Design and Optimization of Multistage Mandrel for Downhole Tubular Expansion

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OUTLINE :

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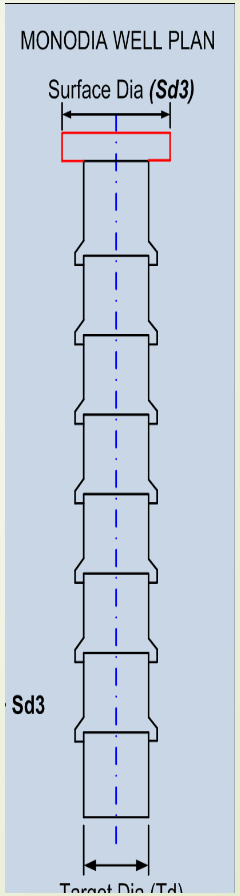
- LITERATURE REVIEW
- FINITE ELEMENT MODEL OF DOWN-HOLE TUBULAR AND MULTISTAGE MANDRAL
- FINITE ELEMENT SIMULATIONS
- CONCLUSION

INTRODUCTION

Expandable tubular technology :

which is expanding a down-hole tubular by a cone until its reach a specific diameter.



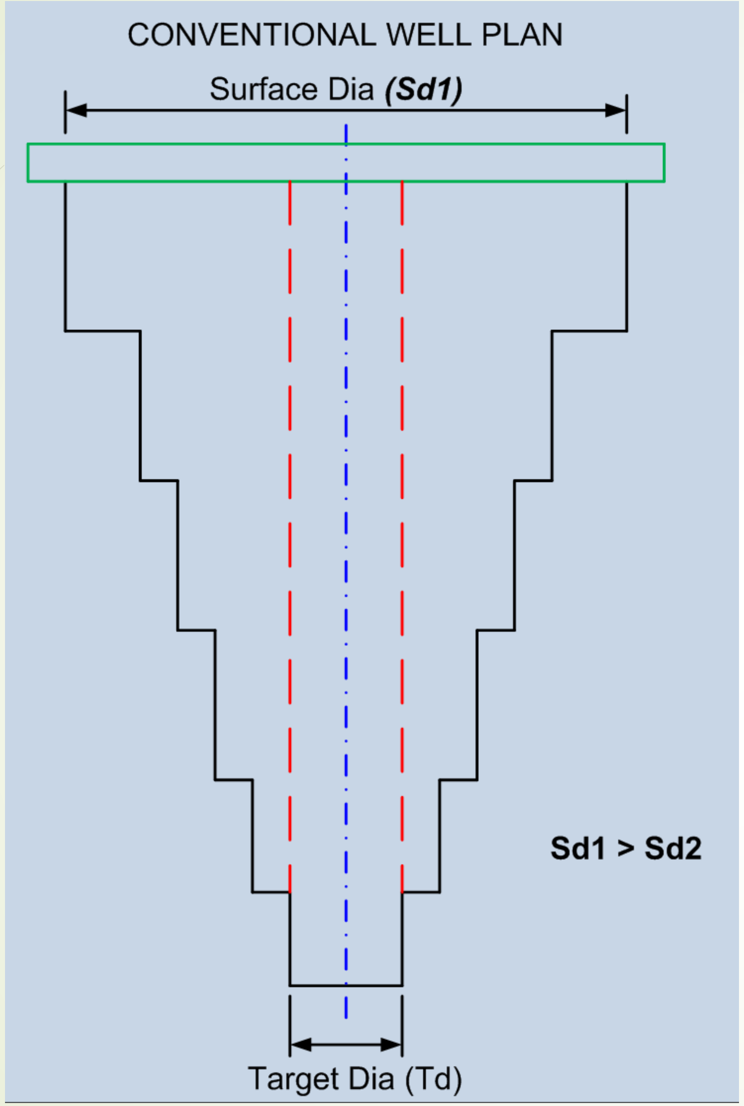
The traditional method of drilling oil and gas wells came with many problems:

