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MECHANICAL PROPERTIES OF DEVELOPED FORGING STEELS

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Key words: alloying elements, forging, heating temperature, tempering temperature, the hardness, percussion toughness, fluidity range.

Abstract. The paper presents the mechanical properties of newly developed forged steel. Considered the effect of alloying elements on the properties of steels, the results of experimental work to determine the hardness of the steel as a function of tempering temperature and the heating temperature and the toughness of the steels at fluidity range of 100 kg/mm^2.

Along with the change wrought crystals at high temperatures, grain growing, as the conditions for the merger of small grains in the large. The phenomenon of grain growth, i.e. association of small grains in the large, is called recrystallization. Grain grow greater, the higher the temperature of forging.

Introduction. Influenced by forging the metal structure varies in two opposite directions. Forging ingot structure takes fibrous (banded) structure. The formation of the fibrous structure is characterized in that forging the ingot liquation zone, gas bubbles, and slag inclusions etc., and at a low temperature and grain steel (dendrites) extend in the direction of metal flow. Coarse-grained structure of the ingot is converted into a fine-grained due to fragmentation of the crystals under the blows of the hammer or pressure press.

Forging metal rolled structural changes occur other metal. Grain varies less as they are partially destroyed in the process of rolling. Unlike forging rolling gives a tangled metal fibers. Therefore, usually, the mechanical properties of the forged metal better mechanical properties than rolled metal.

Along with the change wrought crystals at high temperatures, grain growing, as the conditions for the merger of small grains in the large. The phenomenon of grain growth, i.e. association of small grains in the large, is called recrystallization. Grain grow greater, the higher the temperature of forging.

Lowers recrystallization resistance to deformation of the metal. Therefore, it is necessary to forge the metal at a temperature which promotes grain growth (recrystallization), and should finish forging at a temperature at which no recrystallization occurs metal. This will ensure that the forging consisting of fine grains with improved mechanical properties.

From the above it can be concluded that the structure of the metal, and with it the mechanical properties of the forging depend on grain refinement due to their deformation and recrystallization.

Metal structure also depends on the extent of reduction of (while drawing). Is the ratio of reduction of the cross-sectional billet cross-sectional area of the forging. The more of reduction of (i.e., the value of the hood), the finer grain and more pronounced banded structure of forgings.

Of reduction of the ingot take more than of reduction of the rolled workpiece. The magnitude of reduction of the minimum for carbon steels on the smooth part 3.0; on the flanges and ledges 1.75; for alloyed steels on the smooth part 2.0; on the flanges and ledges 1.5. Forging forged ingot of reduction of the smooth portion is taken 3-4, and in the flange and lip 1.5-1.75.

When forging large ingot broken crystals compacted metal recovery by voids existing in the ingot, and the infusion of bubbles, while the crystalline structure of the rolled profiled metal workpiece has been broken during rolling. The higher the temperature of heating before forging of the metal, the greater must be of reduction.

In excess of reduction of normal occurs improved mechanical properties along their deterioration hoods in the transverse direction. On the mechanical properties of forgings also influenced by processes for their manufacture. One and the same item can be made in different ways and thus obtain forgings having different mechanical properties. Should strive to produce the forging so as not to cut the metal fiber.

Experimental work

One of the goals of this work is to develop new forged metal materials based on steel. In this regard, by adding alloying elements (to 3.48% Cr) as the chemical compound was developed the forged steel.

The chemical compound of steels as follows: **St.1** C – 0.43%; Cr – 3.40%; Si – 0.22%; the rest - Fe. **St.2** – C – 0.42 %; Cr – 3.48%; W – 0.61%; Si – 0.24%; the rest - Fe. **St.3** – C – 0.42 %, Cr – 3.46%; Mo – 1.4%; Si – 0.25%; the rest - Fe. **St.4** – C – 0.43 %, Cr – 3.4%; W – 0.8%; Mo – 1.37; V – 0.18; Si – 1.07%; the rest - Fe.

