

**CONSTRUCTOR
FRAME AND LIFTING ARRANGEMENT
SWL 7 tonnes**



AF25-1012ER01
Calculations Report
Vol 1
Document ref: 1883

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Revision Description

Rev.	Date	Description	Internal			External	
			Originator	Checked	Accepted	Checked	Approved
2	10/12/15	NEW WORK MODULE INTERF.	GVI	AHO	EKB		
1	19/12/12	ISSUED FOR APPROVAL	GVI	AHO	EKB		
A	17/12/12	ISSUED FOR COMMENTS	GVI	AHO	EKB		

Signature Legend

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1 GENERAL

CONSTRUCTOR is a work class hydraulic remotely operated vehicle (ROV) for sub-sea intervention. The vehicle consists of an aluminium frame, a top mounted buoyancy module, and the hydraulic and electronic components comprising the system.

The CONSTRUCTOR weight is 4155kg included 433kg pay load. The ROV including payload is neutrally buoyant in sea-water.

Underneath the vehicle there are 4 receptacles for connection of work modules up to 3000kg. When work modules are installed underneath the ROV, the payload on the ROV is removed to minimise the need for additional buoyancy. The maximum total weight of the vehicle will therefore not exceed 7000kg.

In revision 2 of this document, a new work module interface is added to the Frame Lower Section AF25-1012M50 rev.4 as described in fig. 6.4, fig. 6.5 and in drawing AF25-1012M08 rev.3 (Volume 3).

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2 SCOPE:

This report presents calculations of stresses and deflections of critical parts of the CONSTRUCTOR ROV lifting arrangement, frame and work module interface. The remaining and interfacing equipment is not considered.

The vehicle frame consisting of Main Frame (AF25-1012M20) and Bottom Frame (AF25-1012M50) welded together. Main Frame and Bottom Frame are considered separately in this report, and the weld interface for the two units is described in section 8.9. The frame design is based on the same principle as for the SUPPORTER 2000/3000 frame (ref. DNV GL Certificate S-8454)

All other components considered in this report are the same as for the SUPPORTER 2000/3000. The calculations presented for the lifting arrangement and work module interface, are equal to calculations in Calculation Report AD16-1012ER01 (DNV GL Certificate S-8454).

The following is set as criteria for the calculations:

- Safe working load (SWL): Total of 3 tonnes in the lower lifting lugs
7 tonnes for remaining load carrying structure
- Design dynamic factor: 1.3
- Design temperature (T.d): -20.0 degrees C

The load distribution is described in section 6 in this document.

Analysis logs and description of calculation method is presented in Volume 2 of this report.

AF25-1012M09 is the assembly drawings showing all components comprising the lifting load carrying system. A complete drawing file including this drawing is presented in Volume 3 of this report.

3 OBJECTIVE:

The objective of this report is to ensure sufficient strength of the ROV frame and lifting arrangement, and provide sufficient documentation for implementation in DNV GL Type Approval Certificate S-8554.

4 DESIGN RULES AND GUIDELINES:

NS 3471	- Aluminium structures, design rules	Ref.1
DnV	- Standard for Certification No.2.22, Lifting Appliances.	Ref.2

5 MATERIALS:

ENAW 6082 T6-	Yield stress (R_{p02})	=	255 MPa
A4 100 (U.N.O) -	Yield stress (R_{p02})	=	900 Mpa
AISI 316	Yield stress (R_{p02})	=	220 Mpa
S165M	Yield stress (R_{p02})	=	700 MPa

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6 LOAD CONDITIONS:

Two load cases for the CONSTRUCTOR is considered:

Load case 1: On deck mode with load factor 2,5

Load case 2: Launching mode with load factor 4 (ref. DNV No.2.22, B800 & B900)

A weight and load summary for CONSTRUCTOR is presented below, distribution and application on fig.6.1 to fig.6.4:

Item	Run no:	Load case 1	Load case 2	Description
Weight of complete ROV (kg)	4155	Load case	1-OD mode	2-L mode
Weight of ROV without payload (kg)*	3722	Design Fac	2,5	4
		Mass (kg)	Design load (N)	Design load (N)
Weight of TMS	W_{TMS}	3500	85838	NA
Weight of Main Frame	W_{R1}	116	2845	4552
Weight of Frame Lower Section	W_{R2}	118	2894	4630
Weight of Hydraulic System	K_1	945	23176	37082
Weight of Control System	K_2	184	4513	7220
Weight of payload*	K_3	433	10619	16991
Weight of residuary components	K_4	854	20944	33511
Weight of buoyancy element	W_B	1505	36910	59056
Weight of underhanging load	U	3000	NA	117720
AB89-1010M21 - Adapter	Analysis 10	Load (N)	NA	SWL 7Te on top of flange
		Constraint	NA	Bolt hole
AB891010m12 - Top ring	Analysis 1	Load (N)	NA	SWL 7Te under flange
		Constraint	NA	Washer surface
AD16-1010MM15 - Emergency rec.	Analysis 13	Load (N)	NA	SWL 7Te on lower roller surface
		Constraint	NA	pivot holes
AD16-1010M11-lift plate-(hanging from adaptor)	Analysis 2	Load (N)	NA	SWL 7Te in 2xTension bar contact
		Constraint	NA	Bolt holes
AD16-1010M11	Analysis 22	Load (N)	NA	SWL 7Te in 2xTension bar contact
(hanging from emerg. Recovery)		Constraint	NA	Bolt hole
AD16-1010M21-Tension bolt	Analysis 4	Load (N)	NA	½ SWL 7Te in lower end tension bolt
		Constraint	NA	Bolt holes
AD16-1010M12-Tension bar ret.	Analysis 5	Load (N)	NA	½ SWL 7Te in thread hole
		Constraint	NA	top surface
AF03-1012M20-Main Frame (Launching)	Analysis 2-1	Load 1 (N)	NA	$W_B + W_{R1}$ on frame top
		Load 2 (N)	NA	SWL 7Te on retainer contact faces
		Constraint	NA	Weld face to Frame Lower Section
AF03-1012M20- Main Frame (on deck)	Analysis 1-1	Load (N)	125593	$W_{TMS} + W_B + W_{R1}$ on frame top
		Constraint	NA	Weld face to Frame Lower Section
AF25-1012M50-Frame Lower Sec. (Work Module Interface 1, Launching)	Analysis 2-2	Load 1 (N)	NA	U (SWL 3Te) through 4 brackets
		Load 2 (N)	NA	$WR_2 + \Sigma K_{1-4} (K_3')$ uniform on top face
		Constraint	NA	Weld face to Main Frame
AF25-1012M50-Frame Lower Sec. (on deck)	Analysis 1-2	Load 1 (N)	125593	$W_{TMS} + W_B + W_{R1}$ Main Frame interf.
		Load 2 (N)	62146	$WR_2 + K_1 + K_2 + K_3 + K_4$ on frame top
		Constraint	NA	Skid interface
AD16-1013M20-Bracket underside	Analysis 12	Load (N)	NA	¼ Underhanging load on bolt
		Constraint	NA	Bolt holes

* 278 kg is used as payload (K_3) to achieve a total weight of 4000 kg in Launching mode

Item	Run no:			Description
		Load case 1	Load case 2	
AF25-1012M50-Frame Lower Sec. (Work Module Interface 2, Launching)	Analysis 2-3	Load 1 (N)	NA	U (SWL 3Te) through 4 brackets
		Load 2 (N)	NA	$WR_2 + \sum K_{1-4} (K_3')$ uniform on top face
		Constraint	NA	Weld face to Main Frame

