Using an anisotropic properties of sheetmetal to develop a design of vibrationless cutting tool

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Abstract. The article proposing a new technology for manufacturing of vibration-proof tool with multilayered damping tool holder. Desired damping effect is obtained by anisotropic properties of tool holder plates, as a result from machining by pressure a source material. The experimental research in the piece processing allows to provide effective dynamic absorbing of vibration. This method is more effective (in comparison with standard methods) because it have high coefficients of damping and absorption. The value of dissipative force of multilayered tool holder material (with differently directed structure) is enough to ensure a good damping effect.

Key words: multilayered damping tool holder, heterogeneity of the structures, oriented deformation, adjustable anisotropy, structure of metal-rolling sheet.

Introduction

Many real construction materials are characterised by anisotropy of mechanical properties which is caused by particularities of their internal structure and production technology (Mikljaev & Fridman, 1986; Vishnjakov & Piskarev, 1989). To a large degree unevenness of structures is already formed at the stage of crystallisation of ingot as dendritic segregation that depends on the chemical composition, steel melting technology, method of steel deoxidation and modification and the size of the melted ingot, which, together with the pouring temperature, defines the speed of solidification rate of the ingot. The cast structure is characterised by big crystals of primary crystallisation, along the borders of which layers enriched by additives and non-metallic inclusions are located.

Deformation (forging and rolling) of the cast structure leads to crumbling of crystallites and stretching of their intercrystalline layers that have non-metallic inclusions in the direction of the most intensive flow of metal. In case of deformation of a sufficient degree, non-metallic inclusions form banding of the macrostructure which leads to anisotropy of metal properties. At micro level anisotropy of properties of plastically deformed polycrystals is related to three types of texture: mechanical, dislocational and crystallographic (Vishnjakov & Piskarev, 1989; Borodkina & Spektor, 1981). Crystallographic texture has fundamental effect on all types of anisotropy of crystalline bodies (Vishnjakov et al., 1979).

Respectively, the choice of optimum composition and production technology for structure of metallic materials should be made taking anisotropy into consideration. At the same time assessment of anisotropy should be performed on the basis of results of different types of tests. The most common method is assessment of anisotropy based on the ratio of strength, ductility and impact hardness in different directions relative to the direction of rolling. Valuable information concerning anisotropy can be obtained during analysis of macro and micro fractures of samples of different orientation.

Materials and methods

The flat product from 36NiCrMo16 construction steel of industrial melting the ingots of which were forged into billets and rolled with reduction ratio of 7 into sheets with thickness of 70 mm was used as the material for examination of anisotropy of mechanical properties of hot-rolled steel. The temperature of the beginning of rolling was 1,100…1,200°C, the temperature of the end of rolling was 900…950°C, and the material was cooled outdoors. Heat treatment of the sheet included heat treatment from the temperature of 850–880°C into water and high-temperature tempering under the temperature of 590…620°C.

The test samples were cut out along the direction of rolling (X), perpendicular to the direction of rolling (Y) and perpendicular to the plane of the sheet (Z). Static tension tests were carried out on samples of cylindrical shape using Instron-5000 machine, and impact bending (impact hardness) tests were carried out on samples sized 10x10x55 mm with notch radius of 1 mm using pendulum impact testing machine with blow energy store of 4,635 J. Results of the test are presented in Table 1.

Table 1. Mechanical properties of sheet steel in different directions

Test direction	X	У	Z	Ky-x	Kz-y
Tensile strength, MPa	1,278	1,225	1,153	0.96	0.94
Yield limit, MPa	1,209	1,140	1,126	0.94	0.98
Percentage of elongation, %	15.7	13.5	3.8	0.85	0.28
Percentage reduction in area, %	55.8	50.1	8.8	0.89	0.18
Impact hardness, kJ cm^{-2}	78	67	25	0.86	0.37

As it is seen from these figures, during testing the samples that were cut out across the grain show lower mechanical properties than the samples that were cut out along the grain. The degree of anisotropy of metal in У-X plane constitutes 4…6% with respect to strength properties and 11…15% with respect to ductility properties. Grain direction mostly has effect on ductility and strength of steel. Anisotropy is more evident in the direction that is perpendicular to the direction of rolling Z – spatial anisotropy. The degree of anisotropy of the samples that were perpendicular to the rolling plane with respect to strength is not very high, remaining within 2…4%, while at the same time percentage of elongation is reduced by 3 and reduction in area is reduced by 6.

It is known that in many cases test results of smooth samples characterise average and not local properties of material (Vishnjakov & Piskarev, 1989). Presence of a stress concentrator and dynamic nature of loading during an impact bending test often lead to results that differ from the results of static tests of smooth samples, and at the same time demonstrate more brittle fracture. Since impact hardness characterises both strength and ductility, this property of metal is the most sensitive one to anisotropy (Vishnjakov et al., 1979).

The main reasons for anisotropy of impact hardness of steel products are: mechanical texture, mainly its fibrous character, oriented location of oxide, sulphide and oxysulphide inclusions, and crystallographic texture (lean alloy steel). Anisotropy of impact strength in rolling plane does not exceed 14%, while at the same time spatial anisotropy constitutes 63%, and there is almost a 3-fold difference between impact hardness of transverse and vertical samples.

