_3$ treatment, ×100.

are affected to strike impact during forging and their temperature decreases rather fast because of their small size and contact with cold forging equipment. In this case the end of forging temperature is hardly being controlled precisely. Such visual signs as the glow colour of the heated metal or the colours of surface oxide films do not work in this case. It could be only estimated by rather crude calculations. An estimated cooling curve of an aluminium sample of the given dimensions with initial temperature 520°C placed on an iron incus in air environment with temperature 20°C is shown on Fig. 3.

We can see that that the sample cooled to 450°C less than in 50 seconds. Lower temperatures are not desirable for hot deformation of such material, especially on early stages when the silicon inclusions are not

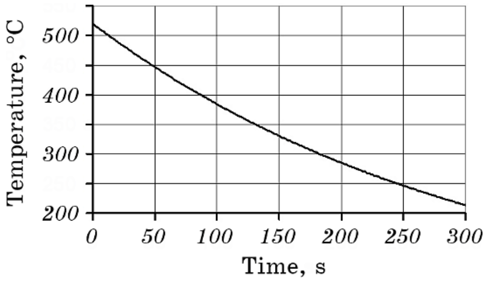


**Fig. 3.** An estimated cooling curve for 8.5×8.5×40 mm specimen.

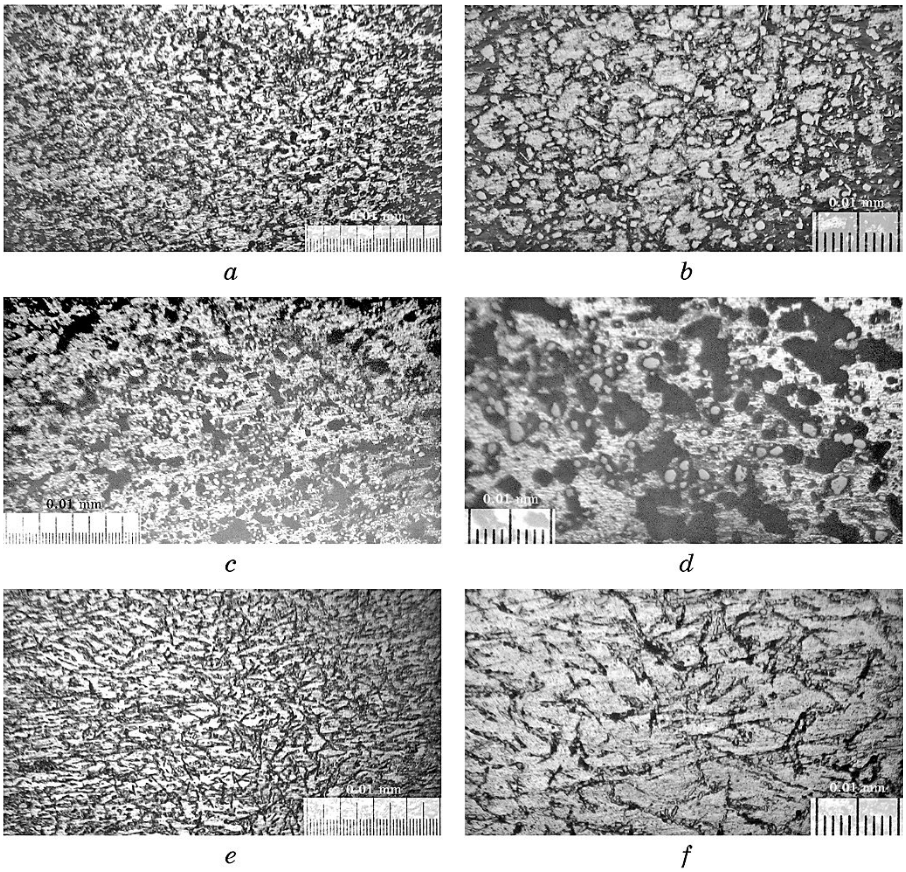
yet crushed and spheroidizated enough and the plasticity is rather low. Hence, on the first stages deformation degree should be low. So, surely being at the safe temperature range deformations could be reached at a single stage are not more than 5%. Actually, they were 3–4%. Bigger deformations, as the practice showed, may cause brittle cracks. Then, when the material gains enough plasticity the temperature of ending forging could be decreased to 400 or even to 350°C. That allows making greater deformations—up to 18–20% at a single stage.

