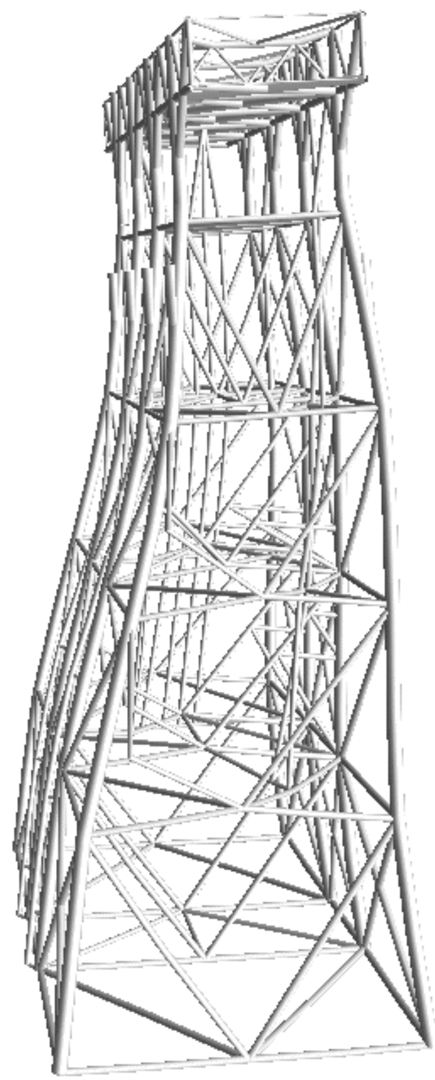
USFOS
Reality Engineering



SAFETY FACTORS

In
USFOS

CONTENTS:

1 Introduction

USFOS is primarily used for Accidental Limit State (ALS) analyses where load- and material factors normally are set to 1.0. Safety factors for the various components are build into the capacity formulations given in codes (f ex column buckling, strength of joints, etc.), such that the capacity obtained is a characteristic value. The characteristic capacity typically represents a value, which will imply that there is less than 5% probability that the resistance is less than this value.
Some codes, such as Norsok, allow for the use of non-linear analyses also documenting capacity for Ultimate limit state (ULS), this requires additional safety factors.
Applying additional load and resistance safety factors in a non-linear analysis can be challenging as application of resistance safety factors on the capacity model for one failure mode may influence the capacity differently for another failure mode.
One example of this is yielding vs. column buckling capacity.

In general it is more practical to prepare one capacity model representing the desired characteristic capacity for all failure modes to be analysed for, and then apply all the safety on the load side, defining a minimum target load level that accounts for both load and resistance safety factors. Using this approach, the same model may be used for both ULS and ALS type of analysis without recalibration of the model. The approach is in line with the recommendation in DNV RP-C208 /3/.

This document describes how the different safety factors are handled, and also how to use USFOS for other types of analyses, such as ULS.

2 Definitions

Definition of resistance safety factors relevant for USFOS analyses:
(Norsok ULS resistance factors are given as example)

- Material Factor: Resistance of cross-sections: 1.15
- Material Factor: Resistance of member to buckling: 1.15
- Material Factor: Soil resistance (of pile group): 1.3

Since USFOS input offers simple mathematical operations, the material factor for resistance of cross-sections could be given for example as: ***355E6/1.15*** for material factor 1.15.

This approach does however influence the column buckling capacity as well as yield/plasticity, but does not give the same safety factor for the buckling failure mode when this is governed by elastic buckling.

We thus recommend moving this safety factor to the load side, and leaving the yield stress as the characteristic value.

3 Summary

In general, the safety factor should be found by *load-level*, for example that the structure should withstand a level =1.5 of the basic (wave) load.

The required *load-level* (or "*reserve strength ratio"*), varies for the different problems and structures, (for example oil company specific), and should be defined under "acceptance criteria" in the "basis for the analysis".

Table 3-1 and Table 3-2 describe the factors to be used for the different components according to Norsok ALS and ULSb and how these load conditions could be checked in USFOS.