Since non-metallic inclusions deformed in the direction of rolling have a direct effect on anisotropy of impact hardness, impurity content in steel (Table 2), including sulphur and oxygen that completely turn into oxide and sulphide inclusions, was also designated (Glebov & Duhovnõi, 1990).

Table 2. Content of a number of elements and impurities in steel

Mn	P	S	Si	O	N	Al	Ce
0.47%	0.013%	0.018%	0.26%	0.0048%	0.007%	0.014%	0.002%

Microstructure of examined steel that became developed through etching in 4% alcohol-nitric acid solution is shown in Fig. 1.

After final heat treatment the microstructure constitutes highly dispersed secondary sorbite.

Actual austenite grain of steel that was developed according to GOST 5639-82 through etching in super saturated solid solution of picric acid heated to 70^{o}C with inclusion of surface-active synthol agent is shown in Fig. 2.

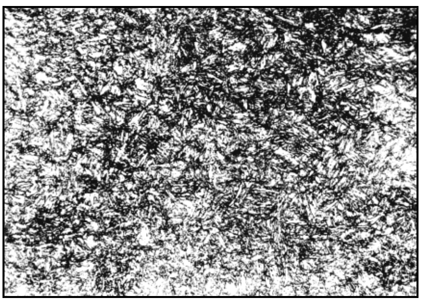


Fig. 1. Microstructure of 36NiCrMo16 steel after final heat treatment, x400.

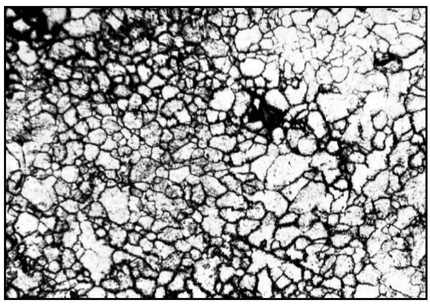
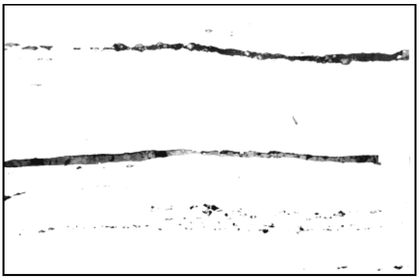


Fig. 2 Size of actual austenite grain of steel after final heat treatment, x100.

Austenite grain is equiaxed and matches number 8–9. As the presented Figures demonstrate, anisotropy of metal is not evident at micro structural level.

Non-metallic inclusions in the examined steel are shown in Fig. 3, a, b. Fig. 3 demonstrates that anisotropy of properties is increased by threads of non-metallic inclusions stretched after rolling that constitute sulphide and oxide inclusions.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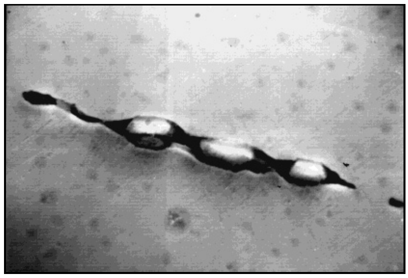
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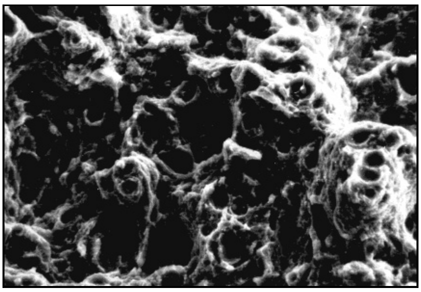
Fig. 3. Non-metallic inclusions in different areas of the explored steel a) x100, b) x200.

Microfractographic analysis of fractures was performed using PSEM-500 – a focused-beam electronic microscope (by Phillips). Fractographic analysis helped to establish that the surface of fractures of the samples cut out in longitudinal (X) and transverse (Y) directions relative to the direction of rolling is ductile and dimpled, which corresponds to ductile intragranular fracture (Fig. 4).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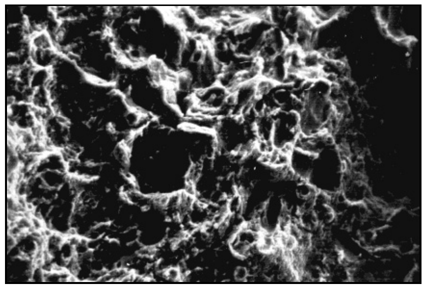
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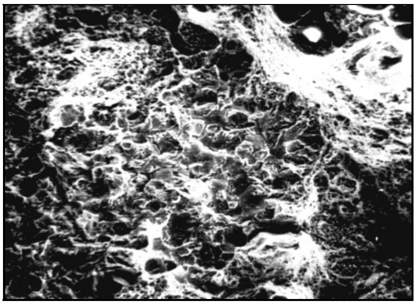
Fig. 4. Focused-beam images of fractures of longitudinal (a) and transverse (b) samples, x430.

