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RISER SYSTEM WEAR – AN UNRECOGNIZED DRILLING RISK

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In recent times, drilling in water depths of 3,000 – 5,000 feet have been attacked and exceeded. Times and technologies have changed, but we may have left a gap in the planning which could create a significant risk to both safety and well control. That gap arises through increased unidentified wear occurring in the riser system.

In 1999 Maurer Engineering Inc. (MEI) investigated a major riser failure in the Gulf of Mexico. It occurred in a new riser, operating for less than 200 hours, in 6,700 feet of water. A sample of the failed riser was subjected to comparative wear testing and found to wear over 15 times faster and almost 5 times greater than the N-80 which was used as a testing standard. Immediately, questions arose about the riser, its metallurgical composition, heat treatment, and physical characteristics at increased depths. Focus was then turned to the magnitude of the problem, and solutions for many riser strings in use in the Gulf of Mexico and elsewhere.

Identified as a drilling engineering problem, wear in the riser is dependent upon: control of the lower flex joint offset angle above the BOP, the drill string used, the tension loads on the riser and the drill string, and any side load on the riser. Wear can occur in several places in the riser system, but is most prevalent within 50 feet from the lower riser section connection to the flex joint. Wear progress can also carry through the flex joint, and if unrecognized, into the BOP. This leads to significant safety and financial concerns regarding component damage and well control problems.

Thus, MEI initiated a Drilling Engineering Association study to minimize wear in deepwater risers, flex joints and BOPs. Investigative efforts revealed that riser wear was not separately reported, but has usually been included as a cost of drilling a well. Before alternative materials, coatings and linings are being tested and evaluated, the appropriateness of using modified X-80 line pipe as drilling riser tube in deep water in questions. This ongoing riser system wear study and its anticipated findings provide a unique opportunity for the drilling industry to solve a growing problem before it becomes a major threat to deepwater drilling.

INTRODUCTION

In the Spring of 1999, while drilling offshore for BP in the Mississippi Canyon, of the Gulf of Mexico, at a water depth of approximately 6700 feet, a Transocean Offshore Inc. crew was rotating a new drill string at 120 - 150 rpm. A decline in riser fluid pressure and the inability to keep their new, 21 inch OD steel riser full, indicated a serious problem after less than 150 hours of drilling (Figure 1). An ROV confirmed a rupture had occurred in the riser during these very few hours of operation (Figure 2). Analysis of the 75 foot long riser section above the flex joint revealed the riser wall had worn thin and burst under pressure. The riser offset angle to the drilling rig was confirmed at 1-½ degrees, which should have been acceptable. The protective hardmetal applied to the tool joints was new, factory installed, on new tool joints and was not considered excessively damaging to casing or riser sections. The question was, why did the riser wear so rapidly and cause this unexpected, costly, failure – which could have been disastrous! This and subsequent questions about protecting the entire riser system prompted worldwide discussions and the initiation of the DEA-137 project, entitled "Minimizing Wear in Deepwater Risers, Flex Joints and BOPs". The causes and potential solutions to reducing this unanticipated drilling risk are explained in this paper.

BACKGROUND

As specialists in determining casing and riser wear, Maurer Engineering Inc. was called upon to investigate the 1999 riser failure which occurred in the Mississippi Canyon. Initially MEI surmised the offset angle to the rig was in excess of 2-½ degrees, but all measurements confirmed the maximum angle was 1-½ degrees. It was also anticipated that the riser material would wear at a rate similar to N-80 casing which was used as a comparative testing standard.

However, a test was run on a small section of the failed riser, and it was found to wear at a rate 15 times faster and produced almost 5 times more wear than N-80 (Figure 3). Since the contractor had operated prudently, in accordance with the best accepted drilling practices, the causes of the problem were undetermined, but recognized as an undefined risk which seemed to occur in deep water.

