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AN EXTENSION TO "ALLOWABLE DESIGN FACTOR" METHOD FOR FREE SPAN CALCULATION OF SUB SEA PIPELINES

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ABSTRACT

Using the design factors is a traditional method in solid mechanics design. This method is still also the base of some design standards in the world [$\lambda \alpha$]. In this paper, a modification has been performed to traditional Von Misses stress check method for the calculation of sub sea pipeline free spanning.

The DNV OS $F^{(*)}$ which is a well known standard for sub sea pipelines has been used for calibration [^r]. A spread sheet type program for free span calculation has been developed for "Force Model" which facilitates the evaluation of the free span length based on the latest DNV proposed method as well as traditional Von Misses stress check. The method statement is the calculation of maximum allowable sub sea pipeline free span, by DNV proposed method and consequently evaluation of allowable stress to result the same free span length in Von Misses traditional method. The design factors which are the Stress Factors (SF) will be calculated by the ratio of existing equivalent Von Misses stress to yield strength of the pipeline material (**fy**).

ASSUMPTION

There are a lot of parameters to be considered in the free span calculation. For calibration purposes, as mentioned above, the following assumption has been set:

-)-Internal pressure is greater than external pressure; hence the equation 4,7%, D4... of section 4 of DNV OS $F(\cdot)$ applies [%].
- γ -The pipeline is on the seabed.
- ^{ξ}-The water current of γ, γ m/s at surface and γ, γ m/s for sea bed have been considered. The power equation of (γ, γ) has been used for current profile calculation.
- °-The water temperature has been considered 1° °C.
- ٦-Pipeline material selected is API ۵L X۵۲.
- Y-The sub sea pipeline is assumed to be in operating condition.
- A-The sub sea pipeline considered is "restrained".
- ⁴-The study has been performed for two safety classes: "high" and "normal" as defined in section ^γ, C^φ·· of DNV OS F¹·¹[^r].

Nomina l D	Diameter (mm)	Thickne ss (mm)	D/t	Design T ° C	Design P (Mpa)	Concrete Coating (mm)	Product Density (kg/m ^r)
<i>ç</i> "	١٦٨,٣	۱۲,۷	۱۳,۲	٨٠.۴٠	10	۴.	4
۸"	719,1	۱۲,۷	۱۷,۲	۸۰.۴۰	10	۴.	۴
۱ • "	222,1	۱۲,۷	۲١,٥	۸۰.۴۰	١٢	۵.	۳۲.
۱۲"	۳۲۳,۹	۱۲,۷	۲۵,۵	۸۰.۴۰	۱.	۵.	۲۸۰
۱۴"	۳۵۵,۶	۱۲,۷	۲۸	۸۰.۴۰	۱.	۵.	۲۸۰
19"	4.9,4	١٢,٧	34	1	٩	0.	40.
۱۸"	407,7	١٢,٧	39	1	٨,۵	۵.	74.
۲."	0.1	١٢,٧	۴.	1	٧,٠	۵.	440
22,	۵۵۸,۸	١٢,٧	44	1	9,0	9 *	۲
7 4 "	9.9,9	١٢,٧	۴٨	٨٠.۴٠	9,0	9 *	19.
۲۶"	99.,4	١٢,٧	27	1	Ŷ,*	9 *	١٨.
۲۸"	٧١١,٢	١٢,٧	09	1	۵,۵	9 *	19.
٣. "	V97	١٢,٧	Ŷ *	٨	۵,۰	٧.	10.

The table \ shows the specifications of the pipelines studied.

TABLE

ASSUMED PIPELINE PROPERTIES

METHOD STATEMENT

The method statement has been completely defined in the Figure $\$ below. As it is shown in the below chart it divided to the $\$ following steps.