The typical samples structures after the deformation heat processing are shown on Fig. 4. From all of the given illustrations we can see spheroidization and shredding of the silicon inclusions. However, the common structure is different and it depends on the initial cast state and the deformation–heat treatment. A significant summary hot deformation of the $AgNO_3$ modified samples leads to overcoming the initial dendrite structure and creation of equiaxial grains with spherical silicon inclusion between them. The average grain size in this case is about 40–50 μm and silicon inclusion size is 5–10 μm. In non-modified samples we can observe rather coarse matrix structure without clearly seen grains bounders. The inclusions spheroidization is obvious, but they have larger size up to about 20 μm, but the smallest ones are less than 5 μm.

In samples after an additional work hardening followed the hot deformation we can see deformed matrix grains (Fig. 4, *e*, *f*). Less hot deformation degree at this case leads to obtaining comparatively larger average grain size—about 70–80 μm. Silicon inclusions are rather small, but less orbed and additionally crushed. We can see their shape clearly on the Fig. 5 that was taken at greater magnification (×1000 with oil immersion).

Some of the inclusions in this case are not evenly disperse over the matrix but form ‘crushed lines’ as we can see at Fig. 5, *a* or fractured conglomerates as it shown on Fig. 5, *b*. Others could be rather separated but not all of them have equiaxial polygonal or close to spherical shape. Size of this inclusions is often less than 10 μm and the smallest ones are less than 1 μm.

In the samples that were affected by NaCl + KCl flux treatment during the casting despite significant summary hot deformation (50% ) the silicon inclusions are comparatively bigger that in the others cases considered there. Their average size is 15–10 μm. However, it is significantly smaller than they were at the as cast state. They are rather equiaxial polygonal and quit evenly distributed in the matrix. The grain boundaries are not clearly manifested, but the average grain size could be estimated to be about 70–90 μm.

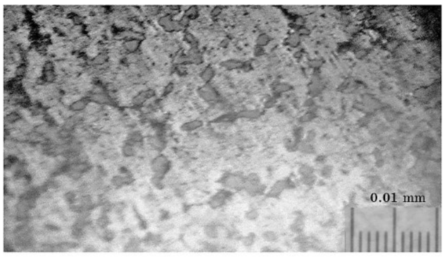


*a* *b*

*c* *d*

*e* *f*

**Fig. 4.** Typical microstructure of the samples after the deformation heat processing: *a*—47% summary hot deformation, $AgNO_3$ treatment, ×40; *b*—47% summary hot deformation, $AgNO_3$ treatment, ×100; *c*—38% summary hot deformation, no modification, ×40; *d*—38% summary hot deformation, no modification, ×100; *e*—30% summary hot deformation + 15% work hardening, $AgNO_3$ treatment, ×40; *f*—30% summary hot deformation + 15% work hardening, $AgNO_3$ treatment, ×100; *g*—50% summary hot deformation, NaCl + KCl flux treatment, ×100.



*g*

*Continuation of Fig. 4.*

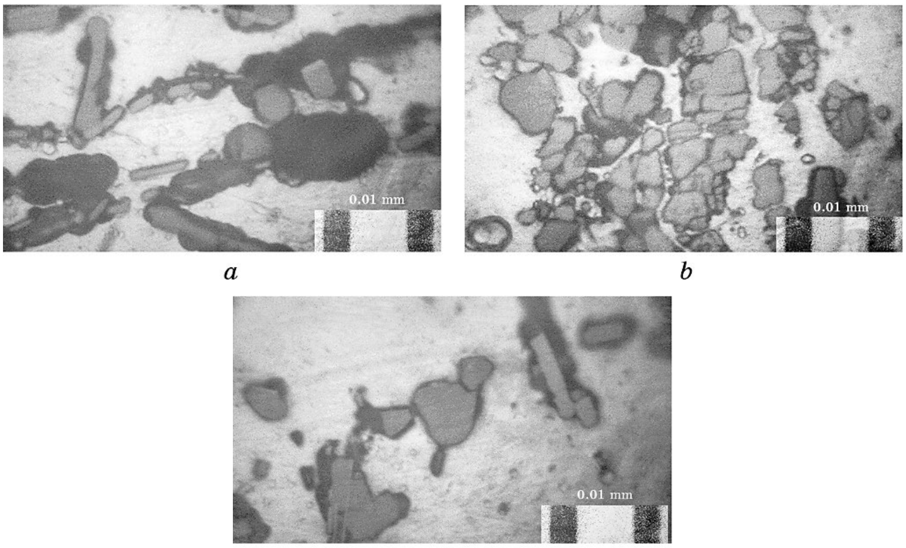
The average values of the main mechanical properties of the studied samples in a cast state and after the deformation heat treatment measured through tensile tests are given in Table 2.

