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State Of Dynamic Stresses in Zones with Stress Concentrators in Case of High Diameter Drill Pipes

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Abstract

The 10¾"drill pipes, used for high diameter drilling of 3.6 m, have a construction characterized by existence of some zones with stress concentrators favoring the nucleation and developing of fatigue cracks. In order to explain the causes of these phenomena of cracking, some dynamic measurements have been made in field conditions. In this paper the drill pipe construction and the measurement carrying out conditions are presented and the analysis of the states of dynamic stresses resulted on the basis of recordings in real time in a drilling well are made.

Key words: *drill pipes, stress concentrators, state of stresses.*

Introduction

The 10¾ in drill pipes in the frame of drill string used for high diameter drilling of 3.6 m have the construction shown in figure 1. It may be found that the pipes are built up among them by using six screws M48, having a fastening role, the torsion moment being transmitted by means of two centering bolts (Ø 52), noted as 2. In this reason, the pipe is built from a body (1), endowed with pins at both of its ends to which the two flanges (2) are built up by threads. In order to prevent the break out during the drilling and to allow the supporting of the drill string during the running of introduction in the well and pulling out of the well, to the neck (3) of each of the flanges a crenellated collar by front weld is assembled, fixed by its turn to the pipe body with side weld inside the crenels. There is also an inside weld between the pin end of the pipe body and the flange.

In the initial construction there were not crenellated collars, each of the flanges being ensured against the break out by outside additional weld, between the flange neck and pipe body, and inside weld, between the pin end and the flange. The use of this construction has brought about technical accidents during the drilling by breakings in the outside additional weld plane, where there is a stress concentrator having a constructive nature (with stiffness variation), represented by the passing section from the flange neck to the pipe body, and a metallurgical nature – heat influenced zone (HIZ) of the additional weld [1].

But, unfortunately, the new construction has not been without problems. So, fissures and breaks in the terminal zone of the side weld seam between the support collar and the pipe body, at the crenellation basis (see figure 2 [1]), brought, although, normally the side welds are not resistance welds. But, this zone is one which has stress concentrators of constructive nature – the passing section from the flange crenellated collar, with a thickness of 25 mm, to the pipe body, with a thickness of 12.57 mm – and of metallurgical nature, the HIZ from the additional weld.

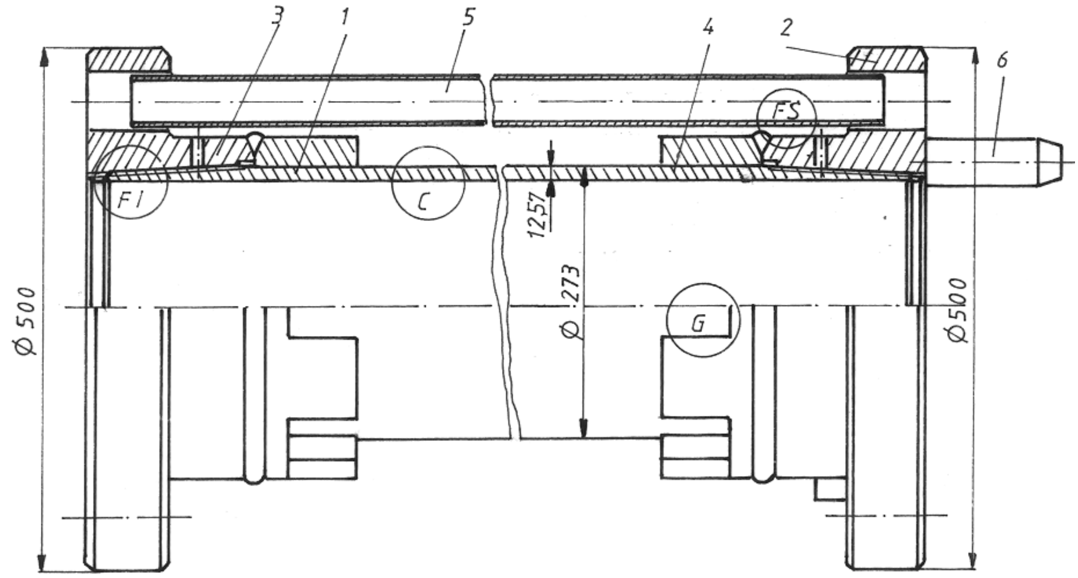

Fig. 1. Longitudinal section through a 10¾ in drill pipe with airlift pipes: 1 – drill pipe body; 2 – flange; 3 – flange neck; 4 – crenellated collar; 5 – airlift pipe; 6 – centering bolt