While investigating the experience of others concerning riser wear, it was learned that in the UK sector of the North Sea, The Atlantic Margin Joint Industry Group (AMJIG) was formed in 1997 to establish guidelines for drilling riser integrity. 2H Offshore Engineering Limited was charged with responsibility to carry out the study and draft a report to the 21 oil company and drilling contractor participants in the group. The study revealed wear could enter into the picture in the Shetlands and the Atlantic Deep where turbulent and deeper waters exist. They also identified soft sub-sea soil conditions as a potential problem because they could effect the riser offset angle at the wellhead and the sub-surface casing alignment below the wellhead which could impart wear in the flex joint, the BOP and the casing (Figure 4).

Observations of other riser failures, the challenge of the Transocean riser failure, and the comments from the AMJIG Project prompted Maurer Engineering Inc. to prepare a joint industry study, DEA-137, entitled “Minimizing Wear in Deepwater Risers, Flex Joints and BOPs”. This two-year study has just commenced, but the investigative findings thus far are encouraging. The Project begins with defining the causes of wear and how to determine wear in the entire drilling riser system.

CAUSES OF WEAR

The primary cause of wear is the development of one or more doglegs in the riser, created by a side loading force. This force primarily results from the relative movement between the drilling vessel and the wellhead or sub-sea currents, and acts to change the relationship between the drilling vessel and the lower flex joint and wellhead assembly. Wear can also occur when there is a reduction in the internal diameters of matching components such as from the riser in the flex joint followed by the wellhead and the BOP. The rotating drill string within the riser is in tension, as is the riser, and the surfaces rubbing together will create wear in the interior wall of the riser where the dogleg exists (Figure 5). Wear in this instance will take the form of keyseating, and usually occurs within 50 feet of the lower flex joint. Unfortunately, if the wear bushings in the flex joint, or even in the BOP, do not diminish or absorb the wear pattern, severe damage can occur and may continue into the casing wall (Figure 6). Wear in any of these components can lead to leaking or failed components, danger to personnel and in the worse financial case, loss of the well. Drilling contractors and operators, as well as manufacturers of flex joints and BOPs, have confirmed our findings. These series of events describe the wellbore scenario.

The use of top drive drilling systems and the location of a flex joint below the moon pool also introduce opportunity for riser wear to occur in close proximity to these connections. With the increasing move into deeper waters, the problem becomes more complex. Higher riser tension loads, which are now reaching 3,000,000 pounds, add to the difficulty of maintaining a stable offset angle (Figure 7). When contractors drilled in water depths ranging from 500 to 3000 feet, an offset angle of up to 2-½ degrees was controllable and acceptable, but as water depths increase, the angle must be reduced to minimize potential wear (Figure 8). Several offshore contractors have determined that no more than 1 degree of offset is acceptable in waters over 5,000 feet deep.

A separate, area of riser wear which has had less impact on major damage, has been in the flanged connections which mate the riser sections. If the connecting bolts are not torqued properly or otherwise become loosened, the connecting surfaces will rub together and damage each other. Wear can become significant enough to cause leakage or damage to the riser assembly.

Prior to 1993, drilling riser was made from seamless, quench and tempered steel pipe. Double Submerged Arc Welded (DSAW) pipe, treated by a Thermal Mechanical Control Process (TMCP), was approved and introduced at that time for riser applications. Already produced in Japan as line pipe, it provided consistent wall thickness and could be readily formed from plate steel into a tubular. It also cost approximately 25-30% less than seamless material and thus began to replace the use of seamless risers. Working with US riser manufacturers, specifications were determined and agreed for risers, which then worked in maximum water depths of 3,000 – 4,000 feet. Today’s drilling riser is made overseas, mainly from grade X-80 DSAW line pipe with reduced carbon content and slightly modified chemistry to improve strength, fatigue and welding characteristics of the pipe. In view of the rapid rate of wear experienced with Transocean’s X-80 riser, comparative wear tests will be completed, with the assistance of the manufacturers of Japanese X-80 and European seamless riser pipe. This may result in recommendations to use seamless steel or other types of riser in the lower section adjacent to the flex joint to minimize the impact of wear.