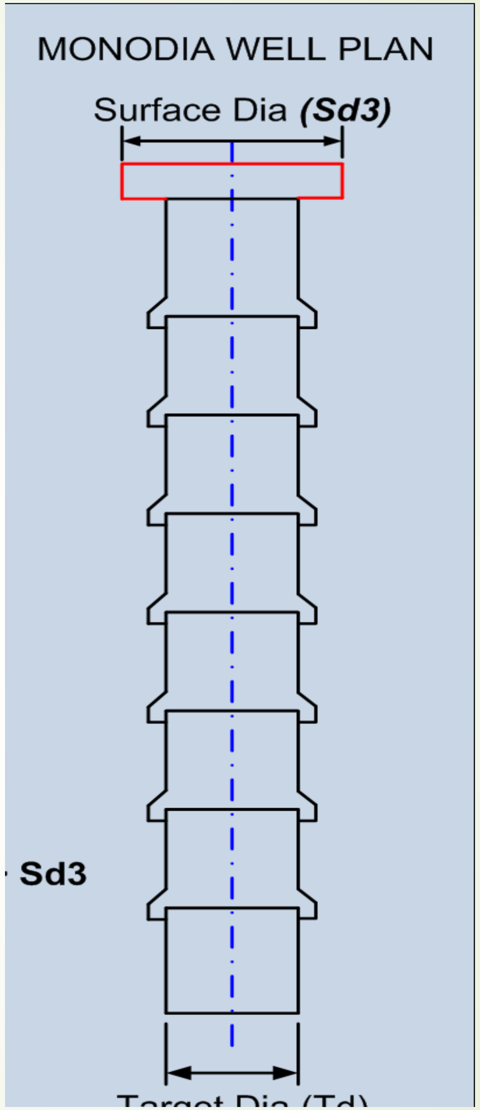
1. High cost.

2. Take time until we reach the required depth.

3. The target diameter is very small comparing with the surface diameter, while in the expandable tubular the target diameter will be nearly to the surface diameter.

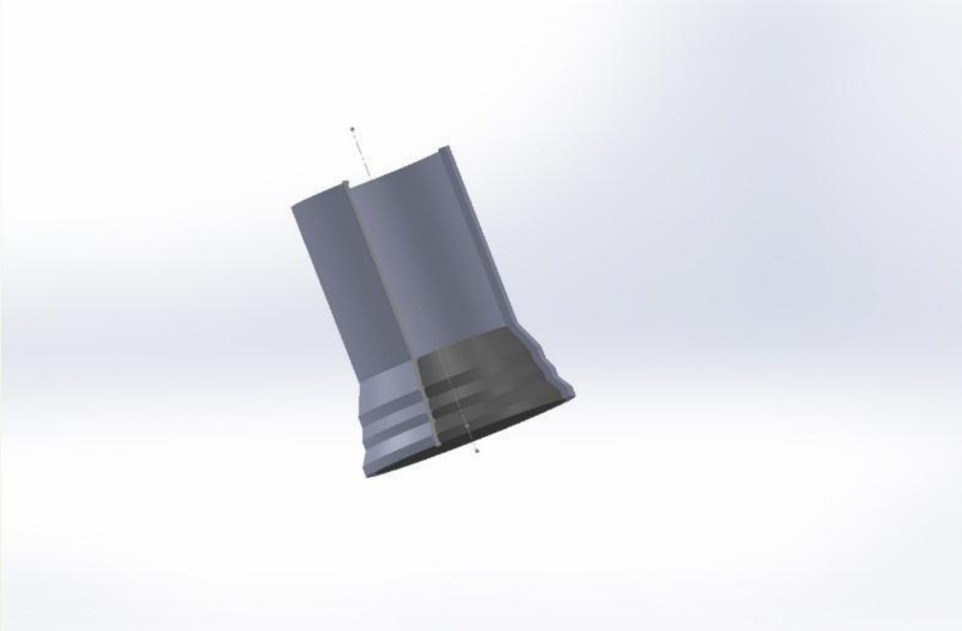
4. Need to case the hole.


CONVENTIONAL WELL PLAN
Surface Dia (Sd1)
Sd1 > Sd2
Target Dia (Td)

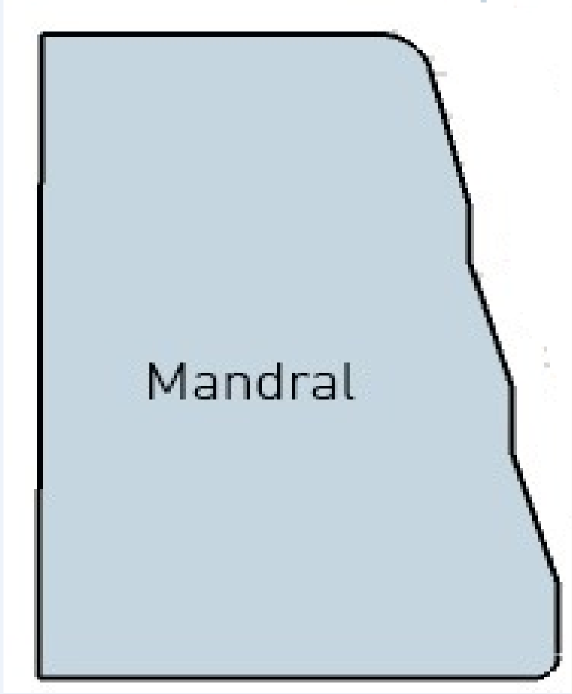

MONODIA WELL PLAN
Surface Dia (Sd3)
Sd3

MOTIVATION

- single stage mandrel can expand the tube for only one expansion ratio, a higher mandrel diameter needed to increase the expansion ratio more.
- To decrease the expansion cost, multistage mandrel has been designed to expand the tube with increasing stages diameter (16%, 20%, and 24%).



