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Analysis of Pressure and Energy on Oil Flow Requirements in Oil Pipelines: "A Case Study of the Al-Feel Oil Field, Libya"

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تحليل ضغط النفط ومتطلبات الطاقة في خطوط انابيب النفط "دراسة حالة في حقل الفيل للنفط ليبيا"

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Abstract:
With the increasing global demand for energy, the transportation of oil and gas has become a critical component of energy infrastructure. As exploration and production activities extend into more remote and challenging environments, efficient and reliable pipeline systems are essential for ensuring a continuous supply of crude oil and natural gas to processing and consumption centers. However, transporting fluids over long distances presents several technical challenges, particularly due to variations in fluid properties and operational conditions. Key factors such as viscosity, density, temperature, and the internal friction of pipeline surfaces significantly influence flow behavior and pressure drop along the pipeline. These variables must be carefully accounted for during the design and optimization of pipeline systems to minimize energy losses and operational costs. In particular, changes in temperature and composition of crude oil can alter its rheological properties, affecting pump efficiency and flow stability. This study focuses on analyzing the performance of an 800 km crude oil pipeline in Libya under varying operating and fluid conditions. To identify the optimal flow parameters that maximize energy efficiency and reduce power consumption, ASPEN HYSYS software was employed to simulate pipeline operations and evaluate the impact of changing fluid and pipeline properties on pressure, temperature profiles, and energy requirements. The results provide valuable insights for improving pipeline design and operational strategies in similar settings

Keywords: **Oil transport, Flow behavior, Bernoulli model, Pipe roughness**

الملخص
مع تزايد الطلب العالمي على الطاقة، أصبحت عملية نقل النفط والغاز أحد المكونات الأساسية للبنية التحتية للطاقة. ومع امتداد أنشطة الاستكشاف والإنتاج إلى مناطق أكثر بُعدًا وصعوبة، أصبحت أنظمة خطوط الأنابيب الفعّالة والموثوقة ضرورية لضمان الإمداد المستمر بالنفط الخام والغاز الطبيعي إلى مراكز المعالجة والاستهلاك. إلا أن نقل الموائع لمسافات طويلة يواجه العديد من التحديات الفنية، لا سيما نتيجة التغيرات في خصائص الموائع وظروف التشغيل. وتؤثر عوامل رئيسية، مثل اللزوجة والكثافة ودرجة الحرارة والاحتكاك الداخلي لأسطح خطوط الأنابيب، بصورة ملحوظة في سلوك الجريان وانخفاض الضغط على طول خط الأنابيب. ولذلك، يجب أخذ هذه المتغيرات في الاعتبار بدقة عند تصميم أنظمة خطوط الأنابيب وتحسينها بهدف تقليل فقد الطاقة وتكاليف التشغيل. وبصفة خاصة، يمكن أن تؤدي التغيرات في درجة الحرارة وتركيب النفط الخام إلى تغيير خصائصه البيولوجية، مما يؤثر في كفاءة المضخات واستقرار الجريان. تركز هذه الدراسة على تحليل أداء خط أنابيب لنقل النفط الخام بطول 800كم في ليبيا تحت ظروف تشغيل وخصائص مختلفة للموائع. ولتحديد معاملات الجريان المثلى التي تحقق أعلى كفاءة في استخدام الطاقة وتقلل من استهلاك القدرة، تم استخدام برنامج ASPEN HYSYS لمحاكاة عمليات تشغيل خط الأنابيب وتقييم تأثير التغير في خصائص المائع وخط الأنابيب على توزيعات الضغط ودرجة الحرارة ومتطلبات الطاقة. وتوفر نتائج الدراسة رؤى مهمة يمكن الاستفادة منها في تحسين تصميم خطوط الأنابيب واستراتيجيات تشغيلها في البيئات والظروف المماثلة.

الكلمات المفتاحية: النفط والغاز، خطوط انابيب النفط، خشونة خطوط الانابيب

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Introduction

Flow of fluids in pipes is a major engineering subject and is well covered in basic engineering courses. However, the complexity of this subject is noticed from the huge size of research efforts by people working in this field. Fluids, in any process, can be either single phase or more than one phase flowing simultaneously. A major part of the energy available today is through hydrocarbon reserves, mainly oil and gas deposits. The development of offshore and onshore drilling technology has allowed these reserves to be tapped. These hydrocarbon reservoirs are produced, drained and transported over large distances through pipelines. During the life cycle of a crude oil pipeline, the properties of transported oil change, because in gathering systems the produced oils come from different wells. New wells may be added, or some wells may go out of production for maintenance and repair. Production rates during the life of wells vary, too. In addition, the properties of crude oil change during production. Due to seasonal variation, the average line temperature may also change. viscosity of crude oil is a strong function of API gravity and temperature.[2] So, flow Assurance is the discipline dealing with the risks in oil and gas production arising from the properties and behaviour of the transported fluids. The efficient operation of pipelines transporting hydrocarbons is crucial. Any change to the internal pipe surface significantly impacts both the pipeline through-put and energy requirements for maintaining design flow rates [2].