The samples affected the tensile tests are actually not the same as ones for which the microstructure photos are given above, but quite similar to make some conclusions.

The cast samples showed an extremely low ductility at tensile tests. Their relative elongation and constriction ratio are close to zero. Also, no explicit yield strength was observed for them. The basic non-modified and not alloyed cast samples type (No. 4) has very low ultimate tensile strength—about 89.0 MPa. It could be significantly increased by the studied here $AgNO_3$ modifying and some alloying with Cu and Ag (No. 5). However, the strength value remains significantly less than it is observed in all of the samples type after the deformation heat treatment.

Even not modified samples after summary 52% hot deformation show a significant growth of the material ultimate tensile strength which becomes averagely 196.4 MPa. Also here appears explicit yield strength. More remarkable that the material acquires some plasticity—the relative elongation has become 6.22% and the constriction ratio 22.45%. Modified samples affected greater summary hot deformation (~70%) and subsequent annealing at about 540°C during 2 hours (No. 6) acquires even more ductility. However, their strength becomes lower, but still higher as it was for not alloyed cast samples and it is close to the alloyed ones after quenching and aging (No. 5).

The observed plasticity growth makes possible an additional work hardening, which is demonstrated with samples of type Nos. 2, 3, and No. 7 from the table above. It should be noticed, that these sample acquire rather close values of ultimate tensile strength after the corresponding deformation heat treatment. Type No. 3 that was affected modifying during the casting and greater hot deformation shows more plasticity remain after the work hardening but the ductility of Nos. 2



*a* *b*

*c*

**Fig. 5.** Typical silicon inclusions in the sample with 30% summary hot deformation + 15% work hardening, ×1000.

and 7 is almost exhausted after even less cold deformation. Less hot deformation degree and also non-modified cast state cause the fact that samples of type No. 7 earlier exhaust their plasticity margin with lower final strength values.

Strength of the material could be even more increased by alloying that makes possible hardening through quenching and aging. This is demonstrated by samples of type No. 8 which were alloyed with some amount of Cu and Ag as it was for the specimen No. 5. Their averaged tensile strength after the deformation heat treatment becomes 333.3 MPa. Their plasticity is rather low but it is a bit higher than in the as cast state.

Samples modified with NaCl + KCl flux sowed a high tendency to hot brittleness during the deformation. Cracks appear from time to time and some specimens even have fallen apart. Also, when machining (turning) of the tensile test samples they were likely to tear. Thus, they were excluded from the most of mechanical properties study. It only could be said that in technological upsetting tests they show very low plasticity—visible cracks appear after about 17–28% of upsetting.

The average hardness of the samples is given in Table 3.

For deeper comprehension of the material plasticity behaviour technological upsetting tests were performed. Its results are shown in Table 4.

**TABLE 2.** Main mechanical properties of the studied samples in a cast state and after deformation heat treatment.

| No. | Sample type | $\sigma_y$, MPa | $\sigma_u$, MPa | $\delta$, % | $\psi$, % |
|---|---|---|---|---|---|
| 1 | 52% summary hot deformation, non-modified | 128.0 | 196.4 | 6.22 | 22.45 |
| 2 | 30% summary hot deformation + 12% work hardening, non-modified | 251.6 | 275.7 | 0.94 | 0.93 |
| 3 | 48% summary hot deformation + 27% work hardening ($AgNO_3$ treatment) | 229.5 | 273.0 | 3.30 | 9.30 |
| 4 | Cast, non-modified, not alloyed | – | 89.0 | ~0 | ~0 |
| 5 | Cast, $AgNO_3$ treatment, + ~2% Cu + ~1% Ag + + ~0,7% Mn, quenching from 510°C and natural aging | – | 139.0 | ~0 | ~0 |
| 6 | 70% summary hot deformation + ~2 h annealing at 540°C, ($AgNO_3$ treatment) | 63.7 | 137.1 | 22.57 | 58.79 |
| 7 | 25% summary hot deformation + 9% work hardening, non-modified | 222.4 | 260.8 | 0.06 | 0.06 |
| 8 | 38% summary hot deformation + 6% work hardening + ~2% Cu + ~1% Ag + ~0,7% Mn, quenching from 510°C and natural aging ($AgNO_3$ treatment) | 288.5 | 333.3 | 1.42 | 1.40 |

Analysis of the obtained complex of the mechanical properties showed that in the studied case correlation between hardness and tensile or yield strength exists but is no very strict, as it could be seen from the plot on Fig. 6.

