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Fracture of Jaw Arm Made of Cast Steel GS-42CrMo4

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Preliminary note

Unsuitable mechanical behaviour of cast steel GS-42CrMo4 (EN) was investigated. In this paper the influence of inclusions and pouring temperature on mechanical properties of arm of carrying jaw made of cast steel GS-42CrMo4 (EN) was investigated. It was found that a high content of aluminium caused the formation of aluminium nitride, AlN which significantly decreased the strength of casting. In the process of solidification, enrichment of lamellas of AlN nitride arise on the grain boundaries. Because of low deformability of AlN nitride, initiation of fracture was possible at minimal deformation. The strength of the casting was not being raised by subsequent heat treatment. High pouring temperature and low cooling rates resulted in coarse-grained microstructure of steel casting. Coarse microstructure was not reduced by subsequent heat treatment.

Prijelom poluge kliješta od čeličnog lijeva GS-42CrMo4

Prethodno priopćenje

Istraživano je nepovoljno mehaničko ponašanje čeličnog lijeva GS-42CrMo4 (EN). U radu je prikazan utjecaj utjecaja i temperature lijevanja na mehanička svojstva poluge kliješta izrađenih od čeličnog lijeva GS-42CrMo4 (EN). Visok sadržaj aluminija uzrokovao je tvorbu aluminijevog nitrida AlN, kojim se bitno umanjila čvrstoća odljevka. Za vrijeme skrućivanja slitine došlo je do obogaćivanja lamela AlN nitrida na granicama kristalnih zrna. Zbog male deformabilnosti AlN nitrida, do iniciranja prijeloma došlo je već kod minimalne deformacije. Čvrstoća odljevka nije se povećala naknadnom toplinskom obradom. Visoka temperatura ulijeivanja prouzrokovala je grubozrnatu strukturu. Grubozrnata struktura nije se usitnila naknadnom toplinskom obradom.

1. Introduction

The analysis of failure with the of carrying jaw arm made of cast steel GS-42CrMo4 (EN) has been done. The jaw arm was produced by sand casting. Optimal temperature of pouring for this steel is approximately 1500 °C. Because of heavy dimension of investigated steel casting, temperature of pouring was 100 °C higher than optimal.

Due to non-uniform size and orientation of grains as well as anomaly of microstructural transformations during the cooling of castings, the load capacity of steel castings is lower than of wrought steels with the same chemical composition. Some of the negative influence of as-cast structure on mechanical properties of steel castings can be neutralized by heat treating processes. The starting point in studying the mechanical properties of steel castings can be the fact that the mechanical properties of steel castings are derived from the mechanical properties of ordinary steel metal matrix reduced by the influence of the typical as-cast structure on those properties [1-9].

Very undesired inclusion in steel castings is aluminium nitride, AlN. Because of brittleness, aluminium nitride, AlN causes very low toughness of steel castings. These inclusions are probably caused by folding in of surface films which are formed in reactions to aluminium and nitrogen from the atmosphere. During solidification and dendrite growth, these AlN films are pushed into the interdendritic regions, i.e., grain boundaries.

2. Fracture of jaw arm

Geometry of fractured jaw arm is shown in Figure 1.

Fracture of the jaw arm takes place in a critical section. Fracture surface and manner of fracture of jaw arm are shown in Figure 2. It can be seen that the character of the fracture was brittle. On the fracture surface there are two distinguishable areas. At surface area of the fracture surface there is 10 to 20 mm depth of coarse-grained area which spreads from surface to core of the casting. At location of the fracture surface which corresponds to the

Symbols/Oznake

R_m - ultimate tensile stress, MPa
- vlačna čvrstoća

$R_{p0.2}$ - yield strength, MPa
- granica razvlačenja

A - percent elongation, %
- istezljivost

KV - impact toughness, J
- udarni rad loma

HB - hardness according to Brinell
- tvrdoća po Brinell-u

internal area of the casting there is a less coarse-grained area, in which dendritic solidification is noticeable. Figure 3 shows detail of the fracture surface.