Material and methods

<u>Principles Of Fluid Flow:</u>

Fluid flow in pipes is governed by both material and energy balances. For a given system such as a segment of pipe, material and energy balance equations are used to develop design equations for the system.

Material Balance: Material balance on system shown on Figure 1 means that:

$$\sum mass\ into\ system =$$

$$\sum mass\ out\ of\ system + mass\ accumulation$$

For constant cross section: $$PV_1 = PV_2 + {d(PV)}/{dt} \dots\dots\dots\dots\dots\dots\dots\dots..(1)$$

For steady state flow, accumulation of mass in system is zero.

$$PV_1 = PV_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(2)$$

This equation is applied for any flowing phase, either liquid or gas, when only one single phase is flowing. This equation is also applied to each phase when two phases are flowing in the same pipe but assuming no mass transfer between phases occurs. This equation is applied for any flowing phase, either liquid or gas, when only one single phase is flowing. This equation is also applied to each phase when two phases are flowing in the same pipe but assuming no mass transfer between phases occurs.

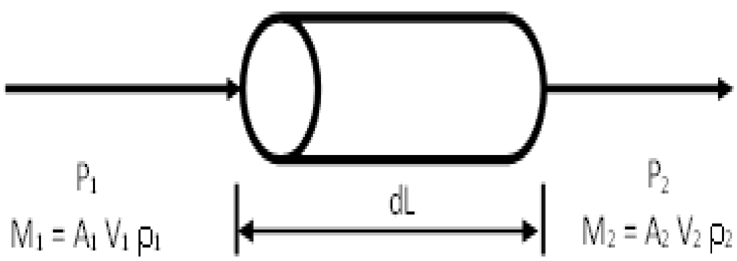

Figure 1: System Boundary for Material Balance

Results and discussion

Produced oil at Al-Feel Oil Field is pumped into a 24",75km pipeline and then into 30",625km pipeline to Melita. Figure (1) shows the elevation and pressure profiles for the existing pipeline. The figure shows the elevation profile along the pipeline. Significant elevation variations are observed, with the elevation decreasing from about 3100 ft at the beginning to nearly zero at the end. These changes affect flow pressure and pumping energy requirements, as shown in Figure 2. This should be considered in pipeline hydraulic calculations. Whereas, Figure (3) presents the required pumping horsepower (HP) as a function of oil flow distance for the Al-Feel pipeline. The results show that the required pumping power increases with increasing flow rate because higher flow rates lead to greater frictional pressure losses along the pipeline. Therefore, increasing the flow rate requires higher pumping energy to maintain the desired oil transportation rate

