알미늄 船樓船의 熱應力分析

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Notes on the Thermal Stresses for Aluminum Superstructures

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Abstract

The effect of thermal stress on a ship's hull is not considered to be serious by most naval architects. Frequently, however, cracking of hulls has been reported which occurred at sea while there were no external forces except the heat from the sun. Detailed investigations have been made of these reports and it has been reliably determined that the damage was initiated by solar heating.

The author is not interested in all steel ship or in the applicability and validity of the formula itself, as it has already been proven by the experiments such as S.S. Boulder Victory. [2], [3]

The author therefore proceeds directly to calculate the stress distribution on the hull and superstructure of the prototype model ship. [5]

These calculations are based on the experimental nonsymetrical temperature gradient data taken earlier on the Boulder Victory. The calculations were made principally to determine the extent of stresses which occurred on an all-steel ship in one case and secondly, those that occurred on a ship with a steel hull and an aluminum superstructure.

From the calculations, the author expected the stress distribution of the two cases would show distinctly different aspects, but the acquired results were very similar. Generally, at the point of junction of the steel hull and aluminum superstructure sharp peak stresses appeared.

At the juncture of the superstructure and the main deck the ship with the aluminum superstructure registered almost 1000 psi more stress than did the ship with the all-steel construction.

In view of these findings, the author recommends to ship designers that they pay particular attention to the point of junction of steel and aluminum plate.

The author has proven that it is extremely important that a greater safety factor be used at the aluminum-steel junction point than at any other point. Although thermal effects cause high juncture-point stresses in all-steel ships, they are not nearly as critical as in a ship constructed of two or more metals.

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** [ ] 안의 數字는 本論文末尾에 紹介한 引用文獻의 番號임.

1. 概　　論

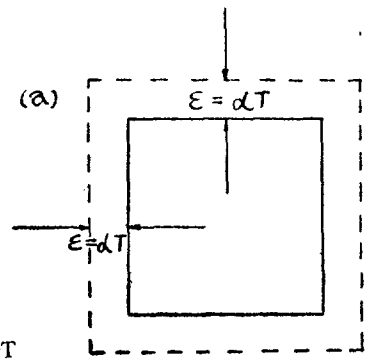
熱應力이 船體에 미치는 影響에 對하여서는 大部分의 造船學者가 等閑히 하고 있는 實情이다. 然이나 往往히 일어나는 船體龜裂中 太陽熱以外에는 何等의 外部力이 없었는데도 龜裂이 일어났다는 報告에 接하여 原因을 分析한 結果 太陽熱에 依한 損傷일 것이라는 信憑性이 짙어지고 있다. 이와 같은 根據를 뒷바침하기 爲하여 여러곳에서 理論的인 開發과 併行하여 實驗을 하여 發表된바 있다. 그 代表的인 例가 Jasper N.H[1]의 理論的인 뒷 바침이며 Meriam J.L 및 Corlett, E.C.B 諸氏[2], [3]의 實驗結果에서 立證되고 있다.

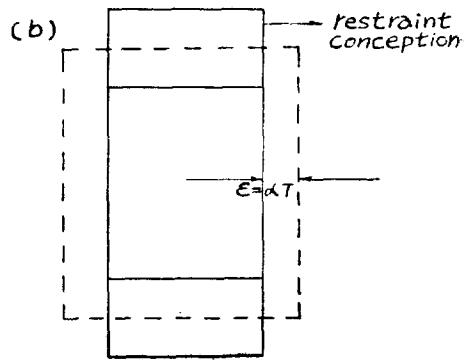
Jasper, N.H 氏의 論文[4]과 Meriam, J.L 氏의 S.S. Boulder Victory의 熱應力 實驗에 對한 報告에 依據하면 Jasper 氏 自身의 導出한 熱應力이 理論的인 計算方法에 큰 過誤가 없음을 明白히 해 준다.

그러므로 本稿에서는 Jasper 氏의 理論에 根據를 두어 Meriam 氏의 "S.S. Boulder Victory"에서 實測한 太陽熱 計測値를 引用하여 Twin aluminum deck house와 Twin steel deck house를 가진 同型船型에 適用하여 計算値를 얻어서 그 應力分布를 比較 檢討하려는 것이다.