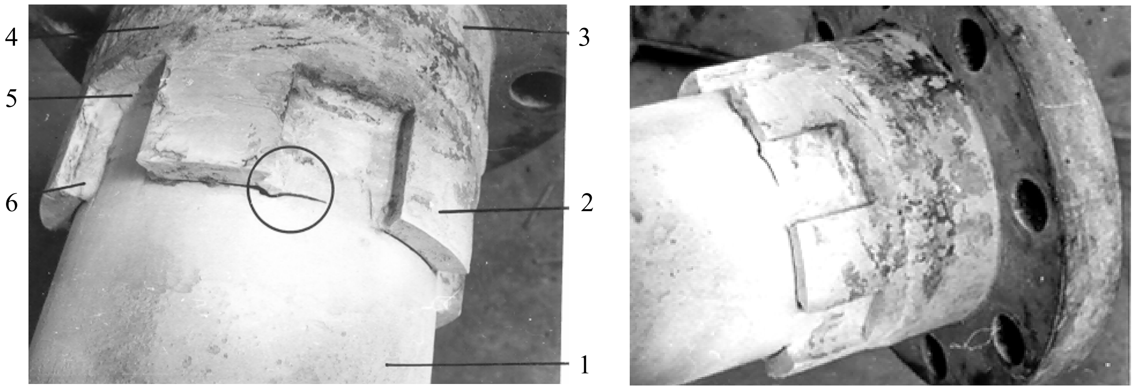

Fig. 2. 10¾ in drill pipe without airlift pipes, series 122: sight of zone with penetrated macro crack; 1 − drill pipe body; 2 − crenellated collar; 3 − flange; 4 − frontal weld seam between the flange neck and the crenellated collar; 5 – additional weld in the crenel inside basis; 6 − side corner weld at the crenel basis

For making evident the reasons of these fissuring and breaking phenomena experimental researches have been started and carried on. In this way, a program of dynamic measurements in field conditions has been elaborated.

Measurement preparation and realization in field conditions

The resistive electric strain gauging method and technics have been used. A drill pipe of 10¾ in (see figure 1) has been equipped with rosettes for: the whole strain measuring on the part of the weld seam between the neck and the collar of the upper flange (zone "FS", with rosette FS having the type "Δ", WA–06–250WY–120, figs. 3 and 4); the whole strain measuring in the zone of the weld seam between the flange collar and the pipe body (zone "G", with rosette G having the type 6/120RY11, figs. 3 and 4); the whole strain measuring in zone of thread joint between the pipe body and flange (zone "FI", with rosettes FI having the type 6/120RY11); the strain measuring due to the complex loading of axial force, bending moment and torsion moment (zone "C", with three strain gauges having the basis of 10 mm, seated in Y, fig. 3). The pipe equipped with these strain gauges and with compensation gauges of the temperature effect, with the respective protections, has been called loading captor (LC) [2].

The direct gauging in traction has shown the presence of a pre-tension state in the thread joint zone (“FI”) and in the zones with weld seams (“FS” and “G”), which has influence on the stresses owing to actions occurring during the drilling and has an important role in fatigue phenomenon yielding.

