Abstrak

Oleh : Desak Made Ayu

Dosen Pembimbing : Prof. Ir. Daniel M. R, Ph.D., M.RINA, Ir. Hasan Ikhwani, M.Sc

Semakin meningkatnya eksplorasi minyak dan gas maka akan semakin dibutuhkannya mode transportasi pengangkut minyak dan gas. Sistem perpipaan merupakan salah satu mode transportasi minyak dan gas yang banyak digunakan dikarenakan lebih efisien dan lebih efektif. Pada saat proses instalasi ada 2 kategori yang harus dianalisa yaitu *overbend* dan *sagbend.* Analisa dilakukan dengan bantuan OFFPIPE untuk menghitung besarnya tegangan *Von Mises* yang bekerja pada saat proses *laying* dengan variasi kedalaman dan sudut *stinger*. Setelah didapatkan tegangannya, maka akan dihitung *local buckling* yang terjadi pada daerah *sagbend* dan *overbend* pada saat proses *laying.* Studi kasus yang digunakan dalam tugas akhir ini adalah proyek saluran pipa baru "EPCI for MRA-MMJ" dari PT. PHE ONWJ. Variasi sudut *stinger* yang digunakan adalah 6.66, 8.88, 11.1, 13.32, 15.54 derajat dan masing-masing *case* memiliki perbedaan pada kedalaman laut mulai *case 1-9* yaitu 14.935, 15.979, 17.023, 18.067, 19.11, 20.155, 21.199, 22.243 dan 23.287 meter. Dari hasil penelitian ini didapatkan hasil bahwa sudut optimal adalah sudut 11.1 derajat. Selain itu dapat dikatakan bahwa *pipeline* tidak mengalami *local buckling* karena memenuhi *premissible combination* dari *code* DNV 1981.

Kata kunci : *Laying, Stress, Stinger, Overbend, Sagbend* dan *Local Buckling*.

Abstract

Oleh : Desak Made Ayu

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With the increase in oil and gas exploration, the mode of transportation of oil and gas transporters will be needed. Piping system is one mode of transportation of oil and gas are widely used due to more efficient and more effective. At the time of the installation process, there are two categories to be analyzed are overbend and sagbend. The analyzes were performed with the help of OFFPIPE to calculate Von Mises tension that works on the laying process with the variation of the depth and angle of the stinger. When the voltage has obtained, it will calculated the local buckling that occurs in the overbend and sagbend area during the laying process. The case study used in this thesis is a new pipeline project "EPCI for MRA-MMJ" of the PT. PHE ONWJ. Variations stinger angle that used are 6.66, 8.88, 11.1, 13:32, 15:54 degrees and each case has a difference in water depths ranging case 1-9, which are 14.935, 15.979, 17.023, 18.067, 19.11, 20.155, 21.199, 22.243 and 23.287 meters. From the results of this study showed that the optimum angle is the angle of 11.1 degrees. Moreover, it can be said that the pipeline did not experience local buckling due to meet permissible combination of DNV code 1981.

Keyword : *Laying, Stress, Stinger, Overbend, Sagbend* dan *Local Buckling*.

DAFTAR NOTASI

A	= *cross sectional area* dari pipa
d	= kedalaman, m
D	= diameter luar pipa, in
E	= modulus young
g	= percepatan gravitasi, ft/s^2
h	= kedalaman laut, ft
M	= bending momen pada pipa
N	= *axial force* pada pipa
P_e	= tekanan ekstrenal, psi
P_i	= tekanan internal, psi
SMYS	= *specified minimum yield strength*, Mpa
t_o	= tebal dinding pipa, in
v	= poison ratio
W	= (*elastic*) sectional modulus (m^3)
α	= simbol yang digunakan pada *buckling formula*
ρ	= densitas fluida, lb/ft^3
σ_f	= yield stress, psi
σ_y	= hoop strees (Pa)
σ_{ycr}	= *critical hoop Stress* (Pa)
σ_x	= *total axis stress* (Pa)
σ_{xcr}	= *critical Longitudinal Stress* (Pa)
η_{xp}	= *permessible buckling usage factor (0.86)*
η_{yp}	= *permissisble buckling usage factor (0.75)*
σ_{xcr}^{M}	= *Critical (maximum) longitudinal stress*
σ_{xcr}^{N}	= *Critical longitudinal stress when N is acting alone* (Pa)

BAB II
TINJAUAN PUSTAKA DAN DASAR TEORI

2.1 Tinjauan Pustaka

Pada saat merancang pipa banyak yang harus diperhatikan dengan teliti hal ini dikarenakan biaya investasi yang mahal. Dalam merancang pipa juga sangat memerlukan teknologi yang canggih dan investasi biaya yang mahal. Kegagalan saluran pipa akan mengakibatkan hilangnya biaya yang cukup besar dan hilangnya produksi selama perbaikan. Sebagai gambaran umum, setiap benda yang dihasilkan manusia mengalami bermacam proses. Dimulai dari menganalisa, merancang, mencetak, menjual serta pengembangan lebih lanjut. Salah satu proses penting adalah merancang. Dalam merancang sebuah produk, dapat dilakukan dengan dua cara yaitu dengan metode konvensional yang sangat tergantung dari kemampuan perancang dan metode optimasi yang dapat menghasilkan produk secara efisien. Untuk memudahkan proses perancangan ketebalan pipa digunakan metode optimasi. Metode optimasi digunakan karena dalam pengambilan keputusan digunakan pendekatan yang terencana yaitu dengan pendekatan saintifik (Rosyid, 1999). Keunggulan metode optimasi adalah perancang dapat mengidentifikasikan variabel desain, fungsi yang akan dioptimalkan dan optimasi sendiri didefinisikan sebagai proses untuk menemukan kondisi yang memberi nilai maksimal atau minimal dari suatu fungsi (Rao, 1984).

Sebelumnya telah ada penelitian mengenai konfigurasi sudut *stinger* telah dilakukan oleh Andini (2011). Peneliti lebih berfokus kepada *lay barge* dan *exit point* tanpa melakukan analisis lebih mendalam untuk melakukan *local buckling check.* Sedangkan oleh Rizaldi (2011) peneliti lebih berfokus membandingan *local buckling* pada DNV 1981 dan FS101 tanpa melakukan optimasi pada sudut *stinger*.

2.2 Dasar Teori

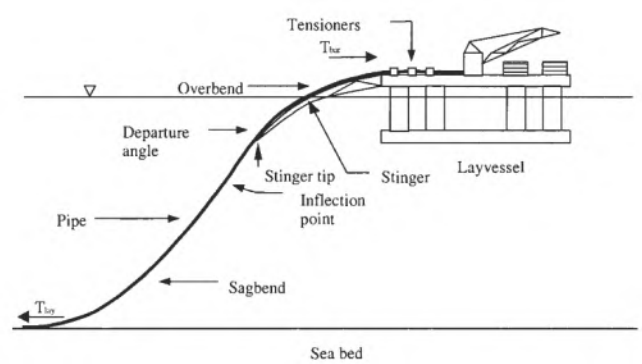
Dasar teori yang digunakan dalam kajian tugas akhir ini meliputi: struktur terapung, *offloading*, sistem tambat, konsep pembebanan, spektrum gelombang, respon struktur, *relative motion*, dan operabilitas.

2.2.1 Metode *Pipelaying*

Proses instalasi pipa bawah laut mengunakan *lay barge*. Ada beberapa metode untuk instalasi pipa bawah laut, metode yang umumnya digunakan yaitu *S-Lay, J-Lay* dan *Reeling.* Berdasarkan pada metode tersebut, pipa akan mengalami beban yang berbeda selama instalasi berlansung. Selama proses instalasi pipa mengalamu pembebanan yang berbeda-beda meliputi pembebanan akibat tekanan hidrodinamis, pembebanan akibat *tension* dan *bending* yang dialami pipa. (Bai, 2001).

2.2.1.1 *S-Lay*

Salah satu metode untuk instalasi pipa bawah laut yaitu menggunakan metode S-Lay, disebut *S-Lay* dikarenakan kurva pipa yang keluar dari *Lay Barge* hingga *seabed* akan berbentuk seperti huruf S. Pada saat pemasangan akan membutuhkan *stinger* dan *tensioner. Roller* ditempatkan pada *stinger* dan pada *vessel,* bersamaan dengan *tensioner,* akan menciptakan kekuatan lengkungan pada pipa (Bai, 2001). Pada metode *S-Lay* ini hanya dapat digunakan untuk perairan yang tidak terlalu dalam.

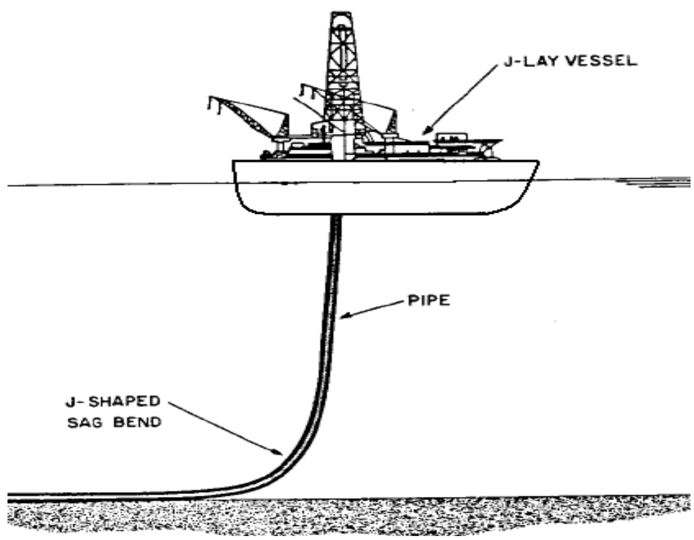


Gambar 2. 1 Instalasi dengan Metode *S-Lay*

(Bai, 2001)

2.2.1.2 *J-Lay*

Metode ini digunakan untuk instalasi pipa bawah laut dengan kedalaman yang sangat dalam. Pipa yang akan dipasang mempunyai sudut yang mendekati vertikal sehingga tidak membutuhkan tensioner. Pada metode ini pengelasan hanya dilakukan oleh satu *section* dan menggunakan berat pipa itu sendiri agar pipa dapat menyentuh dasar laut. Pada metode ini tidak ada daerah kritis pada tekukan atas (*overbend)* dan hanya ada pada bagian tekukan bawah (*sagbend)* sebagai daerah kritis. Pada daerah *sagbend*, gerakan *surge* dan *heave* mempunyai pengaruh yang signifikan terhadap tegangan pada *pipeline* sedangkan gerakan *pitch* tidak signifikan pengaruhnya terhadap tegangan *bending* pada *pipeline.*



Gambar 2. 2 Metode Instalasi Pipa Bawah Laut dengan J-Lay

(Kenny, 1993)

2.2.2 Proses *Pipelaying*

Pada Lay-Barge terdapat tempat untuk melakukan pengelasan pipa (welding station) mesin *tension*, NDT *station* untuk mengecek pengelasan dan *coating station*. *Roller* akan membantu pipa bergerak dari *barge* hingga masuk ke laut. Roller yang ditempatkan pada *stinger* dan *barge*, bersama dengan mesin *tension* membentuk *curved support* utuk pipa. Pipa akan melengkung pada *curved support* ketika akan masuk ke dalam laut dan pada bagian ini *pipeline* akan mengalami *bending* yang disebut *"overbend"*.

Tensioners akan mempertahankan tegangan konstan untuk menahan terjadinya bending yang berlebih dan mengimbangi gerakan dinamis kapal di permukaan air laut. Mesin *tension* yang paling terakhir biasanya terdapat pada bagian buritan (stern) *barge* letaknya berdekatan dengan stinger,fungsinya adalah untuk mengatur *curvature sagbend* dan moment pada *stinger* tetap ketika mensupport *pipeline* bergerak ke laut.

2.2.2.1 *Stinger*

Stinger berfungsi sebagai pengarah pipa pada *roller* yang terletak antara tubular sehingga pipa dapat meluncur ke bawah dari *barge* stern sampai ke *seabed*. *Stinger* terdiri dari beberapa model yang mana sudut kemiringannya dapat berubah, yaitu:

- *Hidraulic*
- *Cable*
- *Bouyancy*

Stinger yang terapung mempunyai *bouyancy* yang mengangkat pipa keatas untuk menyeimbangkan beban pipa.

2.2.2.2 *Overbend*

Daerah *overbend* biasanya dimulai dari tensioner pada deck barge, melalui barge ramp, dan turun ke *stinger* sampai pada titik *lift-off* dimana pipa tidak lagi didukung oleh *stinger*. Pada daerah overbend ini diharapkan total tegangan akibat dari berat pipa sendiri, momen bending pada tumpuan, atau *roller* tidak melebihi 85% SMYS, dengan kata lain bending stress maksimum yang dialami pipa pada daerah *overbend* lebih kecil dari 85% SMYS.

2.2.2.3 *Sagbend*

Daerah *sagbend* biasanya dimulai dari titik *inflection* sampai titik *touch down* pada *seabed.* Tegangan pada *overbend* di kontrol oleh jari-jari *stinger*, *depature angle* dan pengaturan *roller.*

2.2.3 Teori Tegangan

2.2.3.1 Tegangan Normal

Tegangan normal adalah tegangan yang bekerja dalam arah tegak lurus terhadap bidang dan dapat berupa tegangan tarik (*tensile stress*) atau tegangan tekan (*compressive stress*).

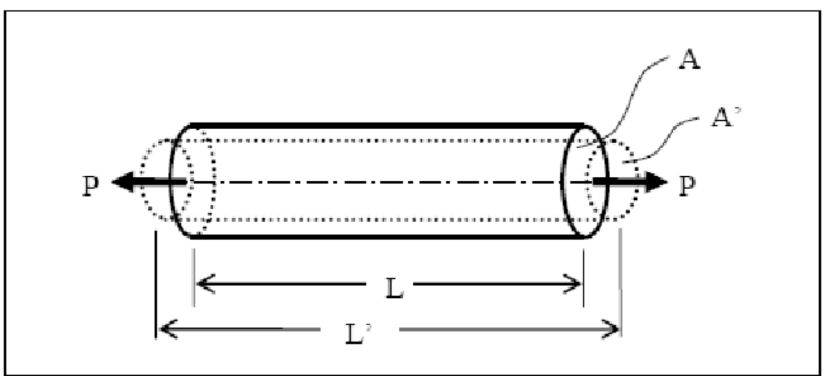
$$\sigma = \frac{P}{A} \qquad (2.1)$$

dengan:

σ = tegangan normal (N/m2)

P = gaya tarik/tekan (N)

A = luas penampang melintang (m2)



Gambar 2. 3 Pembebanan Aksial Pada Batang Tubular

(Gere dan Timoshenko, 2009)

Pada gambar 2.4 batang tubular dengan luas penampang A dan panjang L mengalami pembebanan aksial akibat gaya tarik P. Akibat gaya ini, batang akan mengalami perubahan panjang sebesar:

$$\Delta L = L' - L \quad (2.2)$$

dengan:

ΔL = pertambahan panjang (m)

L' = panjang batang setalah menerima beban (m)

L = panjang batang mula-mula (m)

Perbandingan antara pertambahan panjang (ΔL) dengan panjang mula-mula disebut sebagai regangan aksial dan dirumuskan sebagai berikut:

$$\varepsilon = \frac{\Delta L}{L} \quad (2.3)$$

Hal ini berarti jari-jari penampangnya juga mengalami perubahan dari R menjadi R'. Regangan ini disebut dengan regangan radial dan secara matematis dirumuskan sebagai berikut:

$$\varepsilon = \frac{R' - R}{R} \quad (2.4)$$

dengan:

ε = aksial strain (m)

R = jari-jari penampang mula-mula (m)

R' = jari-jari penampang setelah menerima beban (m)

Perbandingan antara regangan radial dengan regangan aksial disebut sebagai perbandingan Poisson. Secara matematis dirumuskan sebagai berikut:

$$\upsilon = \frac{\varepsilon'}{\varepsilon} \quad (2.5)$$

dengan:

ε = aksial strain (m)

ε' = radial strain (m)

2.2.3.2 Tegangan Geser

Tegangan geser (*shear stress*) adalah tegangan yang bekerja dalam arah tangensial terhadap permukaan bahan.

$$\tau = \frac{V}{A} \tag{2.6}$$

dengan:

τ = tegangan geser (N/m^2)

V = gaya geser (N)

A = luas penampang melintang (m^2)

Tegangan geser yang bekerja pada suatu elemen bahan disertai regangan geser. Tegangan geser tidak mempunyai kecenderungan untuk untuk memeperpanjang atau memperpendek elemen dalam arah x, y, dan z. Ini berarti panjang sisis elemen tidak berubah, oleh karenanya tegangan geser menyebabkan perubahan bentuk elemen.