2. 基 礎 理 論

(1) 物理的 現象





$\varepsilon = \alpha T$

여기에서

ε : Strain

α : Coefficient of thermal expansion

T : Temperature

$\sigma = E\varepsilon = E\alpha T$

σ : Stress

E : Young's modulus

Mechanical strain을 ε^*라 하면

$$\varepsilon = \varepsilon^* + \alpha T$$

$$\varepsilon_x = 1/E(\sigma_x - \mu\sigma_s) + \alpha T$$

ε_x : x 方向의 strain, σ_x : stress in longitudinal direction

σ_s : stress in girth direction, μ : poisson's ratio

整理하면

$$\sigma_x = \frac{E}{1-\mu^2}(\varepsilon_x+\mu\varepsilon_s)-\frac{E\alpha T}{1-\mu}$$

$$\sigma_s = \frac{E}{1-\mu^2}(\varepsilon_s+\mu\varepsilon_x)-\frac{E\alpha T}{1-\mu}$$

(2) 理論의 適用

(a) 第一束縛條件

縱方向의 伸長을 防止키 위하여 힘 $F(x)$을 前後 方向으로 加하고 깊이 方向의 應力을 除去 시키기 위하여 moment M_g를 加한다. 即 $\varepsilon_x=0$, $\sigma_s=0$로 假定하면

$$\sigma_{x1} = E\alpha T$$

(b) 第二束縛條件

$F(x)$ 束縛力을 除去한다. 다시 말해서 bending만을 못한다. 그러면 $\frac{\partial \varepsilon_x^2}{\partial s}=0$이 成立해야 하며 平衡條件을 이르기 爲하여 다음 條件을 滿足시켜야 한다.

即 $$\oint(\sigma_{x1}+\sigma_{x2})dA = 0$$

그러나 σ_{x2}는 깊이 方向의 函數가 아닌고로

$$\sigma_{x2} = -\frac{1}{A}\oint\sigma_{x1}dA = -\frac{E\alpha}{A}\oint TdA$$

(c) 第三束縛條件

第一, 二束縛條件을 모두 除去함으로서 自由로운 變型條件을 이룬다. 그러면 다시 moment의 平衡條件이 成立해야 한다.

한 平面 ($x-z$ plane) 上에서

$$M_3+\oint z(\sigma_{x1}+\sigma_{x2})dA = 0$$

여기서 σ_{x2}는 常數인고로

$$M_3+\oint z\sigma_{x1}dA+\sigma_{x2}\oint zdA = 0$$

여기서 軸을 中心軸에 擇하면

$$\oint zdA = 0$$

$$\therefore M_3 = -\oint z\sigma_{x1}dA$$

$M_3 = \frac{1}{z}\sigma_{x3}$라 보면

$$\sigma_{x3} = -\frac{z}{I}\oint z\sigma_{x1}dA$$

$$= -\frac{zE\alpha}{I}\oint zTdA$$

그러므로 $$\frac{d^2w}{dx^2} = \frac{\sigma_{x3}}{Ez} = \frac{\alpha}{I}\oint zTdA$$

같은 方法으로 橫方向을 生覺하면

$$\sigma_{x4} = \frac{yE\alpha}{I_{oz}}\oint yTdA$$

여기에서 I_{oz}는 橫方向 moment of inertia

(d) 綜合應力

$$\sigma_x = E\alpha\left[-T+\frac{1}{A}\oint TdA+\frac{z}{I_{oy}}\oint zTdA+\frac{y}{I_{oz}}\oint yTdA\right]$$

(3) 異物質로 된 船體斷面인 境遇

$$\sigma_x = E\left[-\alpha T + \frac{\oint E\alpha T dA}{\oint E dA} + Z\frac{\oint zE\alpha T dA}{\oint z^2 E dA} + y\frac{\oint yE\alpha T dA}{\oint y^2 E dA}\right]$$

計算目的을 爲하여 簡略化하면

$$\sigma_{ax} = -\alpha ET + \frac{K}{A\varepsilon}\int \alpha ET dA + \frac{Kz}{(I_{oy})\varepsilon}\int \alpha ETZ dA + \frac{Ky}{(I_{oz})\varepsilon}\int \alpha ETy dA$$

여기서

$$K = \frac{E}{E_s},\quad A\varepsilon = \int \frac{E}{E_s} dA,\quad (I_{oy})\varepsilon = \int \frac{E}{E_s} z^2 dA,\quad (I_{oz})\varepsilon = \int \frac{E}{E_s} y^2 dA$$

그리고 알미늄과 鋼의 E와 α급 μ를 각기 다음과 같이 擇한다.