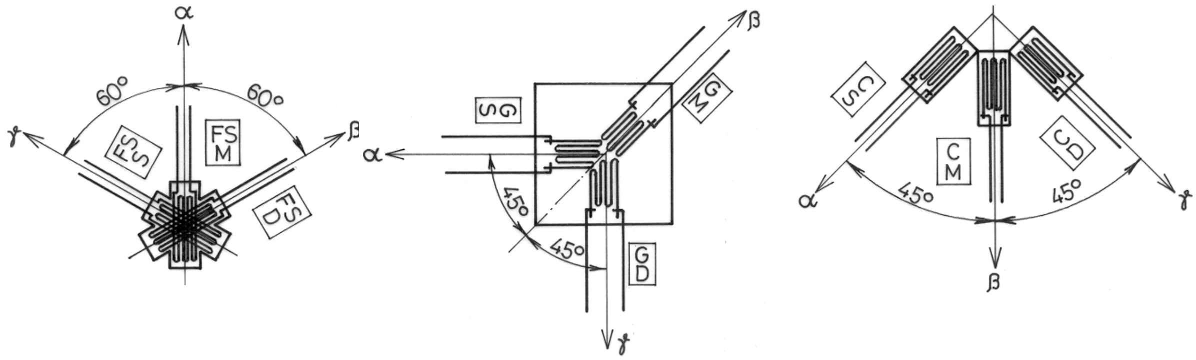

Fig. 3. Rosettes FS, G and C

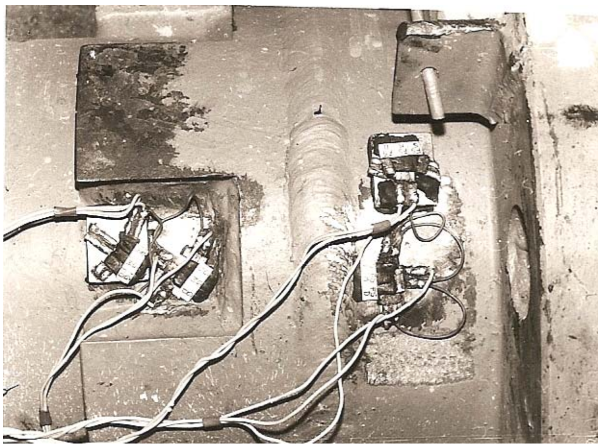

Fig. 4. Placing zones for rosettes FS and G

The gauging allows also the initial strain state determination of the measurement points for a certain static load at the hook. This action was necessary because the measurements in dynamic conditions were carried out after the respective Wheatstone bridges had been equilibrated, the drill string being hung up in the hook in that moment of equilibration. For example, for the traction force of 1.315 MN, the initial specific strains (ε_{x0}, $x = \alpha, \beta, \gamma$) in the measurement points “FS” and “G” are presented in table 1. In this way, during the dynamic measuring in a certain time, the whole specific strain (ε'_x) represents the algebraic sum between ε_{x0} and the specific strain obtained by means of recording (ε_x).

Table 1. Initial specific strains in points “FS” and “G”

ε_{x0}; $\sigma_{eqv.0}$ / Measuring point	$\varepsilon_{\alpha 0}$, μm/m	$\varepsilon_{\beta 0}$, μm/m	$\varepsilon_{\gamma 0}$, μm/m	$\sigma_{eqv.0}$, MN/m^2
FS	6	- 343	238	102,7
G	-137	16	377	112,9

In table 1, the initial equivalent stress ($\sigma_{eqv.0}$) has been determined by means of the relationship admitted by the deviation potential energy theory for the stress plane state.

For an axial force of 1.315 MN the specific strain of the drill pipe body, obtained by gauging, is $\varepsilon_{F.0}$ = 510 μm/m, which produces an axial stress of $\sigma_{F.0}$ = 107.1 MN/m^2. By comparison of this measure $\sigma_{F.0}$ with the equivalent stress measures $\sigma_{eqv.0}$ in the points “FS” and “G” presented in table 1, may be found that the two weld seams take part actually to the axial load over-taking, although they are not realized in this aim.

The dynamic recordings have been made during the drilling of a well with a diameter of 3.6 m in Buştenari by using a drilling rig F320-3DH-M. It has been used a strain gauge chain made up of a loading captor (LC), the binding cables, a collector of sliding contacts and the recording instrumentation in real time [3]. The loading captor (LC) has been mounted on the drill string upper part, as the last drill pipe.

Analysis of the stress state in zone "G" of the drill pipe

This analysis is made only in case of the drill string starting with an electro-hydrostatic driving group being initially in stationary regime of running and the subsequent starting of the second group. In figure 5 the variation of the equivalent stress in the point "G" in this situation is presented.