2.2.3.3 Tegangan Von Mises

Pada elemen tiga dimensi, bekerja tegangan-tegangan searah sumbu x, y, dan z. Pada tiap-tiap sumbu dapat diketahui tegangan utama (σ_1, σ_2, σ_3) yang dihitung dari komponen tegangan dengan persamaan berikut :

$$\begin{bmatrix} \sigma_x - \sigma_0 & \sigma_{xy} & \sigma_{xz} \\ \sigma_{xy} & \sigma_y - \sigma_0 & \sigma_{yz} \\ \sigma_{xz} & \sigma_{yz} & \sigma_z - \sigma_0 \end{bmatrix} = 0 \tag{2.7}$$

dengan:

σ_0 = tegangan utama yang bekerja pada sumbu

σ_x = tegangan arah sumbu x

σ_y = tegangan arah sumbu y

σ_z = tegangan arah sumbu z

σ_{xy} = tegangan arah sumbu xy

σ_{xz} = tegangan arah sumbu xz

σ_{yz} = tegangan arah sumbu yz

Penggabungan tegangan-tegangan utama pada suatu elemen merupakan suatu cara untuk mengetahui nilai tegangan maksimum yang terjadi pada node tersebut. Salah satu cara mendapatkan tegangan gabungan adalah dengan menggunakan formula tegangan *Von Misses* yaitu:

$$\sigma_e = \left[[0.5(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2(\sigma_3 - \sigma_4)^2]\right]^{0.5} \qquad (2.8)$$

dengan:

σ_e = tegangan *Von Misses*

σ_1 = tegangan utama 1

σ_2 = tegangan utama 2

σ_3 = tegangan utama 3

2.2.4 Teori Optimasi

Optimasi adalah sesuatu yang dilakukan untuk mendapatkan hasil yang terbaik untuk kondisi yang tersedia dalam desain konstruksi (pemeliharaan untuk semua *engineering*). Ada beberapa tahap yang harus dilakukan sebelum mengambil keputusan. Tujuan dari optimasi adalah untuk memperoleh hasil yang maksimal ataupun minimal dimana hal tersebut dapat dikatan optimum (Rao, 1984)

2.2.5 Statement Persoalan Optimasi

Persoalan matematis atau optimasi dapat dinyatakan sebagai berikut (Rao, 1984) :

Dapatkan *X* = $\begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ X_n \end{bmatrix}$ untuk meminimalkan f(x)

Dengan kendala :

$Gj \leq \mathbf{0}, j = \mathbf{1}, \mathbf{2}, \ldots, m$

dan $Lj(x) = \mathbf{0}, j = \mathbf{1}, \mathbf{2}, \ldots, p$

Dimana X adalah suatu n dimensi dari yektor yang dinamakan vektor desain, f(x) disebut fungsi obyektif dan Gj(x) dan Lj (x) adalah *inequality* dan *equality constraint*.

2.2.6 Metode Pendekatan Optimasi

Persoalan dapat diselesaikan dengan dua skenario penyelesaian yaitu penyelesaian langsung dan penyelesain tidak langsung. Dalam penyelesaian langsung, pada awal proses optimasi pengambilan keputusan perlu menentukan variable keputusan X sembarang untuk kemudian X secara *iterative* diubah hingga mendekati X yang optimum, yaiu pada saat kriteria konvergen tercapai. Dalam skenario ini, persoalan optimasi dibagi menjadi dua, yaitu: Menentukan arah perubahan variabel keputusan dan menentukan panjang langkah. Dalam skenario langsung ini dari segi ada dan tidaknya kendala dalam optimasi yang ditinjau, tersedia dua prosedur optimasi yaitu prosedur pelacakan langsung *dan prosedur transformasi*, dimana persoalan optimasi terkendala diubah menjadi serangkain persoalan optimasi tanpa kendala. Untuk mendapatkan titik optimum pada grafik dapat mencari beberapa titik variasi kemudia diplotkan. Sehingga didapatkan, grafik masing-masing *constraint.* Kemudian diapatkan titik potong dua grafik tersebut dimana titik tersebut adalah titik optimumnya.

2.2.7 *Local Buckling*

Buckling merupakan keadaan dimana pipa sudah tidak bundar atau mengalami perubahan bentuk akibat tekanan hidrostatis yang besar pada kedalaman tertentu. Kemungkinan terjadi *buckling* pada suatu struktur *pipeline* harus dipertimbangkan untuk menghindari kegagalan pada pipa. *Local Buckling* pada pipa dipengaruhi *external pressure, axial force* dan *bending moment.*

2.2.8 *Local Buckling Check DNV 81*

Pada saat mendesain *pipeline* harus ada beberapa syarat yang terpennuhi terhadap *local buckling* di bawah kombinasi dari *external pressure, axial force* dan *bending moment.* Kombinasi dari tegangan kemudian akan dibandingkan dengan kombinasi kritis yang ada. *Local Buckling* adalah kombinasi kritis tegangan longitudinal dan hoop yang kemudian dicari *permissible check*. Perhitungan untuk *Local Buckling Check* berkesuaian dengan Appendix B dari DNV-1981 :

$$\left(\frac{\sigma_x}{{}^{\eta}{}_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{{}^{\eta}{}_{yp}\sigma_{ycr}} \leq 1 \qquad (2.9)$$

Dengan:

σ_x = *Total axis stress* (Pa)

σ_{xcr} = *Critical Longitudinal Stress* (Pa)

η_{xp} = *Permessible buckling usage factor (0.86)*

σ_y = *Hoop Stress* (Pa)

σ_{ycr} = *Critical Hoop Stress* (Pa)

M = *Bending Moment*

N = *Axial force*

η_{yp} = *Permissible buckling usage factor (0.75)*

σ_x = $\sigma_x{}^N + \sigma_x{}^M$

$\sigma_x{}^N$ = $\frac{N}{A}$

$\sigma_x{}^N$ = $\frac{M}{W}$

A = [π (D − t) t] = *Cross sectional Area* (m^2)

W = $\frac{\pi}{4}[(D-t)^2 t]$ = (elastic) sectional modulus (m^3)

D = *Nominal outer diameter of pipe* (in)

t = *Nominal wall thickness of pipe* (in)

σ_{xcr} $= \frac{\sigma_x{}^N}{\sigma_x} \sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x} \sigma_{xcr}^{M}$ = Critical Longitudinal (Compressive) stress (Pa)

σ_{xcr}^{N} = *Critical longitudinal stress when N is acting alone* (Pa)

σ_{xcr}^{N} $= \sigma_F \left[1 - 0.001 \left(\frac{D}{t} - 2\right)\right]$

σ_f = *Specified yield strength (corresponding to 0.2% residual strain)* (Pa)

σ_{xcr}^{M} = *Critical (maximum) longitudinal stress (when determined as M/W)* when *M is acting alone* (Pa)

σ_{xcr}^{M} $= \sigma_F \left[1.35 - 0.0045 \left(\frac{D}{t}\right)\right]$

α $= 1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

σ_y $= (p_e - p_i) \frac{D}{2t}$ = Hoop stress to be considered in buckling analyses (Pa)

P_e = external pressure (Pa)

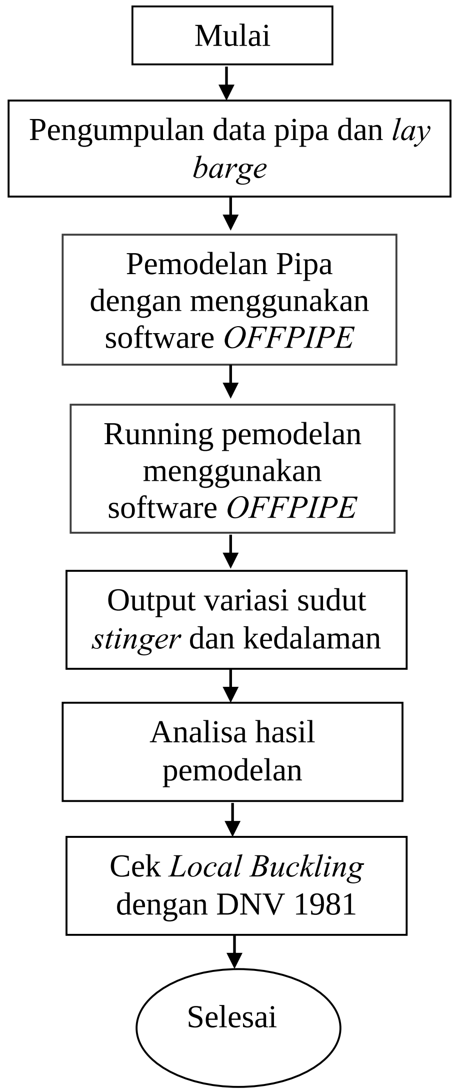
P_i = internal pressure (Pa)