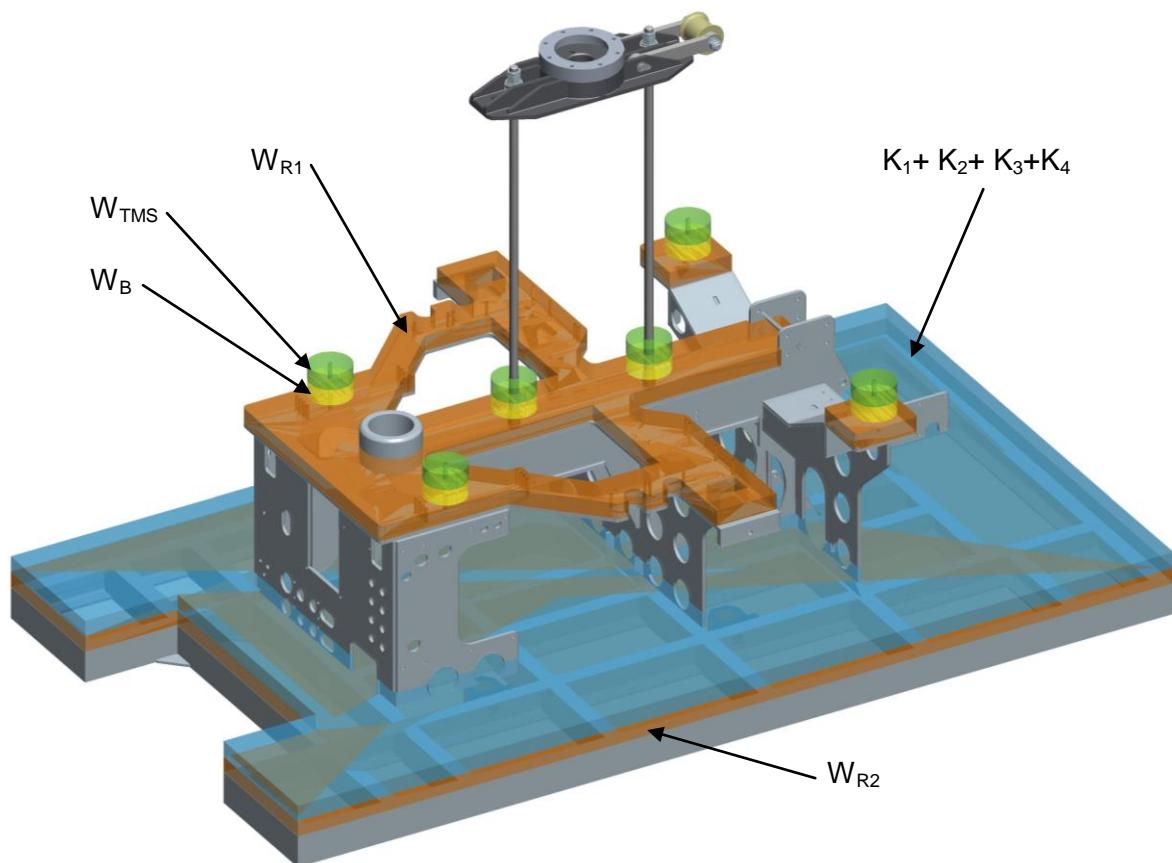


Fig. 6.1 CONSTRUCTOR Mass distribution

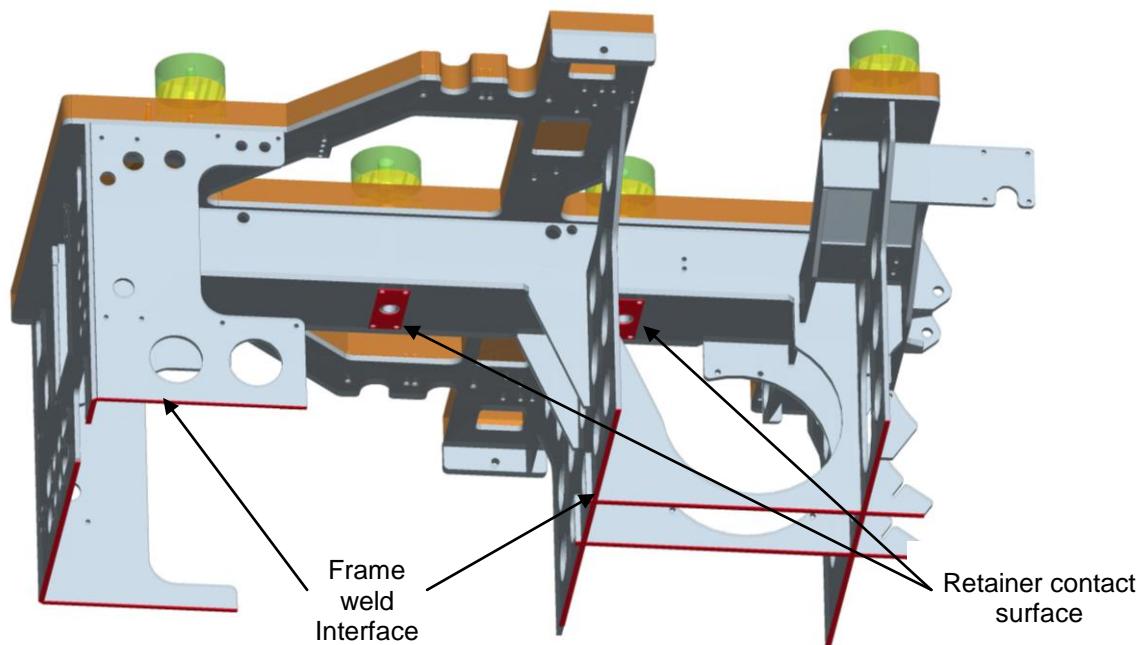


Fig. 6.2 Main Frame Load & Constrain distribution

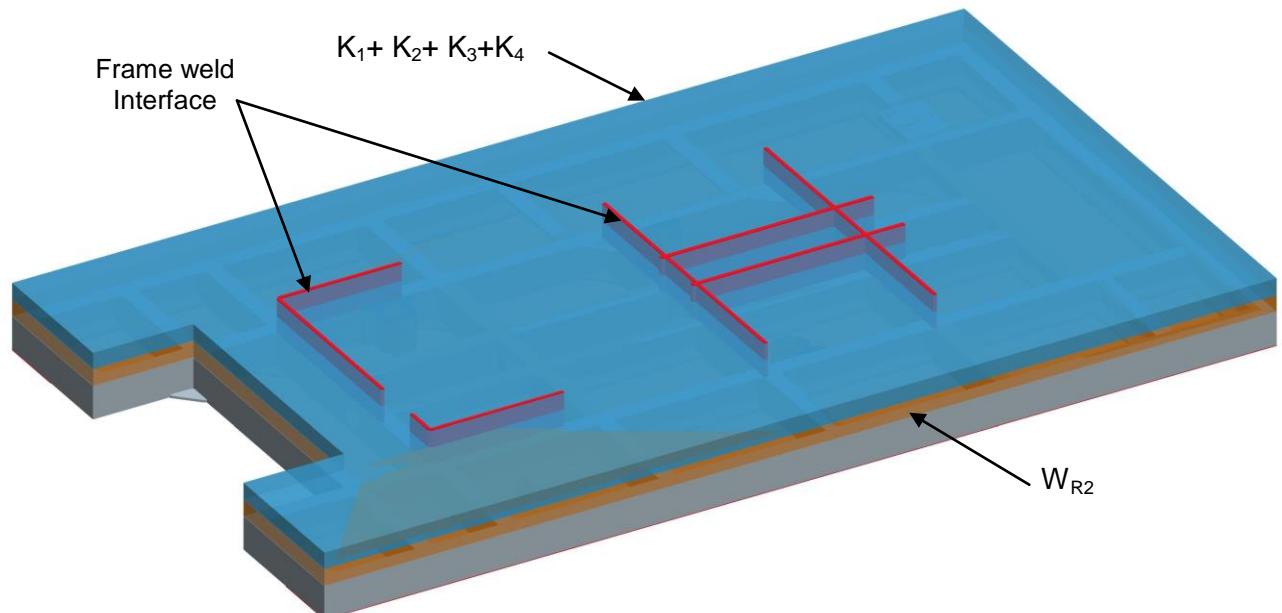


Fig. 6.3 Frame Lower Section Load & Constrain distribution

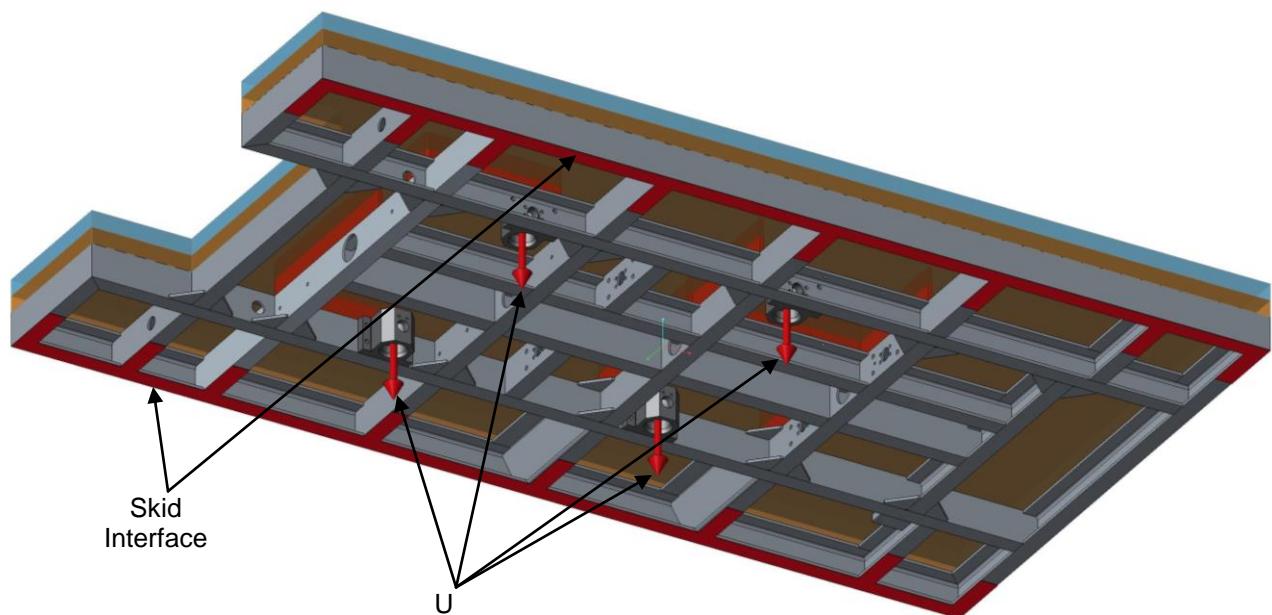


Fig. 6.4 Frame Lower Section Work Module interface 1, Load & Constrain distribution

