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NUMERICAL OPTIMISATION ASSOCIATED WITH THE INFLUENCE OF EXTERNAL FACTORS AND PATCH REPAIR FACTORS ON PIPELINES

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Abstract

Pipeline maintenance is an important process for increasing the useful life of the various structures used to transport fluids, reducing leaks and improving pipeline operation. In this work we have used numerical optimisation to determine the main factors affecting the repair of cracks in pipeline structures. We studied the most important environmental factors present around pipelines, such as humidity and the thickness of the patch used to maintain the pipeline structures.

Index Terms: Pipeline, Optimisation, Humidity, Thickness, Crack.

1. INTRODUCTION

Cracks are the most important factor in the loss of various structures in many fields, such as aviation, shipping and the transport of various liquids and gases. For this reason, these structures need to be protected using several methods to prevent the propagation of cracks and to strengthen structures.

In pressure vessels and piping systems, surface fractures are thought to be the most prevalent Defects [1-3]. It frequently happens that during structural component examination, a surface crack Manages to elude detection [4]. When assessing components with suspected or actual faults using Fracture mechanics, deterministic methods are typically used. These rely on accurate assumptions about the flaw's state, the strength and toughness of the material, and the applied loading [5, 6].

Several methods are used to maintain structures, the most important of which are the patching technique and the stiffening technique [7, 8]. In order to use these two techniques correctly, care must be taken to apply the appropriate adhesive to avoid any technical problems caused by neglecting this process. The aim is to extend the life of the

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structures, increase the load-bearing capacity and reinforce the adhesive joints between the structural units.

In order to really simulate structures, we used one of the most important calculation methods: calculating structures using the finite element method (FEM) is a numerical tool that is frequently used to study the behaviour of structures in different situations. Its aim is to break down a complex structure into small finite elements, which facilitates calculations and gives accurate results.State of the method the main concept of FEM is to represent a structure using mathematical equations that describe how it works. These equations are then solved numerically using computer techniques. This makes it possible to study structures that are subjected to various stresses, taking into account their geometry, material characteristics and loading conditions [9, 10].

In the last part of this work, we used numerical optimisation. The aim is to identify the most important factors affecting the maintenance and repair of structures in order to ensure proper monitoring before, during and after their actual use [11, 12].

2. MATERIAL

In this work, we used several materials commonly used in the field of fuel transport and the maintenance of special pipes used for this purpose. We used materials whose characteristics are listed in the following table.

Table 1: Mechanical Characteristics of the Plate

	E_1 (GPa)	E_2 (GPa)	E_3 (GPa)	V_{12}	V_{13}	V_{23}	G_{12}(GPa)	G_{12}(GPa)	G_{12}(GPa)
Patch(carbon/	150	25	25	0.21	0.21	0.21	7.2	5.5	5.5
Adhesive(FM73)	2.55			0.32					
Pipe(SA312type304)	204			0.3					

3. NUMERICAL SIMULATION

ABAQUS is structured into several modules. A complete ABAQUS simulation of a project is carried out by successively working through these modules. We will try to present the main ABAQUS modules.

Let's take a look at the main ABAQUS modules. Let's consider repairing a pipeline using a composite patch. The outside diameter of the pipeline is Do= 620mm and the inside diameter Di= 480 mm; the thickness of the adhesive ec=0.15mm; the thickness of the patch ep=4 mm. The applied load and pressure is F= 50MPa and P= 100MPA (Fig.1.). The following table shows the properties of the parts to be modelled.

Depending on the case, an analysis may comprise one or more Steps. The choice of mode can be static, general (for a static analysis) or explicit dynamic (for crash or impact studies).

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The analysis consists of two Steps in total: The first step, generated automatically by ABAQUS/CAE (Fig.2.), applies the boundary conditions in terms of displacements (embedding).The second analysis step applies a pressure of 100 MPa and a force of 50 MPA.

In our case, we create a Step for our part in order to simulate its static response under a load of 50MPa and a pressure of 100MPA.