The cause of such behaviour seems to be following. The alloying with subsequent quenching and aging increase both hardness and strength in as cast or deformed state. Its effect is mostly conditioned by precipitation hardening and some solid solution hardening. Reason of the strength increasing after hot deformation of such alloy is different. Growth of strength properties after cold deformation is merely a work hardening that is accompanied with hardness growth and ductility decreasing. The observed increasing of strength and plasticity after the hot deformation by the proposed technique is mostly caused by changing of the silicon inclusions morphology. Large sized sharp plates of silicon it the as cast material although having some strengthening effect also work like stress concentrators and micro defects. That is the most reason of low plasticity of such materials and this also does not allow them to fully show their strengthening effect. However, it does not so much affect the material hardness. Shredded and spheroidized silicon inclusions have significantly less effect as stress concentrators and less likely forming sharp chips during tensile deformation. Hence, this prevents premature material fracture. Another reason of the strength increasing after the hot deformation may be in changing of the metallic

**TABLE 3.** Hardness of the studied samples in a cast state and after deformation heat treatment.

| No. | Hardness, HV |
|---|---|
| 1 | 50.3 |
| 2 | 96.8 |
| 3 | 117.4 |
| 4 | 67.0 |
| 5 | 112.4 |
| 6 | 49.2 |
| 7 | 106.1 |
| 8 | 131.0 |

matrix structure. Instead of rough dendrites there appear equiaxial grains also affected by primary recrystallization. High temperature annealing leads to the collective recrystallization (grain growth) and takes away all the residual deformation stress, which leads to some strength decline.

The results analysis shows that the strength highly depends of both hot and cold deformation degree. There might also occurs their non-additive effect but it is not proofed enough. The dependence is not linear. Summary hot deformation degree up to 40% gives the material additional strength increasing. Higher hot deformations give it additional ductility, however there not observed more strength growth and it could appear even less than it may be obtained after lesser hot deformation. Cold deformation is able to allot the material merely an additional strength as much as the plasticity allows it. Hardness of the alloy is mostly affected by cold deformation (work hardening). The alloying also increases it. However, the hot deformation might even somewhat de-

**TABLE 4.** Results of upsetting tests for the samples in a cast state and after deformation heat treatment.

| No. | Upsetting degree before cracks appear, % |
|---|---|
| 1 | 83.3 |
| 2 | 59.1 |
| 3 | 74.6 |
| 4 | 29.8 |
| 5 | 31.2 |
| 6 | 92.1 |
| 7 | 42.3 |
| 8 | 61.9 |

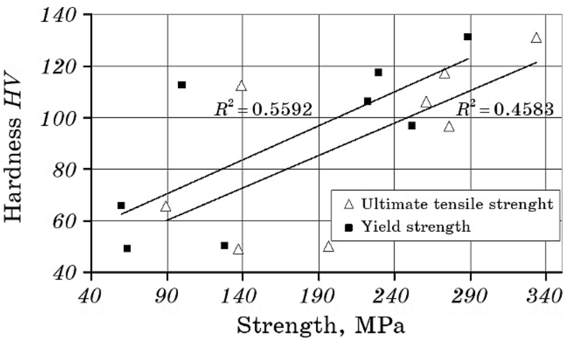


**Fig. 6.** Correlation between hardness and strength properties for the studied samples.

crease the observed hardness. Hardness of the material after the hot deformation remains on the level about 50 HV, which is close to one of the cast material after annealing at temperatures higher than 500°C, which was also observed in our previous study [9]. It is even less than in the as cast state. Some additional investigations were performed for this phenomenon comprehension. In the Table 5 are given the results of additional hardness and micro hardness of the metallic matrix measurements.

In as cast state the metal matrix has some residual thermal stress that results in its hardness increasing. The value of common hardness in this case is very close to the metal matrix micro hardness. Annealing removes them and the metal matrix micro hardness becomes significantly lower. However, it is quite less than the common hardness. The proposed hot deformation treatment technique works like some kind annealing that removes the residual thermal stress and the metal matrix hardness decline. We can also see that its growth with the summary hot deformation degree, which may by the result of the matrix grain structure refinement. But the common hardness stands by the same value about 50 HV as it is observed for the annealed state. Work hardening increases the metal matrix micro hardness to the values higher than the hardness in the annealed state. As a result, the common hardness appears close to this metal matrix micro hardness (a bit higher). The same thing is observed for the as cast material. Hence, there is a specific barrier, which is for this material at about 50 HV. It varies depending on silicon content. For example, for the alloy with 3.5% of Si it will be around 35...36 HV and for one with 9.0% Si—about 56...57 HV. Thus, we come to the conclusion that the common resulting hardness of this material could be mostly conditioned by silicon content or metal matrix hardness. There is a barrier value of hardness that depends on the silicon content. Lower it the common hardness is completely conditioned by