$E_s = 29.5\times10^6$ lb/in^2

$E_a = 10.3\times10^6$ lb/in^2

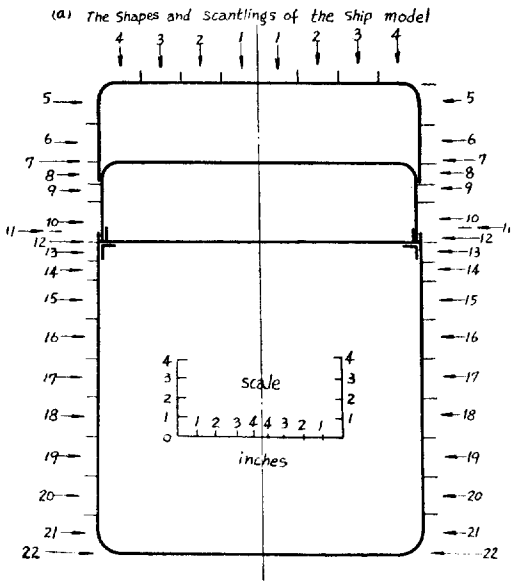
$\alpha_s = 6.5\times10^{-6}$(Fahrenheit)

$\alpha_a = 13.0\times10^{-6}$ (Fahrenheit)

$\mu_s = \mu_a = 0.33$

3. 模型과 그 溫度分布

(1) Corlett. E.C.B 氏의 試船模型 [5]를 本稿의 計算目的에 使用하였으며 그 重要計算値와 scantling은 다음과 같다.



(b) Neutral axis for all steel deck 13.86 inch above base line

(c) Neutral axis for aluminum deck 10.99 inch above base line

(d) $I_{oy} = 866.7$ in^4

$(I_{oy})\varepsilon = 654.4$ in^4

$I_{oz} = 148.8$in^4

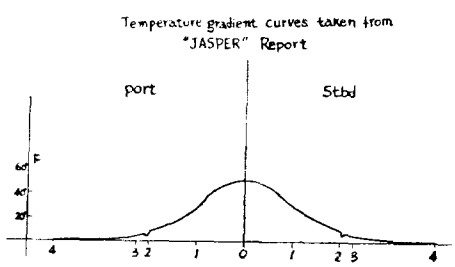
$(I_{oz})\varepsilon = 969.3$ in^4

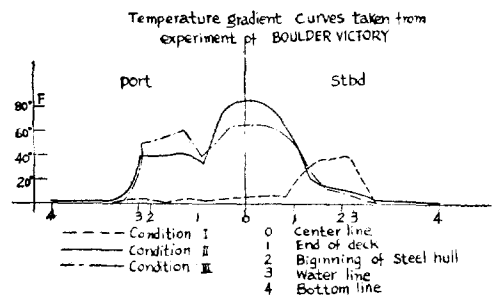
(e) 各 Element의 關聯 치수

1	2	3	4	5	6
Item No	Area actual	$\bar{y}$ of composite deck	$\bar{y}$ of all steel ship	$\bar{z}$ of area (stbd)	$\bar{z}$ of area (port)
1	0.375	13.08	10.21	1.00	−1.00
2	0.375	13.08	10.21	3.00	−3.00
3	0.375	13.08	10.21	5.00	−5.00
4	0.375	13.08	10.21	7.00	−7.00
5	0.375	12.08	9.31	7.71	−7.71
6	0.375	10.18	7.31	7.31	−7.91
7	1.475	9.08	6.21	4.62	−4.62
8	0.305	8.68	5.81	7.81	−7.81
9	0.190	7.68	4.81	7.72	−7.72
10	0.345	6.18	3.31	7.72	−7.72
11	0.180	5.18	2.94	7.72	−7.72
12	1.460	4.86	1.77	4.62	−4.62
13	0.425	4.41	1.54	7.71	−7.71
14	0.190	3.41	0.54	7.91	−7.91
15	0.375	2.01	0.86	7.91	−7.91
16	0.375	−0.01	−2.86	7.91	−7.91
17	0.375	−1.99	−4.86	7.91	−7.91
18	0.375	−3.99	−6.86	7.91	−7.91
19	0.375	−5.99	−8.86	7.91	−7.91
20	0.375	−7.99	−10.86	7.91	−7.91
21	0.375	−9.99	−12.86	7.91	−7.91
22	1.500	−10.89	−13.76	4.62	−4.62

