

Research Article

Investigation of Scraper Trap System by using Finite Element Method (FEM)

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Abstract

The purpose of this paper is to further the knowledge of pigging and scraper trap in terms of FEM as a powerful tool. Where reaction forces and expected displacements have been investigated, consequently a new particular design has been suggested for a pig in scraper trap system, thereafter some concluded points have been illustrated clearly

Keywords: Scraper Trap System, FEM etc.

1. Introduction

Scraper trap (launcher and receiver) is very useful part in pipeline (in oil field) and it is affected on the efficiency of pipeline directly. We will discuss the reasons for pigging for a special available type of pig to accomplish our pigging objectives. Where most companies would not pig on a regular basis; as the years passed and the capacities of the pipelines increased but the efficiency of the lines decreased; the decrease in efficiency relates to increased power costs; so the lines were pigged to increase the efficiency. As pipelines get older we see increased corrosion. This is caused by lack of operational pigging. Whether it is because of water accumulation in the line causing or paraffin accumulation on the walls, or other reasons.



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Fig.1 Manufactured Trap and Pigs

So, we begin pigging the line to clean it or batch inhibitors, etc. So, for the importance of this useful part of pipeline a few aspects have been investigated by using finite element method. Scraper trap and several selected pigs have been illustrated in the above figures:

What is pig in scraper trap: A pig is defined as a device that moves through the inside of a pipeline for the purpose of cleaning, dimensioning, or inspecting this definition covers in excess of 500 different designs and types of pigs; see fig. (2).

Why pig a pipeline: There are various reasons to pig a pipe-line after the pipeline is built. It will be necessary to run pigs to remove any debris left in the line from new construction items such as lunch boxes. Tools welding rods and dead animals trapped in the line etc. pigging will also remove mill scale or welding icicles in the line. The owner may also require a pig to verify the ovality of the pipeline, this will require a special type of pig.

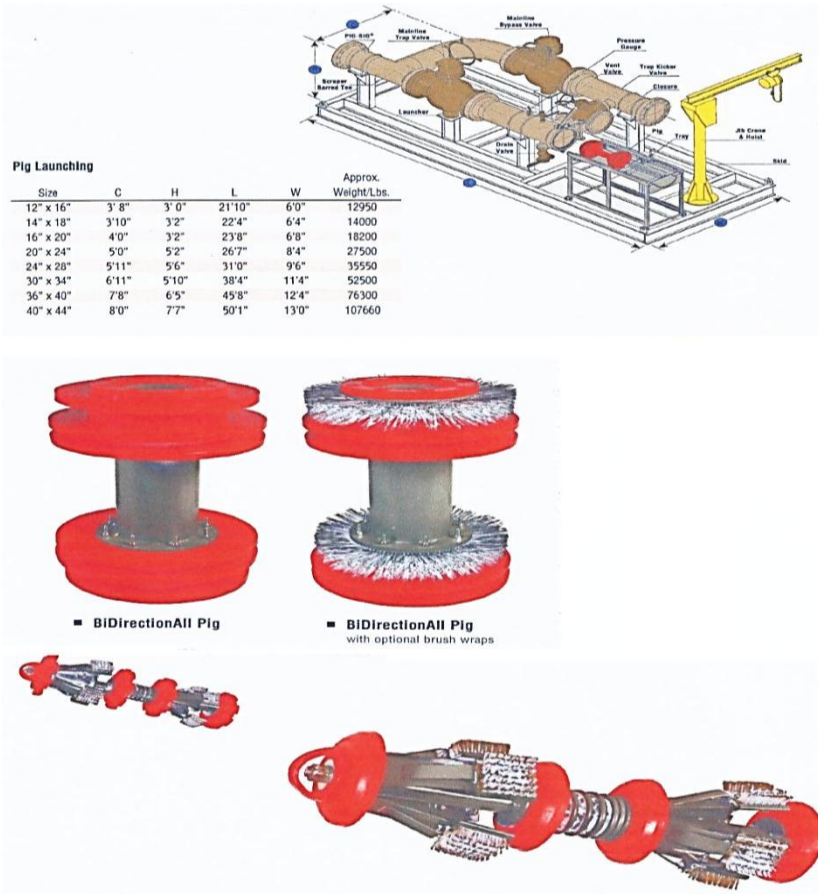


Fig.2 Scraper trap dimensions with several types of pigs for well-known company have been illustrated