Test steels was melted in an induction furnace open and poured into 11 kg ingots. Steel ingots were forged. Forging ingots were performed in the temperature range: 1150-1100 ^{0}C (beginning of forging) and 950-900 ^{0}C (end forging). Heating for forging ingots were carried out in gas furnaces. Forging made on the hammer with a weight of 350 kg falling parts. After forging, the bars were annealed at loading mode into the furnace at a temperature of 400 ^{0}C, heating to 850 ^{0}C, holding for 2 hours and further cooled in air.

Silicium doping increases the quenching temperature 60-75 °C. In this case, the doping is not absolutely change the hardness after tempering steels from said temperature which is determined by the carbon content.

Molybdenum prevents grain growth and improves the ability to calcination. Eliminates the fragility of the hardening process. Upon slow cooling after tempering temperature manifests in some alloys the carbides precipitate at grain boundaries, and this in turn is the cause of embrittlement. Molybdenum eliminates these negative effects. Furthermore, molybdenum increases the creep strength and corrosion resistance of the steel.

Vanadium reduction due to the effect of grains greatly improves fluidity and ultimate tensile strength. Furthermore, increases the potential for quenching, annealing, and has a positive effect on the secondary calcining. These elements are composed of one, two and three-element composition forms carbonitride precipitate in the microstructure and, along with decreasing grain size steel precipitate due to the mechanism of solidification, hardness of the steel increases.

Percussion toughness of the steel St.1 at a hardness of 48 HRC is at KCU=2.10 J/m^2. A heating temperature and viscosity of the investigated steel at yield of 100 kg/mm^2: when heated 490 ^{0}C has toughness 4.4 J/m^2.

Results of experimental work

As a result of the experimental data revealed that the hardness of steel depends on the tempering temperature.

In the figure 1 shows the effect of tempering temperature on the hardness of the steels St. 1, St. 2. Here shows that the tempering temperature greatly affects the hardness of steel. At a tempering temperature of 500 ^{0}C hardness of steel St.1 of 30 HRC, and St.2 of the steel hardness 41 HRC. At a tempering temperature of 600 ^{0}C hardness of steel St.1 - 22 HRC, and St.2 - 30 HRC.

The lowest level of hardness is observed at a temperature of 650 ^{0}C: St.1 – 20 HRC, St.2 – 28 HRC. The maximum level of 48-50 HRC hardness is observed at a temperature of 250 ^{0}C.

Figure 2 shows the effect of tempering temperature on the hardness of the steels St.3, St.4.

The maximum level of hardness is observed at temperatures of 250 to 300 ^{0}C, of steel St. 3 - 49 HRC, 50 HRC, in steel St.4 - 52 HRC, 48 HRC. At temperatures 300-450 ^{0}C hardness of steel St.3 has the same value of 49 HRC.

Significant differences were observed at 550 ^{0}C in steel St.3 - 47 HRC, have become St. 4 - 42 HRC, and at a temperature of 600 ^{0} C in steel St.3 - 45 HRC, have become St. 4 - 31 HRC.

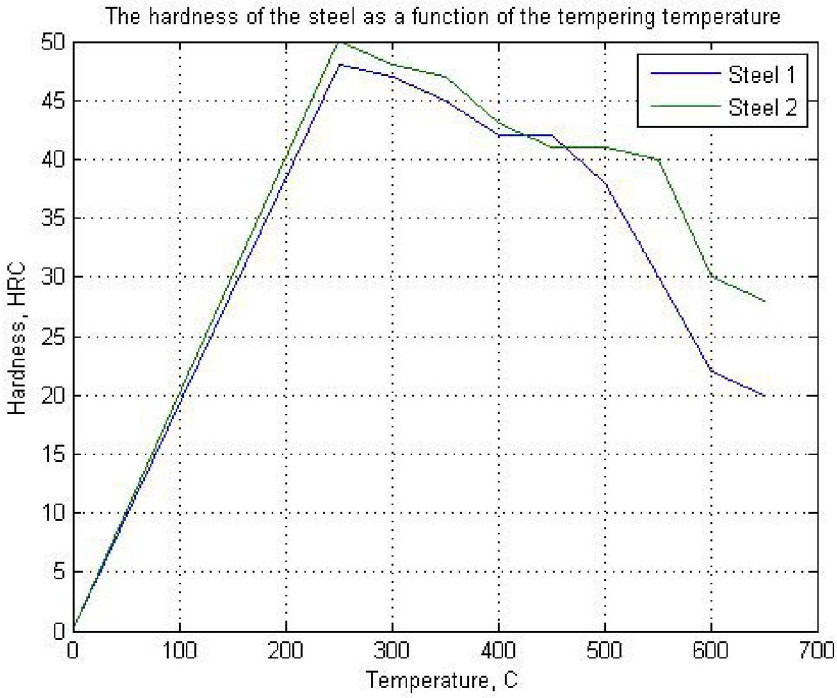

Figure 1 – The hardness of steel St. 1, St. 2 depending on the tempering temperature