σ_{ycr} $= \sigma_{yE} = E \left(\frac{t}{D-t}\right)^2$

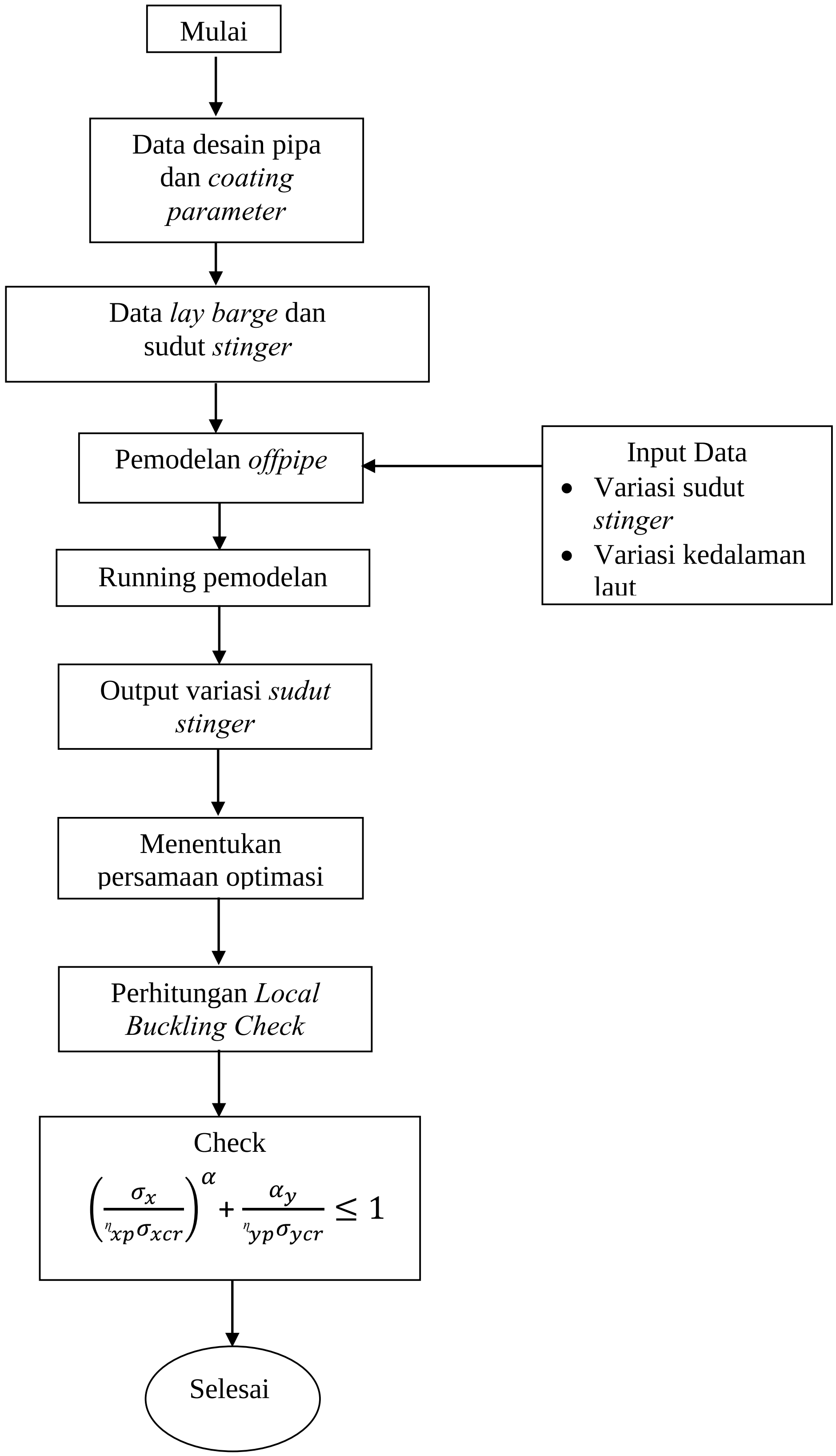
BAB III

METODOLOGI PENELITIAN

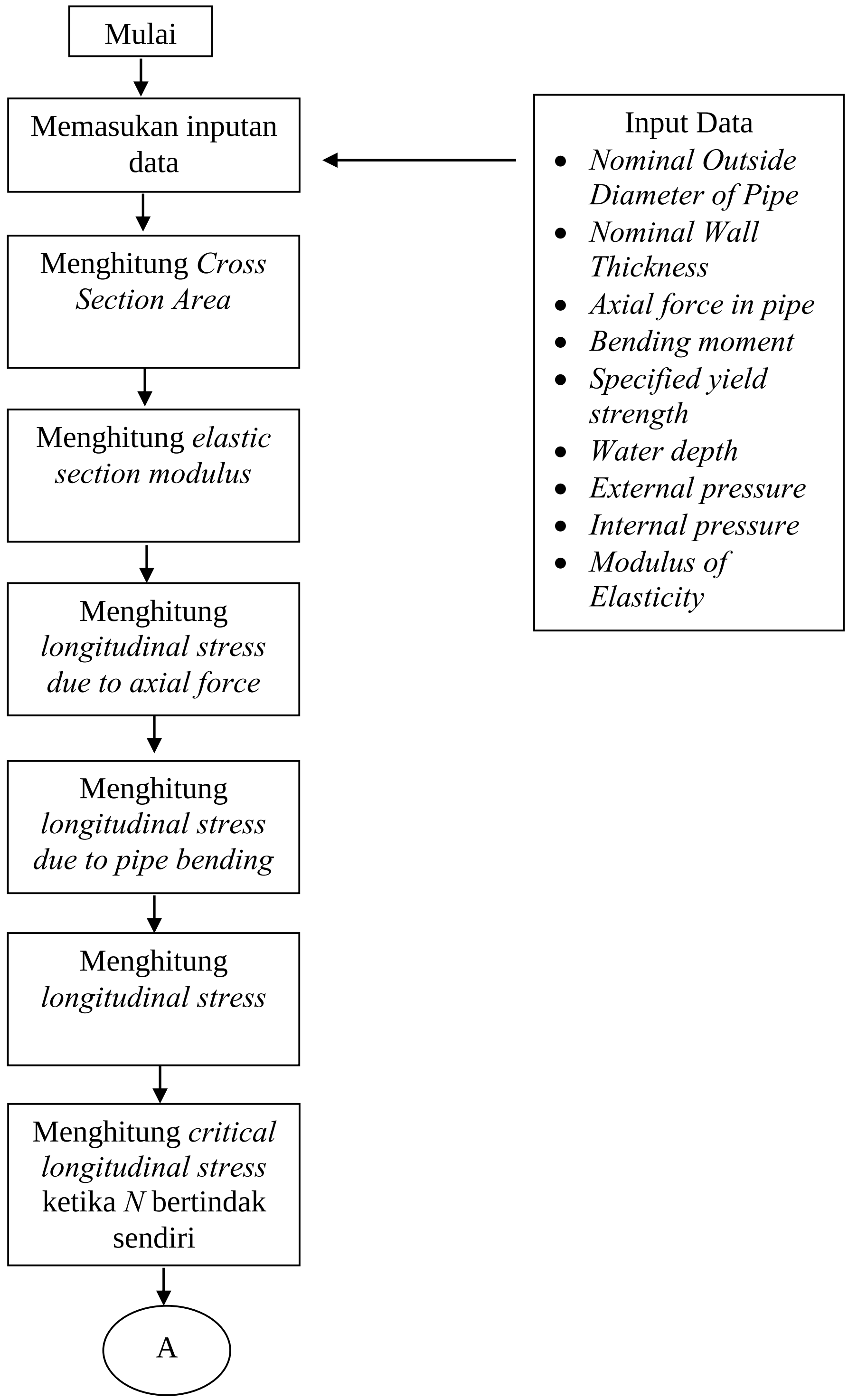
3.1 Skema Diagram Alir

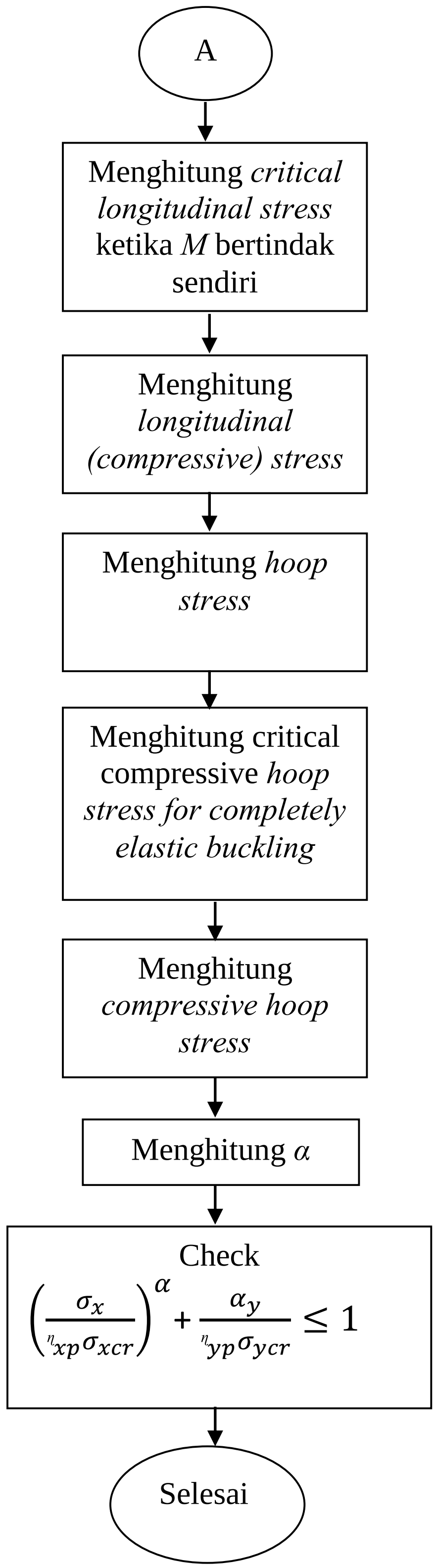


3.2 Skema Diagram Analisis Optimasi Sudut *Stinger* dan *Local Buckling Check*



3.3 Skema Diagram *Local Buckling Check*




A
Menghitung *critical longitudinal stress* ketika *M* bertindak sendiri
Menghitung *longitudinal (compressive) stress*
Menghitung *hoop stress*
Menghitung critical compressive *hoop stress for completely elastic buckling*
Menghitung *compressive hoop stress*
Menghitung α
Check
$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$
Selesai

Pada tugas akhir ini akan dijelaskan secara singkat dan masing-masing urutan kerja yang dilakukan. Langkah-langkah yang dijalani antara lain :

1. Melakukan studi literatur buku-buku,jurnal atau referensi yang berkaitan sebagai bahan penunjang penelitian ini.
2. Data desain pipa dan *coating parameter*

   Data desain pipa dan *coating parameter* milik PT. Pertamina PHE ONWJ
3. Data *lay barge* dan sudut *stinger*

   Data *lay barge* dan sudut *stinger* milik PT. Pertamina PHE ONWJ
4. Pemodelan untuk variasi sudut *stinger* dan kedalam laut dengan menggunakan bantuan program *OFFPIPE*
5. *Running software OFFPIPE* untuk mendapatkan tegangan selama proses instalasi
6. Output variasi sudut *Stinger*
7. Menentukan persamaan optimasi
8. Perhitungan *Local Buckling Check* menggunakan DNV 1981
9. Check hasil
10. Kesimpulan hasil analisa. Melakukan kesimpulan seesuai dengan permasalahan yang diangkat

BAB IV

PEMODELAN, ANALISA HASIL DAN PEMBAHASAN

4.1 Analisa Instalasi Menggunakan Offpipe

Analisa yang akan dilakukan pada tugas akhir ini menggunakan analisa statis. Pemodelan proses instalasi akan menggunakan bantuan software *Offpipe*dimana *laybarge* akan diasumsikan diam (statis). Tegangan yang akan dianalisa adalah pada saat proses instalasi dimulai dari daerah *overbend* dan *sagbend.* Daerah *overbend* saat pipa masih berada di atas *laybarge* sampai *stinger* (kecuali titik *roller* terakhir pada *stinger*), sedangkan daerah *overbend* mulai titik *roller* terakhir pada *stinger* hingga pipa menyentuh titik *touchdown* pada *seabed.* Untuk memulai permodelan instalasi dengan menggunakan bantuan software *OFFPIPE* yang akan dilakukan adalah memodelkan *laybarge, stinger,*dan memasukan data*properties* pipa serta memasukkan data lingkungan seperti kedalaman laut. Berikut adalah *loadcase* untuk pengerjaan tugas akhir :

Tabel 4.1 *Loadcase* dengan Variasi Kedalaman Laut dan Sudut Stinger

STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness
	(m)	(deg)	(cm)	(cm)
CASE 1	14.935	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 2	15.979	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		

Tabel 4.1 *Loadcase* dengan Variasi Kedalaman Laut dan Sudut Stinger (lanjutan)

STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness
	(m)	(deg)	(cm)	(cm)
CASE 3	17.023	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 4	18.067	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 5	19.11	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 6	20.155	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 7	21.199	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		

Tabel 4.1 *Loadcase* dengan Variasi Kedalaman Laut dan Sudut Stinger(lanjutan)

STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness
	(m)	(deg)	(cm)	(cm)
CASE 8	22.243	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		
CASE 9	23.287	6.66	16.827	1.1
		8.88		
		11.1		
		13.32		
		15.54		

Untuk analisa kali ini akan digunakan 9*case*seperti pada tabel diatasyang dimana pada setiap kedalama laut akan divariasikan sudut stingernya. Setelah itu *loadcase* akandimasukan dan setelah itu kita akan mendapatan hasil dari *runningan* OFFPIPE, yaitu :

Tabel 4.2 *Maximum Stress on Overbend & Sagbend* dengan Variasi Kedalaman Laut dan Sudut Stinger

STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness	Maximum Stress On Overbend		Maximum Stress On Sagbend	
	(m)	(deg)	(cm)	(cm)	Total Stress (Mpa)	Pipeline Stress SYMS %	Total Stress (Mpa)	Pipeline Stress SYMS %
CASE 1	14.935	6.66	16.827	1.1	253.9	71	168	47
		8.88			257.1	71	100.6	28
		11.1			237.4	66	100.6	28
		13.32			320.5	89	100.6	28
		15.54			446	124	100.6	28

Tabel 4.2 *Maximum Stress on Overbend & Sagbend* dengan Variasi Kedalaman Laut dan Sudut Stinger(lanjutan)

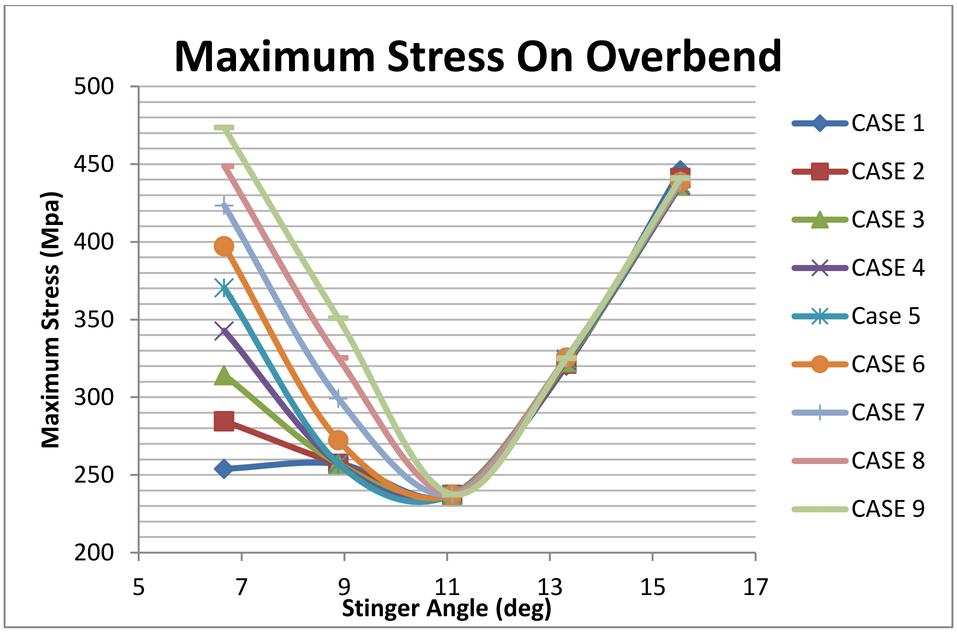
STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness	Maximum Stress On Overbend		Maximum Stress On Sagbend	
	(m)	(deg)	(cm)	(cm)	Total Stress (Mpa)	Pipeline Stress SYMS %	Total Stress (Mpa)	Pipeline Stress SYMS %
CASE 2	15.979	6.66	16.827	1.1	284.6	79	189.3	53
		8.88			257.2	71	100.6	28
		11.1			237.3	66	100.6	28
		13.32			321.6	89	100.6	28
		15.54			441.1	123	100.6	28
CASE 3	17.023	6.66	16.827	1.1	314.2	87	209.8	58
		8.88			257.2	71	121.4	34
		11.1			237.3	66	100.7	28
		13.32			322.7	90	100.7	28
		15.54			436.4	121	100.7	28
CASE 4	18.067	6.66	16.827	1.1	342.8	95	229.7	64
		8.88			257.2	71	142	39
		11.1			237.3	66	100.8	28
		13.32			323.7	90	100.8	28
		15.54			436.4	121	100.8	28
CASE 5	19.11	6.66	16.827	1.1	370.4	103	248.8	69
		8.88			257.3	71	161.9	45
		11.1			237.4	66	100.8	28
		13.32			324.7	90	100.8	28
		15.54			437.4	121	100.8	28
CASE 6	20.155	6.66	16.827	1.1	397.3	110	267.5	74
		8.88			272.4	76	181.1	50
		11.1			237.4	66	100.9	28
		13.32			325.6	90	100.9	28
		15.54			438.4	122	100.9	28

Tabel 4.2 *Maximum Stress on Overbend & Sagbend* dengan Variasi Kedalaman Laut dan Sudut Stinger(lanjutan)

STATIC CASE	Water Depth	Stinger Angle	Outiside Diameter	Wall Thickness	Maximum Stress On Overbend		Maximum Stress On Sagbend	
	(m)	(deg)	(cm)	(cm)	Total Stress (Mpa)	Pipeline Stress SYMS %	Total Stress (Mpa)	Pipeline Stress SYMS %
CASE 7	21.199	6.66	16.827	1.1	423.4	118	285.6	79
		8.88			299.3	83	199.8	56
		11.1			237.5	66	112.6	31
		13.32			325.6	90	101	28
		15.54			439.3	122	101	28
CASE 8	22.243	6.66	16.827	1.1	448.8	125	303.3	84
		8.88			325.5	90	218	61
		11.1			237.5	66	131.3	36
		13.32			325.3	90	101.1	28
		15.54			440.2	122	101.1	28
CASE 9	23.287	6.66	16.827	1.1	473.6	132	320.5	89
		8.88			350.9	97	235.6	65
		11.1			237.5	66	149.5	42
		13.32			325.1	90	101.1	28
		15.54			441.1	123	101.1	28