There are many different techniques used to expand tubes. The main aim of this project is to design shape of multistage mandrel geometry to obtain the required expansion parameters.



OBJECTIVES

1. Understand the parameters and details of down-hole tubular.

2. Develop finite element model of down-hole tubular and multistage mandrel and run the finite element simulations in commercial finite element software ABAQUS.

3. Analyze tubular expansion parameters.

4. Validate finite element model with the published experimental results of tubular expansion.

5. Compare the result of multistage mandrel shape with single stage mandrel.

METHODOLOGY

The activities of the project work is divided into four major phases and then further divided into sub-phases.

Phase 1: Literature Review Of Down-hole Tubular Expansion.

Phase 2: Finite element modeling for Down-hole tubular and multistage mandrel shape.

Phase 3: Model validation.

Phase 4: Finite element simulations.

- **4.1**: Variation of mandrel radius.
- **4.2**: Variation of mandrel angle.
- **4.3**: Variation of mandrel shape.

SOLID EXPANDABLE TUBULAR TECHNOLOGY,(cont..)

- The concept of expandable tubing is not new. The boiler manufacturers have been using expandable tubing as a core technology for many years.
- the case of expanding slotted pipe led to the potential use of the technology
- Particularly critical to the down-hole expansion process are :-

1-Mechanical properties of tubular such as ultimate tensile ductility impact toughness .

2-Mandrel shape.

3-Down hole environment .

4-Tubular connection design.

5-Manufacturing tolerance of the tubular.

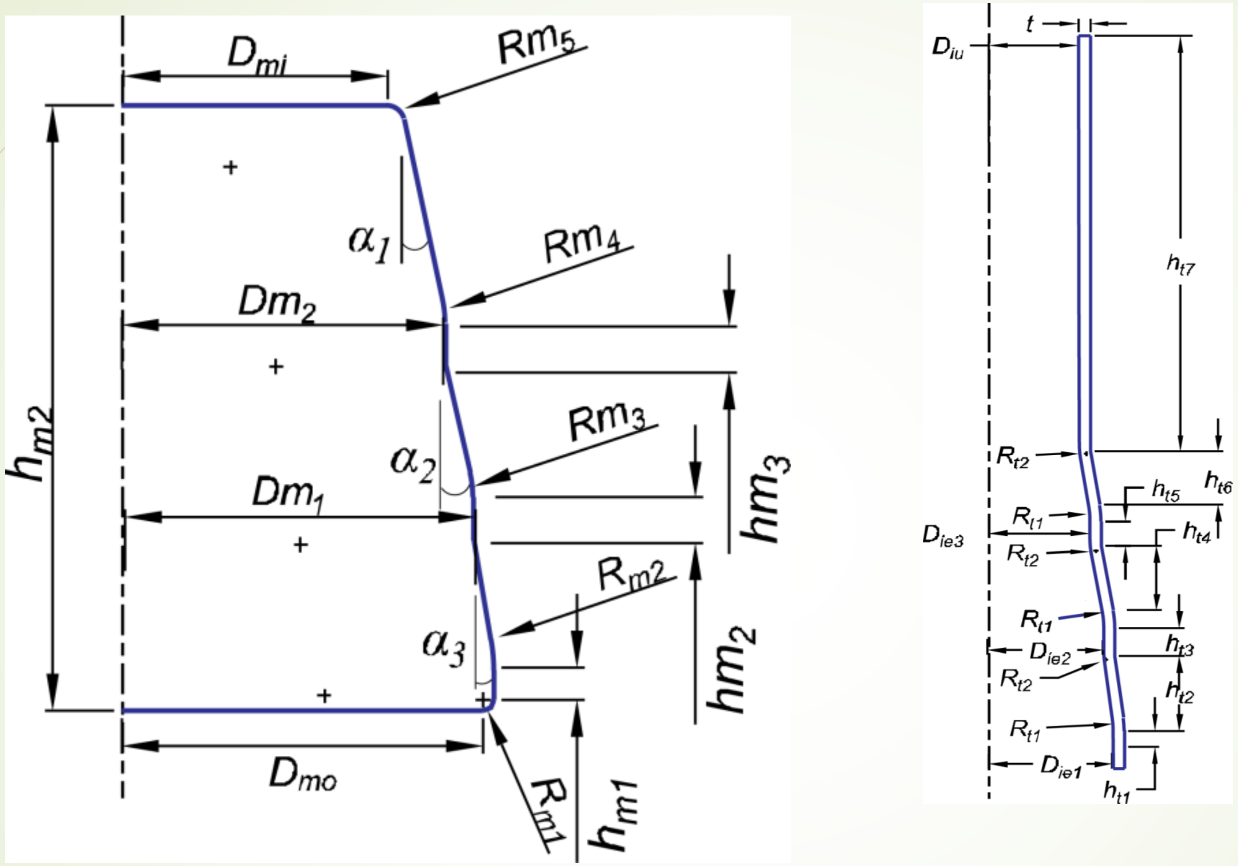
REVIEW OF SOLID EXPANDABLE)TUBULAR TECHNOLOGY(cont..)