Table 3-1 - Required safety factors according to Norsok

	Environmental Load factor	Material factor yield	Material factor buckling	Material factor tubular joints	Material factor Pile groups (Soil)
ALS	1.0	1.0	1.0	1.0	1.0
ULSb	1.3	1.15	1.15	1.15	1.3

Table 3-2 - How to describe (input) the safety factors in USFOS

	Environmental Target Load factor	Material factor yield	Material factor buckling	Material factor tubular joints	Material factor Pile groups (Soil)
ALS	1.0	Use Nom Yield	Use CINIDEF and Norsok option	Use Norsok in Chjoint	Use un-scaled characteristic Curves
ULSb	1.3x1.15	Use Nom Yield	Use CINIDEF and Norsok option	Use Norsok in Chjoint	Divide soil strength with factor 1.3/1.15*1)

*1) This is a compromise; taking part of the soil material safety on the load side (as for steel) and the rest as a reduction of the capacity in order to get the same target load level for steel and soil. If soil strength is an issue we recommend: doing additional ULSb analyses with characteristic capacity and checking the design soil capacity as for linear analyses extracting forces at load level 1.3.

4 Members

Members are assigned a certain imperfection ("out-of-straightness") in order to get a characteristic buckling capacity according to a given code.

The command: CINIDEF is used to specify the buckling curve to use and the orientation of the imperfection.

When CINIDEF is used, USFOS is calibrated to give characteristic buckling resistance according to selected code.
Additional safety factors for ULS type of analyses should be applied on the load side, defining a target load equal to the action factor times the resistance factor.

5 Joints

Load transfer through Tubular joints need to be documented.

The command: CHJOINT is used to specify the strength curve to use (in addition to selection of the joint and chord members).

Different strength levels should be used for the different load types:

- Once-per-lifetime loads (boat impact): Use "**char** ultimate" level
- Repeated loads (waves) : Use "char **first crack**" level

The code variants Norsok, ISO and API all represent characteristic "first crack" resistance levels. The resistance on the tension side is limited in order to avoid cracks due to repeated yielding for repetitive loads.
Additional resistance safety factors for ULS type of analyses should be applied on the load side, defining a target load equal to the load factor times the material factor.

6 Pile-soil

The soil data, (P-Y, T-Z and Q-Z), are either based on the build-in API formulas, or read in (user defined curves).

The SOILCHAR command has a separate factor, which could be used for scaling forces-axis of the curves (i.e. scaling the capacities).

7 Mean capacity levels

USFOS also offers mean capacities, for instance for tubular joint. There is **no** built-in safety to these capacities. These are not at all relevant for ULS or ALS structural checks according to Norsok, which is based purely on characteristic capacities. Other structural codes may allow for the use of mean capacities in certain type of analyses; however the main use for these capacities is in Structural Risk Analyses where you want to aim for the most likely capacity level.

8 Resistance to cyclic storm actions

In Norsok N-006 /4/ it is stated:

"Structures that are checked in ULS and ALS by use of linear analyses need normally not to be checked for cyclic failures during a storm. If the capacity is determined by non-linear methods, it shall be checked that the structure does not undergo deformations that can weaken its ability to resist subsequent load-cycles. Such changes may be due to plastic (permanent) deformations, redistribution of stress-resultants due to local buckling (cross-section) or member buckling, slip in friction grip joints with pre-stressed bolts, etc.

Further cyclic checks are usually not required in cases where the structural resistance is restricted to all of the following requirements:

- *No structural components will experience local or global buckling determined according to NORSOK N-004;*
- *Tubular joints are not utilized above the capacity in NORSOK N-004 (first crack limit);*
- *No plastic mechanism is formed;*
- *No part of the foundation has reached the ultimate soil capacity;*
- *Joints are, by inspection, proven to be free from fatigue cracks or the calculated fatigue loading is negligible."*

The requirements is interpreted that "shakedown" analyses are needed to document ULS and ALS according to Norsok using USFOS if:

- A member buckles before target load level
- A member is fully utilised in pure bending or axial tension (Capacity formulas in Norsok are based on plasticity, so limited yielding/plasticity must be allowed)
- A joint fail before target load level (using first crack values)
- Redistribution of foundation forces between pile groups (i.e. piles at different legs) is needed to reach target load.

Guidance on how to perform shakedown analyses can be found in /1/ and /2/.

9 REFERENCES

/1/ DNV-SINTEF-BOMEL: Ultiguide –Best practice guidelines for use of non-linear analysis methods in documentation of ultimate limit states for jacket type offshore structures, April 1999.

/2/ Bjørn Skallerud and Jørgen Amdahl: Non-linear Analysis of Offshore Structures, Research studies press LTD, 2002. ISBN 0-86380-258-3

/3/ DNV: Determination of structural capacity by non-linear FE analysis methods, recommended practice DNV RP-C208, June 2013.

/4/ Norsok: Assessment of structural integrity for existing offshore load bearing structures N-006, edition 1, March 2009.