IDENTIFICATION OF WEAR

In most instances the best way to identify riser and component wear is through the use of mud magnets and the interpretation of the observed steel cuttings. The rotating drill string will wear the inside of the riser system and the types of wear can be determined from the cuttings. Four types of wear can occur: galling, machining, grinding and polishing. Galling is adhesion failure caused by high lateral loads, no solids inn the drilling fluid and similar hardness levels in the tool joint and the riser or casing hardness (Figure 9). Machining is caused by the tool joint hardbanding, and specifically, the hard inclusions in the softer overlay matrix. When the matrix wears away, these inclusions are exposed and physically machine the internal wall (Figure 10). Grinding occurs when solid particles roll between the tool joints and the riser or casing. Strong particles, of sufficient size, and the absence of softer particles, leads to surface hardening, heat generation and the brittle failure of the steel (Figure 11). Polishing takes place when fine particles, trapped in a soft material, rub the interior walls and produce a very low wear rate. The relative wear rates of these four mechanisms are important: galling = 100, machining = 10, grinding = 1, and polishing = 0.001 (Figure 12).

The output from the mud magnets may indicate the degree of wear, and if the recovered cuttings reflect either machining or galling, severe wear is taking place.

Visual inspection of the riser may not be easy to accomplish. This is especially true in the reduced handling space provided on the designated deepwater rigs (Figure 13). End area and internal inspection of the riser sections may be impractical, but in situ inspection by wall logging and profile defining ultrasonic or electromagnetic systems have not been readily accepted or applied. Choices are limited, but some type of inspection equipment is becoming essential to minimize the risk of not identifying evolving wear problems. One of the objectives of the MEI project is to stimulate the development of improved riser wear inspection tools which is also extremely important to the LMRP, including the flex joint and the BOP. Although the cost of each riser section has increased significantly for deepwater drilling, inspection criteria today is usually established by the drilling contractor, but as we move into new environments, it is appropriate to seek the assistance of API in establishing guidelines for evaluating riser condition, wear, and integrity.

SOLUTIONS TO REDUCE THE RISK OF WEAR

To date only a small amount of information has been available regarding significant damage to the riser or riser system components. Attempts are being made to gather information from drilling contractors, operators and other sources which will be used to generate a data reference base. It is hoped this will bring to light the magnitude of existing wear problems, recognizing that deep and ultra deep water drilling have taken place within recent years (Figure 14). Usually, only when a major failure occurs is wear information addressed in detail, and that has not often been made available to the public. A generic, rather than an identified, approach is essential to this data gathering exercise to protect the interest of all parties. A significant finding is that most of the damage experienced in the riser system is addressed as a cost of drilling, and thus expensed to the well. This greatly restricts the amount of available information.

Although new riser steels and other materials will be considered for the long term solution to the wear problems, immediate attention must be paid to the many riser strings in use throughout the world. Thus investigation of various riser linings and coatings for the interior of risers is moving forward. We have identified that the significant wear areas in the riser system occur at doglegs and where there is an abrupt change in the passage of the drill pipe through the flex joint and into the wellhead and the BOP. If resilient or wear absorbing linings can be formed and secured in these areas, the risk of extreme wear will be reduced. To date, rubber sheeting has exhibited excellent characteristics, although it is subject to flaking or breaking into small pieces when rough tool joint surfaces are encountered. Ceramics, plastics, liquid and solid elastomers and special hardmetals are under consideration for testing. The major problem then becomes one of the physical application of the product within a 75 – 90 foot long riser section, and the in place repair of this product if it becomes necessary.

Action will soon be taken to determine if wear bushings in the upper and lower sections of the flex joint can be lined with resilient or alternative materials to minimize or eliminate wear. Retrievable BOP wear bushings, which have long been available to the drilling industry, may also be considered for use of this type of lining material. The objectives of the study will be to determine how well the wear will be absorbed and to assure that wear will not be transferred to connecting components in the well.