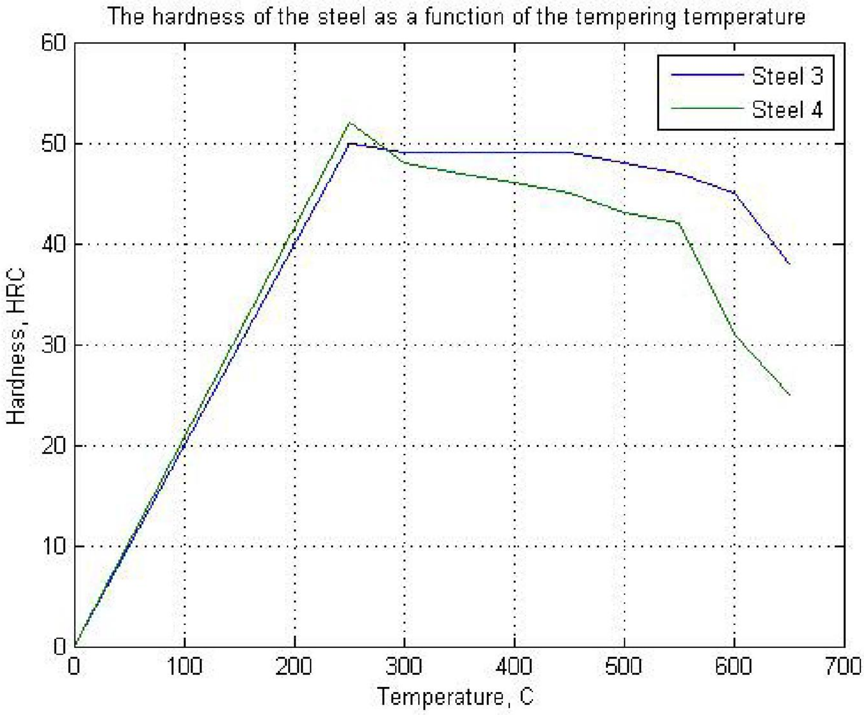

Figure 2 – The hardness of steel St. 3, St. 4 depending on the tempering temperature

Figure 3 shows the comparative characteristics of the hardness of all new forged alloys depending on the tempering temperature.

The minimum level of hardness was observed at a temperature 650^0C of steel St.1 - 20 HRC, have become St. 4 - 25 HRC. And at temperatures $300\text{-}500^0C$ steel hardness is observed within 38-49 HRC.

According to the results of experimental studies have determined that the tempering temperature greatly affects the hardness of steels but also it depends on the chemical compound of the alloy.