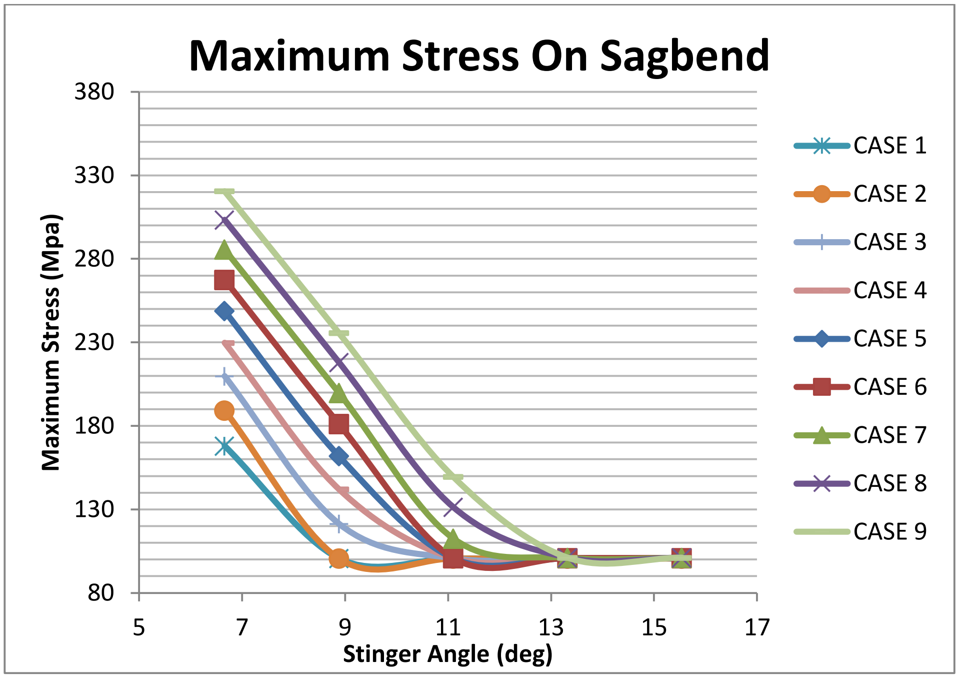
Dari tabel di atas dapat disimpulkan bahwa pipa mengalami *overstress* pada daerah *overbend* pada *static case case 1, case 2*dan *case 3*ketika sudut *stinger* 13.32 dan 15.54 derajat dengan *precentage yield* sebesar 89% SMYS dan 124% SMYS untuk *case 1*, untuk*case 2*yaitu 89% SMYS dan 123% SMYS dan untuk *case 3* yaitu 90% SMYS dan 121% SMYS.Untuk *static case case 4, case 5, case 6* dan*case 7*terjadi *overstress* ketika sudut *stinger* 6.66, 13.32 dan 15.54 derajat dengan *precentage yield* masing-masingsebesar 95% SMYS, 90% SMYS dan121% SMYS untuk *case 4*, sedangkan *case 5precentage yield* masing-masingsebesar 103% SMYS, 90% SMYS, dan 121% SMYS. *Case 6 precentage yield* masing-masingsebesar 110% SMYS, 90% SMYS dan 122%

SMYS, sedangkan *case 7 precentage yield* masing-masing sebesar 118% SMYS, 90% SMYS dan 122% SMYS. Pada *case 8 & 9 overstress*terjadi ketika sudut *stinger* 6.66, 8.88, 13.32 dan 15.54 derajat dengan *precentage yield* sebesar 125% SMYS, 90% SMYS, 90% SMYS dan 122% SMYS untuk *case 8* dan *case 9* sebesar 132% SMYS, 97% SMYS, 90% SMYS dan 123% SMYS untuk *precentage yield.Standart code*yang digunakan adalah DNV 1981 dengan *allowable stress* sebesar 85%. Untuk daerah *sagbend* tidak mengalami *overstress* karena tegangan yang terjadi masih dibawah *allowable stress*.



Gambar4.1 Grafik *Maximum Stress on Overbend* dengan Variasi Kedalaman Lautdan Sudut*Stinger*

Pada Gambar 4.1 dapat terlihat bahwa optimasi terjadi pada sudut*stinger* 11.1 derajat, hal ini dikarenakan pada sudut*stinger* 11.1derajat memiliki nilai stressnya yang paling rendah diantara sudut yang lainnya.Pada *case* 1 *stress* pada sudut*stinger* 11.1sudut253.9Mpa, *case* 2 *stress* pada sudut *stinger*11.1 derajat253.9 Mpa, *case* 3 *stress* pada sudut *stinger* 11.1 derajat237.3Mpa, *case* 4 *stress* pada sudut *stinger*11.1 derajat237.3Mpa, *case* 5 *stress* pada sudut *stinger*11.1 derajat237.4Mpa, *case* 6 *stress* pada sudut *stinger*11.1 derajat237.4Mpa, *case* 7 *stress* pada sudut *stinger*11.1 derajat237.5Mpa, *case* 8 *stress* pada sudut *stinger* 11.1 derajat237.5Mpa dan *case* 9 *stress* pada sudut *stinger* 11.1 derajat237.5Mpa



Gambar4.2Grafik *Maximum Stress on Sagbend* dengan Variasi Kedalaman Lautdan Sudut Stinger

Untuk *Sagbend* semakin besar sudut *stinger* maka akan semakin kecil *stress* yang terjadi, dapat kita lihat pada *case* 1,2,3,4,5,6,7,8 dan 9akan tetapi pada *overbend* akan sangat besar. Pada *case* 9 dapat kita lihat pada sudut6.66 derajat,*stress* yang terjadi sebesar320.5 Pa yang pada akhirnya menurun hingga pada sudut15.54 derajat,*stress* yang terjadi adalah sebesar 101.1 Pa dan pada *case* 1 dapat kita lihat pada saat sudut 6.66 derajat, *stress* yang terjadi adalah sebesar 168 Pa dan akhirnya akan menurun hingga sudut 15.54 derajat *stress* sebesar 100.6 Pa. Maka dari itu penentu optimasi dari sudut *stinger* adalah *stress* yang terjadi pada *overbend*.

4.2Analisa Perhitungan Local Buckling

Setelah mendapatkan hasil dari pemodelan instalasi pipa dengan menggunakan software *Offpipe*maka didapatkan nilai *maximum bending moment* dan *maximum axial force* yang kemudian akan menjadi input untuk melakukan analisa buckling.

Local Buckling dipengaruhi oleh *external pressure, axial pressure dan bending moment* yang kemudian dicari *permissible combination* untuk daerah *overbend* dan *sagbend.* Local Buckling adalah kombinasi kritis dari longitudinal dan hoop stress. *Permissible combination* untuk menghitung *local buckling* yang terjadi pada pipa dengan menggunakan DNV 1981 adalah:

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\propto} + \left(\frac{\sigma_y}{\eta_{yp}\sigma_{ycr}}\right) \leq 1 \quad (4.1)$$

Dengan:

σ_x = *Total axis stress* (Pa)

σ_{xcr} = *Critical Longitudinal Stress* (Pa)

η_{xp} = *Permissible buckling usage factor (0.86)*

σ_y = *Hoop Stress* (Pa)

σ_{ycr} = *Critical Hoop Stress* (Pa)

η_{yp} = *Permissible buckling usage factor (0.75)*

Dibawah ini merupan tahapan tahapan untuk mendapatkan nilai permissible combination untuk menghitung *local buckling check*:

Tabel 4.3 Input Data untuk Perhitungan *Local Buckling Check* Pada *Overbend*

No	Input Data	
1	Nominal Outside Diameter of Pipe	0.168275 m
2	Nominal Wall Thickness of Pipe	0.0109728 m
3	Specified Yield Strength	358527000 Pa
4	Internal Pressure	0 Pa
5	Modulus of Elasticity	2.07E+11 Pa
6	Sea Water Density	1025 kg/ m^3
7	Gravitation Force	9.81 m/ s^2
8	Cross Section Area	0.00542 m^2
9	Elastic Selection Modulus	0.00021 m^3

Tabel 4.4Input Datauntuk Perhitungan *Local Buckling Check* Pada *Sagbend*

No	Input Data	
1	Nominal Outside Diameter of Pipe	0.168275 m
2	Nominal Wall Thickness of Pipe	0.0109728 m
3	Specified Yield Strength	358527000 Pa
4	Internal Pressure	0 Pa
5	Modulus of Elasticity	2.07E+11 Pa
6	Sea Water Density	1025 kg/m^3
7	Gravitation Force	9.81 m/s^2
8	Cross Section Area	0.00542 m^2
9	Elastic Selection Modulus	0.00021 m^3
10	Hoop Stress	0 Pa
11	α	1

Tabel 4.5 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Overbend*

Water Depth (m)	**Axial Force in a Pipe (Pa)**	**Bending Moment (Nm)**	**Longitudinal Stress due to Axial Force (Pa)**	**Longitudinal Stress due to Pipe Bending (Pa)**
14.935	237420	39032	43806180.92	43806180.92
15.979	233360	38998	43057073.46	43057073.46
17.023	233360	39007	43057073.46	183014642.1
18.067	233360	39015	43057073.46	183052176.8
19.11	233360	39023	43057073.46	183089711.6
20.155	233360	39030	43057073.46	183122554.4
21.199	233360	39038	43057073.46	183160089.2
22.243	233360	39045	43057073.46	183192932.1
23.287	233350	39052	43055228.37	183225774.9

Untuk cek *local buckling* kita akan mendapatkan nilai *bending moment*dan *axial force in pipe* dari *output* offpipe. Setelah itu yang pertama adalah menghitung *cross section area* dan *elastic section modulus* yang dimana pada kedalam 14.935 m hingga 23.287 m akan bernilai sama. Setelah itu menghitung*longitudinal stress due to axial force* hingga mendapatkan nilai *premissible combination*untuk tiap kedalaman.

Tabel 4.5 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Overbend* (lanjutan)

Water Depth (m)	Longitudinal Stress (Pa)	Critical Longitudinal Stress when N is acting alone (Pa)	Critical Longitudinal Stress when M is acting alone (Pa)	Critical Longitudinal (Compressive) Stress (Pa)
14.935	226938119.1	3.59E+08	459269352.3	439822915.9
15.979	226029489	3.59E+08	440078622.5	440078622.5
17.023	226071715.6	3.59E+08	459269352.3	440082207
18.067	226109250.3	3.59E+08	459269352.3	440085392.1
19.11	226146785	3.59E+08	459269352.3	440088576.2
20.155	226179627.9	3.59E+08	4.59E+08	440091361.4
21.199	226217162.6	3.59E+08	459269352.3	440094543.4
22.243	226250005.5	3.59E+08	459269352.3	440097326.9
23.287	226281003.3	3.59E+08	459269352.3	440100774.7

Tabel 4.5 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Overbend* (lanjutan)

Water Depth (m)	Critical Compressive Hoop Stress for Completely Elastic Buckling (Pa)	Critical Compressive Hoop Stress (Pa)	Premissible Combination
14.935	1007152456	358526999.9	0.599972226
15.979	1007152456	358526999.9	0.5972228
17.023	1007152456	358526999.9	0.597329507
18.067	1007152456	358526999.9	0.597424358
19.11	1007152456	358526999.9	0.597519209
20.155	1007152456	358526999.9	0.597602204
21.199	1007152456	358526999.9	0.597697055
22.243	358526999.9	358526999.9	0.597780049
23.287	1007152456	358526999.9	0.597857266

Berbeda dari *overbend* pada perhitungan *sagbend* kita harus melakukan perhitungan untuk mendapatkan nilai *external pressure.* Hal ini karena pada *sagbend* sudah memperhitungkan kedalaman laut. Setelah itu perhitungan cek *local buckling* akan sama dengan *overbend* yaitu menghitung*longitudinal stress due to axial force* hingga mendapatkan nilai *premissible combination*untuk tiap kedalaman.

Tabel 4.6 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Sagbend*

Water Depth (m)	Axial Force in a Pipe (Pa)	Bending Moment (Nm)	External Pressure (Pa)	Longitudinal Stress due to Axial Force (Pa)
14.935	219870	12100	1.50E+05	40568043.97
15.979	219160	12100	1.61E+05	40437042.42
17.023	218340	12200	1.71E+05	40285744.85
18.067	217500	12200	1.82E+05	40130757.1
19.11	216790	12200	1.92E+05	39999755.55
20.155	215940	12300	2.03E+05	39842922.71
21.199	227390	14200	2.13E+05	41955553.37
22.243	227360	18000	2.24E+05	41950018.09
23.287	227340	21600	2.34E+05	41946327.91

Tabel 4.6 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Sagbend*(lanjutan)

Water Depth (m)	Longitudinal Stress due to Pipe Bending (Pa)	Longitudinal Stress (Pa)	Critical Longitudinal Stress when N is acting alone (Pa)
14.935	56771276.17	97339320.14	3.59E+08
15.979	56771276.17	97208318.59	3.59E+08
17.023	57240460.27	97526205.12	3.59E+08
18.067	57240460.27	97371217.37	3.59E+08
19.11	57240460.27	97240215.82	3.59E+08
20.155	57709644.37	97552567.07	3.59E+08
21.199	66624142.28	108579695.6	3.59E+08
22.243	84453138.1	126403156.2	3.59E+08
23.287	101343765.7	143290093.6	3.59E+08

Tabel 4.6 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Sagbend* (lanjutan)

Water Depth (m)	Critical Longitudinal Stress when M is acting alone (Pa)	Critical Longitudinal (Compressive) Stress (Pa)	Hoop Stress (Pa)	Critical Compressive Hoop Stress for Completely Elastic Buckling (Pa)
14.935	459269352.3	417283028.9	2303033.395	1007152456
15.979	459269352.3	417362210.7	2464022.137	1007152456
17.023	459269352.3	417655093.9	2625010.88	1007152456
18.067	459269352.3	417749209.3	2785999.622	1007152456
19.11	459269352.3	417828993.2	358526999.9	1007152456
20.155	459269352.3	418123641.1	3107977.106	1007152456
21.199	459269352.3	420342174.3	3268965.848	1007152456
22.243	459269352.3	425835507.6	3429954.59	1007152456
23.287	459269352.3	429778327.3	3590943.333	1007152456

Tabel 4.6 Hasil cek *local buckling* dengan menggunakan DNV 1981 untuk *Sagbend* (lanjutan)

Water Depth (m)	Critical Longitudinal (Compressive) Stress (Pa)	Critical Compressive Hoop Stress (Pa)	α	Premissible Combination
14.935	417283028.9	358526999.9	30.5530126	0.27980817
15.979	417362210.7	358526999.9	32.61885426	0.279990438
17.023	417655093.9	358526999.9	34.68469592	0.281284249
18.067	417749209.3	358526999.9	36.75053757	0.281390378
19.11	417828993.2	358526999.9	38.81440046	0.281572187
20.155	418123641.1	358526999.9	40.88222089	0.282849407
21.199	420342174.3	358526999.9	42.94806255	0.312520555
22.243	425835507.6	358526999.9	45.0139042	0.357913451
23.287	429778327.3	1007152456	47.07974586	0.40103426

Dari hasil di atas dapat kita katakan bahwa pipa aman dari adanya *local buckling* karena *permissible combination* dari seluruh *static case* tidak lebih besar dari 1. *Local buckling check sagbend* dari seluruh *static case* pun tidak lebih besar dari 1, maka dapat dikatakan baik *sagbend*atau pun *overbend* semua memenuhi dan aman.