(2) 温度分布는 4個條件으로 區分 計算目的에 利用하였으며 左右舷 對稱温度 分布條件과 Ⅰ, Ⅱ, Ⅲ 温度分布條件으로 區分하였다. 다음 圖表가 이를 나타내고 있다.

(a) Temperature gradient curves





(b) Temperature gradient table.

Item and Cond. T	Symetric port and stbd	Condition Ⅰ stbd	Condition Ⅰ port	Condition Ⅱ stbd	Condition Ⅱ port	Condition Ⅲ stbd	Condition Ⅲ port
1	51.5	9.1	8.6	85.2	84.7	66.8	65.8
2	48.2	8.6	7.6	82.9	82.2	66.7	62.3
3	42.0	6.5	4.5	76.5	63.2	64.4	48.0
4	38.0	4.8	3.3	60.5	36.5	57.5	39.5
5	24.0	31.5	4.8	37.0	40.0	41.5	55.6
6	20.0	37.3	5.2	19.5	43.7	23.8	59.7
7	17.6	38.1	3.8	14.5	43.8	18.4	59.6
8	16.8	38.3	3.5	14.0	43.3	17.2	58.4
9	14.7	38.5	3.0	13.8	41.8	15.3	56.2
10	12.0	40.0	1.8	12.6	39.8	11.7	53.9
11	10.3	41.3	1.1	11.9	39.4	10.2	53.8
12	4.8	42.2	2.0	11.7	39.1	9.0	53.5
13	7.5	42.5	2.5	11.0	39.0	8.4	52.0
14	5.5	42.0	3.0	10.4	38.5	7.1	50.5
15	3.5	22.0	2.5	8.3	8.2	4.0	6.2
16	2.0	2.1	1.2	4.5	3.1	1.6	1.5
17	1.2	1.2	0.5	1.8	2.0	1.2	0.5
18	0.8	0	0	1.2	1.2	0	0
19	0.3	0	0	1.2	1.2	0	0
20	0.3	0	0	1.2	1.2	0	0
21	0.3	0	0	1.2	1.2	0	0
22	0.3	0	0	1.2	1.2	0	0

Note
Condition Ⅰ (845 Sun's altitude 29 degree.)
condition Ⅱ (1555 Sun's altidude 50 degree)
condition Ⅲ (1810 Sun's altitude 20 degree.)

4. 計 算 結 果

表1에서 보는 바와 같은 sheet를 가지고 計算을 한다면 매우 계산은 機械的으로 진첩되며 容易하다. 本稿에서는 參考삼아 温度條件(1) 때 만 Tabulation 해 둔다.

TABLE 1

Computation of stress distribution in composite deck (condition I)