DRILLRISER, an improved riser wear model, based upon the findings of DEA-137, will be developed and tested for accuracy under different drilling conditions over the next 24 months. It will enable users to calculate riser wear and the strength of worn risers to ensure that risers do not fail as a result of unanticipated wear.

This ongoing study on “Minimizing Wear in Deepwater Risers, Flex Joints and BOPs” provides a unique opportunity for the drilling industry to identify and solve a growing problem before it becomes a major threat to drilling safety and economics (Figure 15).

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PERSONAL BIOGRAPHY

Thomas E. (Tom) Prosser has complied over 30 years of significant domestic and international management experience while functioning in various operations, engineering, manufacturing and marketing functions. An engineer by education at the Georgia Institute of Technology, he has held senior management positions in Reed Tubular Products Company, Baker Hughes Tubular Services Co., Hughes Tool Company, and Energy Ventures Inc. During the past five years, he has been engaged by Maurer Engineering Inc., in business development and the enactment and completion of DEA-42, Phase V, the MEI Casing Wear Technology project. Increased concern regarding several deepwater riser failures, prompted Tom to accept responsibility as Project Manager for the initiation of a new joint industry study, DEA-137. This two year long project is dedicated to the recognition of wear problems in the drilling riser system which have increased with the move of offshore drilling activities into deeper and/or more turbulent waters, and the seeking of solutions.

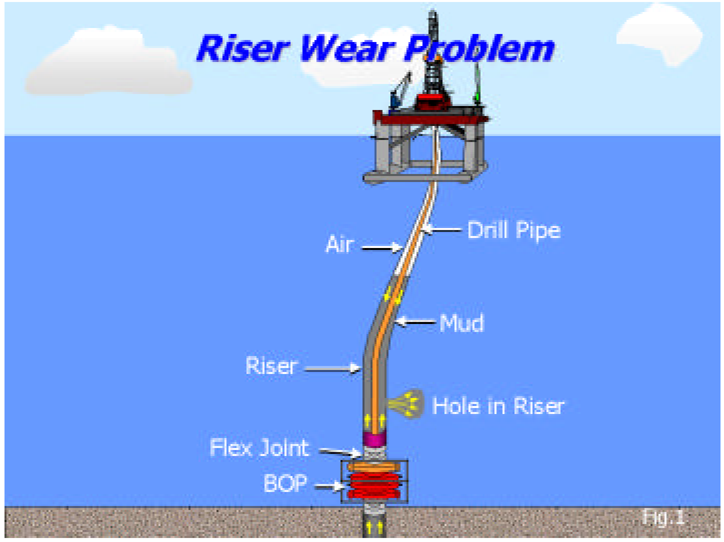
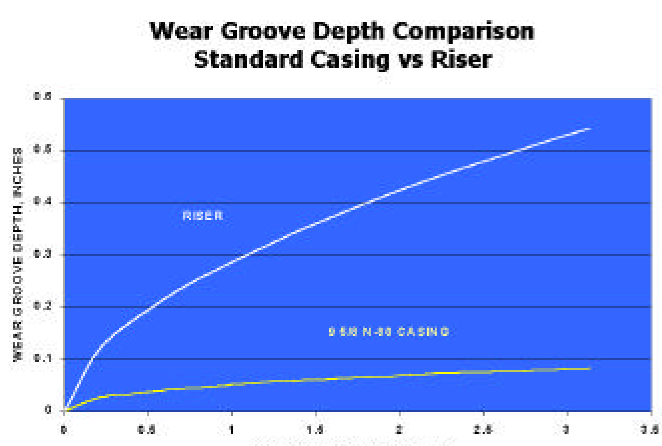