BAB V
KESIMPULAN DAN SARAN

5.1 Kesimpulan

Kesimpulan yang dapat diambil dari hasil penelitian tugas akhir ini antara lain:

- Sudut optimal saat variasi sudut *stinger* dan kedalaman laut adalah sudut 11.1 derajat. Pada variasi sudut *stinger* dengan kedalaman laut kita dapat melihat bahwa semakin besar sudut (13.32 dan 15.54 derajat) maka akan semakin besar pula tegangan *Von Mises* yang didapatkan (dapat dilihat pada Gambar 4.1 dan Gambar 4.2) tetapi hal ini terjadi setelah sudut *stinger* bernilai 11.1 derajat. Jika sudut terlalu besar (13.32 dan 15.54 derajat) dan kedalaman laut tidak terlalu dalam (14.935 m, 17.023 m dan 18.067 m), hal ini menyebabkan tegangan akan semakin besar.
- Tidak terjadi *local buckling* pada daerah *sagbend* dan *overbend* karena nilai *permissible combination* yang didapatkan ≤1 dengan menggunakan *standart code* DNV 1981.

5.2 Saran

Saran yang dapat disampaikan untuk penelitian lebih lanjut adalah sebagai berikut :

- Menggunakan *standart code* DNV OS F101 hal ini dikarenakan *code* DNV OS F101 lebih terbaru dibandingkan dengan DNV 1981. Perhitungan akan lebih detail dibandingkan DNV F101
- Analisa tidak hanya dilakukan dengan analisa statis tetapi juga dengan menggunakan analisa dinamis.

Kedalaman **14.935 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	SOLUTION VERT ANGLE	SUMMARY REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.7	10.3	-11	-54.7	97.7	27
15	LAYBARGE	12.1	3	4.2	31.2	-41.6	-207.4	250.3	70
17	LAYBARGE	-0.1	1.8	5.3	0	5.3	26.3	69	19
20	STINGER	-9	1	6.5	26.7	-36.6	-182.1	224.7	62
22	STINGER	-16.9	-0.2	9.7	15.6	-28.1	-140.2	182.6	51
24	STINGER	-24.8	-1.8	13.3	28.7	-42.5	-211.8	253.9	71
26	SAGBEND	-26.7	-2.2	14.5	0	-25.3	-125.9	168	47
70	SEABED	-113.5	-14.9	0.2	0.7	5.6	28	68.3	19

Kedalaman **15.979 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	SOLUTION VERT ANGLE	SUMMARY REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.7	10.3	-11	-54.7	97.8	27
15	LAYBARGE	12.1	3	4.2	31.2	-41.6	-207.2	250.2	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.2	26.2	68.9	19
20	STINGER	-9	1	6.6	26.9	-36.7	-183.1	225.6	63
22	STINGER	-16.9	-0.2	9.7	14.3	-27	-134.3	176.7	49
24	STINGER	-24.8	-1.8	13.5	32.5	-48.7	-242.5	284.6	79
26	SAGBEND	-26.7	-2.2	14.9	0	-29.5	-147.2	189.3	53
72	SEABED	-117.3	-16	0.2	1.1	4.8	23.8	63.9	18

Kedalaman **17.023 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.7	97.8	27
15	LAYBARGE	12.1	3	4.2	31.2	-41.6	-207.1	250	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.2	26	68.8	19
20	STINGER	-9	1	6.6	27.1	-36.9	-184	226.6	63
22	STINGER	-16.9	-0.2	9.6	13.1	-25.8	-128.7	171.1	48
24	STINGER	-24.8	-1.8	13.7	36.1	-54.6	-272.1	314.2	87
26	SAGBEND	-26.7	-2.3	15.3	0	-33.7	-167.7	209.8	58
73	SEABED	-119.2	-17	0.3	0.3	6.7	33.1	73.2	20

Kedalaman **18.067 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.8	97.8	27
15	LAYBARGE	12.1	3	4.2	31.2	-41.5	-207	249.9	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.2	25.9	68.7	19
20	STINGER	-9	1	6.6	27.4	-37.1	-184.9	227.5	63
22	STINGER	-16.9	-0.2	9.6	11.9	-24.7	-123.2	165.6	46
24	STINGER	-24.8	-1.8	13.9	39.6	-60.4	-300.7	342.8	95
26	SAGBEND	-26.7	-2.3	15.7	0	-37.6	-187.6	229.7	64
75	SEABED	-123	-18.1	0.2	0.8	5.4	27.1	66.9	19

Kedalaman **19.11 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.8	97.8	27
15	LAYBARGE	12.1	3	4.2	31.2	-41.5	-206.9	249.8	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.2	25.8	68.6	19
20	STINGER	-9	1	6.6	27.6	-37.3	-185.7	228.3	63
22	STINGER	-16.9	-0.2	9.5	10.7	-23.7	-117.9	160.3	45
24	STINGER	-24.8	-1.8	14.1	43	-65.9	-328.4	370.4	103
26	SAGBEND	-26.7	-2.3	16	0	-41.5	-206.8	248.8	69
77	SEABED	-126.8	-19.1	0.1	1.3	4	20.2	59.9	17

Kedalaman **20.155 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.8	97.9	27
15	LAYBARGE	12.1	3	4.2	31.1	-41.5	-206.7	249.7	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.2	25.7	68.5	19
20	STINGER	-9	1	6.6	27.8	-37.4	-186.6	229.1	64
22	STINGER	-16.9	-0.2	9.5	9.6	-22.6	-112.8	155.2	43
24	STINGER	-24.8	-1.8	14.3	46.3	-71.3	-355.3	397.3	110
26	SAGBEND	-26.7	-2.3	16.4	0	-45.2	-225.4	267.5	74
78	SEABED	-128.6	-20.2	0.2	0.8	5.4	27.1	66.6	19

Kedalaman **21.199 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	SOLUTION VERT ANGLE	SUMMARY REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.8	97.9	27
15	LAYBARGE	12.1	3	4.2	31.1	-41.5	-206.6	249.5	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.1	25.6	68.4	19
20	STINGER	-9	1	6.6	28	-37.6	-187.4	230	64
22	STINGER	-16.9	-0.2	9.4	8.5	-21.6	-107.8	150.2	42
24	STINGER	-24.8	-1.8	14.5	49.6	-76.5	-381.4	423.4	118
26	SAGBEND	-26.7	-2.3	16.7	0	-48.9	-243.6	285.6	79
79	SEABED	-130.4	-21.2	0.3	0.3	6.7	33.4	72.8	20

Kedalaman **22.243 m**

NODE NO.	PIPE SECTION	X COORD	Y COORD	SOLUTION VERT ANGLE	SUMMARY REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.9	97.9	27
15	LAYBARGE	12.1	3	4.2	31.1	-41.4	-206.5	249.4	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.1	25.5	68.3	19
20	STINGER	-9	1	6.6	28.2	-37.8	-188.2	230.7	64
22	STINGER	-16.9	-0.2	9.4	7.4	-20.7	-103	145.4	40
24	STINGER	-24.8	-1.8	14.7	52.7	-81.7	-406.9	448.8	125
26	SAGBEND	-26.7	-2.3	17.1	0	-52.4	-261.2	303.3	84
81	SEABED	-134.2	-22.2	0.2	1.1	4.9	24.3	63.6	18

Kedalaman **23.287 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.6	31.1	9
11	TENSIONR	26.6	3.5	1.4	3.4	1	5	48.1	13
13	LAYBARGE	21.3	3.4	1.8	10.4	-11	-54.9	97.9	27
15	LAYBARGE	12.1	3	4.2	31.1	-41.4	-206.4	249.3	69
17	LAYBARGE	-0.1	1.8	5.3	0	5.1	25.4	68.2	19
20	STINGER	-9	1	6.6	28.3	-37.9	-189	231.5	64
22	STINGER	-16.9	-0.2	9.4	6.3	-19.7	-98.2	140.6	39
24	STINGER	-24.8	-1.8	14.9	55.7	-86.6	-431.6	473.6	132
26	SAGBEND	-26.7	-2.3	17.4	0	-55.9	-278.4	320.5	89
82	SEABED	-136.1	-23.3	0.2	0.7	5.9	29.5	68.7	19

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	48	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.4	27
15	LAYBARGE	12.1	3	4.3	31.5	-43	-214.2	257.1	71
17	LAYBARGE	-0.1	1.7	6.3	8	-8.7	-43.5	86.3	24
20	STINGER	-9	0.6	8.5	27	-40	-199.5	242	67
22	STINGER	-16.9	-0.8	12.2	19.7	-32.1	-159.9	202.2	56
24	STINGER	-24.7	-2.7	14.5	12.7	-16.4	-81.6	123.7	34
56	SAGBEND	-85.5	-14	4.6	0	12.1	60.1	100.6	28
68	SEABED	-109.5	-14.9	0.2	0.5	6.1	30.4	70.7	20

Kedalaman **15.979 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	48	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.4	27
15	LAYBARGE	12.1	3	4.3	31.5	-43	-214.2	257.2	71
17	LAYBARGE	-0.1	1.7	6.3	7.9	-8.7	-43.3	86	24
20	STINGER	-9	0.6	8.6	27.3	-40.3	-200.7	243.2	68
22	STINGER	-16.9	-0.8	12.1	18.3	-30.8	-153.7	196	54
24	STINGER	-24.7	-2.7	14.8	16.6	-22.8	-113.7	155.7	43
58	SAGBEND	-89.4	-15.1	4.5	0	12.1	60.3	100.6	28
70	SEABED	-113.3	-16	0.2	0.8	5.5	27.3	67.4	19

Kedalaman **17.023 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	48	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.4	27
15	LAYBARGE	12.1	3	4.3	31.5	-43	-214.3	257.2	71
17	LAYBARGE	-0.1	1.7	6.3	7.9	-8.6	-43	85.8	24
20	STINGER	-9	0.6	8.6	27.6	-40.5	-202	244.5	68
22	STINGER	-16.9	-0.8	12.1	17	-29.7	-147.8	190.1	53
24	STINGER	-24.7	-2.7	15	20.4	-29	-144.4	186.5	52
26	SAGBEND	-26.6	-3.2	15.8	0	-15.9	-79.5	121.4	34
72	SEABED	-117.2	-17	0.1	1.1	4.6	23	63	17

Kedalaman **18.067 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	48	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.4	27
15	LAYBARGE	12.1	3	4.3	31.5	-43	-214.3	257.2	71
17	LAYBARGE	-0.1	1.7	6.3	7.8	-8.6	-42.8	85.6	24
20	STINGER	-9	0.6	8.6	27.8	-40.8	-203.1	245.6	68
22	STINGER	-16.9	-0.8	12	15.8	-28.5	-142.1	184.4	51
24	STINGER	-24.7	-2.7	15.2	24.1	-34.9	-174.1	216.1	60
26	SAGBEND	-26.6	-3.2	16.2	0	-20.1	-100	142	39
73	SEABED	-119	-18.1	0.3	0.4	6.5	32.3	72.2	20

Kedalaman **19.11 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	47.9	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.4	27
15	LAYBARGE	12.1	3	4.3	31.6	-43	-214.4	257.3	71
17	LAYBARGE	-0.1	1.7	6.3	7.8	-8.6	-42.6	85.4	24
20	STINGER	-9	0.6	8.6	28.1	-41	-204.2	246.7	69
22	STINGER	-16.9	-0.8	12	14.5	-27.4	-136.6	178.9	50
24	STINGER	-24.7	-2.7	15.4	27.6	-40.7	-202.7	244.7	68
26	SAGBEND	-26.6	-3.2	16.6	0	-24.1	-119.9	161.9	45
75	SEABED	-122.9	-19.1	0.2	0.9	5.2	26.1	65.8	18

Kedalaman **20.155 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	47.9	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.3	27
15	LAYBARGE	12.1	3	4.3	31.6	-43	-214.4	257.3	71
17	LAYBARGE	-0.1	1.7	6.3	7.7	-8.5	-42.4	85.2	24
20	STINGER	-9	0.6	8.6	28.3	-41.2	-205.3	247.8	69
22	STINGER	-16.9	-0.8	11.9	13.4	-26.3	-131.2	173.5	48
24	STINGER	-24.7	-2.7	15.6	31	-46.3	-230.5	272.4	76
26	SAGBEND	-26.6	-3.3	16.9	0	-27.9	-139.2	181.1	50
76	SEABED	-124.7	-20.2	0.3	0.3	6.8	33.8	73.4	20

Kedalaman 21.199 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	47.9	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.3	27
15	LAYBARGE	12.1	3	4.3	31.6	-43	-214.4	257.3	71
17	LAYBARGE	-0.1	1.7	6.3	7.7	-8.5	-42.2	85	24
20	STINGER	-9	0.6	8.6	28.6	-41.4	-206.4	248.9	69
22	STINGER	-16.9	-0.8	11.9	12.2	-25.3	-126.1	168.4	47
24	STINGER	-24.7	-2.7	15.8	34.3	-51.7	-257.4	299.3	83
26	SAGBEND	-26.6	-3.3	17.3	0	-31.7	-157.9	199.8	56
78	SEABED	-128.5	-21.2	0.2	0.9	5.2	26.1	65.5	18

Kedalaman 22.243 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	47.9	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.3	27
15	LAYBARGE	12.1	3	4.3	31.6	-43	-214.5	257.4	71
17	LAYBARGE	-0.1	1.7	6.3	7.7	-8.4	-42	84.8	24
20	STINGER	-9	0.6	8.6	28.8	-41.6	-207.4	249.9	69
22	STINGER	-16.9	-0.8	11.9	11.1	-24.3	-121	163.3	45
24	STINGER	-24.7	-2.7	16	37.5	-56.9	-283.5	325.5	90
26	SAGBEND	-26.6	-3.3	17.6	0	-35.3	-176	218	61
79	SEABED	-130.3	-22.2	0.3	0.4	6.5	32.4	71.7	20

Kedalaman **23.287 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.2	8
5	LAYBARGE	48.2	4.1	1.4	11.7	-8.5	-42.3	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.5	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-1.9	-9.5	31	9
11	TENSIONR	26.6	3.5	1.4	3.5	1	4.9	47.9	13
13	LAYBARGE	21.3	3.4	1.7	10.1	-10.7	-53.3	96.3	27
15	LAYBARGE	12.1	3	4.3	31.6	-43	-214.5	257.4	72
17	LAYBARGE	-0.1	1.7	6.3	7.6	-8.4	-41.8	84.6	23
20	STINGER	-9	0.6	8.6	29	-41.8	-208.4	250.9	70
22	STINGER	-16.9	-0.8	11.8	10	-23.3	-116.1	158.4	44
24	STINGER	-24.7	-2.7	16.2	40.6	-62	-309	350.9	97
26	SAGBEND	-26.6	-3.3	18	0	-38.9	-193.7	235.6	65
81	SEABED	-134.1	-23.3	0.1	1.1	4.7	23.2	62.4	17

Kedalaman **14.935 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.5	237.4	66
17	LAYBARGE	-0.1	1.7	7.4	22.4	-32.8	-163.4	206.1	57
20	STINGER	-9	0.3	10.9	23.6	-37.5	-186.6	229.1	64
22	STINGER	-16.8	-1.4	14.3	20.9	-30.9	-154	196.2	55
24	STINGER	-24.5	-3.6	15.5	0	5	25.1	67	19
55	SAGBEND	-83.5	-14.1	4.3	0	12.1	60.1	100.6	28
66	SEABED	-105.5	-14.9	0.3	0.3	6.8	33.8	74.1	21