1	2	3	4	5	6	7	8	9	10	11	12	13
Stbd Item	Area $\triangle A$ (in^2)	$\bar{y}$ (in)	$\bar{z}$ (in)	T (deg F)	αET	$\alpha ET \times \triangle A$	$\alpha ET(\triangle A) \times \bar{y}$	$\alpha ET(\triangle A) \times \bar{z}$	$\sigma_1+\sigma_2$ (psi)	σ_3	σ_4	$\sigma=\sigma_1+\sigma_2+\sigma_3+\sigma_4$
1	0.375	13.08	1.00	9.1	1166	416	5441	416	−297	+1250	+102	+1055
2	0.375	13.08	3.00	8.6	1102	413	5402	1239	−233	+1250	+306	+1323
3	0.375	13.08	5.00	6.5	833	312	4081	1560	+36	+1250	+511	+1797
4	0.375	13.08	7.00	4.8	615	231	3021	1617	+254	+1250	+715	+2219
5	0.375	12.18	7.71	31.5	4035	1513	18428	11665	−3166	+1164	+788	−1214
6	0.375	10.18	7.91	37.3	4778	1791	18232	14167	−3909	+973	+808	−2118
7	1.475	9.08	4.62	38.1	4881	7199	65367	33259	−4012	+868	+472	−2672
8	0.305	8.68	7.81	38.3	4906	1496	12985	11689	−4037	+830	+798	−2409
9	0.190	7.68	7.42	38.5	4932	937	7196	7233	−4067	+734	+798	−2540
10	0.345	6.18	7.72	40.0	5124	1767	10920	13641	−4255	+591	+798	−2875
11	0.180	5.18	7.72	41.3	8363	1505	7796	11619	−5755	+1486	+2367	−1902
12	1.460	4.86	4.62	42.2	8546	12477	60638	57644	−5938	+1394	+1416	−3128
13	0.425	4.41	7.71	42.5	8606	3658	16132	28203	−5998	+1265	+2364	−2369
14	0.190	3.41	7.91	42.0	8505	1616	5511	12783	−5897	+978	+2425	−2494
15	0.375	2.01	7.91	22.0	4455	1671	3359	13218	−1847	+577	+2245	+1155
16	0.375	0.01	7.91	2.1	425	159	2	1258	+2183	+3	+2425	+4611
17	0.375	−1.99	7.91	1.2	243	91	−181	720	+2365	−571	+2425	+4219
18	0.375	−3.99	7.91	0	0	0	0	0	+2608	−1145	+2425	+3888
19	0.375	−5.99	7.91	0	0	0	0	0	+2608	−1719	+2425	+3314
20	0.375	−7.79	7.91	0	0	0	0	0	+2608	−2292	+2425	+2741
21	0.375	−9.99	7.91	0	0	0	0	0	+2608	−2866	+2364	+2106
22	1.500	−10.9	4.62	0	0	0	0	0	+2608	−3124	+1416	+900

1	2	3	4	5	6	7	8	9	10	11	12	13
Port Item	Area $\triangle A$ (in^2)	y (in)	z (in)	T (deg F)	αET	$\alpha ET \times \triangle A$	$\alpha ET(\triangle A) \times \bar{y}$	$\alpha ET(\triangle A) \times \bar{z}$	$\sigma_1+\sigma_2$ (psi)	σ_3	σ_4	$\sigma=\sigma_1+\sigma_2+\sigma_3+\sigma_4$
1	0.375	13.08	−1.00	8.6	1102	413	5402	−413	−233	+1250	−102	+915
2	0.375	13.08	−3.00	7.1	910	341	4460	−1023	−41	+1250	−306	+903
3	0.375	13.08	−5.00	4.5	576	216	2825	−1080	+293	+1250	−511	+1032
4	0.375	13.08	−7.00	3.3	423	159	2080	−1113	+446	+1250	−715	+981
5	0.375	12.18	−7.17	4.8	615	231	2814	−1781	+254	+1164	−788	+630
6	0.375	10.18	−7.91	5.2	666	250	2545	−1978	+203	+973	−808	+368
7	1.475	9.08	−4.62	3.8	487	718	6519	−3317	+382	+868	−472	+778
8	0.305	8.68	−7.81	3.5	448	137	1189	−1090	+421	+830	−798	+452
9	0.190	7.68	−7.72	3.0	384	73	561	−564	+485	+934	−789	+430
10	0.345	6.18	−7.72	1.8	231	80	494	−518	+638	+571	−789	+440
11	0.180	5.18	−7.72	1.7	344	62	321	−479	+2264	+1486	−2367	+1383
12	1.460	4.86	−4.62	2.0	405	591	−872	−2730	+2203	+1394	−1416	+2081
13	0.425	4.41	−7.71	2.5	506	215	948	−1658	+2102	+1265	−2364	+1003
14	0.190	3.41	−7.91	3.0	608	116	356	−918	+2060	+978	−2425	+553
15	0.375	2.01	−7.91	2.5	506	190	382	−1503	+2102	+577	−2425	+254
16	0.375	0.01	−7.91	1.2	243	91	1	−720	+2365	+3	−2425	−57
17	0.375	−1.99	−7.91	0.5	101	38	−76	−301	+2587	−571	−2425	−489
18	0.375	−3.99	−7.91	0	0	0	0	0	+2608	−1145	−2425	−962
19	0.375	−5.99	−7.91	0	0	0	0	0	+2608	−1719	−2425	−1536
20	0.375	−7.99	−7.91	0	0	0	0	0	+2608	−2292	−2425	−2109
21	0.375	−9.99	−7.71	0	0	0	0	0	+2608	−2866	−2364	−2622
22	1.500	−10.8	−4.62	0	0	0	0	0	+2608	−3124	−1416	−1932
						$\Sigma_7$41173	$\Sigma_8$278013	$\Sigma_9$200660				