- The use of finite element analysis shortened the time needed to develop a system that can address the operator's major concerns.
- A finite element model for tubular-mandrel system has been developed using software ABAQUS and has been validated through experimental observations.
- Finite element model is then used for simulations of tubular expansion to study the effects of mandrel velocity (strain rate) on post-expansion characteristics of tubular.

FINITE ELEMENT MODEL OF DOWN-HOLE TUBULAR AND MULTISTAGE MANDRAL

- Development of finite element model in software ABAQUS was done.
- The following section dedicate to the modeling of down-hole tubular and multistage mandrel, a step by step procedure shows the process of development the models :
- **1 – modeling** : The way of how the physical system can be modeled can significantly effects the result, and clearly can affect the computational time.
- Tubular and mandrel have been modeled as 2D axisymmetric.

FINITE ELEMENT (cont..)

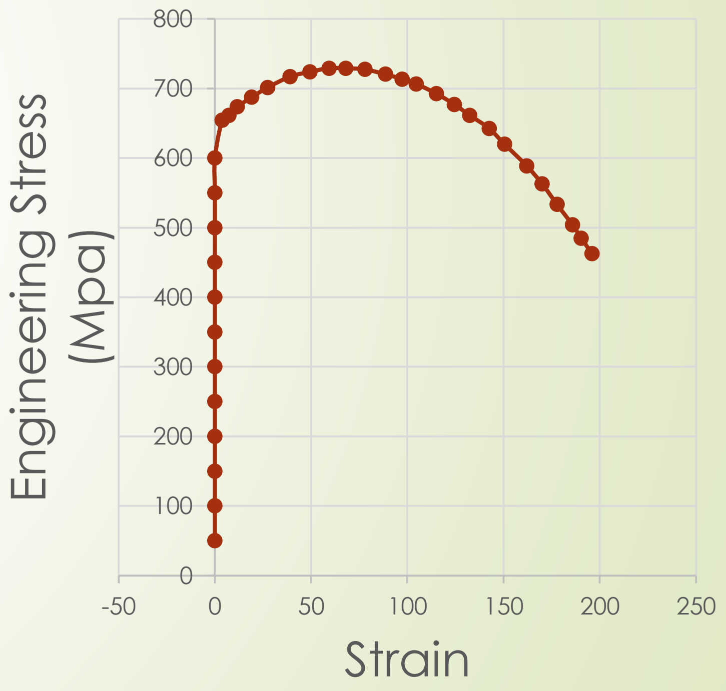


Geometrical dimensions parameters: a) mandrel ; b) tubular

Name	D_{mo}	D_{m1}	D_{m2}	D_{mi}	h_m	h_{m1}	h_{m2}	h_{m3}	h_{m4}	h_{m5}	h_{m6}	R_{m1}	R_m	R_{m3}	a_1	a_2	a_3
Model-7	105.8	104.85	101.9	79.4	206.5	8.47	17.49	7.64	18.79	6.79	111.71	2	50	2	8.06	6.48	10

FINITE ELEMENT (cont..)