Kedalaman 15.979 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.9	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.3	237.3	66
17	LAYBARGE	-0.1	1.7	7.4	22.6	-33	-164.3	207	58
20	STINGER	-9	0.3	10.8	22.5	-36.5	-181.7	224.2	62
22	STINGER	-16.8	-1.4	14.5	24.1	-36.3	-180.8	223	62
24	STINGER	-24.5	-3.6	16	0.4	3.5	17.3	59.2	16
56	SAGBEND	-85.4	-15	4.6	0	12.1	60.3	100.6	28
68	SEABED	-109.3	-16	0.2	0.6	6	29.8	69.9	19

Kedalaman 17.023 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.9	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.4	237.3	66
17	LAYBARGE	-0.1	1.7	7.4	22.6	-32.9	-164.1	206.8	57
20	STINGER	-9	0.3	10.8	22.8	-36.7	-183	225.4	63
22	STINGER	-16.8	-1.4	14.5	22.8	-35.1	-174.7	216.9	60
24	STINGER	-24.5	-3.6	16.3	4.4	-3	-14.7	56.7	16
58	SAGBEND	-89.2	-16.1	4.5	0	12.2	60.6	100.7	28
70	SEABED	-113.2	-17	0.2	0.9	5.3	26.6	66.6	18

Kedalaman **18.067 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.9	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.4	237.3	66
17	LAYBARGE	-0.1	1.7	7.4	22.5	-32.9	-163.8	206.6	57
20	STINGER	-9	0.3	10.9	23	-37	-184.2	226.6	63
22	STINGER	-16.8	-1.4	14.4	21.5	-33.9	-168.7	210.9	59
24	STINGER	-24.5	-3.6	16.5	8.2	-9.1	-45.5	87.5	24
60	SAGBEND	-93	-17.2	4.4	0	12.2	60.8	100.8	28
72	SEABED	-117	-18.1	0.1	1.2	4.5	22.2	62.1	17

Kedalaman **19.11 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT

NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.4	237.4	66
17	LAYBARGE	-0.1	1.7	7.4	22.5	-32.8	-163.6	206.3	57
20	STINGER	-9	0.3	10.9	23.3	-37.2	-185.3	227.8	63
22	STINGER	-16.8	-1.4	14.4	20.2	-32.7	-163	205.2	57
24	STINGER	-24.5	-3.6	16.7	11.8	-15.1	-75.2	117.1	33
61	SAGBEND	-94.9	-18.1	4.7	0	12.2	61	100.8	28
73	SEABED	-118.9	-19.1	0.2	0.5	6.3	31.6	71.3	20

Kedalaman 20.155 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.5	237.4	66
17	LAYBARGE	-0.1	1.7	7.4	22.4	-32.8	-163.4	206.1	57
20	STINGER	-9	0.3	10.9	23.5	-37.4	-186.5	228.9	64
22	STINGER	-16.8	-1.4	14.3	19	-31.6	-157.5	199.7	55
24	STINGER	-24.5	-3.6	16.9	15.3	-20.8	-103.9	145.8	40
63	SAGBEND	-98.7	-19.2	4.5	0	12.3	61.2	100.9	28
75	SEABED	-122.7	-20.2	0.2	1	5.1	25.3	64.9	18

Kedalaman 21.199 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0

3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.5	237.5	66
17	LAYBARGE	-0.1	1.7	7.4	22.4	-32.8	-163.2	205.9	57
20	STINGER	-9	0.3	10.9	23.8	-37.6	-187.6	230	64
22	STINGER	-16.8	-1.4	14.3	17.8	-30.5	-152.2	194.4	54
24	STINGER	-24.5	-3.6	17.1	18.7	-26.4	-131.6	173.5	48
26	SAGBEND	-26.4	-4.2	17.8	0	-14.2	-70.8	112.6	31
76	SEABED	-124.5	-21.2	0.3	0.4	6.6	33	72.4	20

Kedalaman **22.243 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8
9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39	-194.5	237.5	66
17	LAYBARGE	-0.1	1.7	7.4	22.4	-32.7	-163	205.7	57
20	STINGER	-9	0.3	10.9	24	-37.9	-188.6	231.1	64
22	STINGER	-16.8	-1.4	14.2	16.7	-29.5	-147	189.2	53
24	STINGER	-24.5	-3.6	17.3	22	-31.8	-158.6	200.4	56
26	SAGBEND	-26.4	-4.2	18.2	0	-18	-89.5	131.3	36
78	SEABED	-128.3	-22.2	0.2	1	5	25.1	64.4	18

Kedalaman **23.287 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.4	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.6	29.1	8

9	LAYBARGE	33.4	3.7	1.6	5.8	-2	-9.8	31.2	9
11	TENSIONR	26.6	3.5	1.4	3.2	1.1	5.3	48.4	13
13	LAYBARGE	21.3	3.4	1.8	11	-11.6	-57.8	100.8	28
15	LAYBARGE	12.1	3	4.1	28.2	-39.1	-194.6	237.5	66
17	LAYBARGE	-0.1	1.7	7.4	22.3	-32.7	-162.8	205.5	57
20	STINGER	-9	0.3	10.9	24.3	-38.1	-189.6	232.1	64
22	STINGER	-16.8	-1.4	14.2	15.6	-28.5	-142	184.2	51
24	STINGER	-24.5	-3.6	17.5	25.2	-37.1	-184.7	226.6	63
26	SAGBEND	-26.4	-4.2	18.5	0	-21.6	-107.7	149.5	42
79	SEABED	-130.1	-23.3	0.2	0.5	6.3	31.5	70.6	20

Kedalaman **14.935 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.8	-12.4	-62	105.1	29
15	LAYBARGE	12.1	3	4	25.1	-35.3	-175.7	218.6	61
17	LAYBARGE	-0.1	1.7	8.4	35.9	-55.8	-277.9	320.5	89
20	STINGER	-9	0	13.4	25.2	-39.4	-196.4	238.8	66
22	STINGER	-16.7	-2.1	15.6	6.2	-6.7	-33.4	75.5	21
24	STINGER	-24.5	-4.2	15.2	0	8.7	43.6	85.4	24
53	SAGBEND	-79.5	-14	4.6	0	12.1	60.1	100.6	28
65	SEABED	-103.5	-14.9	0.2	0.6	6	30	70.3	20

Kedalaman **15.979 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.8	-12.5	-62.1	105.1	29

15	LAYBARGE	12.1	3	4	25.1	-35.2	-175.5	218.5	61
17	LAYBARGE	-0.1	1.7	8.4	36.1	-56	-279	321.6	89
20	STINGER	-9	0	13.3	23.9	-38.3	-190.6	233	65
22	STINGER	-16.7	-2.1	15.9	10	-13	-64.9	107	30
24	STINGER	-24.4	-4.3	15.9	0	7.8	38.6	80.5	22
55	SAGBEND	-83.4	-15.1	4.5	0	12.1	60.3	100.6	28
67	SEABED	-107.3	-16	0.2	0.9	5.3	26.3	66.4	18

Kedalaman 17.023 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.8	-12.5	-62.1	105.2	29
15	LAYBARGE	12.1	3	4	25	-35.2	-175.3	218.3	61
17	LAYBARGE	-0.1	1.7	8.5	36.3	-56.2	-280	322.7	90
20	STINGER	-9	0	13.3	22.6	-37.1	-185	227.4	63
22	STINGER	-16.7	-2.1	16.1	13.7	-19.1	-95.2	137.4	38
24	STINGER	-24.4	-4.4	16.5	0	6.8	33.9	75.7	21
57	SAGBEND	-87.2	-16.2	4.4	0	12.2	60.6	100.7	28
69	SEABED	-111.2	-17	0.1	1.2	4.3	21.5	61.5	17

Kedalaman 18.067 m

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.8	-12.5	-62.1	105.2	29

15	LAYBARGE	12.1	3	4	25	-35.1	-175.1	218.1	61
17	LAYBARGE	-0.1	1.7	8.5	36.5	-56.4	-281	323.7	90
20	STINGER	-9	0	13.2	21.5	-36	-179.6	222	62
22	STINGER	-16.7	-2.1	16.3	17.3	-25	-124.5	166.6	46
24	STINGER	-24.4	-4.4	17.1	0	5.9	29.3	71.1	20
58	SAGBEND	-89	-17.1	4.6	0	12.2	60.8	100.8	28
70	SEABED	-113	-18.1	0.2	0.5	6.1	30.4	70.3	20

Kedalaman **19.11 m**

SOLUTION SUMMARY

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.9	-12.5	-62.2	105.2	29
15	LAYBARGE	12.1	3	4	25	-35.1	-175	217.9	61
17	LAYBARGE	-0.1	1.7	8.5	36.7	-56.6	-282	324.7	90
20	STINGER	-9	0	13.2	20.3	-35	-174.4	216.8	60
22	STINGER	-16.7	-2.1	16.5	20.8	-30.7	-152.8	194.9	54
24	STINGER	-24.4	-4.5	17.6	0	5	24.8	66.6	19
60	SAGBEND	-92.9	-18.2	4.5	0	12.2	61	100.8	28
72	SEABED	-116.8	-19.1	0.1	1.1	4.8	23.8	63.5	18

Kedalaman **20.155 m**

SOLUTION SUMMARY

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.9	-12.5	-62.2	105.3	29

15	LAYBARGE	12.1	3	4	24.9	-35.1	-174.8	217.7	60
17	LAYBARGE	-0.1	1.7	8.5	36.9	-56.8	-283	325.6	90
20	STINGER	-9	0	13.2	19.2	-34	-169.4	211.8	59
22	STINGER	-16.7	-2.1	16.7	24.1	-36.2	-180.2	222.3	62
24	STINGER	-24.4	-4.5	18.2	0	4.1	20.5	62.3	17
61	SAGBEND	-94.7	-19.2	4.7	0	12.3	61.2	100.9	28
73	SEABED	-118.7	-20.2	0.2	0.5	6.3	31.2	70.7	20

Kedalaman **21.199 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.9	-12.5	-62.2	105.3	29
15	LAYBARGE	12.1	3	4	24.9	-35.1	-174.8	217.7	60
17	LAYBARGE	-0.1	1.7	8.5	36.9	-56.8	-282.9	325.6	90
20	STINGER	-9	0	13.2	19.3	-34.1	-169.8	212.2	59
22	STINGER	-16.7	-2.1	16.7	23.4	-35.8	-178.4	220.5	61
24	STINGER	-24.4	-4.6	18.4	3.1	-1.1	-5.4	47.1	13
63	SAGBEND	-98.5	-20.3	4.5	0	12.3	61.4	101	28
75	SEABED	-122.5	-21.2	0.2	1	4.9	24.6	64	18

Kedalaman **22.243 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.9	-12.5	-62.2	105.3	29

15	LAYBARGE	12.1	3	4	25	-35.1	-174.8	217.8	60
17	LAYBARGE	-0.1	1.7	8.5	36.9	-56.7	-282.7	325.3	90
20	STINGER	-9	0	13.2	19.5	-34.3	-170.9	213.3	59
22	STINGER	-16.7	-2.1	16.6	22.3	-34.7	-173.1	215.2	60
24	STINGER	-24.4	-4.6	18.6	6.5	-6.6	-33.1	74.9	21
64	SAGBEND	-100.3	-21.3	4.8	0	12.4	61.7	101.1	28
76	SEABED	-124.3	-22.2	0.3	0.4	6.5	32.3	71.5	20

Kedalaman **23.287 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	=====
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	=====
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2	-10	31.5	9
11	TENSIONR	26.6	3.5	1.4	2.9	1.2	5.8	48.9	14
13	LAYBARGE	21.3	3.4	1.8	11.9	-12.5	-62.2	105.3	29
15	LAYBARGE	12.1	3	4	25	-35.1	-174.9	217.8	61
17	LAYBARGE	-0.1	1.7	8.5	36.8	-56.7	-282.5	325.1	90
20	STINGER	-9	0	13.2	19.7	-34.5	-171.9	214.3	60
22	STINGER	-16.7	-2.1	16.6	21.1	-33.7	-167.9	210	58
24	STINGER	-24.4	-4.6	18.8	9.8	-12.1	-60.1	101.8	28
66	SAGBEND	-104.1	-22.4	4.5	0	12.4	61.9	101.1	28
78	SEABED	-128.1	-23.3	0.2	1.1	4.9	24.3	63.4	18

Kedalaman **14.935 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.3	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.6	1.3	6.3	49.4	14
13	LAYBARGE	21.3	3.4	1.8	12.8	-13.4	-66.7	109.8	30
15	LAYBARGE	12.1	3	3.8	21.6	-31.1	-154.9	197.8	55
17	LAYBARGE	-0.1	1.7	9.6	51.5	-81	-403.5	446	124
20	STINGER	-9	-0.3	15.3	16.7	-26.7	-132.9	175.2	49

22	STINGER	-16.7	-2.6	16.2	0	5.6	28.1	70.2	19
24	STINGER	-24.4	-4.7	15	0	10.6	52.8	94.6	26
52	SAGBEND	-77.5	-14	4.6	0	12.1	60.1	100.6	28
64	SEABED	-101.5	-14.9	0.2	0.5	6.1	30.6	70.9	20

Kedalaman **15.979 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.3	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.4	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.5	109.6	30
15	LAYBARGE	12.1	3	3.8	21.8	-31.3	-155.8	198.7	55
17	LAYBARGE	-0.1	1.7	9.5	50.6	-80	-398.6	441.1	123
20	STINGER	-9	-0.3	15.5	20.2	-32.4	-161.6	203.9	57
22	STINGER	-16.6	-2.6	16.8	0	4.7	23.6	65.6	18
24	STINGER	-24.3	-4.9	15.6	0	10.5	52.1	93.9	26
54	SAGBEND	-81.3	-15.1	4.5	0	12.1	60.3	100.6	28
66	SEABED	-105.3	-16	0.2	1	5.1	25.2	65.4	18

Kedalaman **17.023 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.2	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.2	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.3	109.4	30
15	LAYBARGE	12.1	3	3.8	21.9	-31.4	-156.6	199.6	55
17	LAYBARGE	-0.1	1.7	9.5	49.6	-79	-393.8	436.4	121
20	STINGER	-9	-0.3	15.8	23.5	-38	-189.3	231.7	64

22	STINGER	-16.6	-2.7	17.3	0	3.8	19.2	61.2	17
24	STINGER	-24.3	-5	16.3	0	10.3	51.4	93.2	26
55	SAGBEND	-83.2	-16	4.7	0	12.2	60.5	100.7	28
67	SEABED	-107.2	-17	0.3	0.3	6.7	33.5	73.5	20

Kedalaman 18.067 m

SOLUTION SUMMARY

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.2	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.2	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.3	109.4	30
15	LAYBARGE	12.1	3	3.8	21.9	-31.4	-156.6	199.6	55
17	LAYBARGE	-0.1	1.7	9.5	49.6	-79	-393.8	436.4	121
20	STINGER	-9	-0.3	15.8	23.1	-38.1	-189.7	232.1	64
22	STINGER	-16.6	-2.7	17.6	3	-1.2	-6.1	48.2	13
24	STINGER	-24.3	-5.1	16.9	0	9.5	47.4	89.2	25
57	SAGBEND	-87	-17.1	4.6	0	12.2	60.8	100.8	28
69	SEABED	-111	-18.1	0.2	0.7	5.6	28.1	68	19