$E_{ST}=30\times10^6$ $\quad (E\alpha)_{AL}=128.1$ $\quad \frac{E_s}{E\alpha}=3$ $\quad (I_{0z})\varepsilon=969.3$ $\quad \sigma_2=\frac{\Sigma_7}{A_\varepsilon}K=2608K$

$AE=15.79$ $\quad (E\alpha)_{ST}=202.5$ $\quad K=\frac{1}{3}$ $\quad (I_{0y})\varepsilon=654.4$ $\quad \sigma_3=\frac{\Sigma_8 Ky}{(I_{0z})\varepsilon}=286.7Ky$

$\sigma_4=\frac{\Sigma_9 Kz}{(I_{0y})\varepsilon}=306.6K\bar{z}$

TABLE 2

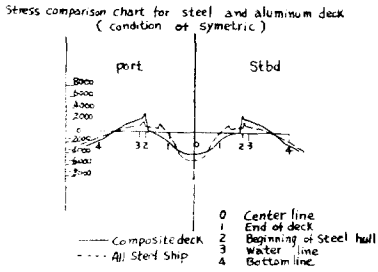
Computation of stress distribution in all steel ship (Condition I)

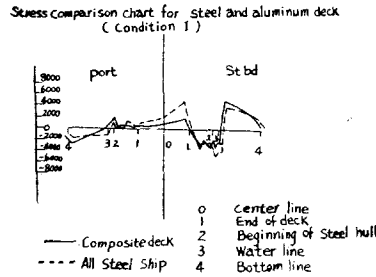
1	2	3	4	5	6	7	8	9	10	11	12	13
Stbd Item	Area $\triangle A$ (in^2)	$\bar{y}$ (in)	$\bar{z}$ (in)	T (deg F)	αET	$\alpha ET \times \triangle A$	$\alpha ET(\triangle A) \times \bar{y}$	$\alpha ET(\Delta A) \times \bar{z}$	$\sigma_1+\sigma_2$ (psi)	σ_3	σ_4	$\sigma=\sigma_1+\sigma_2+\sigma_3+\sigma_4$
1	0.375	10.21	1.00	9.1	1843	691	7055	691	+536	+1620	+288	+2444
2	0.375	10.21	3.00	8.6	1742	653	6667	1959	+637	+1620	+863	+3120
3	0.375	10.21	5.00	6.5	1316	494	5044	2470	+1063	+1620	+1438	+4121
4	0.375	10.21	7.00	4.8	972	365	3727	2555	+1407	+1620	+2013	+5040
5	0.375	9.31	7.71	31.5	6379	2392	22270	18442	−4000	+1477	+2217	−306
6	0.375	7.31	7.91	37.3	7553	2832	20702	22401	−5174	+1160	+2275	−1739
7	1.475	6.21	4.62	38.1	7715	11380	70670	52576	−5336	+986	+1829	−3221
8	0.305	5.81	7.81	38.3	7756	2366	13746	18478	−5377	+722	+2246	−2209
9	0.190	4.81	7.72	38.5	7796	1481	7124	11433	−5417	+734	+3320	−2663
10	0.345	3.31	7.72	40.0	8000	2795	9251	21577	−5721	+525	+2220	−2976
11	0.180	2.94	7.72	41.3	8363	1505	4425	11619	−5984	+467	+2220	−3291
12	1.460	1.99	4.62	42.2	8546	12477	24829	57644	−6167	+316	+1329	−4522
13	0.425	1.54	7.71	42.5	8606	3658	5633	28203	−6227	+244	+2217	−3766
14	0.190	0.54	9.91	42.0	8505	1616	873	12783	−6126	+86	+2275	−3765
15	0.375	−0.86	7.91	22.0	4455	1671	−1437	13218	−2076	−136	+2275	+763
16	0.375	−2.86	7.91	2.1	425	159	−455	1258	+1954	−454	+2275	+3775
17	0.375	−4.86	7.91	1.2	243	91	−442	720	+2136	−771	+2275	+3640
18	0.375	−6.86	7.91	0	0	0	0	0	+2379	−1089	+2275	+3565
19	0.375	−8.86	7.91	0	0	0	0	0	+2379	−1406	+2275	+3248
20	0.375	−10.86	7.91	0	0	0	0	0	+2379	−1723	+2275	+2931
21	0.375	−12.86	7.71	0	0	0	0	0	+2379	−2041	+2217	+2555
22	1.500	−13.76	4.62	0	0	0	0	0	+2379	−2184	+1329	+1524