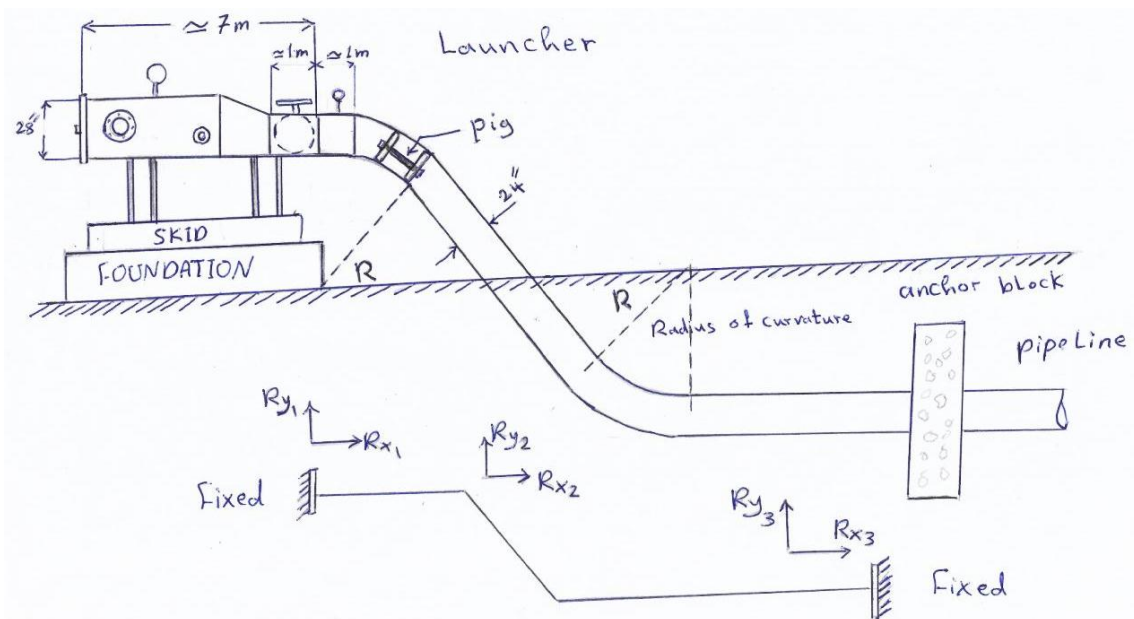


Fig.3 Demonstrate the Pigging Procedure of the Case Study

After the pipeline has been cleaned, the next phase is acceptance testing where pigs are used for filling the line with water for hydrostatic testing. Dewatering (removing the water after testing), and drying if it is a liquid line, a pig is used to fill the line with a product during the commissioning and startup of the line.

When the pipeline is in service, it will be necessary to pig the line to maintain line efficiency and aid in the control of corrosion. It is necessary to remove the liquids in wet gas system remove accumulated water in product pipelines, and paraffin removal and control in crude oil pipelines, Pigs are also used to batch

inhibitors; the following depict (fig. 3)state the route of the pig in pipeline.

As well as the following figure (fig.4) represent debris as a sequence of pigging.

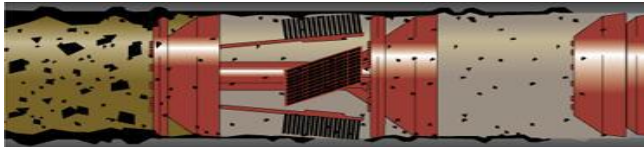


Fig.4 Pig with Debris

Specification of Case Study

1. Pipe API 5LX42 (Carbon steel pipe).
2. LSAW (Longitudinal submerged arc welding)
3. Hot bends considered as a part of this (i.e.same specification)
4. Diameter of pipeline, hot bends & minor part of launcher trap = 24",diameter of major part of launcher trap = 28",Thickness of pipe (t) = 11.1 mm , Young modulus E = 200GPa
5. Bidirectional pig weight =(around 100 kg) (T.D.W.)
6. Pipe line has been built for crude oil service.