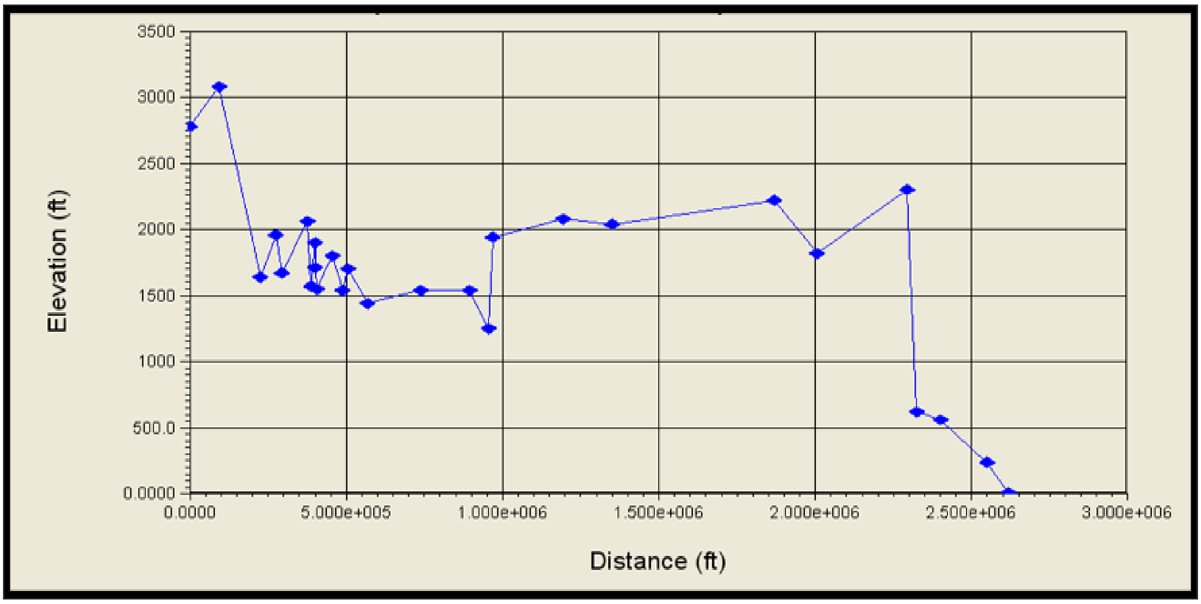

Figure 1: The elevation profile for the pipeline

Figure 2: The pressure profile for the pipeline

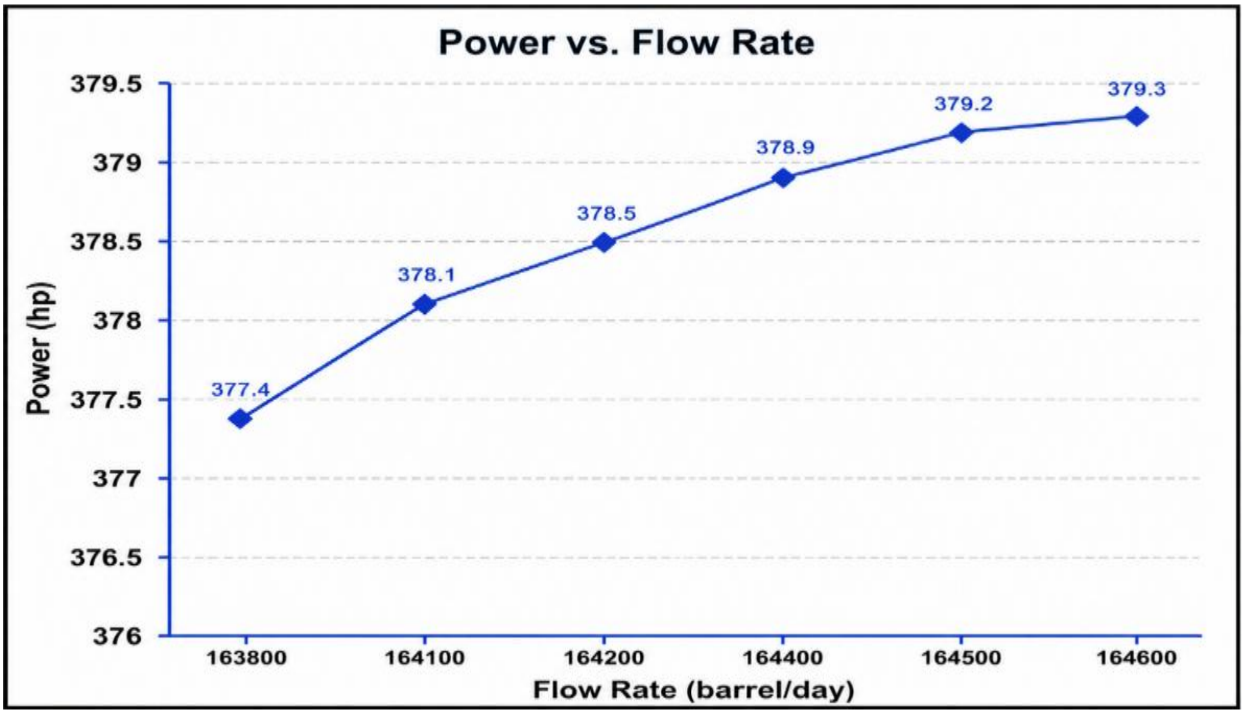

Figure 3: The required HP for pumping versus oil flow rate.

Figure 4 presents the effect of temperature (F) on the pipeline length in (m) along the 30-in, 800-km pipeline. The results indicate that the inlet fluid temperature has a noticeable effect mainly in the initial section of the pipeline, after which its influence gradually decreases due to heat transfer with the surrounding environment. Consequently, the effect of inlet temperature on the required pump horsepower (HP) becomes limited over long pipeline distances.

