FATIGUE BEHAVIOUR OF AUSTENITIC Cr-Mn-N-STEELS USED FOR DRILL COLLARS

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Using MWD (Measuring While Drilling) systems for determining drilling parameters like azimuth, drift and tool face in the case of deep drilling, nonmagnetic materials are required for the drill collars since the measuring system is based on the terestric magnetic field. The most frequently used material for non-magnetic drill collars are cold worked austenitic Cr-Mn-N-steels with yield strengths about 750 to 850 N/mm². In Table 1 the typical chemical composition of actually used Cr-Mn-N-steels is listed.

Table 1 - Typical chemical composition of Cr-Mn-N-steels

C	Mn	S	Cr	Mo	Ni	N
0,05	19,0	0,005	14,0	0,40	2,0	0,25

The packaging of an increasing number of sensors and electronic devices into drill collars causes raising stresses due to introduction of boreholes and notches. These stresses are usually cyclic. This results in a great demand for enhanced fatigue properties of the collar material.

Austenitic stainless steel in its solution annealed condition is with exception of ductility and toughness known as a material with inferior mechanical properties e.g. yield strength and fatigue limit. For improving these properties changing of alloy composition as well as an optimized thermomechanical treatment have been investigated.

To enhance the fatigue behaviour the nucleation and growth of fatigue cracks has to be retarded or completely prevented. The fatigue relevant parameters and their influence on the fatigue properties are discussed in brief. The most important parameters are the grain size, as grain boundaries are known to hinder small crack growth, and the stability of the dislocation structure, which has to be destroyed to produce slip bands acting as crack nucleation sites. The predominant mechanism for fatigue crack initiation in the steel investigated is nucleation in slip bands within surface grains. These slip band induced small cracks decelerate at grain boundaries which are acting as obstacles, some of them stop growing but others accelarate after overcoming the grain boundary growing to a small and then further to a large crack destroying the specimen.

The influence of grain size on the yield stress is covered by the cold working. Some results which will be reported elsewhere give an evidence, that the S/N behaviour can be improved by decreasing grain size.

The cyclic stress necessary for crack nucleation is shifted to

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higher stress levels by increasing the yield stress. This can be done by additional solid solution strengthening due to a higher nitrogen content. Fig. 1 indicates that an increasing nitrogen content improves the S/N-behaviour of the solution annealed material slightly. Much more effective than the solid solution strengthening in raising the yield stress is cold working of the material of about 10 to 15 % which enables yield stresses between 750 and 850 MPa. The influence of nitrogen and cold working on the mechanical behaviour is summarized in Table 2.

Table 2 - Mechanical properties of the materials investigated

condition	$R_{po,2}$	R_m	A_5	Z
0,25 % N, solution annealed	385	692	63	78
0,35 % N, solution annealed	416	745	57	73
0,35 % N, 15 % cold worked	876	968	31	68
0,35 % N, 30 % cold worked	998	1090	20	63

Cold working is advantageous especially in the field of high cyclic stresses, Fig. 1. Most efficient are cold working degrees up to 15 %, further cold working leads only to an unessential improvement of the S/N behaviour. With increasing lifetime the benefit of cold working gets smaller but it doesn't vanish completly. Cold working is applied by forging the collar which results in a very inhomogeneous deformation distribution over the cross section. One of the problems arising due to cold forging is the introduction of internal stresses. Depending on forging parameters these internal stresses are the reason for an appreciable amount of cyclic plastic deformation at stresses even far below yield stress. The reason for this behaviour is the nonequal flow in the various directions leading to the well known Bauschinger effect. This effect is large particularly for uniaxial flow. The plastic strain amplitudes due to this effect are responsible for an accelerated damage of surface grains, because the dislocation substructure is altered by these strains favouring the nucleation of slip bands. The stability of the dislocation substructure was tested by low cycle fatigue experiments. Fig. 2 shows the response of the material under constant plastic amplitude test. Material in the annealed condition undergoes first cyclic harding, followed by softening, the cold worked material softens through the whole test without reaching a steady state region. Transmission electron studies of the cycled material show, that the highly disordered dislocation structure after cold working is converted predominantely to cells at the higher strain amplitudes, Fig.3a, at the lower strain amplitudes the deformation occurs localized in shear bands, Fig.3b. On the contrary plastic cycling the solution annealed material results in dislocation introduction during the first few cycles, during further cycling these dislocations are rearranged to cells accompanied by cyclic softening. The Coffin-Manson Plot in Fig. 4 indicates, that the cold worked material has a slightly decreased lifetime compared to the solution annealed material.

