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Reliability Analysis and Numerical Simulation for a Drilling Rig

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Abstract

The latter can be of various types (according to its complexity and performance features).
In order to identify some models destined to the simulation of various working conditions there are used the methods of analysing system structure and plant compunds. Due to these methods there can be carried out the logistic analysis of a relevant number of situations encountered in practice.

Key words: *structural analysis, reliability function, technical risks*

Structural Models

The core problem of the reliability model's analysis is to determine the extent to which the characteristic parameters can remain within the limits set for the system's working condition

From this point of view, the structural analysis is aimed at identifying the way a plant works. This shows the way in which main and auxiliary operating systems are grouped. Oil plants for drilling and drawing destined to ground and off-shore oil recovery are structured according to the appropriate technological processes.

A main operating system performs the functions necessary for the drilling technological process and consists of the driving system and the producer. The driving system consists of the engine or engine group (M) and gearing.The driving system, the structure is presented in (tabela.1), where the producer is the draw works (TF), and the actuator is the swivel hook (C).

A main operating system (SM) carries out the functions necessary for the technological drilling process and consists of the driving system (SA) and the producer. SA consists of the engine (M), the gearing (T) and the gear box (CV). The latter can be of various types (with power take off from draw works or from gearing ($T \equiv T1 \cap T2 \cap T3 \cap T4$), according to its complexity and performance features.

Determining reliability parameter of broad interest is very important especially in the designing phase because the designer must solve not only the problems related to the system's functions but also those related to its safe operation. In the calculation of every system, the system's structure is shown by the structural model (MS), which may not differ from the block diagram of the system's functioning.

Starting from these aspects, the structural analysis only presents the drilling plant as a complex system consisting of interconnected subsystems in order to identify some networks whose analysis can become operational.

The reliability functions of the comprising subsystems are:

Rm – for engine; Rt – for gearing; Rtf – for draw works; Rc – for assembly crown-block cable – hook crane, Rgf – for drill column and Rs – for drill rod.

The systems are equipped with the same gearing, and the table – with a mechanical power take off and a gear box (CV) for MR. Below we will note the structural schemes for the rotating system (SR) and for the circulation system (SC), respectively. For the centralised or group operating mode the main operating systems (SM, SR and SC) are operated by the same engine or group of engines.

Table 1. Structural systems and modes

Engines	Gearing(s)	Machines work	Execution elements	Swivel	Structure
M1 *Rm1*	T1 *Rt1*	TF *Rtf*	C *Rc*	CH *Rch*	Drive (SM) Sistem
M5 *Rm2*		CV R_{CV}			
M2 *Rm2*	T2 *Rt2*	MR *Rmr*	R *Rr*		Rotary System (SR)
M3 *Rm3*	T3 *Rt3*	PF1 *Rpf1*	P1 *Rp1*		Circulation (SC) System
M4 *Rm4*	T4 *Rt4*	PF2 *Rpf2*	P2 *Rp2*		

The total reliability function for this operating mode is calculated using the features of structural analysis methods, as follows:

$$R_{G1} = Rm \cdot Rt \cdot [1-(1-Rtf\text{-}c\text{-}r)(1-Rpf\text{-}p)]\cdot Rch \qquad (1)$$

where:

$Rtf\text{-}c\text{-}r = Rtf \cdot [\, 1-(1-Rc)(1-Rcv\cdot Rmr\cdot R\mathrm{r})]$

$Rpf\text{-}p = [1-(1-Rpf1 \cdot Rp1)(1\text{-}Rpf2 \cdot Rp2)]$

$Rm = 1-\prod_{i=1}^{n}(1-Rmi)$, the reliability function of the group of n engines

Rch – the reliability function of swivel casing

There is also a second variant for the group operating mode, G2, where one of the pumps has its own group of engines and gearing, and for MR the power take off is connected either to TF or directly to T1, as shown in the chart below:

The total reliability function in this case is:

$$R_{G2} = [1-(1-R_I)\cdot(1-R_{II})]\cdot Rch \quad (2)$$

where:

$R_I = Rm_{1,2} \cdot Rt \cdot [1-(1-Rtf\text{-}c-r)\cdot(1-Rpf1\cdot Rp1)]$
$R_{II} = Rm_3 \cdot Rt2 \cdot Rpf2 \cdot Rp2$

the values of variables are known.
Another operating mode would be the one for which SM and SR receive the energy flux from a common group of engines by means of common gearing, and SC works independently. This operating mode is called mixed1 (M1) because it refers to the logistic configuration 1 of subsystem connecting.
We notice that M1 differs from G1 and G2 by the complete separation of SC (tabela 1), [3], [1] which has major implications on the whole IF project. These are to be found in the analysis of the whole system's reliability and in that of its technical security due to the physical separation of working areas.
Thus, there appears mechanical gearing T2 (only for SC), given the fact that T has been replaced by T1 whose complexity decreased due to the removal of chain PF1-P from G2 and its transfer to M1.
Similarly, from the logistic perspective of plant exploitation there can be organised an IF and an operating mode by means of which driving and rotating systems work together and circulation works independently.