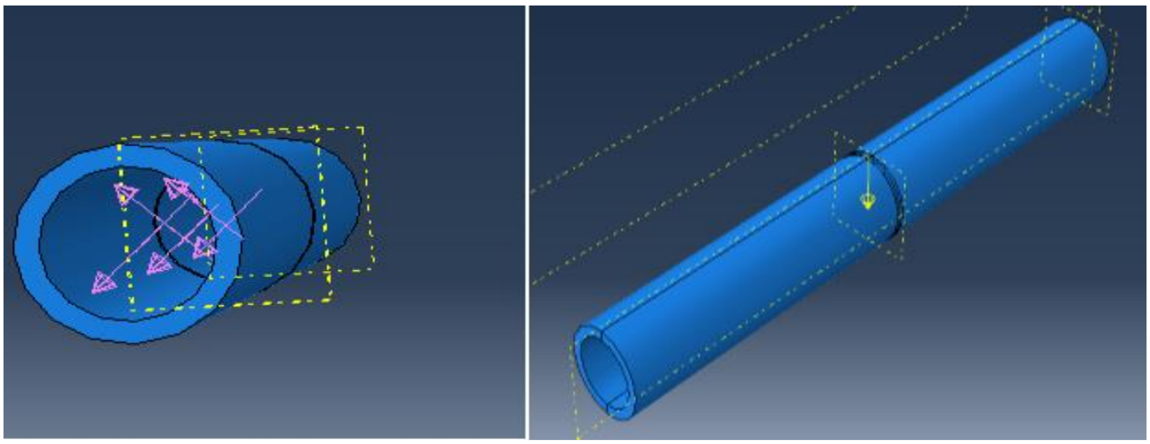

Figure 1: Applying Pressure and Force

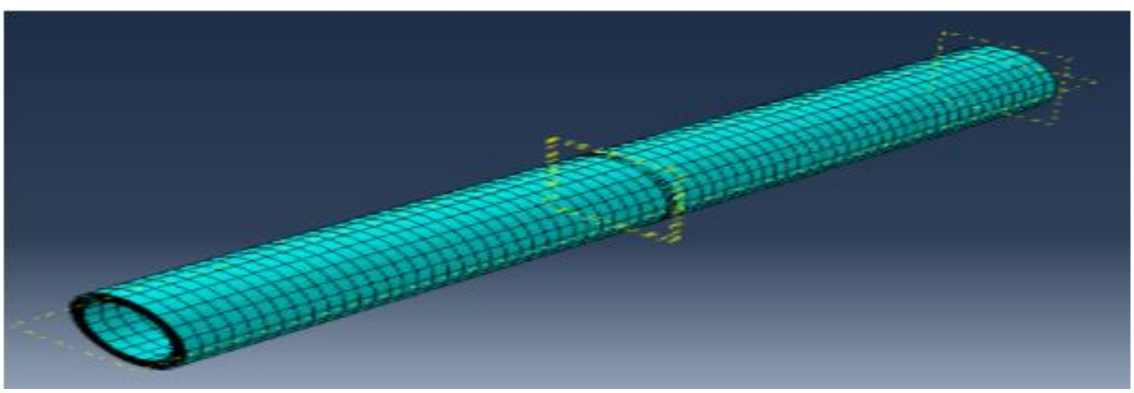

Figure 2: Numerical Modelling

4. NUMERICAL OPTIMISATION

We used numerical optimisation to predict the most important factors influencing pipeline repair for immersion during 10 days-30 days-90 days, and we used modde5 software from the results ulistrated from ABAQUS software it is represented in the following table

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Worksheet

	1	2	3	4	5	6	7	8
	Exp No	Exp Name	Run Order	Incl/Excl	E	ep	cont	J
3	3	N3	2	Incl	125000	2	147000	20
4	4	N4	17	Incl	125000	2	147000	20
5	5	N5	5	Incl	134000	2	135000	17
6	6	N6	12	Incl	134000	2	135000	17
7	7	N7	8	Incl	122000	3	152000	19
8	8	N8	13	Incl	125000	3	152000	17
9	9	N9	11	Incl	134000	3	129000	14
10	10	N10	3	Incl	122000	5	147000	16
11	11	N11	16	Incl	122000	5	147000	16
12	12	N12	18	Incl	125000	5	143000	12
13	13	N13	4	Incl	125000	5	143000	12
14	14	N14	15	Incl	134000	5	124000	7
15	15	N15	10	Incl	134000	5	124000	7
16	16	N16	14	Incl	134000	5	124000	7
17	17	N17	9	Incl	134000	5	124000	7
18	18	N18	6	Incl	134000	5	124000	7