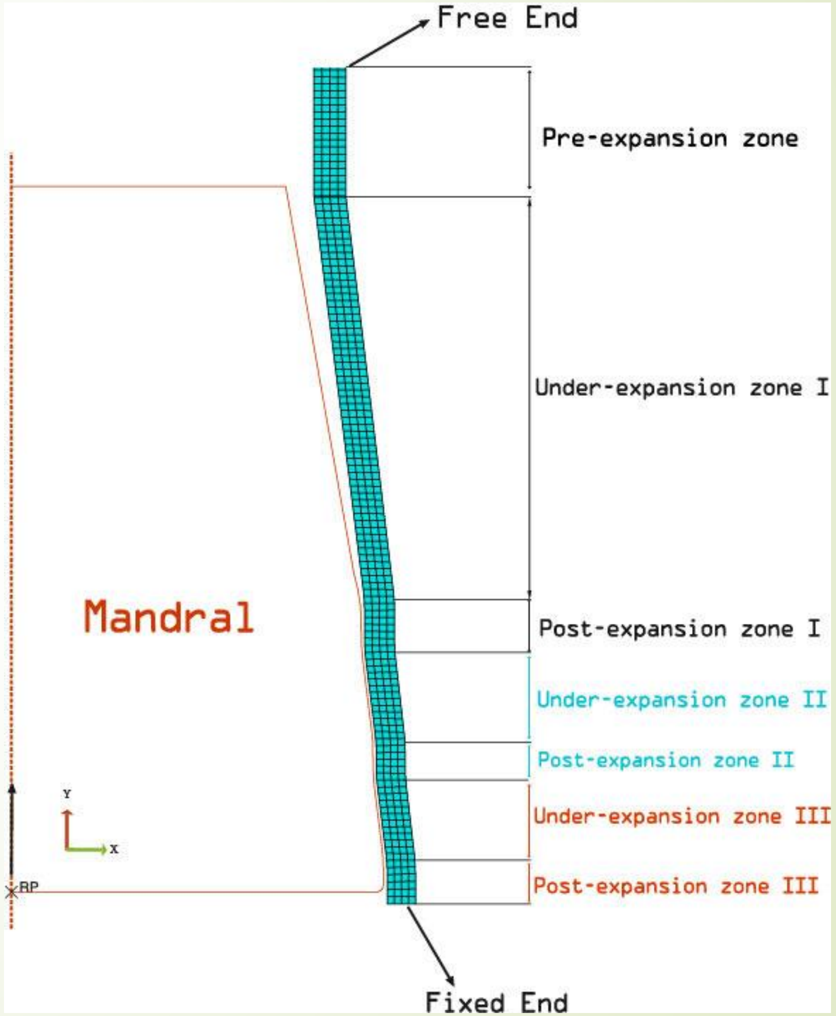
- **2 - MATERIAL MODELS :**
- The tubular is made of high strength low-alloy steel with the following major alloying elements (weight percent): 0.23% C, 1.34% Mn, 0.23% Si, 0.01% Ni, 0.121% Cr, and 0.065% Mo . The yield strength is 610 to 641 MPa, and ultimate tensile strengths, 706 to 728 Mpa.
- The mandrel is modeled as rigid body .
- **3 - INTERACTION MODULE :** the interaction is surface to surface with friction coefficient 0.07



Stress strain behavior of tubular material subjected to uniaxial tensile load

FINITE ELEMENT (cont..)

- **4 - BOUNDARY CONDITIONS :**
- The tubular boundary condition can be defined as Fixed-Free displacement boundary condition, as show in Figure



FINITE ELEMENT (cont..)

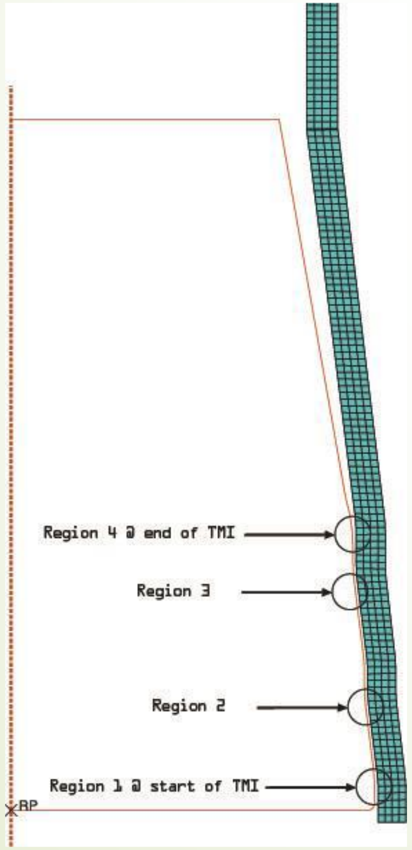
- **5 - DISCRETIZE THE MODEL: MESHING :**
- The element type used for discretize the tubular is (CAX4R) which is a 4-node bilinear axisymmetric quadrilateral .
- The total number of element is counted to be 2366 elements.