Two cases have been investigated by using finite element method where stiffness matrix has been established, thereafter displacements and reaction forces has been estimated to focus on the effect of these displacement and forces upon trapping system consequently a new suggested design of pig has been suggested ina manner these displacements and forces will be diminished

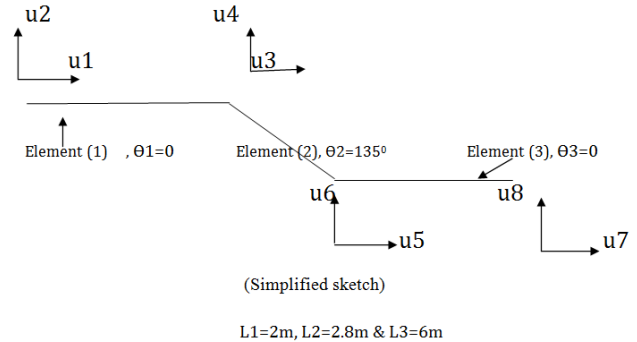
1. 1stcasewe consider a hot bend with radius of curvature equal to 15 D (where an action force practically estimated to be equaled to 1.7 times pig weight (i.e. = 1666N)).
2. 2ndcasewe consider a hot bend with radius of curvature equal to 30 D (where an action force practically estimated to be equaled to 2 times pig weight (i.e. = 1960N)).

Finite Element (FE) Analysis

By using FEM the following matrix has been used as an examination tools to estimate the displacements and reaction forces in the system.

$$[K^{(e)}]=Ke \begin{bmatrix} C2 & SC & -C2 & -SC \\ SC & S2 & -SC & -S2 \\ -C2 & -SC & C2 & SC \\ -SC & -S2 & SC & S2 \end{bmatrix}$$

Where Ke = EA/L (characteristic axial stiffness & the element) and: (C = COS θ , S = SIN θ)



$$[K^{(1)}] = EA \begin{bmatrix} 0.5 & 0 & -0.5 & 0 \\ 0 & 0 & 0 & 0 \\ -0.5 & 0 & 0.5 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$[K^{(2)}] = EA \begin{bmatrix} 0.177 & 0.177 & -0.177 & -0.177 \\ 0.177 & 0.177 & -0.177 & -0.177 \\ -0.177 & -0.177 & 0.177 & 0.177 \\ -0.177 & -0.177 & 0.177 & 0.177 \end{bmatrix}$$

$$[K^{(3)}] = EA \begin{bmatrix} 0.166 & 0 & -0.166 & 0 \\ 0 & 0 & 0 & 0 \\ -0.166 & 0 & 0.166 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$[K_{Global}] =$

$$EA \begin{bmatrix} 0.5 & 0 & -0.5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.5 & 0 & 0.677 & 0.177 & -0.177 & -0.177 & 0 & 0 \\ 0 & 0 & 0.177 & 0.177 & -0.177 & -0.177 & 0 & 0 \\ 0 & 0 & -0.177 & -0.177 & 0.354 & 0.177 & -0.166 & 0 \\ 0 & 0 & -0.177 & -0.177 & 0.177 & 0.177 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.166 & 0 & 0.166 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$[K_{Global}][U] = [R]$

Boundary Conditions (B.C.):(u1, u2, u5, u6, u7 & u8) =0

Area (c.s.) = $\frac{\pi di^2}{4} = 0.0208 \text{ m}^2$, E = 200GPa

$[K] = EA \begin{bmatrix} 0.677 & 0.177 \\ 0.177 & 0.177 \end{bmatrix} \begin{bmatrix} u3 \\ u4 \end{bmatrix} = \begin{bmatrix} 1960 \\ 0 \end{bmatrix}$

$u3 = 9.4 \times 10^{-7} \text{ m}$, $u4 = -9.4 \times 10^{-7} \text{ m}$

To find the reaction at 2ndhot bend (Rx3, Ry3)

$K53u3 = Rx3 = EA (0.177)(9.4 \times 10^{-7})$

$K63u3 = Ry3 = EA (0.177)(9.4 \times 10^{-7})$

$Rx3 = Ry3 = 693.8N$

$\frac{Rx2}{Rx3} = \frac{1960}{693.8} = 2.8$

For the second case action force considered as 1.7 times of pig weight (estimated roughly but practically in the site).

$[K] = EA \begin{bmatrix} 0.677 & 0.177 \\ 0.177 & 0.177 \end{bmatrix} \begin{bmatrix} u3 \\ u4 \end{bmatrix} = \begin{bmatrix} 1666 \\ 0 \end{bmatrix}$

$u3 = 8 \times 10^{-7} \text{ m}$, $u4 = -8 \times 10^{-7} \text{ m}$

To find the reaction at 2ndhot bend (Rx3, Ry3) you have to follow the global stiffness matrix, as indicated here under

$$K_{53u3} = R_{x3} = EA (0.177)(8 \times 10^{-7})$$

$$K_{63u3} = R_{y3} = EA (0.177)(8 \times 10^{-7})$$

$$A_{sR_{x3}} = R_{y3} = 589.7N$$

$$\frac{R_{x2}}{R_{x3}} = \frac{1666}{589.7} = 2.8$$

Displacement In 1st case $u_3 = 9.4 \times 10^{-7}$ m

Displacement In 2nd case $u_3 = 8 \times 10^{-7}$ m

$$\frac{\text{Displacement In 1st case}}{\text{Displacement In 2nd case}} = 1.175$$

It is clear that the displacement has been reduced by 17.5% comparing with 1st case.