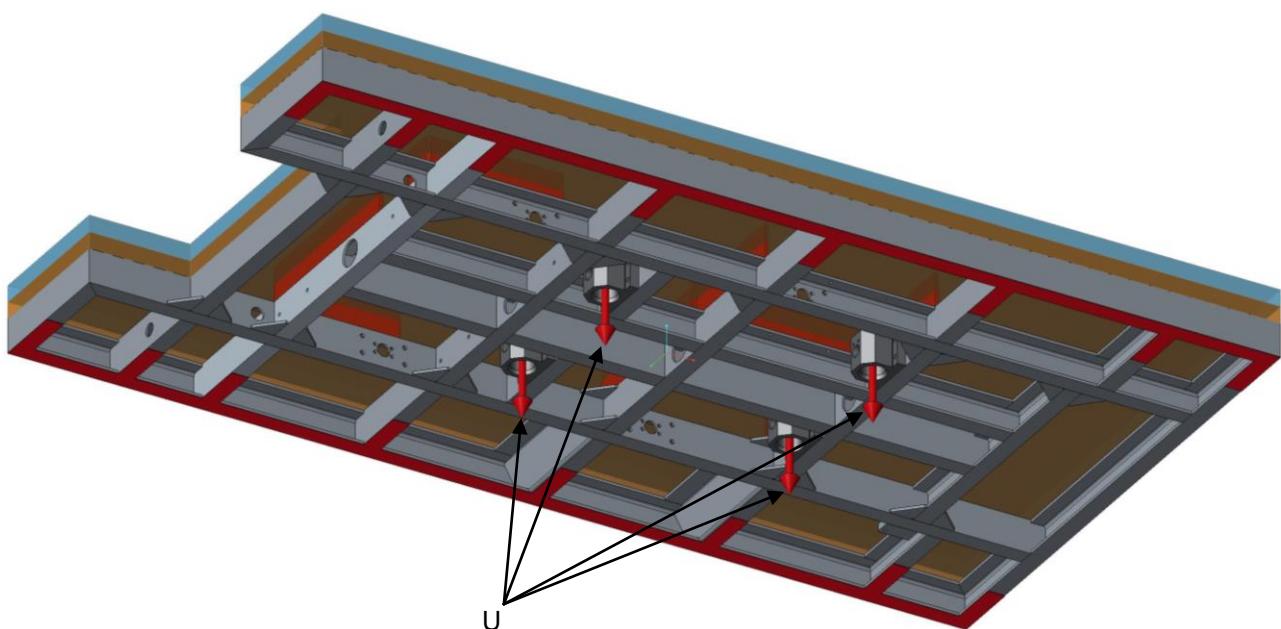


Fig. 6.5 Frame Lower Section Work Module interface 2, Load & Constrain distribution

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7 PERMISSIBLE STRESSES :

Material coefficients : $\gamma_m = \text{lowest value of } \gamma_k \cdot \gamma_g \text{ or } \gamma_k \cdot \gamma_b = 1.05 \cdot 1.05 \text{ or } 1.05 \cdot 1.1$
 $= 1.155$

The material coefficient is derived based on extensive workshop control, all materials delivered with certificates according to EN 10204 3.1.b, extensive failure consequences and general ordinary control of calculations. Reduction factor in heat affected zones is 0.7 for 6082.

<u>In components :</u>		AL 6082	A4-100	AISI 316	S165M
Tension/Compression (MPa)	σ_a	= 220	779	190	606
Shear (MPa)	τ_a	= 127	449	109	350
von Mises (MPa)	$(\sigma^2 + 3\tau^2)^{\frac{1}{2}}$	≥ 220	779	190	606

In welds:

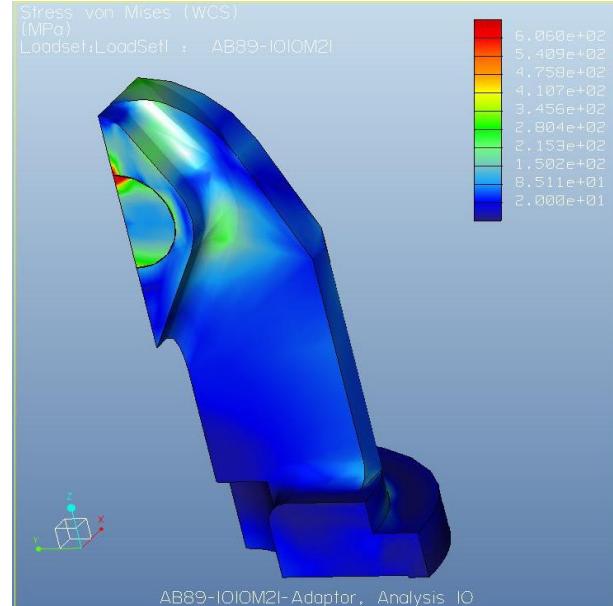
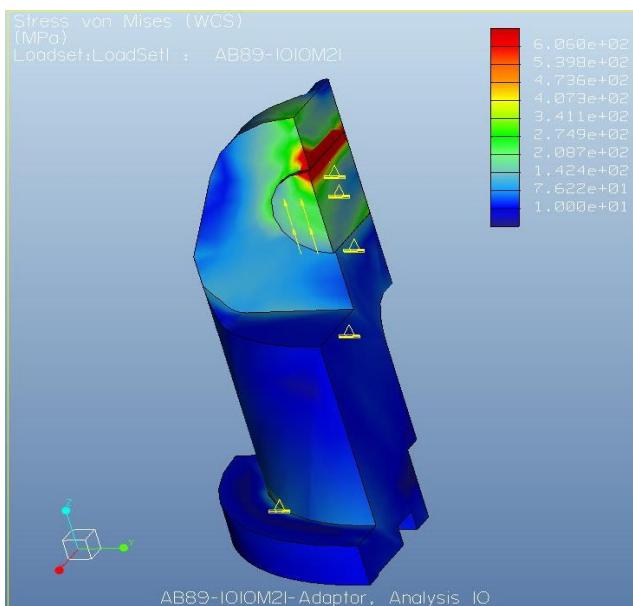
Tension/Compression (MPa)	σ_a	= 155	NA	NA	NA
Shear (MPa)	τ_a	= 90	NA	NA	NA
von Mises (MPa)	$(\sigma^2 + 3\tau^2)^{\frac{1}{2}}$	≥ 155	NA	NA	NA

8 CALCULATED STRESSES:

The stresses are calculated for each component using the ProMechanica FEM analysis program, which is integrated with ProEngineer, using the same models as the drawings are produced from as input. A detailed summary of the calculations is given in Volume 2 of this report.

8.1 AB89-1010M21 – ADAPTOR FOR STEEL ARMOURED UMBILICAL

Load condition 2 Launching

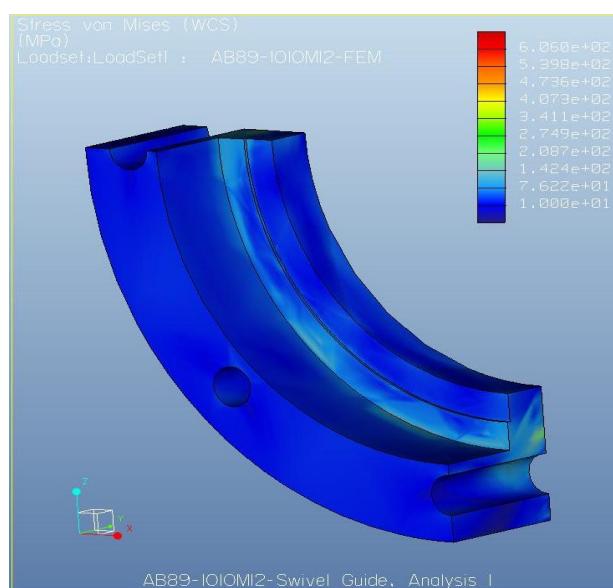
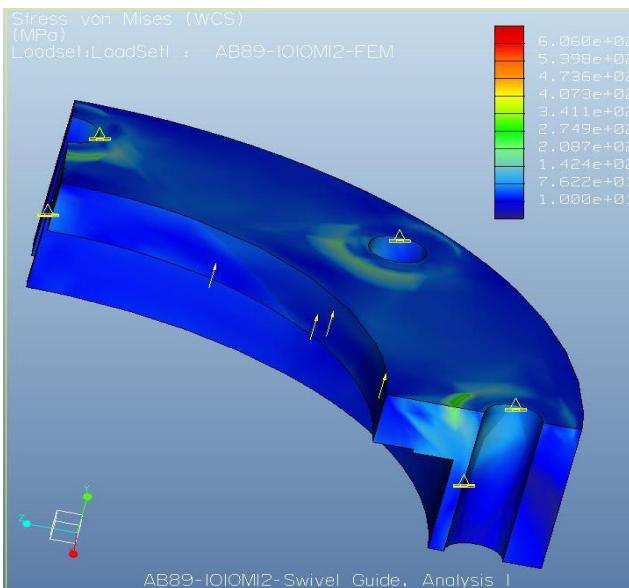


Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA		
AB89-1010M21 - Adapter	Analysis 10	Constraint	NA	274680	SWL 7Te on top of flange Bolt hole