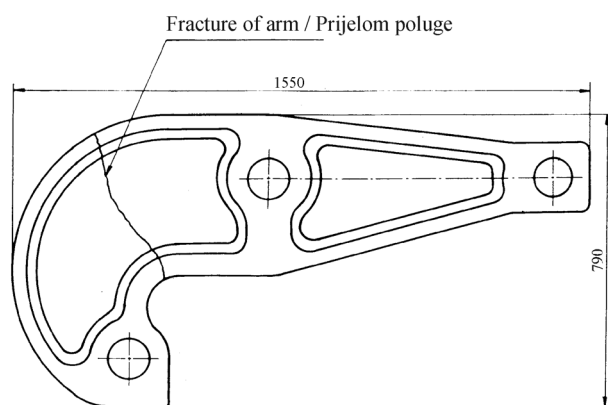


Figure 1. Geometry of fractured jaw arm

Slika 1. Geometrija polomljene poluge kliješta

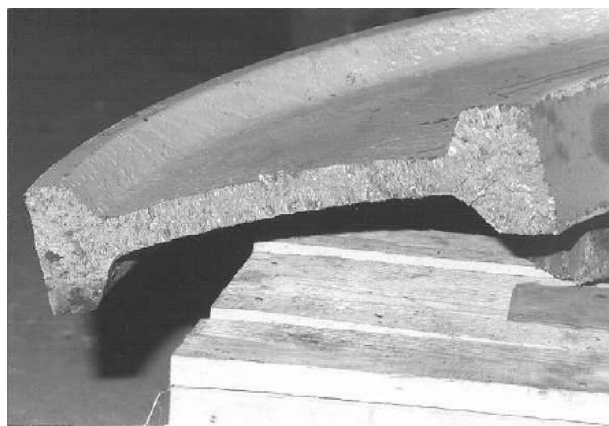


Figure 2. Fracture surface of jaw arm

Slika 2. Površina loma poluge kliješta

Coarse-grained microstructure at surface region of fracture indicates that temperature of pouring was too high.



Figure 3. Detail of the fracture surface

Slika 3. Detalj s površine loma

3. Analysis of chemical composition of jaw arm

The chemical composition of investigated arm is shown in Table 1. Chemical composition of investigated arm fits the chemical composition of GS-42CrMo4 (EN) with increased phosphorus and silicon content (Table 2).

Table 1. Chemical composition of investigated arm

Tablica 1. Kemijski sastav ispitivane poluge

C, %	Si, %	Mn, %	P, %	S, %	Cr, %	Mo, %	Al, %
0.45	0.57	0.56	0.038	0.021	0.91	0.24	0.16

Table 2. Chemical composition of GS-42CrMo4 (EN)

Tablica 2. Propisani kemijski sastav čeličnog lijeva GS-42CrMo4 (EN)

C, %	Si, %	Mn, %	P, %	S, %	Cr, %	Mo, %
0.38-0.45	0.15-0.35	0.50-0.80	0.035 max	0.035 max	0.90-1.20	0.15-0.25

Through chemical compositions analysis, it was found that the content of aluminium was 0.16 %, which is too high a content for this kind of cast steel.

4. Analysis of mechanical properties of jaw arm

Results of mechanical testing are shown in Table 3.

Because of extremely brittle fracture of tensile test specimen, it was not been possible to determine the yield strength of investigated steel. Likewise, because the fracture occurs in elastic area percent elongation was equal to zero.

Mechanical properties of cast steel GS-42CrMo4 (EN) are shown in Table 4.

Table 3. Results of mechanical testing

Tablica 3. Rezultati mehaničkih ispitivanja

Ultimate tensile stress / Vlačna čvrstoća, R_m , MPa	Yield strength / Granica razvlačenja, $R_{p0.2}$, MPa	Percent elongation / Produljenje, A , %	Hardness / Tvrdoća, HB	Impact toughness / Udarni rad loma, KV, J
744	-	-	320	15

Table 4. Mechanical properties of cast steel GS-42CrMo4 (EN)

Tablica 4. Mehanička svojstva čeličnog lijeva GS-42CrMo4 (EN)

Ultimate tensile stress / Vlačna čvrstoća, R_m , MPa	Yield strength / Granica razvlačenja, $R_{p0.2}$, MPa	Percent elongation / Produljenje, A , %	Hardness / Tvrdoća, HB	Impact toughness / Udarni rad loma, KV, J
900-1050	680	> 8	-	40

Results of mechanical testing show inadequate levels of ultimate tensile stress, yield stress, percent elongation, and impact toughness. The jaw arm was designed based on mechanical properties shown in Table 4 that are much better than actual the mechanical properties of the investigated jaw arm.

5. Analysis of microstructure of jaw arm

Microstructure of investigated casting is shown in Figure 4.

Microstructure consists of tempered martensite and bainite. Interdendritic segregations, which can be distinguished in the surface and internal area of the fracture surface, are shown in Figure 5. Non-metallic inclusions, which are mainly found on sulphides, are placed in dendrite pockets.