Step $\$, evaluating the free span length "L" in accordance with DNV OS F $\$ section \diamond and by using the following formula ["].

$$\chi_{SC} \gamma_m \left(\frac{S_d}{\alpha_C S_P} \right) + \gamma_{SC} \gamma_m \left(\frac{M_d}{\alpha_C M_P} \sqrt{1 - \left(\frac{\Delta p_d}{\alpha_C p_b(t_\tau)} \right)^{\tau}} \right) + \left(\frac{\Delta p_d}{\alpha_C p_b(t_\tau)} \right)^{\tau} \leq 1$$

(1)

۱,

Step \checkmark , stress calculation, the unsupported pipe section will be subjected to longitudinal bending stresses resulting from the submerged weight of the pipe as well as environmental loads in addition to the stresses caused by the design temperature and pressure. The corresponding stresses with above calculated L will be as follows [\diamond]:

$$\sigma_{B} = \frac{FDL^{*}}{KI}$$

(۲)

 s_B = Existing bending stresses

D =Outside diameter of the pipe

I= Moment of Inertia of the pipe

K= Constant for end fixity, γ^{φ} for fix-fix, γ^{φ} for pin-pin. A value of γ corresponding to fix-pin condition has been considered in this study.

F =Uniform Loading on pipe

$$F = \sqrt{W_{SUB}^{\prime} + (F_D + F_I)^{\prime}}$$

(٣)

 W_{SUB} =Total submerged weight of the pipe F_D =Environmental Drag force F_I = Environmental Inertia force

$$\sigma_{h} = \frac{\gamma_{p} (p_{ld} - p_{e})(D - t_{\tau})}{\tau_{t_{\tau}}}$$

(۴)

 s_h =Hoop stress g_p =Pressure load factor t_r = Pipeline corroded wall thickness p_{ld} =pipeline design pressure p_e =External pressure

$$S_F = -\Delta p_i A_i (1 - \gamma \nu) - A_S E \alpha \Delta T$$

 (Δ)

 S_F = Effective functional axial force for restrained section

 Dp_i = Internal pressure difference relative to external pressure

 A_i = Cross sectional area relative to inside diameter

 A_s = Cross sectional area of the pipe steel

DT = Operating Temperature difference with water Temperature

E = Modulus of Elasticity

a = Steel expansion temperature coefficients

$$\sigma_X = \frac{S_F}{A_S} + \sigma_B$$

(9)

$$\sigma_e = \sqrt{\sigma_X^{\prime} + \sigma_h^{\prime} - \sigma_X \sigma_h}$$

 $Df(SF) = \frac{\sigma_e}{\sigma_e}$

 (\forall)

Step^{γ}, evaluating the design factors (stress factors), Df (SF)

(\wedge)

 f_y =Characteristic pipeline material properties with consideration of temperature de-rating as specified at DNV OS F (\cdot) SECTION \diamond , B $\hat{\tau} \cdot \cdot$ [$\tilde{\tau}$].



The above mentioned stepwise procedure has been exercised for the pipelines in Table 1.

RESULTS & CONCLUSIONS

The figure- γ has shown the results of the analysis. Investigation of calculated stress design factors shows the following results:

-)-The stress design factors have not been limited to a figure as stated into traditional theory.
- Y-The important parameters such as D/t_r (D=external diameter of the pipe & t_r =pipeline corroded wall thickness) and design temperature (T) play crucial role.
- \checkmark -The variation of SF with D/t_Y is almost linear.



FIGURE-^{*}

As a result of this study the following equation for evaluation of the stress factors (SF) in accordance with $(D/t_r, T)$, is developed :

$$SF_{N} = \cdot \cdot \wedge \cdot - \cdot \cdot \cdot \uparrow \stackrel{D}{t_{\tau}} + \left(\cdot \cdot \cdot \wedge \cdot \stackrel{Q}{t_{\tau}} - \cdot \cdot \cdot \cdot \stackrel{Q}{\tau_{\tau}} \right) \frac{(T - \stackrel{\varphi}{\tau} \cdot)}{\stackrel{\varphi}{\cdot}}$$

$$(\stackrel{Q}{})$$

$$SF_{H} = \cdot \cdot \vee \uparrow - \cdot \cdot \cdot \uparrow \stackrel{Q}{\tau} \frac{D}{t_{\tau}} + \left(\cdot \cdot \cdot \vee \stackrel{Q}{\tau} - \cdot \cdot \cdot \cdot \stackrel{Q}{\tau} \frac{D}{t_{\tau}} \right) \frac{(T - \stackrel{\varphi}{\tau} \cdot)}{\stackrel{\varphi}{\tau}}$$

 $(1 \cdot)$

 SF_N = Stress factor in Normal safety condition SF_H = Stress factor in High safety condition T = Design Temperature

The use of the above two equations, is recommended in the following condition:

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