RED AREAS = STRESS>PERMISSIBLE

8.2 AB89-1010M12 – SWIVEL GUIDE

Load condition 2 Launching

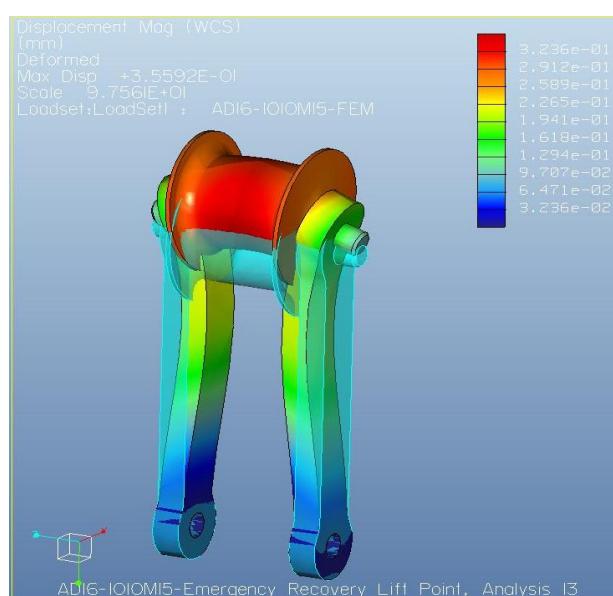
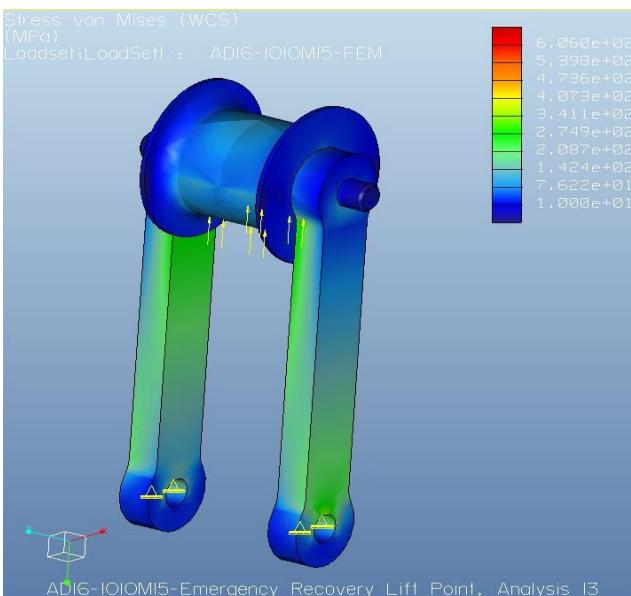


Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	274680	SWL 7Te under flange
AB891010m12 - Top ring	Analysis 1	Constraint	NA		Washer surface

RED AREAS = STRESS>PERMISSIBLE

8.3 AD16-1010M15 – RECOVERY LIFTING POINT

Load condition 2 Launching

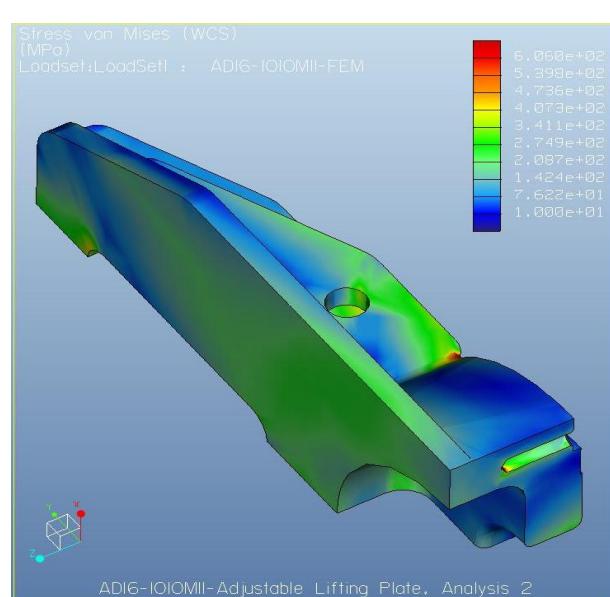
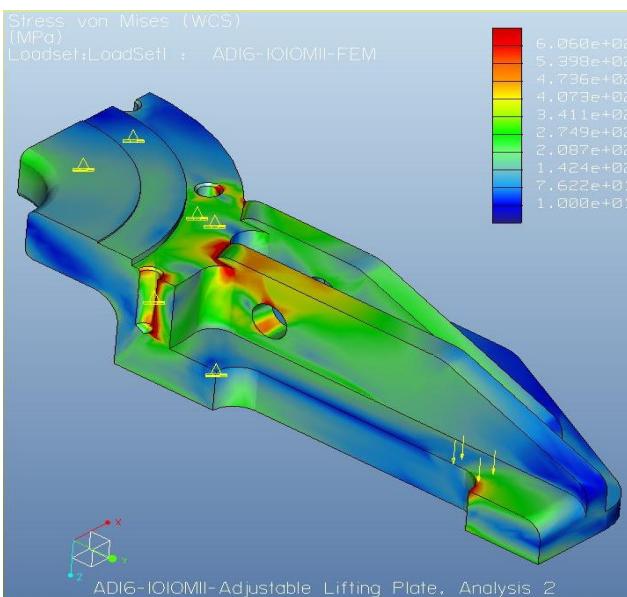


Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	274680	SWL 7Te on lower roller surface
AD16-1010MM15 - Emergency rec.	Analysis 13	Constraint	NA		pivot holes

RED AREAS = STRESS>PERMISSIBLE / MAX DISPLACEMENT

8.4 AD16-1010M11 – ADJUSTABLE LIFTING PLATE

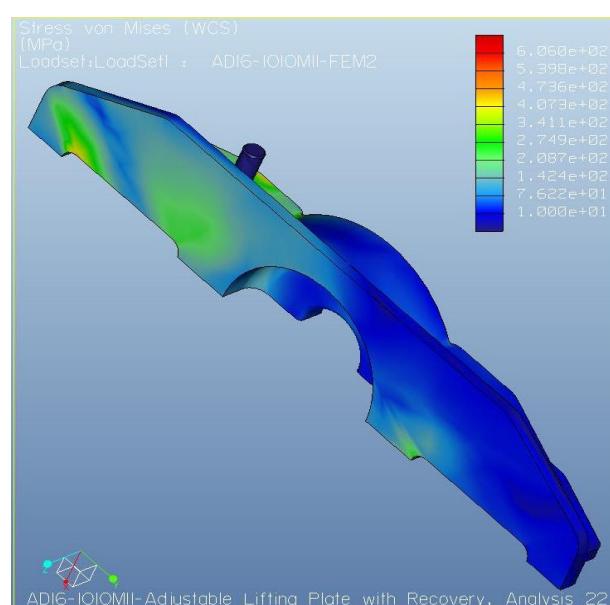
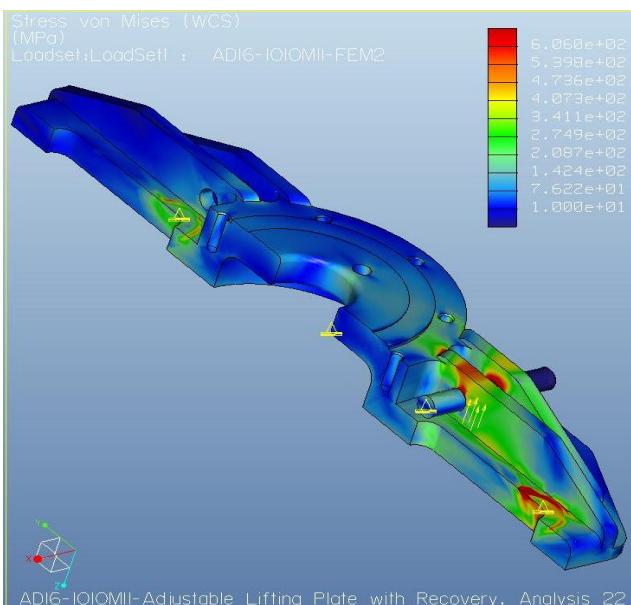
Load condition 2 Launching, holding in lift adaptor/bolts



Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	274680	
AD16-1010M11-lift plate- (hanging from adaptor)	Analysis 2	Constraint	NA	Bolt holes	

RED AREAS = STRESS>PERMISSIBLE

Load condition 2 Launching, holding in emergency recovery lift point



Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	274680	
AD16-1010M11 (hanging from emerg. Recovery)	Analysis 22	Constraint	NA	Bolt hole	