Fig.1

Fig.2



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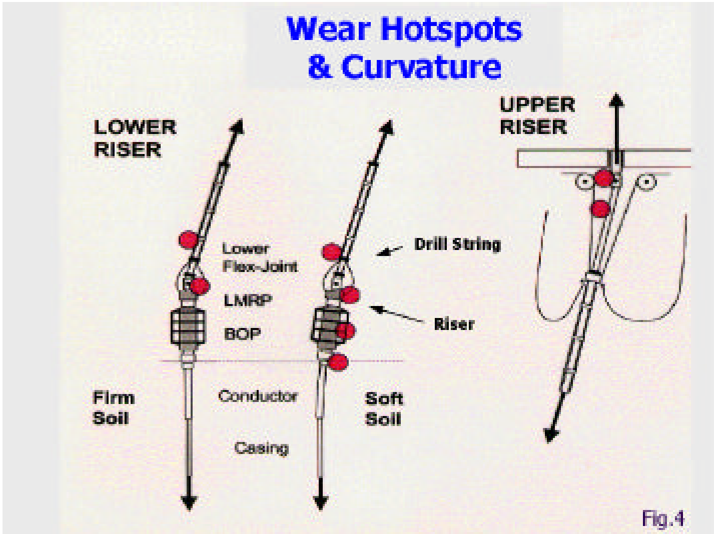

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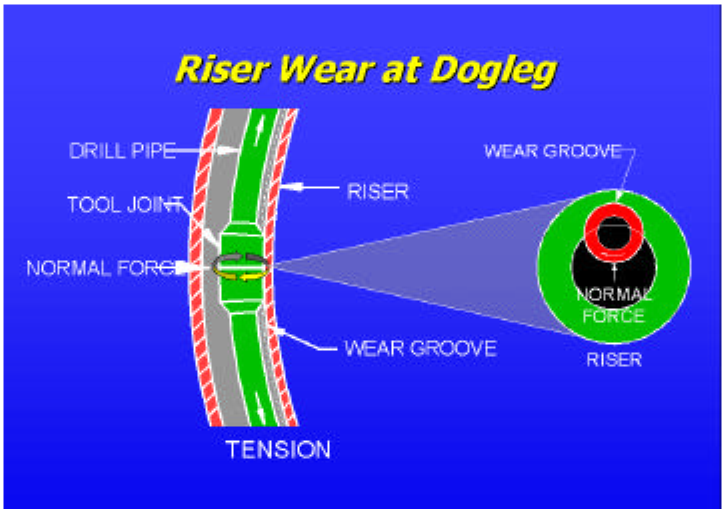