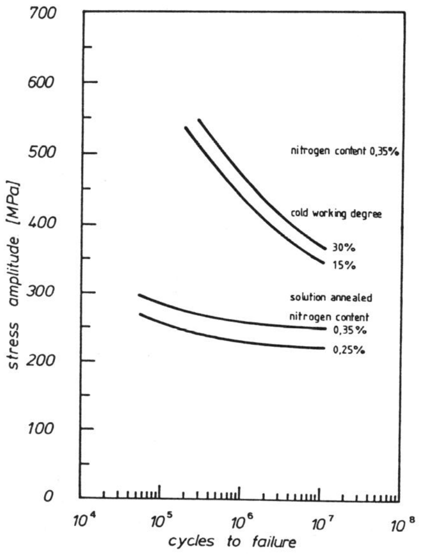

Fig.1 Influence of nitrogen content and cold working on the S/N-behaviour

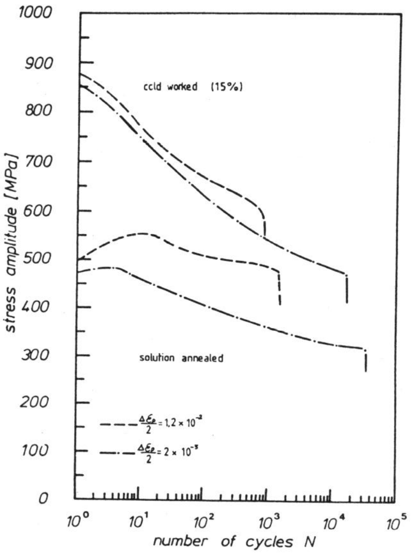

Fig.2 Material response to cycling at constant plastic strain amplitude

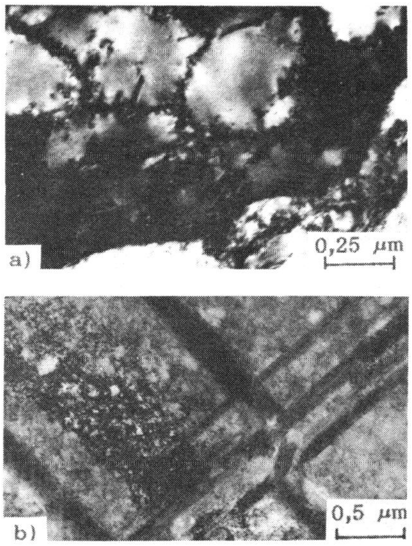

Fig.3a Cells at high strain amplitudes, 3b: Localized deformation at low strain ampl.

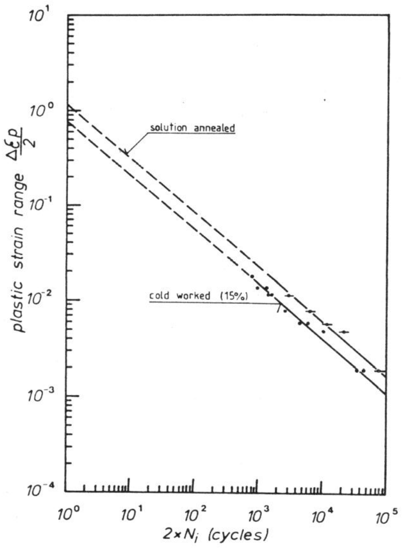

Fig.4 Coffin-Manson plot of cold worked and solution annealed material