RED AREAS = STRESS>PERMISSIBLE

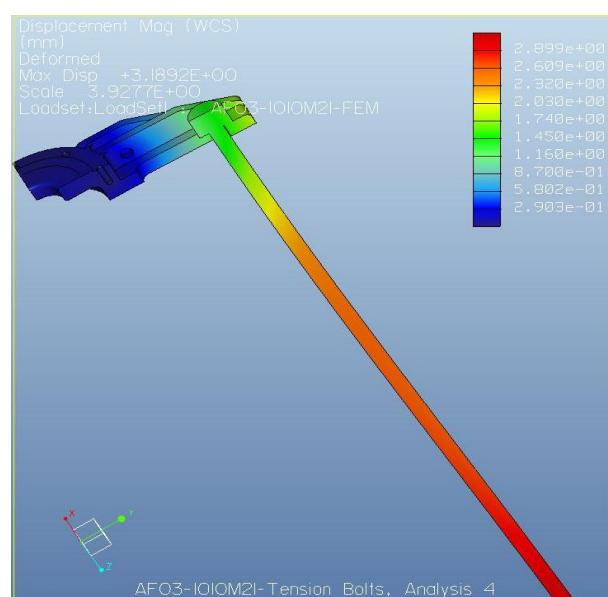
8.5 A4-100 M12 BOLTS

Load condition 2 Launching

Dimension: M12
 Effective area: $A_s = 84,3\text{mm}^2$
 Material: A4 100
 Yield stress: $\sigma_u = 900\text{MPa}$
 Material factor: $\gamma_{Mb} = 1.15$
 Total Load = 274680N Quantity:= 8
 Load each bolt = 34335N
 Tension stress bolt = 407MPa

8.6 AF03-1010M21 – TENSION BOLTS

Load condition 2 Launching

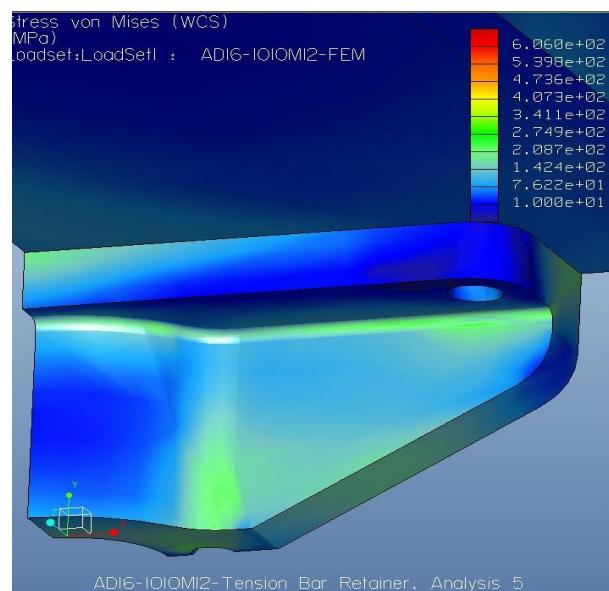
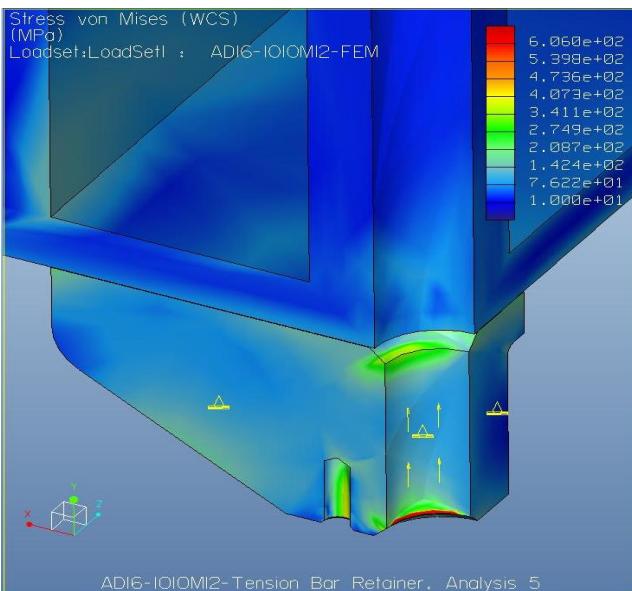


Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	137340	
AF03-1010M20-Tension Bolt	Analysis 4	Constraint	NA		Bolt holes

RED AREAS = STRESS>PERMISSIBLE / MAX DISPLACEMENT

8.7 AD16-1010M12 – TENSION BAR RETAINER

Load condition 2 Launching



Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	137340	½ x SWL 7Te on thread hole
AD16-1010M12-Tension bar ret.	Analysis 5	Constraint	NA		top surface

RED AREAS = STRESS>PERMISSIBLE

8.8 MAIN FRAME & FRAME LOWER SECTION WELDING

Load condition 2 Launching

Material: ENAW 6082-T6

Permissible Tension stress in welds: 155MPa

Weld dimensions: 10mm / 12mm

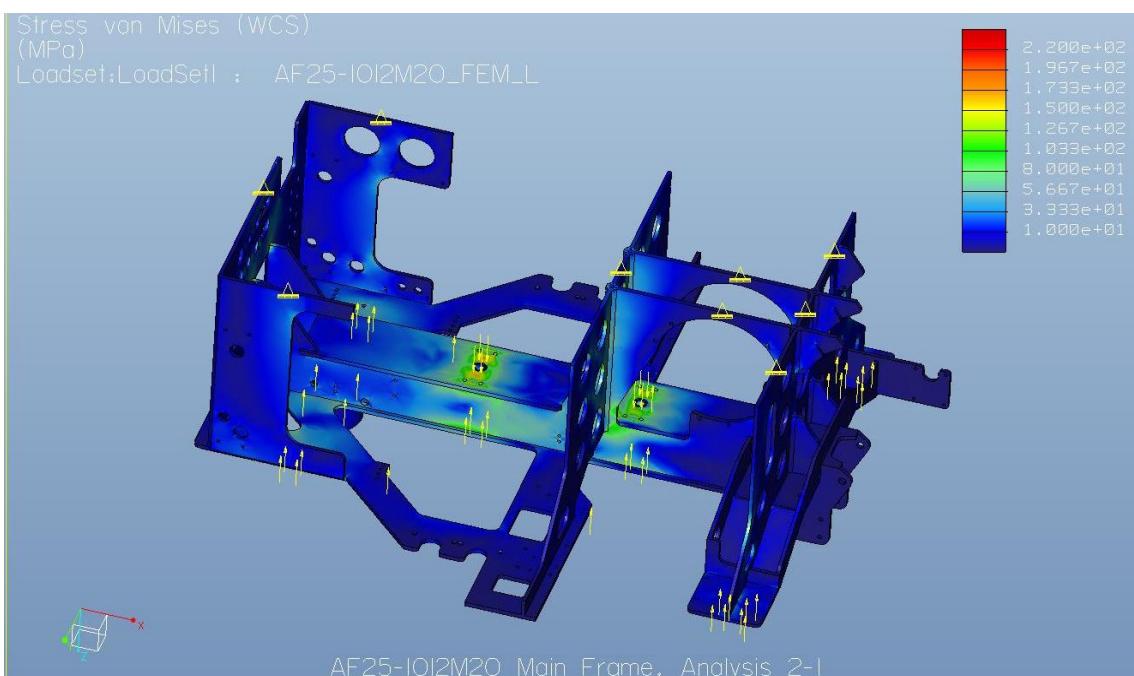
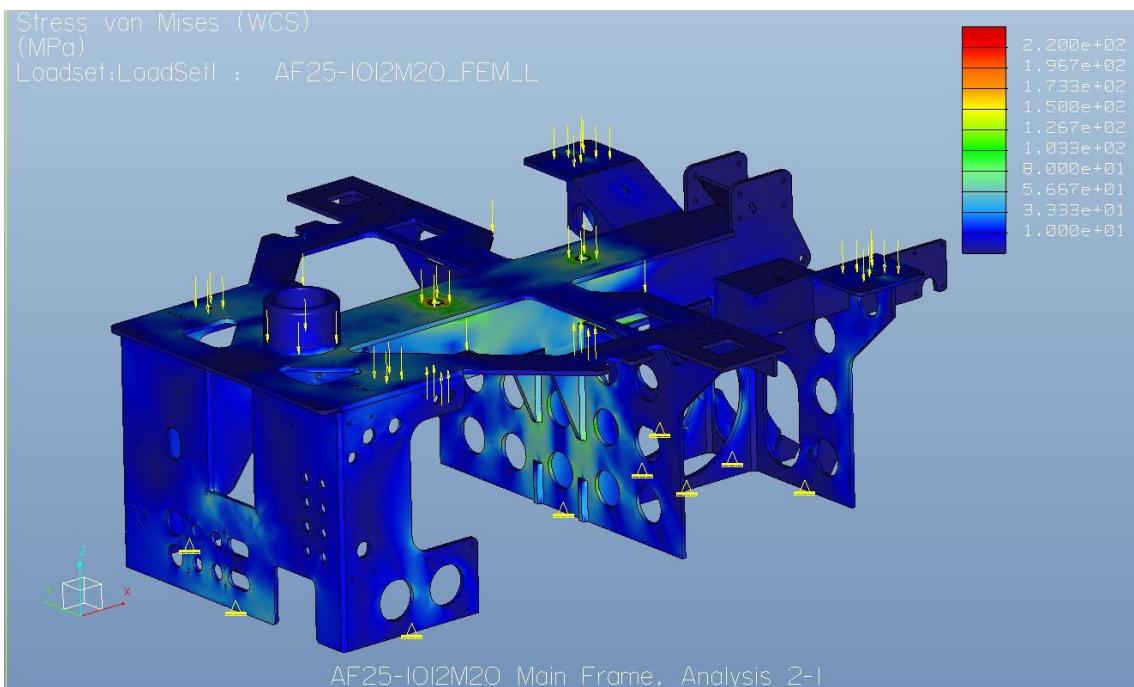
Total effective weld area: 45 948mm²