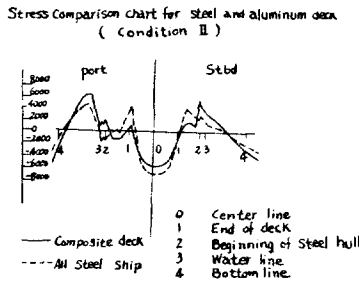
1	2	3	4	5	6	7	8	9	10	11	12	13
Port Item	Area $\triangle A$ (in^2)	$\bar{y}$ (in)	$\bar{z}$ (in)	T (deg F)	αET	αET $\times \triangle A$	$\alpha ET(\triangle A)$ $\times \bar{y}$	$\alpha ET(\triangle A)$ $\times \bar{z}$	$\sigma_1+\sigma_2$ (psi)	σ_3	σ_4	$\sigma=\sigma_1+\sigma_2$ $+\sigma_3+\sigma_4$
1	0.375	10.21	−1.00	8.6	1742	653	6667	−653	+637	+1620	−288	+1969
2	0.375	10.21	−3.00	7.1	1438	539	5503	−1617	+341	+1620	−863	+1698
3	0.375	10.21	−5.00	4.5	911	342	3492	−1710	+1468	+1620	−1438	+1650
4	0.375	10.21	−7.00	3.3	668	251	2563	−1757	+1711	+1620	−2013	+1318
5	0.375	9.31	−7.71	4.8	972	365	3398	−2814	+1407	+1477	−2217	+667
6	0.375	9.31	−7.91	5.2	1053	395	2287	−3124	+1326	+1160	−2275	+878
7	1.475	6.21	−4.62	3.8	770	1136	7055	−5248	+1609	+986	−1327	+1266
8	0.305	5.81	−7.81	3.5	709	216	1255	−1687	+1670	+922	−2246	+346
9	0.190	4.81	−7.72	3.0	608	116	558	−896	+1771	+734	−2220	+285
10	0.345	3.31	−7.72	1.8	365	126	417	−973	+2014	+525	−2220	+319
11	0.180	2.94	−7.72	1.7	344	62	182	−479	+2035	+467	−2220	+282
12	1.460	1.99	−4.62	2.0	405	591	1176	−2730	+1974	+316	−1329	+961
13	0.425	1.54	−7.71	2.5	506	215	331	−1658	+1873	+244	−2217	−100
14	0.190	0.54	−7.91	3.0	608	116	63	−918	+1771	+86	−2275	−418
15	0.375	−0.86	−7.91	2.5	506	190	−163	−1503	+1873	−136	−2275	−538
16	0.375	−2.86	−7.91	1.2	243	91	−260	−720	+2136	−454	−2275	−593
17	0.375	−4.86	−7.81	0.5	101	38	−180	−301	+2278	−771	−2275	−768
18	0.375	−6.86	−7.91	0	0	0	0	0	+2379	−1089	−2275	−785
19	0.375	−8.86	−7.91	0	0	0	0	0	+2379	−1406	−2275	−1302
20	0.375	−10.86	−7.91	0	0	0	0	0	+2379	−1723	−2275	−1619
21	0.375	−12.86	−7.71	0	0	0	0	0	+2379	−2041	−2217	−1879
22	1.500	−13.76	−4.62	0	0	0	0	0	+2379	−2184	−1329	−1134
						$\Sigma_7$52068	$\Sigma_8$235621	$\Sigma_9$249239				