Figure 4. Microstructure of the casting: tempered martensite and bainite, 500:1, nital

Slika 4. Mikrostruktura odljevka, popušteni martenzit i bainit, 500:1, nital

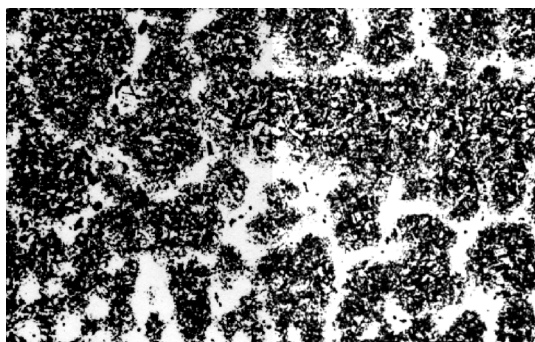


Figure 5. Interdendritic segregations, 30:1, nital

Slika 5. Meždendritno razlučivanje, 30:1, nital

6. Microanalysis of fracture surface

Microanalysis of fracture surface by scanning electron microscope showed that micromorphology and microtopology differences between surface area and internal area of fracture surface is far less expressed than was shown by a macroscopic examination.

Figure 6 shows intergranular fracture in surface area. Figure 7 shows intergranular part of fracture in internal area.

Through microanalysis, it was also found, that in internal area or area near the surface of the fracture, individually fields of ductile transgranular fracture are surrounded by an intergranular part of the fracture. Figure 8 shows transgranular parts of fracture. In fracture dimples, which are characteristic for ductile fracture, there are inclusions which are mainly found on sulphides.

By scanning electron microscope analysis of the fracture surface many lamellas on the fracture surface were found. These lamellas indicated that the jaw arm was fractured because of too high content of aluminium nitride, AlN, in the casting. So, the main reason for increased brittleness of the investigated jaw arm is too high a content of aluminium. The aluminium was added in the process of deoxidation of steel casting. An adequate

amount of the aluminium is necessary to add in the melting bath to reduce dissolved oxygen in the process of deoxidation. Too high an amount of aluminium could cause formation of the brittle aluminium nitride, AlN.



Figure 6. Fracture surface in jaw arm surface area, 1000:1

Slika 6. Izgled loma u površinskom dijelu, 1000:1

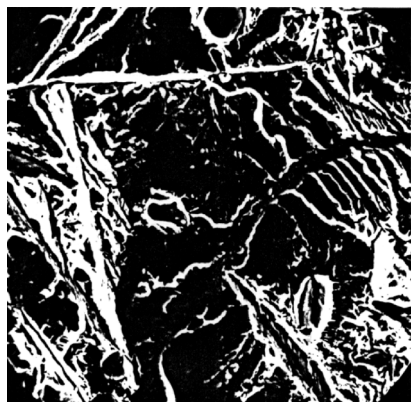


Figure 7. Fracture surface in internal area, 1000:1

Slika 7. Izgled loma u unutrašnjem dijelu, 1000:1

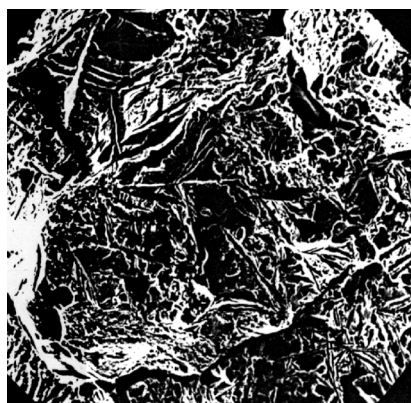


Figure 8. Fracture surface in internal area, 1000:1

Slika 8. Izgled loma u unutrašnjem dijelu, 1000:1

7. Conclusion

Based on the results of investigation of failure of jaw arm, it can be concluded that chemical composition of investigated steel casting conforms to the requirement on chemical composition, and that the temperature of pouring was too high. Because of high content of aluminium, high temperature of pouring was necessary in order to achieve good castability. Furthermore, high

content of aluminium caused formation of aluminium nitride, AlN, which significantly decreased the strength of casting. In the process of solidification, an amount of lamellas of AlN nitride was found in grain boundaries. Because of low deformability of AlN nitride, initiation of fracture is possible at very low strain. The strength of the casting was not raised by applied subsequent heat treatment. High temperature of pouring resulted in coarse-grained microstructure, which was not refined by subsequent heat treatment.

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