New Recommended Design of Pig (With Spring)

Springs are energy absorbing unites whose function it is to store energy and restore it slowly or rapidly depending on the practical application.

In motor vehicle applications the springs act as a buffers between the vehicle itself and the external forces applied through the wheels by an even road conditions. In such cases the shock loads are converted into strain energy of the spring and the resulting effect on the vehicle body is much reduced (hearn) the same idea and applications have been illustrated in the new suggested design of pig where the assumed action force in case (1) and (2) (1960N&1666N) that causes a tiny displacement ($u_3=9.4 \times 10^{-7}$ for 1st case) and ($u_3=8 \times 10^{-7}$ for 2nd case) respectively upon the hot bend (above ground) at which u_3 is located; for practical convenience we was so keen to select a spring in a manner to be compatible with our case study and to be available practically.

Specification of Spring for Practical Convenience

Max compression of the spring is limited to 250 mm (much safer than usual but we are sure it is convenience to the practical case).

The reaction force in the 1st case is more suitable to be selected = 1960 N for comparison.

The specification of spring described hereunder

1. (Max. compression of spring, max. stress, $G \& R=8r$) are selected from example in (Hearn book) which is compatible with practical consideration.
2. A closed helical spring is required to absorb (2.25×10^3) joules and (18000 N) of energy, the following assumption have been considered :
3. T_{max} (maximum shear stress is not to exceed 400 MN/m²)
4. The max. compression of spring is limited to 250 mm.
5. The mean diameter of the spring can be assumed to be each times that of the wire (i.e. $R=8r$)
6. For the spring material : ($G=70 \text{ GN/m}^2$, $D= 240 \text{ mm}$, $r=15 \text{ mm}$, $n=7$)
7. Total expected deflection (δ) = 250 mm

The reasons that's lead to select this spring (specification) are illustrated hereunder

The assumed action force on the hot bend is equal to 1960 N (around twice times of its weight) whereas the selected spring had been designed to bear 18000N (i.e. = 9 times of assumed action force) in other word a little bit consideration had been taken, such as as lightly friction force with internal surface of the pipe plus accumulated debris plus fluid pressure and misuse of the valve in kicker line (i.e. opening it completely instead of opening it partially (so this mistake should be prevented during execution) adding to this the safety factor; see fig.(5)

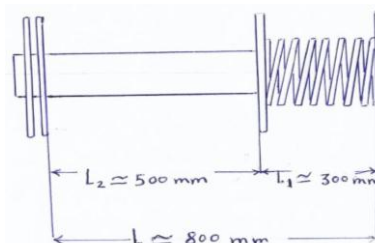


Fig.5 New Suggested Design of Pig

A little consideration will show that the cost of spring is much lesser than any damage that may be happened in the system as sequence of design mistake that may be appeared in the foundation of the scraper trap (launcher or receiver) during pigging due to reaction force of pig (RX2) or due to mistakes that may be done by workers during pigging process that causes a damage in the joint between launcher skid and foundation which is connected by bolts (see fig. 3).

A little consideration will show also that the new suggested design will diminish the reaction effect force where this force (multiplied by disp.) will be converted to strain energy in the spring that is assumed in the pig (this action will be occur at 1st hot bend and second hot bend) so that any expected disp.(u_3) will be occur at the pig spring and the effect will not be transmitted to the foundation bolts.

Conclusions

1. It is found out clearly that in case (2) the reaction force and displacements will be eliminated, furthermore we found out that the displacement (regarding 1st hot bend) was eliminated in 2nd case by around 17% comparing with 1st case.
2. The reaction force at 1st hot bend is equal to around 2.8 times the reaction force at 2nd hot bend for each case where the first bend absorb the most impact pigging force.
3. A new suggested design of pig has been recommended that diminish the displacement and reaction forces on the hot bends where all the reaction forces and displacements will be converted into the selected spring as strain energy.

References

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