Total separation Load : 211072N (SWL 7Te – W_{R1}-W_B)

Tension stress in welds = 4.6MPa

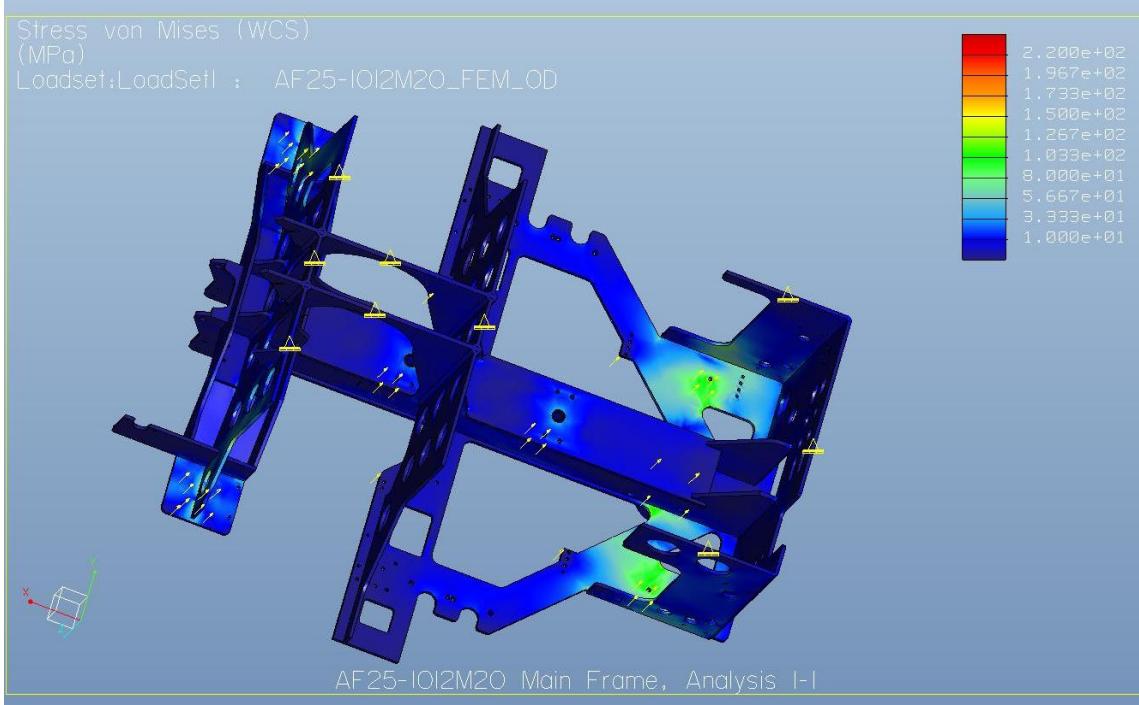
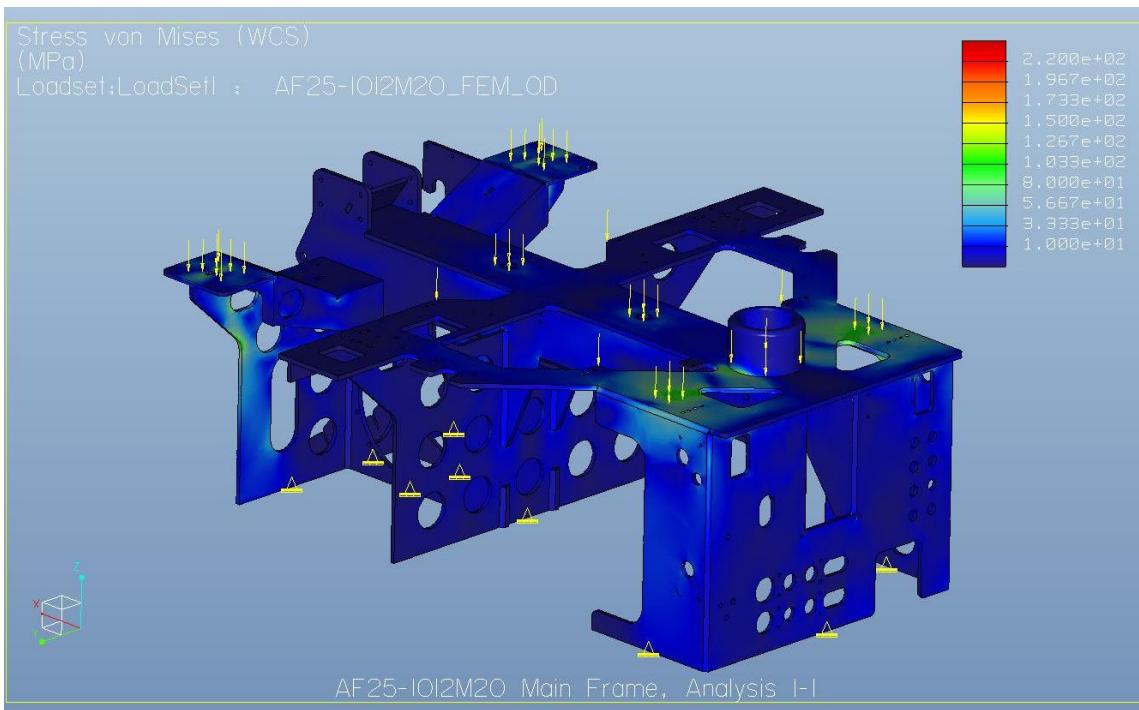
8.9 AF25-1012M20 – ROV FRAME CENTRE PART

Load condition 2 Launching



Item	Run no:	Load case 1			Point of Application
		Load case 1	Load case 2	Point of Application	
AF25-1012M20 Main Frame	Analysis 2-1	Load 1 (N)	NA	63608	$W_B + W_{R1}$ on frame top
		Load 2 (N)	NA	274680	2 x retainer contact
		Constraint	NA		Weld face to Frame Lower Section

RED AREAS = STRESS>PERMISSIBLE

Load condition 1 on deck


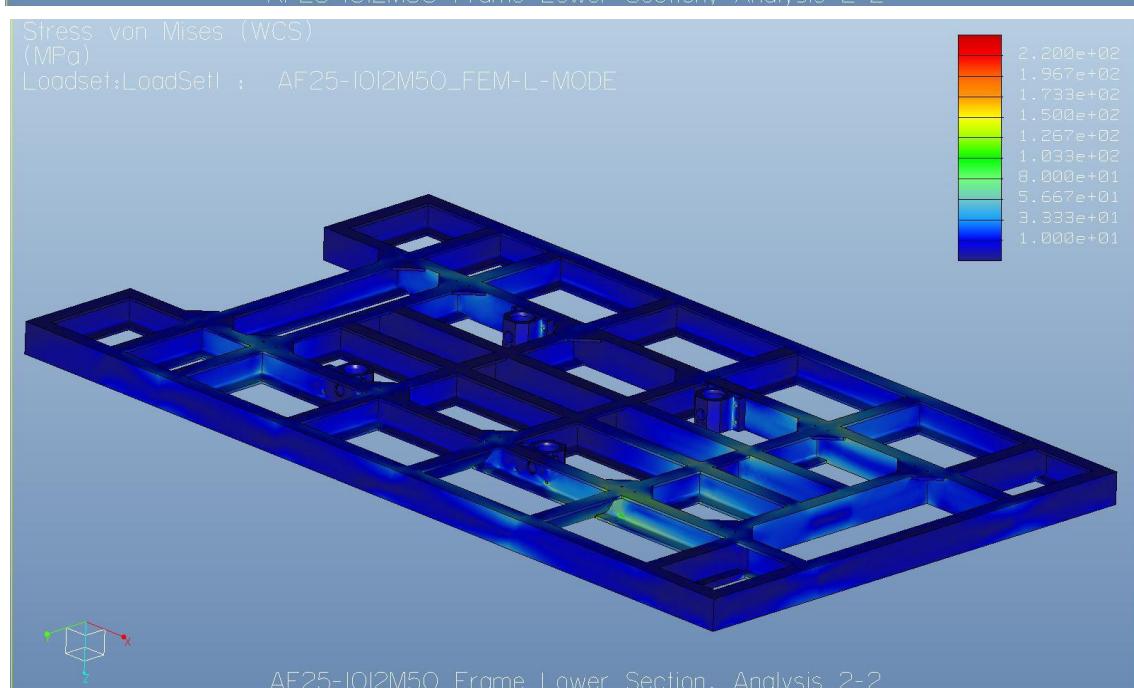
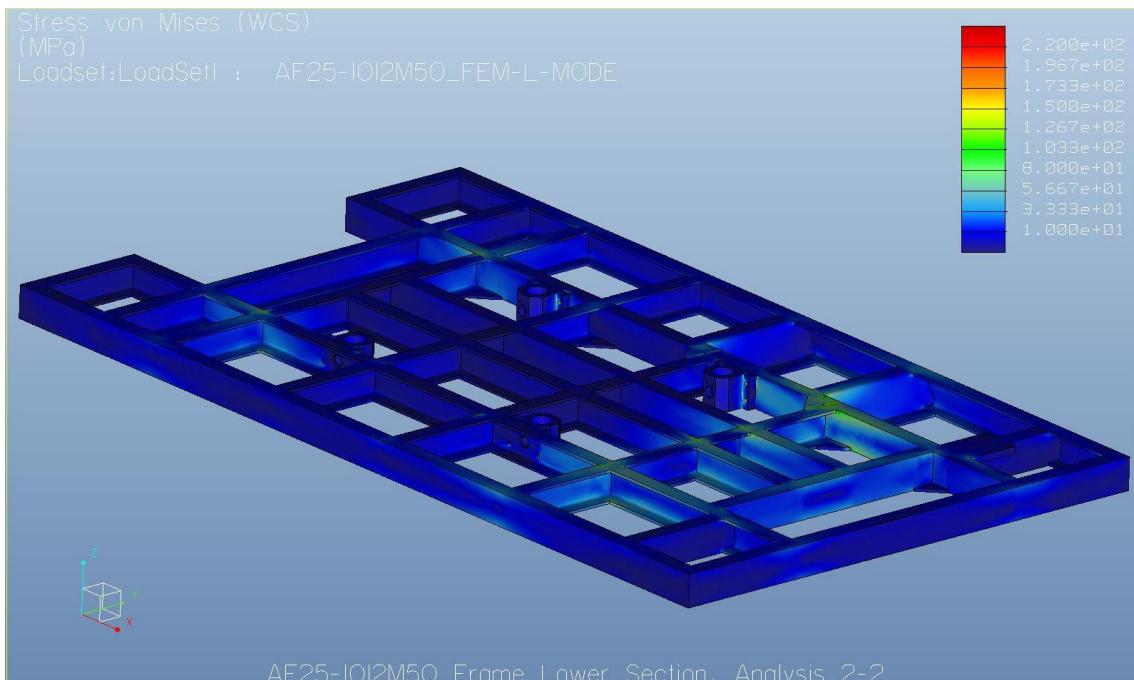
Item	Run no:	Load case 1			Point of Application
		Load (N)	125593	NA	
AF25-1012M20 Main Frame	Analysis 1-1	Constraint		NA	W _{TMS} +W _B +W _{R1} on frame top
					Weld face to Frame Lower Section