**TABLE 5.** Common hardness and metal matrix micro hardness.

| Sample type | Hardness, HV | Metal matrix microhardness, HV |
|---|---|---|
| 52% summary hot deformation | 50.3 | 48.2 |
| 29% summary hot deformation | 50.2 | 43.4 |
| As cast state | 67.0 | 65.9 |
| Annealing for 1.5 h at 520–540°C | 49.2 | 41.8 |
| 48% summary hot deformation + + 27% work hardening | 117.4 | 114.2 |
| Annealing for 3 h at 520–540°C (3.5% Si) | 35.2 | 29.5 |
| 60% summary hot deformation (3.5% Si) | 35.6 | 33.3 |
| Annealing for 1.5 h at 520–540°C (9.0% Si) | 56.1 | 40.2 |
| 25% summary hot deformation (9.0% Si) | 56.7 | 44.6 |

silicon content, higher it mostly caused by the metal matrix hardness with only a slight effect of silicon.

In the dependence of the ductility properties ($\delta$ and $\psi$) there was nothing unexpected—they are increasing with hot deformation degree growth, and subsequent work hardening declines them. Values of $\delta$ and $\psi$ are in strict linear correlation between each other.

Technological upsetting tests showed that even in the as cast state the material could have some plasticity even at the home temperature. However, it is significantly less than it is observed for all the studied samples after the deformation heat treatment.

## 4. CONCLUSIONS

1. A technique of deformation heat treatment was proposed for Al–Si alloys that allows significant both strength and ductility increasing. The method consists in a serial of small hot deformations with intermediate cooling and short annealing between the deformations. The hot deformations beginning temperature should be about 490–540°C. The hot deformations finishing temperature should be about 450°C the first stages and could be reduced to 400 or even 350°C for the final stages when the material obtains enough plasticity. Owing to the ductility acquisition the material could be affected to work hardening to increase its strength even more. Samples affected 70% of summary hot defor-

mation could withstand up to 90% upsetting degree at the home temperature. However, it reduces the final plasticity. Strength and hardness of this alloy could be even more increased though alloying which makes possible a hardening by quenching and aging.

2. The growth of both ductility and strength increasing after the hot deformation is mostly caused by changing of the silicon inclusions morphology. They are shredding and their shape becomes polyhedral close to spherical. Such inclusions still not as much effect as stress concentrators and micro defects tearing the metal matrix during deformation. Intermediate cooling between the hot deformations lead to some changing of Si content in the solid solution. According to the phase diagram its equilibrium content at the heating temperature is about 1% and at the home temperature it is about 0.01%. So there occurs some dissolution of the silicon inclusions surface when heating and re-deposition when cooling. This effect might additionally promote the inclusions spheroidization.

3. The initial cast structure has an effect to the structure and properties in the deformed state. Finer, modified with disperse parcels, structure allows obtaining of smaller silicon inclusions and disperse equiaxial grains of the metal matrix. It results in greater values of its plasticity after the hot deformation and bigger residual ductility after the work hardening. Such material could withstand greater degree of cold plastic deformation. However, treatment of the melt with NaCl + + KCl flux was not benefit for the case. Nevertheless, it affects the cast structure, especially silicon inclusions shape, the size of the inclusions remains rather large. Also, samples modified in such a way show a high tendency to hot brittleness during hot deformation.

4. It was observed an unusual behaviour of the material hardness after the hot deformation. Although the material tensile and yield strength increasing, the hardness do not grow and becomes even less than in the as cast state remaining on the level of annealed cast product. The only way to increase the hardness in this case is alloying and/or work hardening. Nevertheless, the hardness of the metal matrix could slightly grow with the hot deformation degree increasing, the common hardness remains on the same level. It was found out that for the studied material there exist a barrier value of the hardness which mostly depends on silicon content only. If the metal matrix hardness is lower than this barrier value the common hardness is standing on it. If the metal matrix hardness overcomes this value, it becomes mostly affect the common hardness, which will be only slightly greater than the metal matrix hardness.

5. Dependence of the strength properties from the hot deformation degree is nonlinear. Increasing the summary hot deformation degree to the values up to 40% results in the additional strength growth. Higher summary hot deformation degrees could additionally increase the ductility, but do not give an additional effect to the material strength.

There could be obtained even less strength values than after lesser hot deformation.

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