Kedalaman 19.11 m

SOLUTION SUMMARY

NODE NO.	PIPE SECTION	X COORD	Y COORD	VERT ANGLE	REACTION	BENDING MOMENT	BENDING STRESS	TOTAL STRESS	PCT YLD
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.2	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.4	109.4	30
15	LAYBARGE	12.1	3	3.8	21.9	-31.4	-156.4	199.4	55
17	LAYBARGE	-0.1	1.7	9.5	49.8	-79.2	-394.9	437.4	121
20	STINGER	-9	-0.3	15.7	21.9	-37	-184.4	226.8	63

22	STINGER	-16.6	-2.7	17.8	6.5	-7	-35.1	77.1	21
24	STINGER	-24.3	-5.2	17.4	0	8.6	42.9	84.6	23
59	SAGBEND	-90.8	-18.2	4.4	0	12.2	61	100.8	28
71	SEABED	-114.8	-19.1	0.1	1.2	4.4	22	61.7	17

Kedalaman **20.155 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.2	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.4	109.4	30
15	LAYBARGE	12.1	3	3.8	21.9	-31.4	-156.3	199.2	55
17	LAYBARGE	-0.1	1.7	9.5	50	-79.4	-395.8	438.4	122
20	STINGER	-9	-0.3	15.7	20.8	-36	-179.3	221.6	62
22	STINGER	-16.6	-2.7	18	10	-12.7	-63.2	105.2	29
24	STINGER	-24.2	-5.2	18	0	7.7	38.4	80.1	22
60	SAGBEND	-92.7	-19.2	4.7	0	12.3	61.2	100.9	28
72	SEABED	-116.6	-20.2	0.2	0.6	6	29.9	69.5	19

Kedalaman **21.199 m**

=====	========	=======	=======	SOLUTION	SUMMARY	=======	========	========	======
NODE	PIPE	X	Y	VERT	REACTION	BENDING	BENDING	TOTAL	PCT
NO.	SECTION	COORD	COORD	ANGLE		MOMENT	STRESS	STRESS	YLD
=====	========	=======	=======	=========	========	========	========	========	======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.3	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.4	109.5	30
15	LAYBARGE	12.1	3	3.8	21.8	-31.3	-156.1	199	55
17	LAYBARGE	-0.1	1.7	9.5	50.2	-79.6	-396.8	439.3	122
20	STINGER	-9	-0.3	15.6	19.7	-35	-174.3	216.6	60

22	STINGER	-16.6	-2.7	18.2	13.3	-18.1	-90.4	132.4	37
24	STINGER	-24.2	-5.3	18.6	0	6.9	34.1	75.8	21
62	SAGBEND	-96.5	-20.3	4.5	0	12.3	61.5	101	28
74	SEABED	-120.5	-21.2	0.1	1.2	4.5	22.2	61.6	17

Kedalaman **22.243 m**

===== NODE NO. =====	======== PIPE SECTION ========	======= X COORD =======	======= Y COORD =======	SOLUTION VERT ANGLE =========	SUMMARY REACTION ========	======= BENDING MOMENT ========	======== BENDING STRESS ========	======== TOTAL STRESS ========	====== PCT YLD ======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.3	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.3	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.5	109.5	30
15	LAYBARGE	12.1	3	3.8	21.8	-31.3	-155.9	198.9	55
17	LAYBARGE	-0.1	1.7	9.5	50.4	-79.8	-397.7	440.2	122
20	STINGER	-9	-0.3	15.6	18.6	-34	-169.4	211.8	59
22	STINGER	-16.6	-2.7	18.4	16.5	-23.4	-116.8	158.8	44
24	STINGER	-24.2	-5.3	19.1	0	6	30	71.6	20
63	SAGBEND	-98.3	-21.3	4.7	0	12.4	61.7	101.1	28
75	SEABED	-122.3	-22.2	0.2	0.7	5.7	28.6	67.9	19

Kedalaman **23.287 m**

===== NODE NO. =====	======== PIPE SECTION ========	======= X COORD =======	======= Y COORD =======	SOLUTION VERT ANGLE =========	SUMMARY REACTION ========	======= BENDING MOMENT ========	======== BENDING STRESS ========	======== TOTAL STRESS ========	====== PCT YLD ======
1	LAYBARGE	64.2	4.5	1.5	0.3	0	0	0	0
3	LAYBARGE	59.7	4.4	1.6	9.7	-6	-30.1	30.1	8
5	LAYBARGE	48.2	4.1	1.4	11.8	-8.5	-42.4	42.5	12
7	TENSIONR	38.1	3.8	1.4	7.4	-1.5	-7.5	29	8
9	LAYBARGE	33.4	3.7	1.6	5.9	-2.1	-10.3	31.7	9
11	TENSIONR	26.6	3.5	1.4	2.7	1.3	6.3	49.4	14
13	LAYBARGE	21.3	3.4	1.8	12.7	-13.3	-66.5	109.6	30
15	LAYBARGE	12.1	3	3.8	21.8	-31.3	-155.8	198.7	55
17	LAYBARGE	-0.1	1.7	9.5	50.6	-80	-398.6	441.1	123
20	STINGER	-9	-0.3	15.5	17.5	-33.1	-164.7	207	58

22	STINGER	-16.6	-2.7	18.6	19.7	-28.6	-142.5	184.6	51
24	STINGER	-24.2	-5.4	19.6	0	5.2	25.9	67.5	19
65	SAGBEND	-102.1	-22.4	4.4	0	12.4	61.9	101.1	28
76	SEABED	-124.1	-23.3	0.3	0.3	6.9	34.4	73.5	20

LOCAL BUCKLING CHECK

CASE 1

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	237420	N
4	Bending Moment	M	=	39032	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	14.935	m
7	External Pressure	Pe	=	0	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43806180.92 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183131938.1 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

226938119.1 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} =$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

$\sigma_{xcr} =$ $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^{M} =$

= 439822915.9

9 Hoop Stress

$\sigma_y =$ $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

$\sigma_{yE} =$ $E\left(\frac{t}{D-t}\right)^2$

1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} > \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp}=$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha}+\frac{\alpha_y}{\eta_{yp}\sigma_{ycr}}\leq 1$$

0.599972226 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 2

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275
2	Nominal Wall Thickness of Pipe	t	=	0.010973
3	Axial Force in a Pipe	N	=	233360
4	Bending Moment	M	=	38998
5	Specified Yield Strength	σ_F	=	3.59E+08
6	Water Depth	d	=	15.979
7	External Pressure	Pe	=	0
8	Internal Pressure	Pi	=	0
9	Modulus of Elasticity	E	=	2.07E+11

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

182972415.5 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N+\sigma_x{}^M$

= 226029489 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} = \sigma_F$

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} = \sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^{M} =$

= 440078622.5

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation	Operation	
Loading condition	Pipelines and risers	Pipelines Zone 1	Pipelines Zone 2 and risers

	risers				risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.5972228 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 3

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275
2	Nominal Wall Thickness of Pipe	t	=	0.010973
3	Axial Force in a Pipe	N	=	233360
4	Bending Moment	M	=	39007
5	Specified Yield Strength	σ_F	=	3.59E+08
6	Water Depth	d	=	17.023
7	External Pressure	Pe	=	0
8	Internal Pressure	Pi	=	0
9	Modulus of Elasticity	E	=	2.07E+11

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = M

$\overline{W}$

= 183014642.1 Pa

5 Longitudinal Stress

$\sigma_x =$ $\sigma_x^{N} + \sigma_x^{M}$

= 226071715.6 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} =$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

$\sigma_{xcr} =$ $\frac{\sigma_x^{N}}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x^{M}}{\sigma_x}\sigma_{xcr}^{M} =$

= 440082207

9 Hoop Stress

$\sigma_y =$ $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

$\sigma_{yE} =$ $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \le 1$$

0.597329507 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 4

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275 m
2	Nominal Wall Thickness of Pipe	t	=	0.010973 m
3	Axial Force in a Pipe	N	=	233360 N
4	Bending Moment	M	=	39015 Nm
5	Specified Yield Strength	σ_F	=	3.59E+08 Pa
6	Water Depth	d	=	18.067 m
7	External Pressure	Pe	=	0 Pa
8	Internal Pressure	Pi	=	0 Pa
9	Modulus of Elasticity	E	=	2.07E+11 Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N =$ $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M =$ $\frac{M}{W}$

= 183052176.8 Pa

5 Longitudinal Stress

$\sigma_x =$ $\sigma_x{}^N + \sigma_x{}^M$

= 226109250.3 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^N =$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^M =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

$\sigma_{xcr} =$ $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^N + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^M =$

= 440085392.1 Pa

9 Hoop Stress

$\sigma_y =$ $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

$\sigma_{yE} =$ $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \le \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F \left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 **α** = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 **Premissible Combination**

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.597424358 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 5

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275
2	Nominal Wall Thickness of Pipe	t	=	0.010973
3	Axial Force in a Pipe	N	=	233360
4	Bending Moment	M	=	39023
5	Specified Yield Strength	σ_F	=	3.59E+08
6	Water Depth	d	=	19.11
7	External Pressure	Pe	=	0
8	Internal Pressure	Pi	=	0
9	Modulus of Elasticity	E	=	2.07E+11

B Calculation

1 **Cross Section Area**

A = π (D – t) t

= 0.005419783 m^2

2 **Elastic Section Modulus**

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183089711.6 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 226146785 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ {}_{xcr}^{N}=$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ {}_{xcr}^{M}=$ $\sigma_F\left[1.35-0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma\ {}_{xcr}^{N}+\frac{\sigma_x{}^M}{\sigma_x}\sigma\ {}_{xcr}^{M}=$

= 440088576.2

9 Hoop Stress

σ_y = $(p_e-p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers η_{xp}	Installation: Pipelines and risers η_{yp}	Operation: Pipelines Zone 1 η_{xp}	Operation: Pipelines Zone 1 η_{yp}	Operation: Pipelines Zone 2 and risers η_{xp}	Operation: Pipelines Zone 2 and risers η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.597519209 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 6

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	233360	N
4	Bending Moment	M	=	39030	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	20.155	m
7	External Pressure	Pe	=	0	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183122554.4 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 226179627.9 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ _{xcr}^{N}$= σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ _{xcr}^{M}$= $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma\ _{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma\ _{xcr}^{M} =$

= 440091361.4

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{}$

$2t$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

σ_{ycr} = 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers η_{xp}	Installation: Pipelines and risers η_{yp}	Operation: Pipelines Zone 1 η_{xp}	Operation: Pipelines Zone 1 η_{yp}	Operation: Pipelines Zone 2 and risers η_{xp}	Operation: Pipelines Zone 2 and risers η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^\alpha + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.597602204 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 7

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	233360	N
4	Bending Moment	M	=	39038	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	21.199	m
7	External Pressure	Pe	=	0	Pa

8	Internal Pressure	Pi	=	0 Pa
9	Modulus of Elasticity	E	=	2.07E+11 Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183160089.2 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 226217162.6 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ {}_{xcr}^{N}=$ σ_F

3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ {}_{xcr}^{M}=$ $\sigma_F\left[1.35-0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\ldots}\sigma\ {}^N + \frac{\sigma_x{}^M}{\ldots}\sigma\ {}^M$ ...

$$\frac{}{\sigma_x}\sigma_{xcr} + \frac{}{\sigma_x}\sigma_{xcr} =$$

= 440094543.4 Pa

9 **Hoop Stress**

$$\sigma_y = (p_e - p_i)\frac{D}{2t}$$

= 0 Pa

10 **Critical Compressive Hoop Stress for Completely Elastic Buckling**

$$\sigma_{yE} = E\left(\frac{t}{D-t}\right)^2$$

= 1007152456 Pa

11 **Critical Compressive Hoop Stress**

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 **α** = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 **Premissible Combination**

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers η_{xp}	Installation: Pipelines and risers η_{yp}	Operation: Pipelines Zone 1 η_{xp}	Operation: Pipelines Zone 1 η_{yp}	Operation: Pipelines Zone 2 and risers η_{xp}	Operation: Pipelines Zone 2 and risers η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^\alpha + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.597697055 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 8

A **INPUT DATA**

1 Nominal Outside Diameter of Pipe D = 0.168275 m

2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	233360	N
4	Bending Moment	M	=	39045	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	22.243	m
7	External Pressure	Pe	=	0	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 43057073.46 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183192932.1 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 226250005.5 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

σ_{xcr}^N= σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x^{N}}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x^{M}}{\sigma_x}\sigma_{xcr}^{M} =$

= 440097326.9

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} . \frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp} =$ 0.75

$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$

0.597780049 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 9

A	**INPUT DATA**				
1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	233350	N
4	Bending Moment	M	=	39052	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	23.287	m
7	External Pressure	Pe	=	0	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa

B Calculation

1 Cross Section Area

A = π (D − t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

43055228.37 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 183225774.9 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 226281003.3 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} =$ σ_F

3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^{M} =$

= 440100774.7

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 0 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}}.\frac{\sigma_y}{\sigma_{ycr}}$

= 1

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η = 0.86

$\eta_{xp} =$

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.597857266 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 1

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	219870	N
4	Bending Moment	M	=	12100	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	14.935	m
7	External Pressure	Pe	=	1.50E+05	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw} g WD$	
			=	1.50E+05	Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N = \frac{N}{A}$

= 40568043.97 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M = \frac{M}{W}$

= 56771276.17 Pa

5 **Longitudinal Stress**

$\sigma_x =$ $\sigma_x{}^N + \sigma_x{}^M$

97339320.14 Pa

6 **Critical Longitudinal Stress when N is acting alone**

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} =$ σ_F

= 3.59E+08 Pa

7 **Critical Longitudinal Stress when M is acting alone**

$\sigma_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 **Critical Longitudinal (Compressive) Stress**

$\sigma_{xcr} =$ $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^{M} =$

= 417283028.9

9 **Hoop Stress**

$\sigma_y =$ $(p_e - p_i)\frac{D}{2t}$

= 2303033.395 Pa

10 **Critical Compressive Hoop Stress for Completely Elastic Buckling**

$\sigma_{yE} =$ $E\left(\frac{t}{D-t}\right)^2$

1007152456 Pa

11 **Critical Compressive Hoop Stress**

2/3 σF = 239018000

for $\sigma_{yE} > \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 **α** = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 30.55301

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers η_{xp}	Installation: Pipelines and risers η_{yp}	Operation: Pipelines Zone 1 η_{xp}	Operation: Pipelines Zone 1 η_{yp}	Operation: Pipelines Zone 2 and risers η_{xp}	Operation: Pipelines Zone 2 and risers η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \le 1$$

0.27980817 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 2

A INPUT DATA

No.	Description	Symbol		Value	Unit
1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	219160	N
4	Bending Moment	M	=	12100	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	15.979	m
7	External Pressure	Pe	=	1.61E+05	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw} gWD$	
			=	1.61E+05	Pa