The total reliability function R_{M1} is calculated considering R_I and R_{II} shunted together, and the result concatenated with Rch is:

$$R_{M1} = [1-(1-R_I)(1-R_{II})]\cdot Rch \quad (3)$$

where:

$R_I = Rm12 \cdot Rt \cdot Rtf\text{-}c\text{-}r$
$R_{II} = Rm3 \cdot Rt2 \cdot [1-(1-Rpf1\cdot Rp1)(1-Rpf2\cdot Rp2)]$

the variables' values are already known.

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Similarly there can be analyzed an alternative structure for the mixed operating mode, configuration 2, called mixed 2 (M2). Within this structure SR is completely separated from SM and SC, which operate on high power.

As regards the physical charateristics of the main operating systems, complete separation can be distinguished as a design variant, so that each main operating system should work autonomously. That leads to a general approach to each operating system in such a way that every system's module is analysed. (tabela 1), [3], [1].

The total reliability function R_{IND} is calculated considering R_I and R_{II} shunted together, and the result concatenated with Rch is:

$$R_{IND} = [1-(1-R_I)\cdot(1-R_{II})\cdot(1-R_{III})\cdot(1-R_{IV})]\cdot Rch \quad (4)$$

where:

$R_I = (1-(1-Rm1)\cdot(1-Rm2))\cdot Rt1\cdot Rtf\cdot Rc$

$R_{II} = Rm3 \cdot Rt2 \cdot Rm \cdot Rr$
$R_{III} = Rm4 \cdot Rt3 \cdot Rpf1 \cdot Rp1$
$R_{IV} = Rm5 \cdot Rt4 \cdot Rpf2 \cdot Rp2$

the variables' values are already known.

Simulations by Models

The system functions (R) contained by the models described above can be continuous or discrete or signal functions (known reliability functions or chance number generating functions following various distributions simulated by means of the programming mode (MathCad)) and will replace block functions (R) within computer-assisted simulation. The structural models thus obtained can allow us to carry out simulations useful to the design of safe and efficient systems, enhancing their performances.

This software package provides the user with a complete series of probability distributions with continuous or discrete variation and the chance number generators distributed according to the corresponding partition law.

The partition law WEIBULL adapts to the reliability study of technological plants during their running, when failures occur mainly because of the plant's runout and/or ageing. The NORMAL partition law adapts to the various technical systems whose failures occur because of a great number of factors, which generally lead to materials' wear and breakage.

Table 2. Reliability results modes

Number simulations	Reliability total values			
	Group1	Group2	Mixt1	Individual
100	0.860	0.960	0.959	0.984
1000	0.852	0.963	0.958	0.983
10000	0.846	0.962	0.956	0.982
100000	0.846	0.960	0.955	0.982
1000000	0.846	0.960	0.955	0.982

For the estimation of the probability of failure by frequency of into occurrence the sufficiently large number of computer simulations should be performed as Gauss and Weibull trials. Each trial consists of the generations of the random realizations all input quantities, performing the deterministic analysis of the values R as the functions of these realizations. Analysis of accuracy must be performed using the asymptotic distribution of the obtained estimate not the quantity of gives probability.

Then the average of these values from all trial is calculated with MathCad Program Modeling. The average this method its similarity and higher effectiveness it comparison which the estimation of the random probability frequency (rnorm and rweibull).

PROGRAM MODELING

dates

$N := 100 \qquad J := 0..N-1$

random distribution

$RM := rweibull(N, 110) \qquad RCV := rweibull(N, 110) \qquad RPF := rweibull(N, 110)$

$RT := rnorm(N, 0.85, 0.1) \qquad RTF := rweibull(N, 110) \qquad RC := rnorm(N, 0.85, 0.1)$

$RMR := rnorm(N, 0.85, 0.1) \qquad RR := rnorm(N, 0.85, 0.1) \qquad RCH := rweibull(N, 110)$