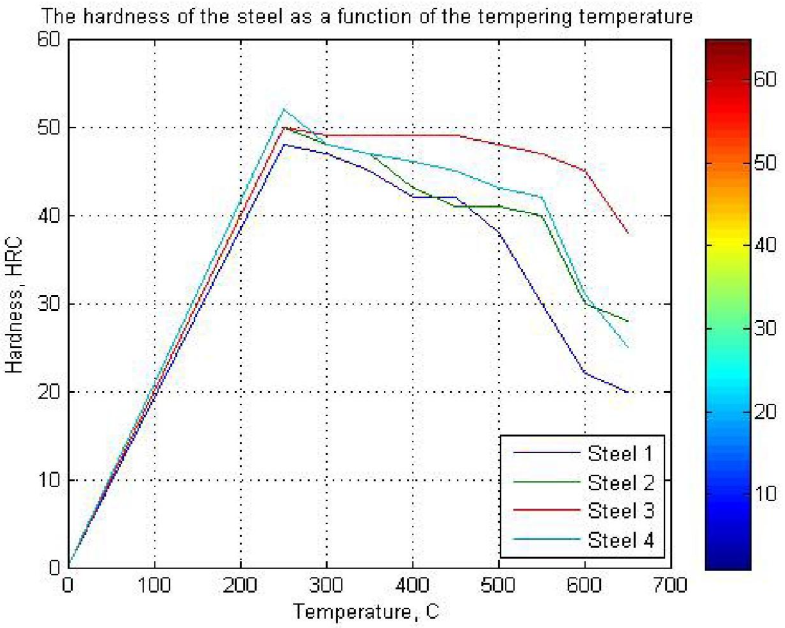

Figure 3 – Results of comparative hardness of all developed steels depending to tempering temperature

Table 1 – Effect of alloying elements on steel toughness (hardness 45 HRC)

Steel	Percussion toughness KCU, J/m^2
St.1	2.7
St.2	3.8
St.3	3.8
St.4	4.5

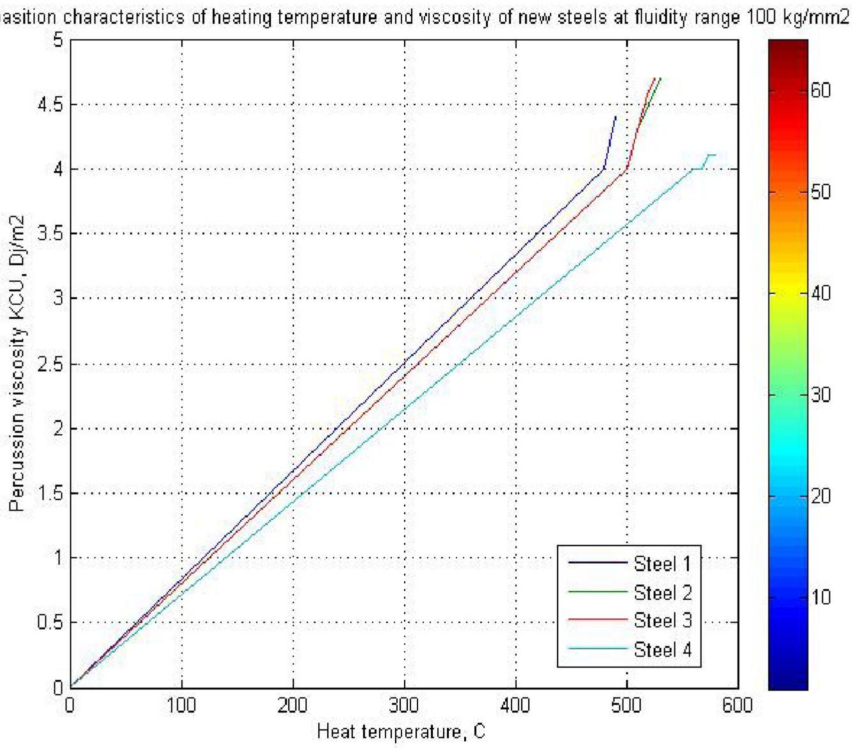

Figure 4 – Results of comparative of heating temperature and toughness of new steels at fluidity range 100kg/mm^2

Thus, getting a higher toughness at rationally alloy steels with more than 3% of chromium due to the fact that the said toughness and the hardness achieved after tempering at temperatures (460-630 ^{0} C) lying above the interval of the first kind of embrittlement.

Decrease in strength properties when heated at most significantly become more 3.42 Cr, including further doped only with tungsten or vanadium. These steels retain high tensile strength (100 kg/mm^2) upon heating to 480-530 ^{0}C, while the more alloyed steel (St. 4) remains the same fluidity range up to temperatures of 550-590 ^{0} C (Table).

Conclusion. Alloying steels with 3.22% chromium over molybdenum as a 1.5% increase in toughness and fluidity range. The introduction of silicon in a complex alloy steel has a beneficial effect on the heat resistance, toughness and fluidity range. Molybdenum has a beneficial effect on the properties of steels than tungsten and vanadium.