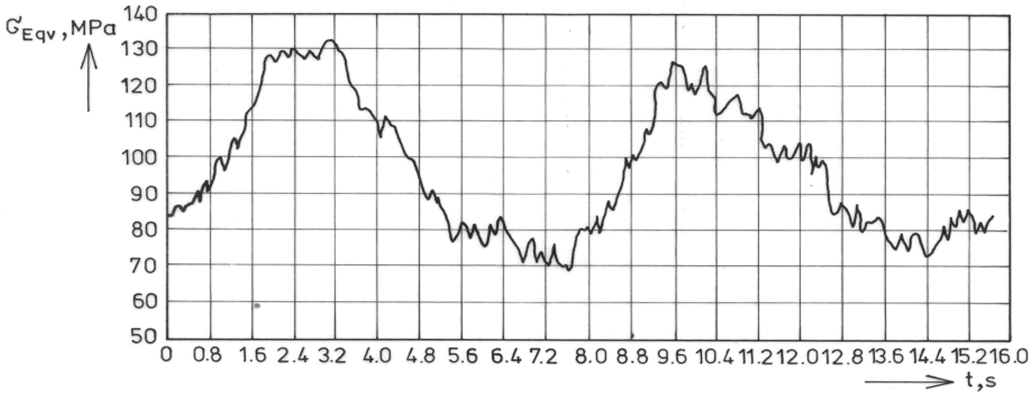

Fig. 5. Variation of the equivalent stress σ_{eqv} in point "G" of the drill pipe (LC) during the drill string starting by means of only a driving group and the subsequent starting of the second one

A very well-marked variation of the equivalent stress in the recording period of 15.68 s may be observed. The initial measure of the equivalent stress is 84.7 MPa. On the range [0; 1.52]·s some oscillations of the equivalent stress with increases of {3; 2; 2; 6; 8; 9; 6}·MPa in short time ranges of {0.08; 0.08; 0.08; 0.08; 016; 0.16; 0.16}·s may be ascertained. After that, other increases of {4; 5; 7.0; 7.5}·MPa in time ranges of 0.16 s will follow. In the period [1.84; 3.04]·s some oscillations with increasing amplitudes from 1.5 MPa to 2.5 MPa appear again. In time 3.04 s the maximum measure of 132.8 MPa is reached, which is greater with about 12 MPa than the maximum measure of the equivalent stress recorded in the same conditions in the cross section of the drill pipe body (zone "C"). After obtaining the maximum measure, the equivalent stress decreases in the range [3.04; 7.68]·s, the minimum measure being 70 MPa in time 7.68 s. In time 9.6 s, after starting the second driving group, the second peak is reached, with the measure of 127 MPa, which is greater with about 20 MPa than the corresponding measure of the equivalent stress recorded in the same conditions in the cross section of the drill pipe body (point "C"). It follows another equivalent stress decreasing, with stronger oscillations.

Analysis of the stress state in zone "FS" of the drill pipe

Two recordings for two different situations have been made: 1) drill string starting by using only a driving group (recording number 36); 2) drilling by using working conditions characterized by: n_B = 10.6 rot/min (rotative speed of the bit) şi W_B = 120 kN (weight-on-bit) (recording number 37).

In figure 6 the time variation of the equivalent stress in this zone “FS” during the drill string starting by using only a driving group is presented.

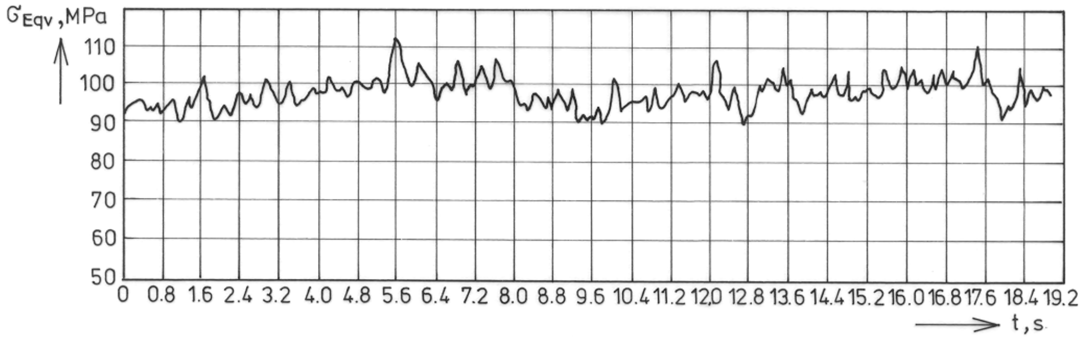

Fig. 6. Equivalent stress variation in the point “FS” of the drill pipe (LC) during the drill string starting by means of only a driving group and the subsequent starting of the second one

From this diagram analysis, the following observations have been found:

• The equivalent stress variation at starting is less marked; it is characterized by the initial measure $\sigma_{eqv.0}$ = 90.7 MPa, the minimum measure $\sigma_{eqv.m}$ = 90.5 MPa, and the maximum measure $\sigma_{eqv.M}$ = 112.9 MPa;

• The maximum measure is reached in the time t = 5.6 s;

• the maximum measure of the equivalent stress is with 8 MPa smaller than the maximum measure of this stress determined in the same conditions in the drill pipe body (point “C”) and with 20 MPa smaller than the maximum measure of the equivalent stress in zone “G”, at starting (see the subchapter Zone “G”);

• After the equivalent stress decreases at the measure of 91.2 MPa in the range [5.60; 9.84]·s, the second increase is recorded, corresponding to setting in running of the second driving group, until the measure of 111.3 MPa, in the time range [9.84; 17.44]·s;

• Two periods may be ascertained, being as long as T = 9.4 s, regarding the equivalent stress variation between the measures of 91 MPa and 111.3 MPa, therefore with $\Delta\sigma_{eqv}$ = 20.3 MPa.