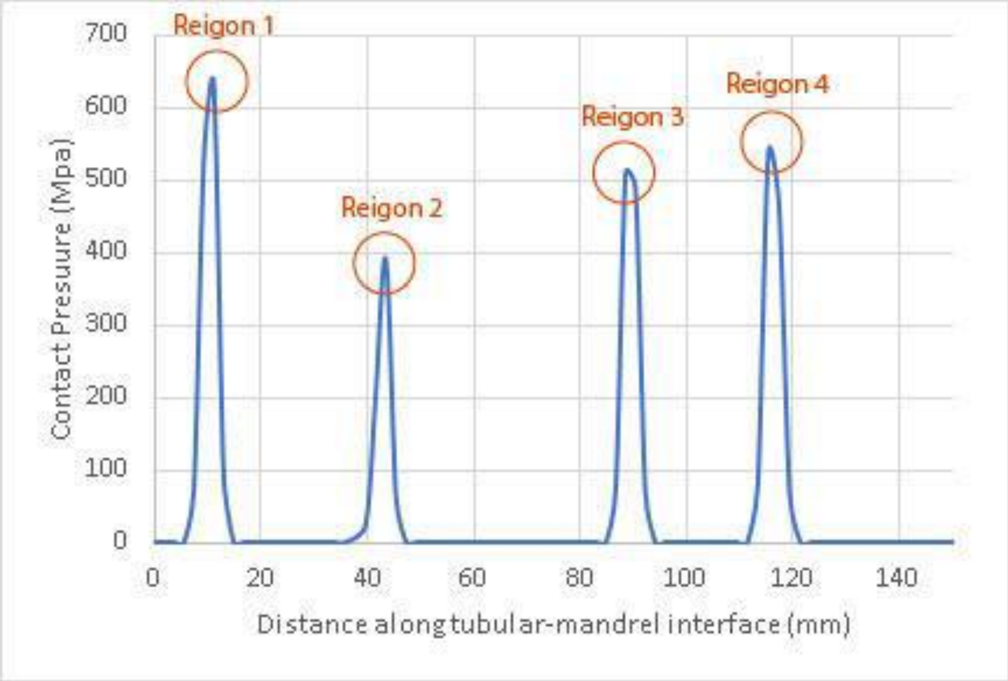
Finite elements simulations

- Finite elements simulations are preformed to investigate the effects of multistage mandrel on different tubular post-expansion properties.
  - Contact pressure
  - Equivalent stress
  - Expansion Force
  - Equivalent plastic strain
  - Thickness reduction
  - Length shortening.

Contact Pressure

- Contact pressure is an important parameter needs to be study.
- If the contact pressure exceed the Ultimate strength a failure may occur.
- The increase in contact pressure can result a higher thickness reduction.