REFERENCES

[1] Мозберг Р.К. Материаловедение. Учеб. пособие. – 2-е изд. перераб. – М.: Высшая школа, 1991. – 448 с. с ил.

[2] Корнеев Н. И. и др. Ковка и штамповка цветных металлов. Справочник. – М.: Машиностроение, 1971. – 232 с.

[3] Жумадилова Ж.О. Физико-механические свойства конструкционных сталей // Сб. мат-лов «Механические свойства современных конструкционных материалов». Международные научные чтения им. чл.-корр. РАН И. А. Одинга. – 4-5 сентября 2014 г, г. Москва. – М.: ИМЕТ РАН, 2014. – 122 с.

[4] Бестаев А.Ш. Зависимость демпфирующих свойств стали от параметров горячей ковки // Сб. мат-лов XI Российской ежегодной конференции молодых научных сотрудников и аспирантов «Физико-химия и технология неорганических материалов» (с международным участием), Москва, 16-19 октября 2014 г. – М.: ИМЕТ РАН, 2014. 30 с.

[5] Жумадилова Ж.О., Бабаев Ш.Е., Бестаев А.Ш. Влияние легирующих элементов на характеристики сталей // Вестник КазНТУ им. К. И. Сатпаева. – 2014. – № 3. – 439 с.

REFERENCES

[1] Mozberg R.K. Materialovedenie. Ucheb. Posobie. 2-e izd. pererab. M.: Vysshaja shkola, 1991. 448 p. s il.

[2] Korneev N. I. i dr. Kovka i shtampovka cvetnyh metallov. Spravochnik. M.: Mashinostroenie, 1971. 232 p.

[3] Zhumadilova Zh.O. Fiziko-mehanicheskie svojstva konstrukcionnyh stalej. Sbornik materialov «Mehanicheskie svojstva sovremennyh konstrukcionnyh materialov». Mezhdunarodnye Nauchnye chtenija im. chl.-korr. RAN I. A. Odinga. 4-5 sentjabrja 2014 g., g. Moskva. M.: IMET RAN, 2014. 122 p.

[4] Bestaev A.Sh. Zavisimost' dempfirujushhih svojstv stali ot parametrov gorjachej kovki. Sbornik materialov XI Rossijskoj ezhegodnoj konferencii molodyh nauchnyh sotrudnikov i aspirantov «Fiziko-himija i tehnologija neorganicheskih materialov» (s mezhdunarodnym uchastiem), Moskva, 16-19 oktjabrja 2014 g. M.: IMET RAN, 2014. 30 p.

[5] Zhumadilova Zh.O., Babaev Sh.E., Bestaev A.Sh. Vlijanie legirujushhih jelementov na harakteristiki stalej. Vestnik KazNTU imeni K. I. Satpaeva. 2014. N 3. 439 p.

ДАЙЫНДАЛҒАН СОҚҚЫЛАУ БОЛАТТАРЫНЫҢ МЕХАНИКАЛЫҚ ҚАСИЕТТЕРІ

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Тірек сөздер: легірлеуші элементтер, соққылау, қыздыру температурасы, босату температурасы, қаттылық, соққылы тұтқырлық, аққыштық шегі.

Аннотация. Жұмыста жаңадан дайындалған соққылау болаттарының механикалық қасиеттері келтірілген. Легірлеуші элементтердің болат қасиетіне әсері қарастырылған, болат қаттылығының босату температурасына тәуелділігін анықтау бойынша, сонымен қатар аққыштық шегі 100кг/мм^2-та болаттың қыздыру температурасы мен тұтқырлығын анықтау бойынша эксперименттік жұмыстардың нәтижелері ұсынылған.

МЕХАНИЧЕСКИЕ СВОЙСТВА РАЗРАБОТАННЫХ КОВАНЫХ СТАЛЕЙ

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Ключевые слова: легирующие элементы, ковка, температура нагрева, температура отпуска, твердость, ударная вязкость, предел текучести.

Аннотация. В работе представлены механические свойства новых разработанных кованых сталей. Рассмотрены влияние легирующих элементов на характеристики сталей, представлены результаты экспериментальных работ по определению твердости сталей в зависимости от температуры отпуска, а также температуры нагрева и вязкость сталей при пределе текучести 100 кг/мм^2.

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