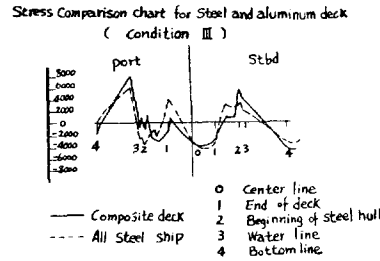
$E_{ST}=30\times10^6$ $\quad I_{0z}=1484.8$ $\quad \sigma_2=\frac{1}{A}\Sigma_7=2379$ $\quad \sigma_4=\frac{z}{I_{0y}}\Sigma_9=287.6z$

$A=21.89$ $\quad I_{0y}=866.7$ $\quad \sigma_3=\frac{y}{I_{0z}}\Sigma_8=158.7y$ $\quad$ N.A. is 13.86″ above B.L.









5. 討 論

(1) 對稱溫度條件 때

(a) 溫度調節을 電氣的으로 하였는 고로 그 分布曲線은 매우 圓滑하며 따라서 應力分布 亦是 smooth 한 傾向을 가지나 aluminum 과 steel 의 接合部와 鋼船일때는 二層 甲板點에서 頂點(peak point)을 이루고 있다.

(b) 全般的인 關點에서 볼때 그 分布現象이 兩船 거이 같다.

(c) 鋼船인 境遇 甲板部分은 알미늄 船樓船보다 約 1000 psi 나 應力이 더 크나 外板은 이와 反對로 100 psi 程度 작다.

(2) 第一溫度條件 때

(a) 溫度分布로 早期計測 (0845 右舷 29° 太陽高度)을 擇하였음.

(b) 두 曲線은 對稱條件時와는 判異하게 많은 頂點을 가지고 있다.

(c) 右舷의 甲板 모서리는 應力이 急作히 떨어져서 伸長力이 壓縮力으로 變化되며 水面部分에서는 急激히 反對應力으로 變位된다.

(d) 第一, 二 甲板部分에서 다 같이 頂點을 가진다.

(e) 左舷 쪽은 과히 심한 溫度變位가 없는고로 그 應力 亦是 特記할 만한 事項이 없으나 接合部와 第一甲板部分에 頂點은 나타나고 있다.

(f) 接合部를 除外하고 남어지 部分은 鋼船으로 되었을 時 그 應力이 더 많은 것을 봄은 재미 있는 現象이다.

(3) 第二溫度條件 때

(a) 溫度分布를 午後 計測値 (1515 太陽高度 50°)로 擇하였음.

(b) 左右舷 모두 相當한 溫度變位를 받았으며 左舷은 좀더 심하다.

(c) 應力分布는 아주 不規則的으로 活潑히 變化되고 있다.

(d) 兩曲線이 모두 第一溫度條件 때와 똑 같은 頂點을 나타내고 있으며 그 高低는 더욱 심하다.

(e) 溫度變位에 따른 最高應力은 約 8000 psi에 이르고 있으며 이와 같은 事實은 S.S. Boulder Victory의 實驗에서 이미 밝힌 바이다.

(4) 第三溫度條件 때

(a) 溫度分布를 저녁 무렵 (1810 太陽高度 20°)의 計測値로 擇하였다.

(b) 左舷側의 side steel의 溫度는 매우 높음으로서 水線部分은 急作히 壓縮應力으로 부터 約 8000 psi의 伸長壓力에 이르게 되니 結果的으로 보면 이 部分의 應力이 約 10,000 psi에 힘을 받는 폭이 된다.

(c) 이때 亦是 第一, 二溫度條件 때와 같은 頂點들을 가진다.

6. 結　　論

結果를 얻기 前에 期待했던 것과는 달리 兩船의 境遇 거의 同一 樣相을 보여 주고 있다.

그러나 接合部에서의 應力은 알미늄 船樓船이 鋼船 樓船보다 어떤 境遇를 莫論하고 約 1,000 p.s.i. 程度 많으며 其他部分에서는 오히려 鋼船보다 적다.

그러므로 上甲板의 輕 重量을 얻고자 알미늄 船樓船을 設計할 때에는 steel과 aluminum의 接合部에서만 注意를 하면 熱應力에 對한 別다른 關心을 가지지 않아도 된다는 結論에 이른다. 끝으로 本稿에 不充分한 點이 許多함을 自認하며 特히 實驗値를 얻지 못하였음을 甚히 遺憾되게 生覺한다.

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