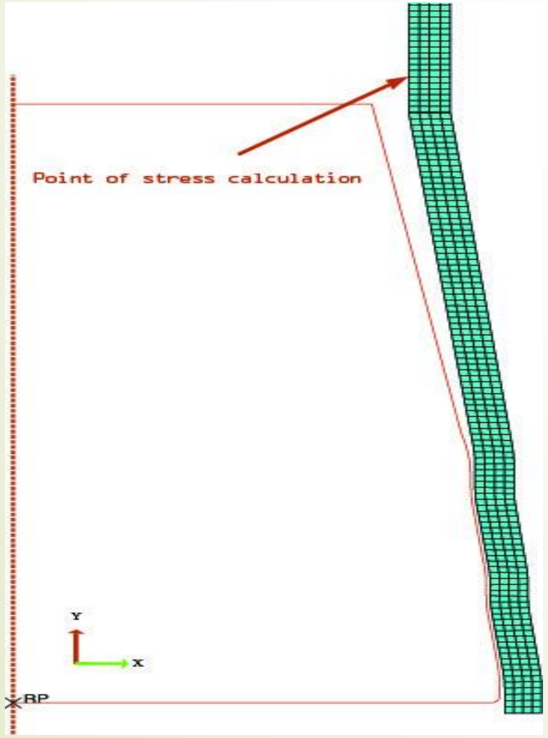


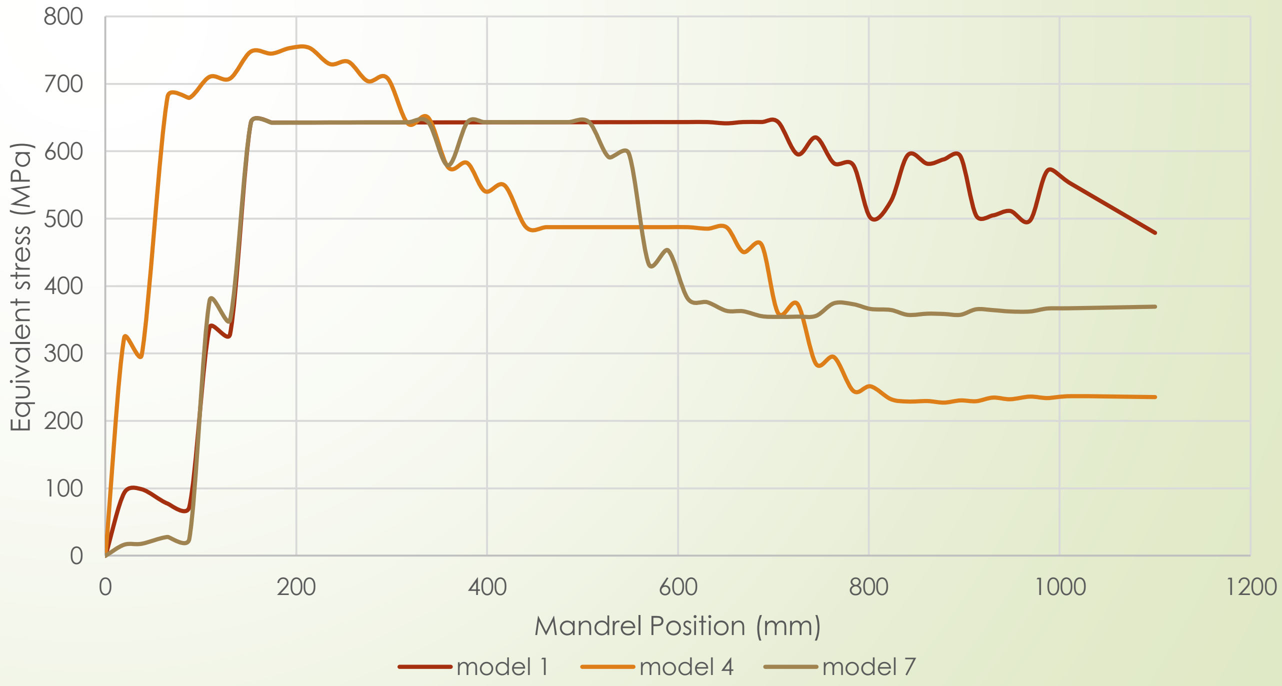
Model No.	Total Mandrel height (h_m) (mm)	Mandrel Fillet Radius (R_m), (mm)	Max. Contact Pressure (MPa)
1	449.86	10	1.63×10^3
2	364.86	10	1.45×10^3
4	206.5	10	1.42×10^3
7	206.5	50	640

- The following table shows that, the contact pressure depends significantly on the size of the mandrel and mandrel fillet radius.
- the optimum value for contact pressure can be estimate at 206.5 mm total mandrel height, and 50 mm fillet radius.

Equivalent Stress

- The optimum model for minimalizing the maximum equivalent stress and the residual stress is model-7.
- The maximum equivalent stress found equal to 650 Mpa.
- The residual stress after the expansion found equal to 360 MPa.
- The residual stress may reduce burst and collapse strength of tubular.





Expansion Force

- The following Figure shows the expansion force for most varying models.
- The expansion force for model-7 equal to 1.4 MN.
- This result shows that, the expansion force can be more cost effective comparing to single stage expansion.
- The dynamic effect can be eliminated by simulating the problem as quasi-static.