Figure 3: Table of data

Optimizer

	Factor	Role	Value	Low Limit	High Limit
1	E	Free		122000	134000
2	ep	Free		2	5

	Response	Criteria	Weight	Min	Target	Max
1	cont	Minimize	1		122447	125710
2	J	Minimize	1		6,24815	7,75316

Iteration: 5000 Iteration slider:

	1	2	3	4	5	6
	E	ep	cont	J	iter	log(D)
1	134000	4,9998	124080	7,0013	4104	-0,6013
2	134000	5	124079	7,0008	3908	-0,602
3	134000	4,7	125195	7,8905	5000	-0,0223
4	134000	5	124078	7,0007	2296	-0,6021

Figure 4: Result of optimisation in the case of minimising outputs

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Coefficient List - cont

	1	2	3	4	5
1	cont	Coeff. SC	Std. Err.	P	Conf. int(±)
2	Constant	140375	2124,41	9,57523e-017	4628,66
3	E	-11744,1	704,54	1,15639e-009	1535,05
4	ep	-4571,07	647,423	1,31829e-005	1410,61
5	E*E	717,688	1820,6	0,700346	3966,73
6	ep*ep	-389,681	1759,04	0,828404	3832,59
7	E*ep	-308,943	715,791	0,673678	1559,57
8					
9	N = 18	Q2 =	0,929	Cond. no. =	7,7078
10	DF = 12	R2 =	0,974	Y-miss =	0
11		R2 Adj. =	0,963	RSD =	2406,6411
12				Conf. lev. =	0,95

Figure 5: Table for extracting the formula for minimising the maximum stress at pipe pressure

Cont=140375-11744, 1*E-4571, 07*ep+717,688*E^2-389,681*ep^2-308,943*E*ep

Where:

Cont: the maximum stress

E: young modulus

ep: thickness

Coefficient List - J

	1	2	3	4	5
1	J	Coeff. SC	Std. Err.	P	Conf. int(±)
2	Constant	13,581	0,299413	8,59822e-015	0,652363
3	E	-3,3644	0,0992977	2,77729e-013	0,21635
4	ep	-4,16071	0,0912477	8,07464e-015	0,198811
5	E*E	1,53323	0,256595	6,45745e-005	0,55907
6	ep*ep	0,374897	0,247918	0,156369	0,540165
7	E*ep	-0,963444	0,100883	5,87567e-007	0,219805
8					
9	N = 18	Q2 =	0,992	Cond. no. =	7,7078
10	DF = 12	R2 =	0,997	Y-miss =	0
11		R2 Adj. =	0,996	RSD =	0,3392
12				Conf. lev. =	0,95

Figure 6: Table for extracting the formula for minimising the integral J at pipe pressure

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J=13,581-3, 3644*E-4, 16071*ep+1, 53323*E^2+0, 374897*ep^2-0, 963444*E*ep

Where:

J: Integral J

E: young modulus

ep: thickness

5. CONCLUSIONS

In conclusion, the optimisation of composite patches to repair pipelines under the effect of moisture is a crucial process for ensuring the durability and quality of repairs in the long term. Composite patches offer an effective and economical alternative to repairing damaged pipes, and also make repairs easier and quicker.

However, moisture is a key factor that can have a significant impact on the performance of these patches. Composite patches need to be optimised for moisture, using techniques and materials that are moisture resistant and can protect the glass fibres or resins in the composite from the effects of moisture.

It is also important to consider other factors that can affect the performance of composite patches, such as temperature, pressure, handling and preparation of the pipe surface.

In short, to ensure the effectiveness and reliability of composite patches, it is essential to follow appropriate design and repair protocols, choosing materials and application techniques that are suitable for the installation environment, including humidity.

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