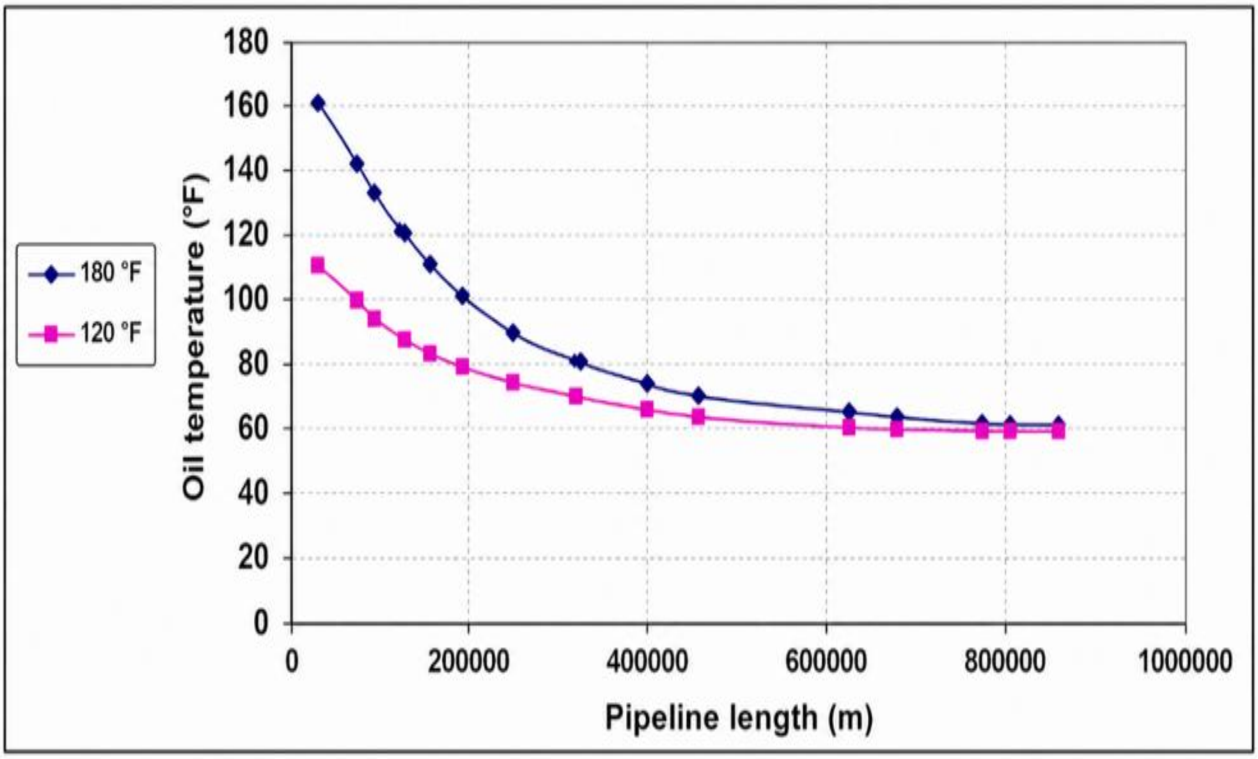

Figure 4: Oil temperature with pipeline length

Conclusion

Based on the results of this work, the following conclusions are presented

a. An increase in inlet temperature results in a reduction of oil viscosity and density. This results in less pressure drop and less pumping energy (HP).

b. Inlet oil temperature has a strong effect on fluid flow through long-distance pipelines.

c. Drag reduction chemicals would have a significant effect on fluid flow in pipes through the reduction of pipe roughness and the friction factor.

Heating of high pour point crude oil would result in a significant loss from the storage tank

Future perspectives

Based on the results obtained from this research, this study has sought to delve into the intricate and multi-faceted physics governing Oil and gas flow within pipelines. While it has provided crucial insights for the development of efficient energy systems and ensuring the safety of Oil and gas transport, it has also brought to light notable research gaps in leakage modelling. Understanding the distinct fluid dynamic behaviours resulting from OIL low viscosity and high diffusivity is vital, yet further exploration is needed. Recognizing the challenges and safety concerns associated with oil and gas transportation, this review emphasizes the need for more detailed investigations into Oil and GAS leakage during pipeline transport under varying conditions.

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