Figure 18 expansion force for different models

Variation of Thickness

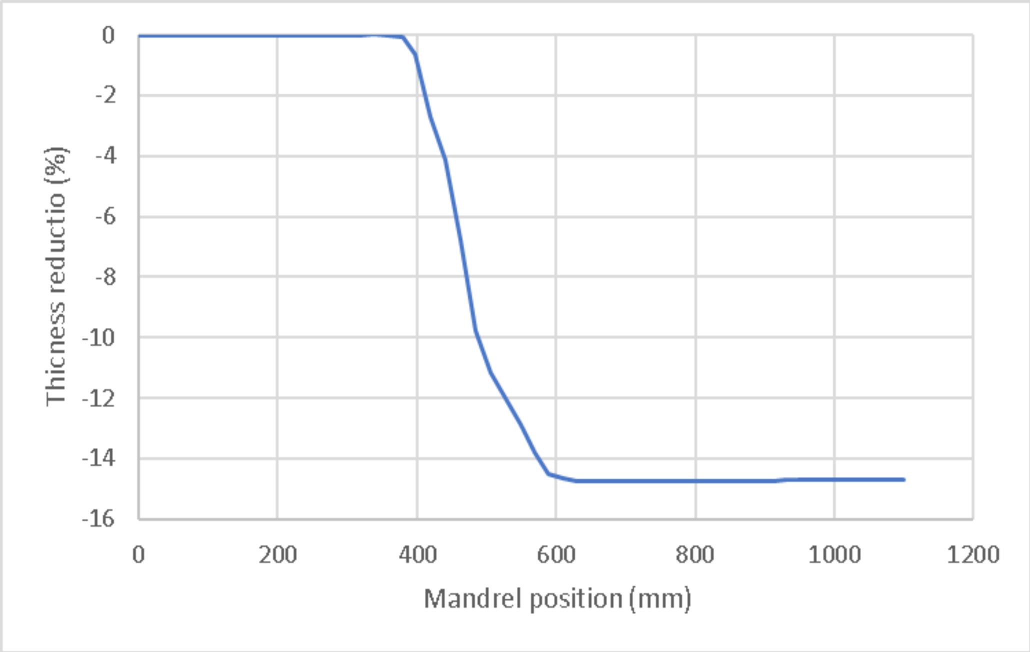
- tubular thickness before and after

the expansion ware measured at three

different locations, and an average value

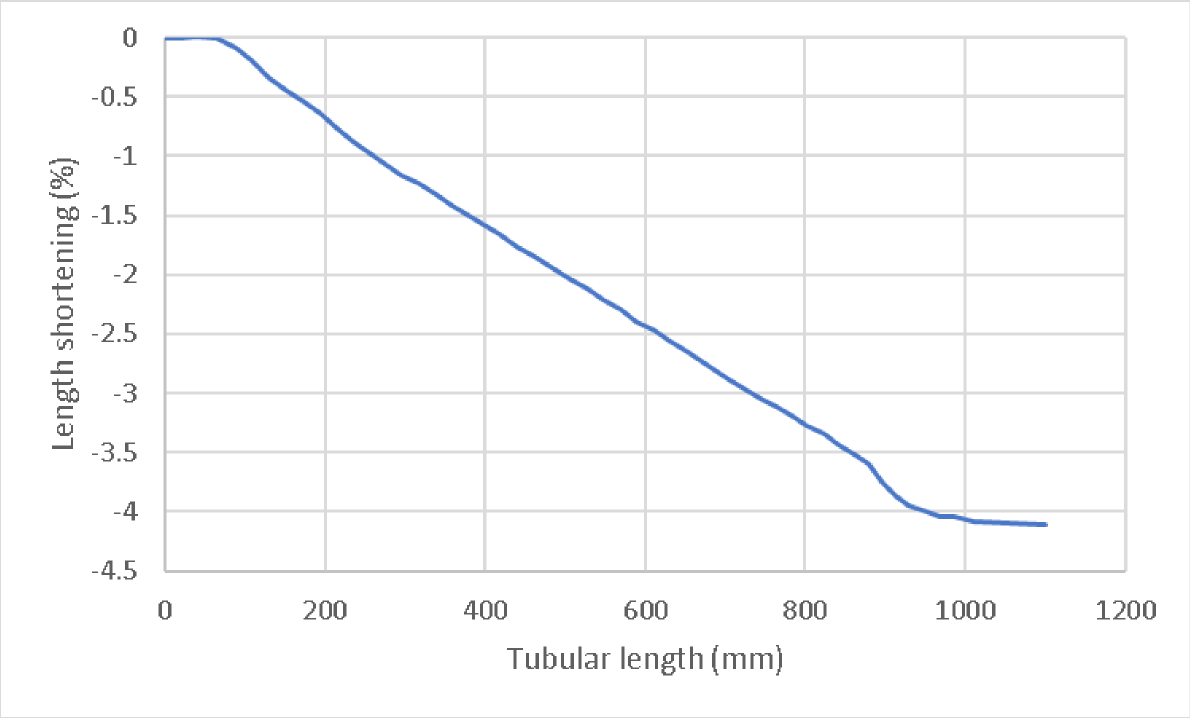
of thickness reduction was calculated.

- The reduction found equal to 14.3%
- Thickness reduction can affect the burst and collapse strength.



Length Shortening

- length shortening is a critical post-expansion property of tubular.
- It is very important when two expanded tubulars are assembled in a well.
- The shortening in the tube length reach 4% from the original length.



Conclusion

- Geometrical optimization was done to investigate the effects of expansion with multistage mandrel on post-expansion properties.
- Geometrical optimization shows that, The contact pressure can be affected by mandrel total size and fillet radius.
- The contact pressure for the optimum design on mandrel tubular interface found equal to 640 MPa.
- Maximum equivalent stress found equal to 650 MPa.
- The expansion force found equal to 1.4 MN, which can consider more cost effective comparing with single stage with three expansions processes (16%, 20%, and 24%).

Thank you …