RED AREAS = STRESS>PERMISSIBLE

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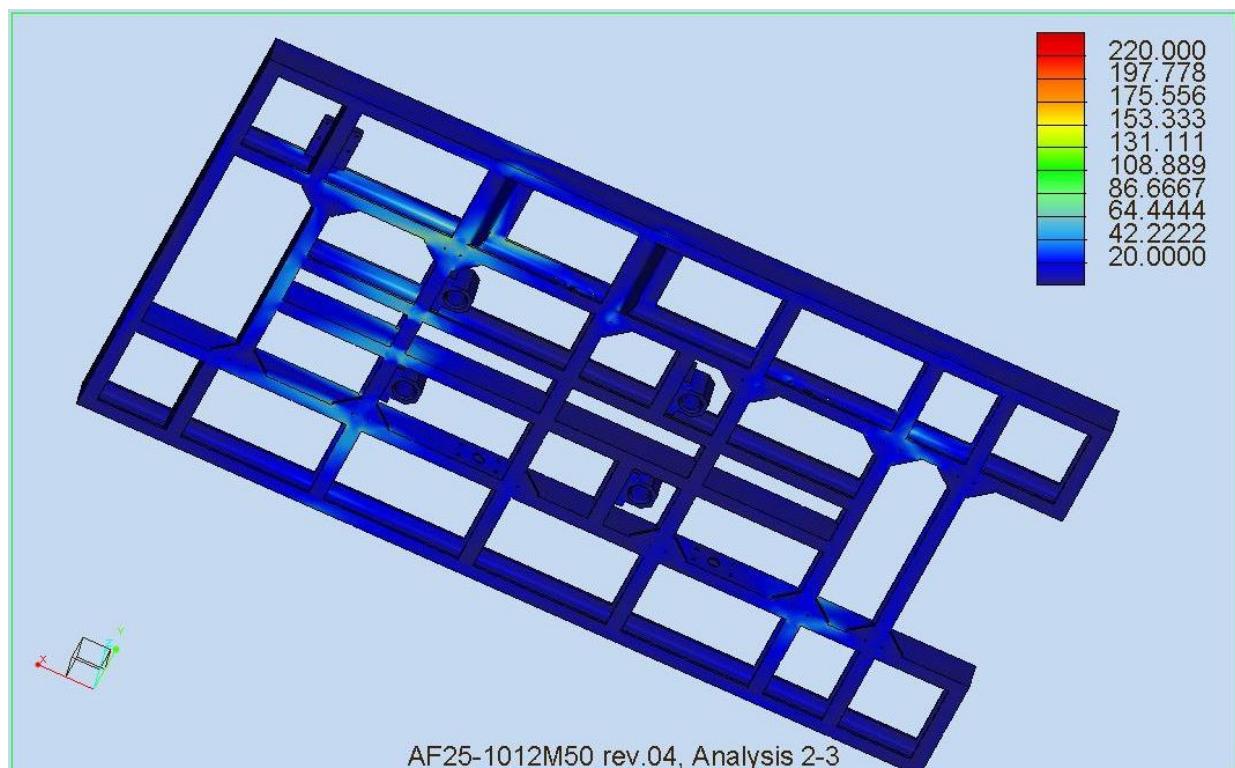
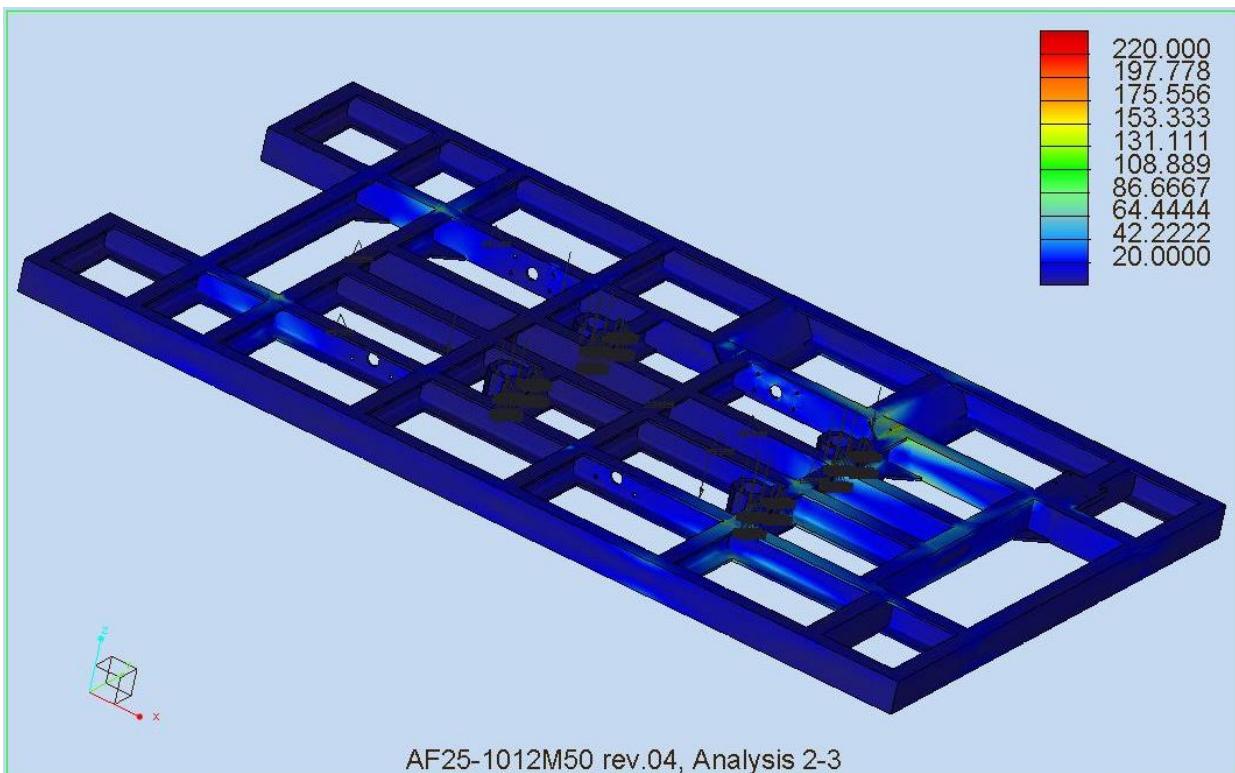
8.10 AF25-1012M50 – ROV FRAME LOWER SECTION