B Calculation

1 Cross Section Area

A = π (D − t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 40437042.42 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

56771276.17 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 97208318.59 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

σ_{xcr}^N= σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

σ_{xcr}^M= $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^N + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^M =$

= 417362210.7

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 2464022.137 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 32.61885

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers η_{xp}	Installation: Pipelines and risers η_{yp}	Operation: Pipelines Zone 1 η_{xp}	Operation: Pipelines Zone 1 η_{yp}	Operation: Pipelines Zone 2 and risers η_{xp}	Operation: Pipelines Zone 2 and risers η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp} = 0.86

η_{yp} = 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.279990438 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 3

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	218340	N
4	Bending Moment	M	=	12200	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa

6	Water Depth	d	=	17.023	m
7	External Pressure	Pe	=	1.71E+05	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw} gWD$	
			=	1.71E+05	Pa

B Calculation

1 Cross Section Area

A = π (D − t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 40285744.85 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 57240460.27 Pa

5 Longitudinal Stress

σ_x = $\sigma_x{}^N + \sigma_x{}^M$

= 97526205.12 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

σ_{xcr}^{N} = σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} = \sigma_F \left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

$\sigma_{xcr} = \frac{\sigma_x^{N}}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x^{M}}{\sigma_x}\sigma_{xcr}^{M} =$

= 417655093.9

9 Hoop Stress

$\sigma_y = (p_e - p_i)\frac{D}{2t}$

= 2625010.88 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

$\sigma_{yE} = E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 34.6847

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers		Operation: Pipelines Zone 1		Operation: Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η = 0.86

$xp-$

$\eta_{yp}=$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha}+\frac{\alpha_y}{\eta_{yp}\sigma_{ycr}}\leq 1$$

0.281284249 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 4

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	217500	N
4	Bending Moment	M	=	12200	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	18.067	m
7	External Pressure	Pe	=	1.82E+05	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	ρ_{sw}gWD	
			=	1.82E+05	Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 40130757.1 Pa

4 **Longitudinal Stress due to Pipe Bending**

$\sigma_x{}^M =$ $\frac{M}{W}$

= 57240460.27 Pa

5 **Longitudinal Stress**

$\sigma_x =$ $\sigma_x{}^N + \sigma_x{}^M$

= 97371217.37 Pa

6 **Critical Longitudinal Stress when N is acting alone**

D/t = 15.33564815

for D/t < 20

$\sigma\ {}_{xcr}^{N} =$ σ_F

= 3.59E+08 Pa

7 **Critical Longitudinal Stress when M is acting alone**

$\sigma\ {}_{xcr}^{M} =$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 **Critical Longitudinal (Compressive) Stress**

$\sigma_{xcr} =$ $\frac{\sigma_x{}^N}{\sigma_x}\sigma\ {}_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma\ {}_{xcr}^{M} =$

= 417749209.3 Pa

9 **Hoop Stress**

$\sigma_y =$ $(p_e - p_i)\frac{D}{2t}$

= 2785999.622 Pa

10 **Critical Compressive Hoop Stress for Completely Elastic Buckling**

$\sigma_{yE} =$ $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 **Critical Compressive Hoop Stress**

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F \left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 **α** = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 36.75054

13 **Premissible Combination**

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.281390378 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 5

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275 m
2	Nominal Wall Thickness of Pipe	t	=	0.010973 m
3	Axial Force in a Pipe	N	=	216790 N
4	Bending Moment	M	=	12200 Nm
5	Specified Yield Strength	σ_F	=	3.59E+08 Pa
6	Water Depth	d	=	19.11 m
7	External Pressure	Pe	=	1.92E+05 Pa
8	Internal Pressure	Pi	=	0 Pa
9	Modulus of Elasticity	E	=	2.07E+11 Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03 kg/m^3
11	Gravitation Force	g	=	9.81E+00 m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw}gWD$
			=	1.92E+05 Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 39999755.55 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 57240460.27 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 97240215.82 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ {}_{xcr}^{N}=$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ {}_{xcr}^{M}=$ $\sigma_F\left[1.35-0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma\,{}_{xcr}^{N}+\frac{\sigma_x{}^M}{\sigma_x}\sigma\ {}_{xcr}^{M}=$

= 417828993.2 Pa

9 Hoop Stress

σ_y = $(p_e - p_i)\dfrac{D}{2t}$

= 2946834.16 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\dfrac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

σ_{ycr} = 358526999.9 Pa

12 α = $1 + \dfrac{300}{\frac{D}{t}} . \dfrac{\sigma_y}{\sigma_{ycr}}$

= 38.8144

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation		Operation			
	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp}= 0.86

η_{yp}= 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.281572187 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 6

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	215940	N

4	Bending Moment	M	=	12300 Nm
5	Specified Yield Strength	σ_F	=	3.59E+08 Pa
6	Water Depth	d	=	20.155 m
7	External Pressure	Pe	=	2.03E+05 Pa
8	Internal Pressure	Pi	=	0 Pa
9	Modulus of Elasticity	E	=	2.07E+11 Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03 kg/m^3
11	Gravitation Force	g	=	9.81E+00 m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw} gWD$
			=	2.03E+05 Pa

B Calculation

1 Cross Section Area

A = $\pi (D - t) t$

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

${\sigma_x}^N$ = $\frac{N}{A}$

= 39842922.71 Pa

4 Longitudinal Stress due to Pipe Bending

${\sigma_x}^M$ = $\frac{M}{W}$

= 57709644.37 Pa

5 Longitudinal Stress

σ_x= ${\sigma_x}^N + {\sigma_x}^M$

= 97552567.07 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ {}_{xcr}^{N}=$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ {}_{xcr}^{M}=$ $\sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{{\sigma_x}^N}{\sigma_x}\sigma\ {}_{xcr}^{N} + \frac{{\sigma_x}^M}{\sigma_x}\sigma\ {}_{xcr}^{M} =$

= 418123641.1 Pa

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 3107977.106 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \le \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}}.\frac{\sigma_y}{\sigma_{ycr}}$

= 40.88222

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp}=$ 0.86

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.282849407 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 7

A	**INPUT DATA**				
1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	227390	N
4	Bending Moment	M	=	14200	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	21.199	m
7	External Pressure	Pe	=	2.13E+05	Pa
8	Internal Pressure	Pi	=	0	Pa
9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	ρ_{sw}gWD	
			=	2.13E+05	Pa

B **Calculation**

1 **Cross Section Area**

A = π (D − t) t

= 0.005419783 m^2

2 **Elastic Section Modulus**

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 **Longitudinal Stress due to Axial Force**

$\sigma_x{}^N =$ $\frac{N}{A}$

= 41955553.37 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M = \frac{M}{W}$

= 66624142.28 Pa

5 Longitudinal Stress

$\sigma_x = \sigma_x{}^N + \sigma_x{}^M$

= 108579695.6 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^{N} = \sigma_F$

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^{M} = \sigma_F\left[1.35 - 0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

$\sigma_{xcr} = \frac{\sigma_x{}^N}{\sigma_x}\sigma_{xcr}^{N} + \frac{\sigma_x{}^M}{\sigma_x}\sigma_{xcr}^{M} =$

= 420342174.3 Pa

9 Hoop Stress

$\sigma_y = (p_e - p_i)\frac{D}{2t}$

= 3268965.848 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

$\sigma_{yE} = E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 **α** = $1 + \frac{300}{\frac{D}{t}} \cdot \frac{\sigma_y}{\sigma_{ycr}}$

= 42.94806

13 **Premissible Combination**

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation		Operation			
	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

$\eta_{xp} =$ 0.86

$\eta_{yp} =$ 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \le 1$$

0.312520555 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 8

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275 m
2	Nominal Wall Thickness of Pipe	t	=	0.010973 m
3	Axial Force in a Pipe	N	=	227360 N
4	Bending Moment	M	=	18000 Nm
5	Specified Yield Strength	σ_F	=	3.59E+08 Pa
6	Water Depth	d	=	22.243 m
7	External Pressure	Pe	=	2.24E+05 Pa
8	Internal Pressure	Pi	=	0 Pa
9	Modulus of Elasticity	E	=	2.07E+11 Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03 kg/m^3
11	Gravitation Force	g	=	9.81E+00 m/s^2
NB :	External Pressure	Pe	=	ρ_{sw}gWD
			=	2.24E+05 Pa

B Calculation

1 Cross Section Area

A = π (D – t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N$ = $\frac{N}{A}$

= 41950018.09 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M$ = $\frac{M}{W}$

= 84453138.1 Pa

5 Longitudinal Stress

σ_x= $\sigma_x{}^N + \sigma_x{}^M$

= 126403156.2 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma\ _{xcr}^{N}=$ σ_F

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma\ _{xcr}^{M}=$ $\sigma_F\left[1.35-0.0045\left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x}\sigma\ _{xcr}^{N}+\frac{\sigma_x{}^M}{\sigma_x}\sigma\ _{xcr}^{M}=$

= 425835507.6 Pa

9 Hoop Stress

σ_y = $(p_e-p_i)\frac{D}{2t}$

= 3429954.59 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \leq \frac{2}{3}\sigma_F$ TRUE

$$\sigma_{ycr} = \sigma_{yE} = \sigma_F\left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} . \frac{\sigma_y}{\sigma_{ycr}}$

= 45.0139

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

Loading condition	Installation: Pipelines and risers		Operation: Pipelines Zone 1		Operation: Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0.86	0.75	0.72	0.62	0.50	0.43
b)	1.00	0.98	0.96	0.82	0.67	0.56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp}= 0.86

η_{yp}= 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^{\alpha} + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \leq 1$$

0.357913451 ≤ 1 TRUE

LOCAL BUCKLING CHECK

CASE 9

A INPUT DATA

1	Nominal Outside Diameter of Pipe	D	=	0.168275	m
2	Nominal Wall Thickness of Pipe	t	=	0.010973	m
3	Axial Force in a Pipe	N	=	227340	N
4	Bending Moment	M	=	21600	Nm
5	Specified Yield Strength	σ_F	=	3.59E+08	Pa
6	Water Depth	d	=	23.287	m
7	External Pressure	Pe	=	2.34E+05	Pa
8	Internal Pressure	Pi	=	0	Pa

9	Modulus of Elasticity	E	=	2.07E+11	Pa
10	Sea Water Density	ρ_{sw}	=	1.03E+03	kg/m^3
11	Gravitation Force	g	=	9.81E+00	m/s^2
NB :	External Pressure	Pe	=	$\rho_{sw} gWD$	
			=	2.34E+05	Pa

B Calculation

1 Cross Section Area

A = π (D − t) t

= 0.005419783 m^2

2 Elastic Section Modulus

W = $\frac{\pi}{4}[(D-t)^2 t]$

= 0.000213136 m^3

3 Longitudinal Stress due to Axial Force

$\sigma_x{}^N = \frac{N}{A}$

= 41946327.91 Pa

4 Longitudinal Stress due to Pipe Bending

$\sigma_x{}^M = \frac{M}{W}$

= 101343765.7 Pa

5 Longitudinal Stress

$\sigma_x = \sigma_x{}^N + \sigma_x{}^M$

= 143290093.6 Pa

6 Critical Longitudinal Stress when N is acting alone

D/t = 15.33564815

for D/t < 20

$\sigma_{xcr}^N = \sigma_F$

= 3.59E+08 Pa

7 Critical Longitudinal Stress when M is acting alone

$\sigma_{xcr}^M = [1.35 - 0.0045\left(\frac{D}{t}\right)]$

σ_{xcr} $\sigma_F \left[1.35 - 0.0045 \left(\frac{D}{t}\right)\right]$

= 459269352.3 Pa

8 Critical Longitudinal (Compressive) Stress

σ_{xcr} = $\frac{\sigma_x{}^N}{\sigma_x} \sigma_{xcr}^N + \frac{\sigma_x{}^M}{\sigma_x} \sigma_{xcr}^M =$

= 429778327.3 Pa

9 Hoop Stress

σ_y = $(p_e - p_i)\frac{D}{2t}$

= 3590943.333 Pa

10 Critical Compressive Hoop Stress for Completely Elastic Buckling

σ_{yE} = $E\left(\frac{t}{D-t}\right)^2$

= 1007152456 Pa

11 Critical Compressive Hoop Stress

2/3 σF = 239018000

for $\sigma_{yE} \le \frac{2}{3}\sigma_F$ TRUE

$\sigma_{ycr} = \sigma_{yE} = \sigma_F \left[1 - \frac{1}{3}\left(\frac{2\sigma_F}{3\sigma_F}\right)^2\right]$

$\sigma_{ycr} =$ 358526999.9 Pa

12 α = $1 + \frac{300}{\frac{D}{t}} . \frac{\sigma_y}{\sigma_{ycr}}$

= 47.07975

13 Premissible Combination

Table B.2 Permissible usage factors — typical D/t

	Installation		Operation			
Loading condition	Pipelines and risers		Pipelines Zone 1		Pipelines Zone 2 and risers	
	η_{xp}	η_{yp}	η_{xp}	η_{yp}	η_{xp}	η_{yp}
a)	0,86	0,75	0,72	0,62	0,50	0,43
b)	1,00	0,98	0,96	0,82	0,67	0,56

Empty (airfilled) liquid pipes during «operation» may be considered as during «installation».

η_{xp}= 0.86

η_{yp}= 0.75

$$\left(\frac{\sigma_x}{\eta_{xp}\sigma_{xcr}}\right)^\alpha + \frac{\alpha_y}{\eta_{yp}\sigma_{ycr}} \le 1$$

0.40103426 ≤ 1 TRUE

BIODATA PENULIS

Dilahirkan di Jakarta pada tanggal 9 Juli 1992, penulis merupakan anak kedua dari tiga bersaudara. Terlahir dengan nama Desak Made Ayu Pradmya Putri. Riwayat pendidikan formal yang telah ditempuh adalah SD Maria Fransisca, SMP PUTRA I, SMAN 71 Jakarta. Lulus dari SMA pada tahun 2010, penulis melanjutkan pendidikan formalnya ke jenjang Strata 1 (S1). Diterima di Jurusan Teknik Kelautan – Fakultas Teknologi Kelautan – Institut Teknologi Sepuluh Nopember, terdaftar dengan NRP 4310100019. Penulis mengambil konsentrasi bidang keahlian "Perancangan dan Produksi Bangunan Lepas Pantai (Design and Production of Offshore Structure)". Selama perkuliahan, penulis aktif pada kegiatan yang sifatnya akademis dan non akademis. Pada kegiatan non akademik, penulis pernah menjabat sebagai staff hubungan luar 2011-2012 HIMATEKLA-FTK-ITS. Pada kegiatan non akademik diluar kampus, penulis pernah menjabat sebagai Ketua Wirausaha IMAJAS (Ikatan Mahasiswa Jakarta dan Sekitarnya) pada tahun 2012-2013. Penulis pernah melakukan kerja praktek di PT. Global Martime. Serta penulis juga aktif dalam beberapa kegiatan seminar dan pelatihan, baik yang diselenggarakan oleh pihak dari Jurusan Teknik Kelautan ataupun dari luar.

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