$RP := rweibull(N, 110)$

expresion solving

$$RPFP_J := \left[1 - \left[1 - \left(RPF_J\right)\cdot RP_J\right]\cdot\left(1 - RPF_J\cdot RP_J\right)\right]$$

$$RTFCR_J := RTF_J\cdot\left[1 - \left(1 - RC_J\right)\cdot\left[1 - \left(RCV_J\right)\cdot\left(RMR_J\right)\cdot\left(RR_J\right)\right]\right]$$

$$RG1_J := \left(RM_J\right)\cdot\left(RT_J\right)\cdot\left[1 - \left(1 - RTFCR_J\right)\cdot\left(1 - RPFP_J\right)\right]$$

$$RI_J := \left(RM_J\right)\cdot\left(RT_J\right)\cdot\left[1 - \left(1 - RTFCR_J\right)\cdot\left[1 - \left(RPF_J\right)\cdot\left(RP_J\right)\right]\right]$$

$$RII_J := \left(RM_J\right)\cdot\left(RT_J\right)\cdot\left(RPF_J\right)\cdot\left(RP_J\right)$$

$$RG2_J := \left[1 - \left(1 - RI_J\right)\cdot\left(1 - RII_J\right)\right]\cdot RCH_J$$

$$R1_J := \left(RM_J\right)\cdot\left(RT_J\right)\cdot\left(RTFCR_J\right)$$

$$R2_J := \left(RM_J\right)\cdot\left(RT_J\right)\cdot\left[1 - \left(1 - RPF_J\cdot RP_J\right)\cdot\left(1 - RPF_J\cdot RP_J\right)\right]$$

$$RM1_J := \left[1 - \left(1 - R1_J\right)\cdot\left(1 - R2_J\right)\right]\cdot RCH_J$$

$$RA_J := \left[1\left(RM_J\right)\cdot\left(1 - RM_J\right)\cdot RT_J\cdot RTF_J\cdot RC_J\right]$$

$$RB_J := RM_J\cdot RT_J\cdot RM_J\cdot RR_J \qquad RC_J := RM_J\cdot RT_J\cdot RPF_J\cdot RP_J \qquad RD_J := RM_J\cdot RT_J\cdot RPF_J\cdot RP_J$$

$$RIND_J := \left[1 - \left(1 - RA_J\right)\cdot\left(1 - RB_J\right)\cdot\left(1 - RC_J\right)\cdot\left(1 - RD_J\right)\right]\cdot RCH_J$$

$$FRG1 := \frac{\left(\sum RG1\right)}{N} \qquad FRG2 := \frac{\left(\sum RG2\right)}{N} \qquad FRM1 := \frac{\left(\sum RM1\right)}{N} \qquad FRIND := \frac{\left(\sum RIND\right)}{N}$$

total reliability

$FRG1 = 0.86 \quad FRG2 = 0.965 \quad FRM1 = 0.959 \quad FRIND = 0.984$

Conclusions

The author proposes that the method should be also applied for the other operating modes of drilling plants which were mentioned taking into account their characteristics. In are presented three structural models (G1, G2, IND and M1, whose graphs are displayed in descending order of reliability analysis and numerical simulation for a drilling plant.

The procedure of calculations is as fallows: at which realisation of variable R is generated in accordance with its probability density function(this function MathCad is supposed to be know) and the value of the probability distribution function of quantity R corresponding is determined(this distribution is generated at MathCad system).

The average this method its similarity and higher effectiveness it comparison which the estimation of the probability frequency. Analysis of accuracy must be performed using the asymptotic distribution of the obtained estimate not the quantity of gives probability.

The main contribution this article makes is the introduction of structural models in the calculation of complex systems' reliability (drilling plants or production installations).

In order to carry out some purely reliability comparative analyses of finding the optimal operating mode, the designer may choose his own values for simulation so that he could decide which of the operating modes leads to a convenient value of reliability according to the number of elements taken into account and their grouping mode.

References

1. S t a n, M. – *Metode avansate de proiectare a utilajului petrolier*, Editura Universităţii Petrol – Gaze Ploieşti, Ploieşti, 2006.
2. S t a n, M. – *Estimarea fiabilităţii instalaţiilor de foraj utiliznd modele matematice de structură,* Buletinul Universităţii Petrol – Gaze Ploieşti LVII 2/2005.
3. S t a n, M. – *Logistic plants' in oil reliability*, IMT ORADEA 2007, ISSN 1583-0691, 2007.

Analiza fiabilităţii şi simularea numerică la instalaţiile de foraj

Rezumat

Contribuţiile aduse în acest articol referitor la studiul fiabilitătii instalaţiilor de foraj în funcţie de modul de acţionare,constau în algoritmizarea analizei structurale şi simularea pe modele matematice flexibile a unor situaţii reale cu prezentarea şi interpretarea rezultatelor. Metoda prezintă o aplicabilitate sporită prin îmbinarea fazei de concepere structurală a modelului pornind de la dezideratele proiectării cu simularea numerică folosind biblioteca de funcţii de repartiţie şi de generatoare de distribuţii aleatoare de valori ale mediului integrat de calcul MathCad.