Load condition 2 Launching, Work Module Interface 1



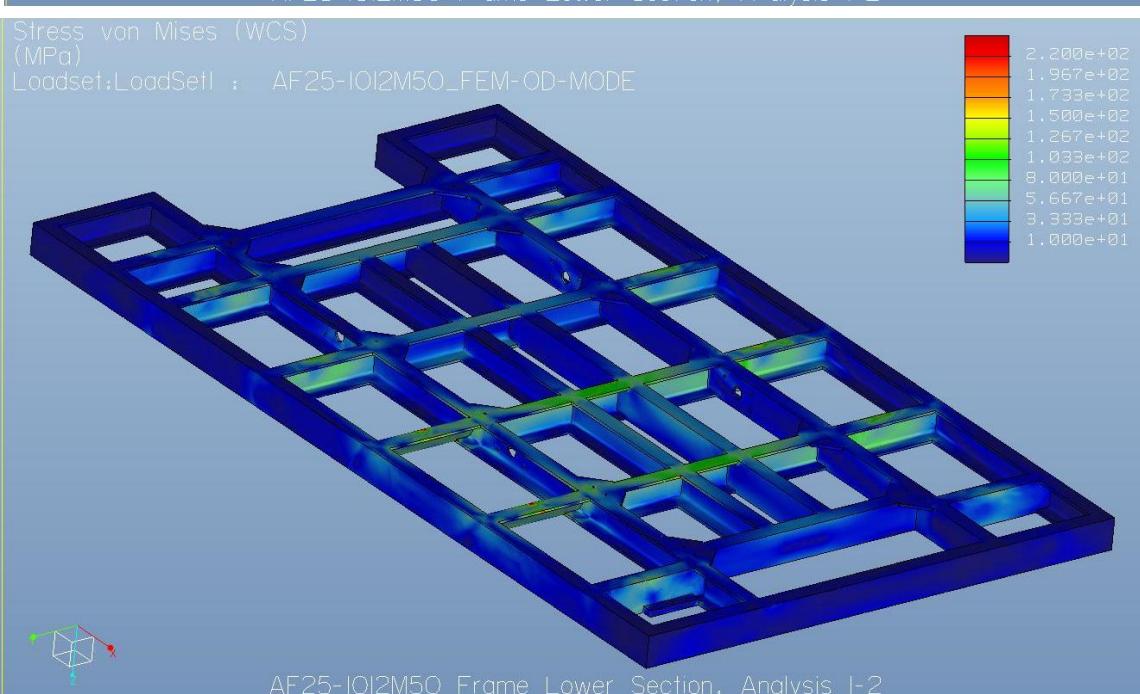
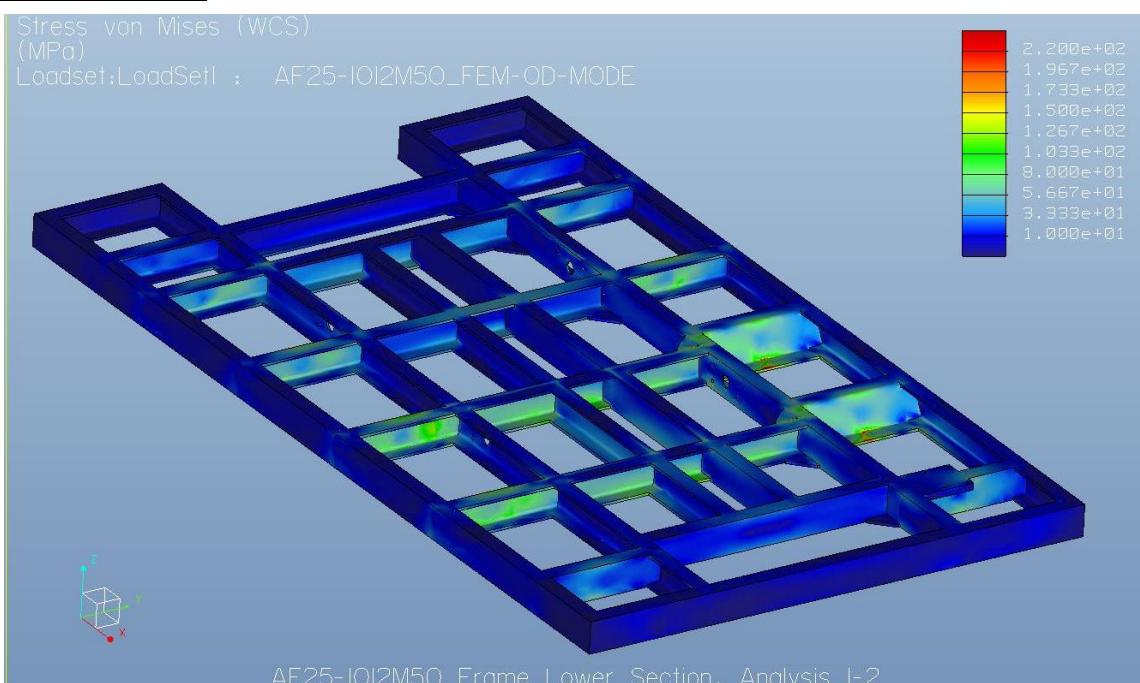
Item	Run no:	Load case 1		Load case 2	Point of Application
		Load 1 (N)	NA	117720	
AF25-1012M50-Frame Lower Sec.	Analysis 2-2	Load 2 (N)	NA	93352	WR ₂ +ΣK ₁₋₄ uniform on top face
		Constraint	NA		Weld face to Main Frame

RED AREAS = STRESS>PERMISSIBLE

Load condition 2 Launching, Work Module Interface 2


Item	Run no:	Load case 1			Point of Application
		Load 1 (N)	NA	117720	
AF25-1012M50-Frame Lower Sec.	Analysis 2-3	Load 2 (N)	NA	93352	WR ₂ +ΣK ₁₋₄ uniform on top face
		Constraint	NA		Weld face to Main Frame

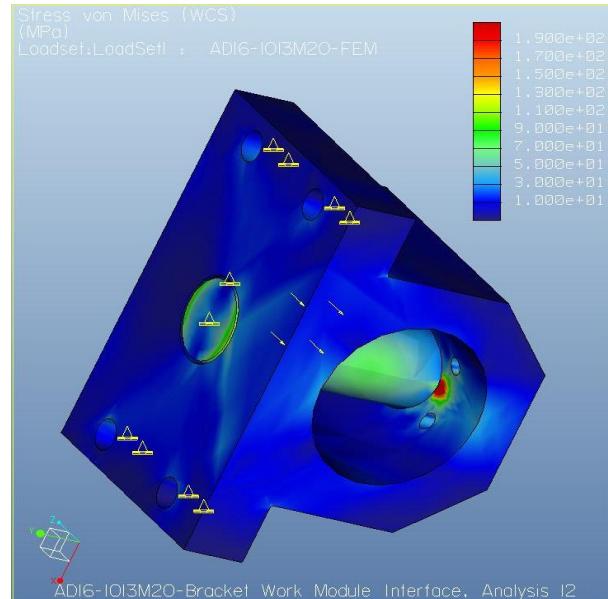
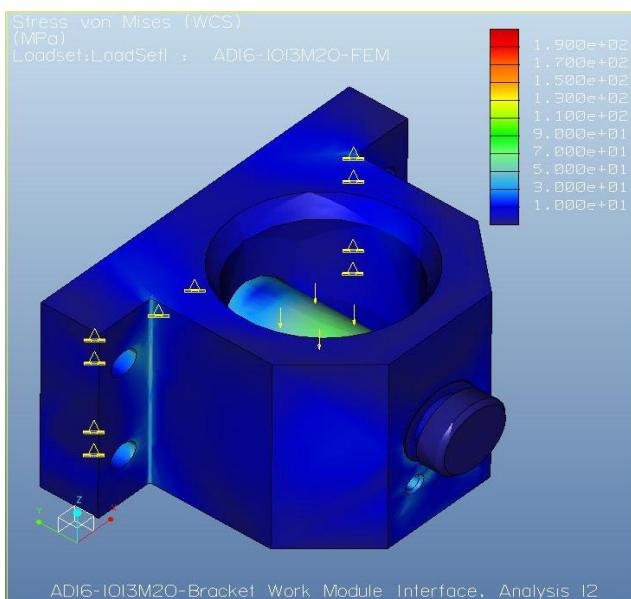
RED AREAS = STRESS>PERMISSIBLE

Load condition 1 on deck


Item	Run no:	Load case 1			Point of Application
		Load case 1	Load case 2	Point of Application	
AF25-1012M50-Frame Lower Sec.	Analysis 1-2	Load 1 (N)	125593	NA	$W_{TMS} + W_B + W_{R1}$ on Main Frame interface
		Load 2 (N)	62146	NA	$WR_2 + \sum K_{1-4}$ uniform on frame top
		Constraint		NA	Skid interface

RED AREAS = STRESS>PERMISSIBLE

8.11 AD16-1013M20 – BRACKETS FOR UNDERHANGING LOADS



Item	Run no:	Load case 1		Load case 2	Point of Application
		Load (N)	NA	29430	1/4 x SWL 3Te on bolt
AD16-1013M20-Bracket Work Module Interface	Analysis 12	Constraint	NA		Bolt holes

RED AREAS = STRESS>PERMISSIBLE

9 CONCLUSIONS AND RECOMMENDATIONS

The stress levels calculated are found acceptable in all the parts considered. In areas of critical welds, the stress levels are found to be well below the permissible stresses taking into account reduction factors for welds. Some local “hot spots” are found, where stresses are found higher than the permissible values. The stresses are however not exceeding the yield stress values over any significant areas/volumes. The local high stresses are around areas of load application or constraint locations in the model, and are amplified by the “rigidity” of the load areas. As the hot spots are considered small, the effect will in reality be distributed by small local yielding.