Ideal shape of the fractures is evident in samples cut out in vertical direction (Figs 5 and 6). Fractographic analysis established that the fracture has a layered structure consisting of terraces connected with plastic ductile bridges. Plane of the terraces is predominantly filled with oxide and oxysulphide inclusions (Figs 5–6).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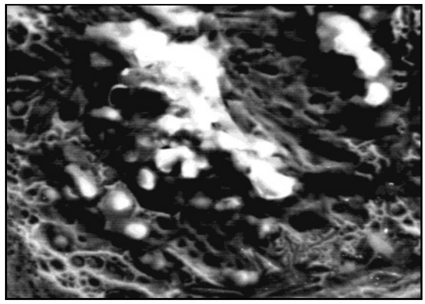
b)

Fig. 5. Clusters of oxide nonmetallic inclusions in fractures: a) x40, b) x320.

In some fractures there also were rough rolled eutectic manganous sulphides (Fig. 6, b) and small areas of brittle intergranular and quasi-brittle intragranular fracture.

a) b)

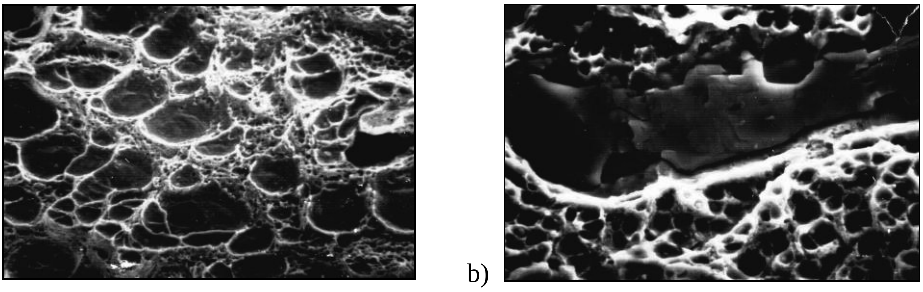

Fig. 6. Oxysulphide (a) and eutectic sulfide (b) inclusions in fractures: x160.

Results of microfractographic analysis demonstrated that in fractures of the samples that were cut out in transverse or longitudinal directions, propagation of crack resulting from fracture goes according to ductile intragranular mechanism.

Conclusions

In fractures of vertical samples fracture mainly goes through clusters of non-metallic inclusions of different sizes and morphology. Fracture through main metal free of non-metallic inclusions did not exceed 20% of the area of fracture and constituted predominantly ductile intragranular fracture. Separate small areas of quasi-brittle intragranular fracture and brittle intragranular fracture were located near eutectic manganous sulphide (Maksarov & Olt, 2008a).

During production of critical items it is necessary to take into consideration anisotropic properties of construction materials, factors having effect on them at all stages of technological conversions (Maksarov et al., 2008 ; Maksarov & Olt, 2008b; Maksarov et al., 2011), as well as the option of creation of products with designated or adjustable anisotropy.

It was established that anisotropy of mechanical properties causes abnormal changes of speeds of elastic waves, trajectories of their propagation and coefficient of their dispersion (decay), which creates the possibility to use anisotropic properties typical to most real construction materials for development and creation of construction of the instrument with increased damping properties.

References

Mikljaev, P.G., Fridman, J.B. 1986. *The anisotropy of mechanical properties of the metal*. Metallurgy, Moskow, 224 pp. (in Russian).

Vishnjakov, J.D., Piskarev, V.D. 1989. *Control of residual stresses in metals and alloys*. Metallurgy, Moskow, 254 pp. (in Russian).

Borodkina, M.M., Spektor E.N. 1981. *Radiographic analysis of the texture of metals and alloys*. Metallurgy, Moskow, 272 pp. (in Russian).

Vishnjakon, J.D., Babpeko A.D., Vladimirov A.D. 1979. *The theory of the formation of textures in metals and alloys*. Nauka, Moskow, 329 pp. (in Russian).

Glebov, A.G., Duhovnõi, A.S. 1990. The influence of nonmetallic inclusions on the fracture resistance of high strength steel plate. *The strength and fracture of steels at low temperatures*. Metallurgy, Moskow, pp. 86–94. (in Russian).

Maksarov, V., Olt, J. 2008a. Methods of preliminary local physical action on the workable surface of the blank. *The 7th International Scientific Coference. Engineering for Rural Development*. Jelgava, Latvia, pp. 224–228.

Maksarov, V., Olt, J., Leemet, T. 2008a. Increase in the stability of technological system with control of the process of the cutting. *International science conference of material science and manufacturing technology*. Prague, Czech Republic, pp. 136–140.

Maksarov, V., Olt, J. 2008b. Analysis of the rheological model of the process of chip formation with metal machining . *The International Scientific Conference. Engineering of Agricultural Technologies*, Kaunas, Lithuania, pp. 249–253.

Maksarov V.V, Olt U, Leonidov P.V, Limin P.P. 2011. Application of anisotropic properties metal-rolling sheet for manufacturing of vibration-proof tool. *Metalworking*, **62**(2), pp. 5–11. (in Russian).