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Fig.6

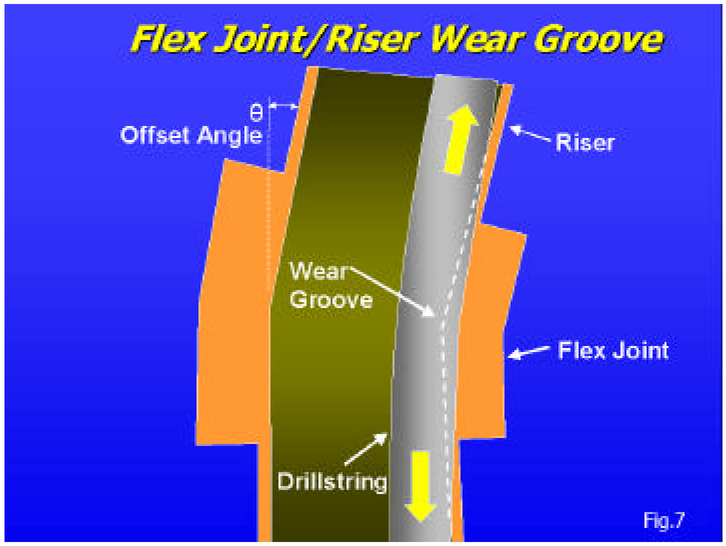


Fig.7

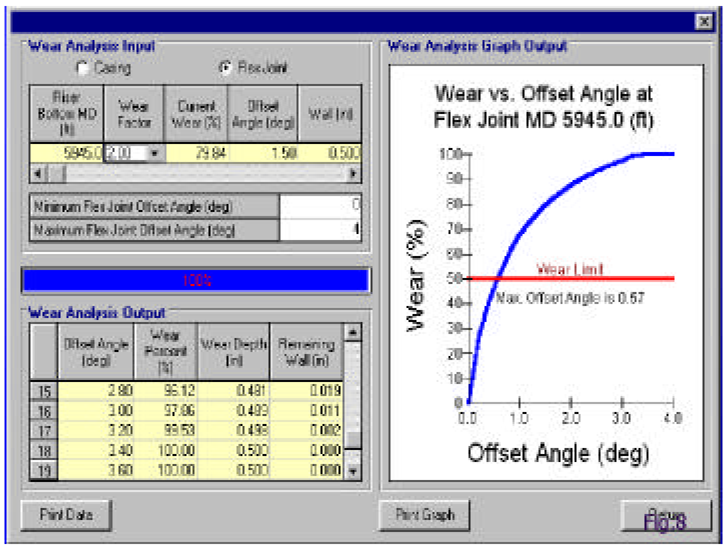
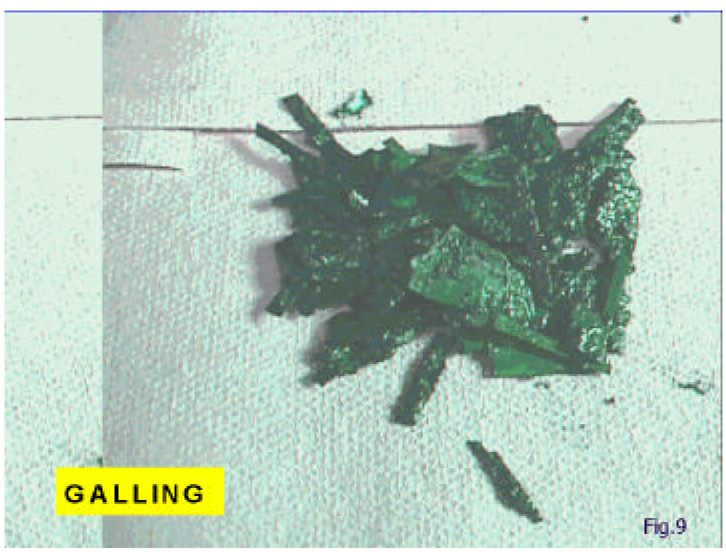


Fig.8



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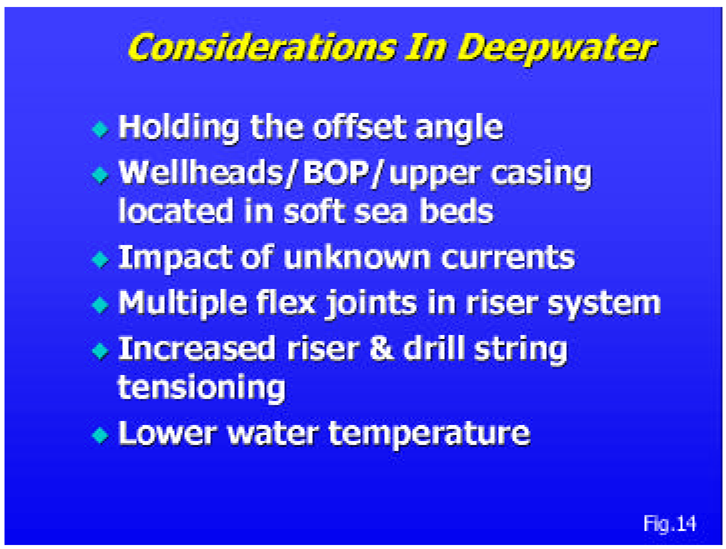

Fig.14

Fig.15