The second situation is represented by the recording number 37, from which the following observations about the equivalent stress variation will result:

• The equivalent stress variation in the zone “FS” during a complete rotation of the drill string cannot be expressed as a certain law;

• The equivalent stress oscillations take place between $\sigma_{eqv.m}$ = 93 MPa and $\sigma_{eqv.M}$ = 105 MPa; therefore, the variation is $\Delta\sigma_{eqv}$ = 12 MPa;

• Oscillations take place about the mean measure $\sigma_{eqv.n}$ = 97.7 MPa;

• In comparison with the drill pipe body cross section, for the same working regime, characterized by W_B = 120 kN, the mean measure of the equivalent stress is with 7.6 MPa smaller and these stress oscillations have amplitudes about two times smaller;

• The equivalent stress mean measure in zone “FS” is very close to the equivalent stress measure of 98 MPa, determined in static conditions, by submitting to traction of the drill pipe with an equal force as the mean measure of the axial force (F = 1178 kN) for the regime with W_B = 120 kN;

• These measures of the equivalent stress will demonstrate the very little influence of the torsion and bending loadings, in comparison with the axial loading, in the frame of complex loadings which arise from this zone.

Conclusions

The analysis of the state of dynamic stresses in zone “G” of the drill pipe (LC) carried out in case of the drill string starting by using only a driving group and the subsequent starting of the second one, shows that this zone with stress concentrators, represented by passing from the flange collar to the drill pipe body, and by building it up using side and front weld seams of the two elements, are characterized by equivalent stresses having greater measures at least with 10% than those which appear in the cross section of the drill pipe body (zone “C”) and oscillations much more pronounced. The direct gauging of the loading captor (LC) has shown (according to [2]) the occurring of some states of pre-tension in zone “G”, which have influence on the stresses due to actions taking place during the drilling and have an important role in yielding of the fatigue phenomenon. In this way, may be demonstrate that zone “G” is a dangerous zone in the drill pipe from point of view of the equivalent stress and its variability, a zone favorable to fatigue degradation appearance, especially that it represents, with a great probability, also the crack nucleation place [1]. Also, the dynamic equivalent stress variation during its starting quickens the degradation process in this zone, by the crack propagation speed increasing, as during the measurements has been ascertained. So, after 16 hours, as long as the measurements lasted, which in different conditions had been carried out (of drilling in different regimes, of starting of the drill string and of its dead rotation a.s.o.), in case of the drill string pulling, a penetrated macro-crack in the terminal zone of the side weld seam between the support collar and the drill pipe body, at the basis of a crenellation, had been observed.

From analysis of the stress state in zone “FS” of the drill pipe (LC) may be found that the butt-jointed seam between the flange neck and the crenellated collar take effectively part to the loading over-taking, although this weld is not made in this aim (see also [2]), but it may be considered that this zone with stress concentrator represents a less dangerous zone for fatigue degradation appearance even than the drill pipe body, in conditions where the welding technology is respected. This situation is due to the greater section of the flange neck and to the welding better technological conditions.

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Starea de tensiuni dinamice din zonele cu concentratori de tensiune de la prăjinile de foraj de diametru mare

Rezumat

Prăjinile de foraj de 10¾", utilizate pentru forajul de diametru mare, de 3.6 m, au o construcție caracterizată prin existența unor zone cu concentratori de tensiune, care au favorizat nucleația şi dezvoltatea unor fisuri de oboseală. Pentru a elucida cauzele producerii acestor fenomene de fisurare, s-au efectuat măsurări dinamice în condiții de şantier. În această lucrare, se prezintă construcția prăjinii de foraj, condițiile de desfăşurare a măsurărilor şi se face o analiză a stărilor de tensiuni dinamice rezultate pe baza înregistrărilor în timp real de la o sondă în foraj.