Effect of Ploughing Speed on Stress Development on the Steyr Tractor Lift System on Clay Loam Soil Of Bauchi-Nigeria in the Northern Guinea Savannah

S. Sule[1], M. G. Yisa[2] and C. N Ohanwe[1].

1. Agricultural Engineering Technology Department
Federal Polytechnic, Bauchi.
Bauchi State-Nigeria
Sulesamuel@yahoo.co.uk

2. Agricultural Engineering Department
Federal University of Technology, Minna
Niger State-Nigeria

ABSTRACT

Otmianowski, (1983) stated that all agricultural machines that work on the farm are exposed to the dynamic effect of undulating terrain as well as rolling friction on both loose soil and bed-like farmland. These and other factors all contribute to the development of stress on the agricultural machine elements which may either lead to breakdowns or failures of some parts. As part of an effort to investigate into the frequent failures of the Steyr tractor lift system, the effects of ploughing speed on the development of stress on the Steyr tractor lift system (stabilizers and brackets) on a clay loam soil of Bauchi-Nigeria in the Northern Guinea Savannah were investigated using quarter-bridge strain gauge circuit with temperature compensation. It was found that stress on these parts of the three-point linkage system increased with increase in speed of ploughing. The average stress values obtained were relatively higher when compared with the yield point stress ($0.23 kN/mm^2$) of bracket material. The use of a spring loaded 'U' bolt was found to reduce the stress.

Keywords: Ploughing, speed, stress, strain gauge, stabilizers, Nigeria.

1. INTRODUCTION

The three-point lift system is made up of the upper link, the right lower link and the left lower link. Fig.1 shows the connections in the Steyr tractor lift system. Barger *et al* (1963) stated that as with most other design problems, one best hitch system does not exist, but perhaps for a specific application.

Khurmi and Gupta (2002) stated that machine parts are subjected to various forces which may be due to either energy transmitted by the weight of machine, frictional resistances, inertia of reciprocating parts or change of temperature and lack of balance of moving parts. The different forces acting on a machine part produce various types of stresses. Stress (σ) is defined as the effect of force or load acting on a unit area of a body. Barger *et al* (1963) stated that when a tractor is being used to propel an implement which may strike an obstacle – for example a plough striking a rock - some provision must be made for protecting the implement, tractor and hitch from excessive stresses. Excessive stress development on machine parts can be destructive and every effort must be taken to prevent or eliminate this occurrence. Draught as an important parameter that contributes to the development of stress has been investigated by various researchers (Oni et al., 1992; Shirin et al., 1993; Fielke, 1996; Kushwaha and Linke, 1996; McKyes and Maswaure, 1997; Onwualu and Watts, 1998; Al-Suhaibani and Al-Janobi, 1997; Manian et al., 2000; Shrestha et al., 2001; Gratton et al., 2003; McLaughlin and Campbell, 2004; Mamman and Oni, 2005; Manuwa and Ademosun, 2007). Natsis et al. (2002) used tillage force dynamometer to measure draught of mouldboard plough in a clay soil.

The specific draught of agricultural tools and implements varies widely under different conditions. Strain gauges also known as electrical dynamometers are frequently used in mechanical engineering research and development to measure the stresses generated by machinery.

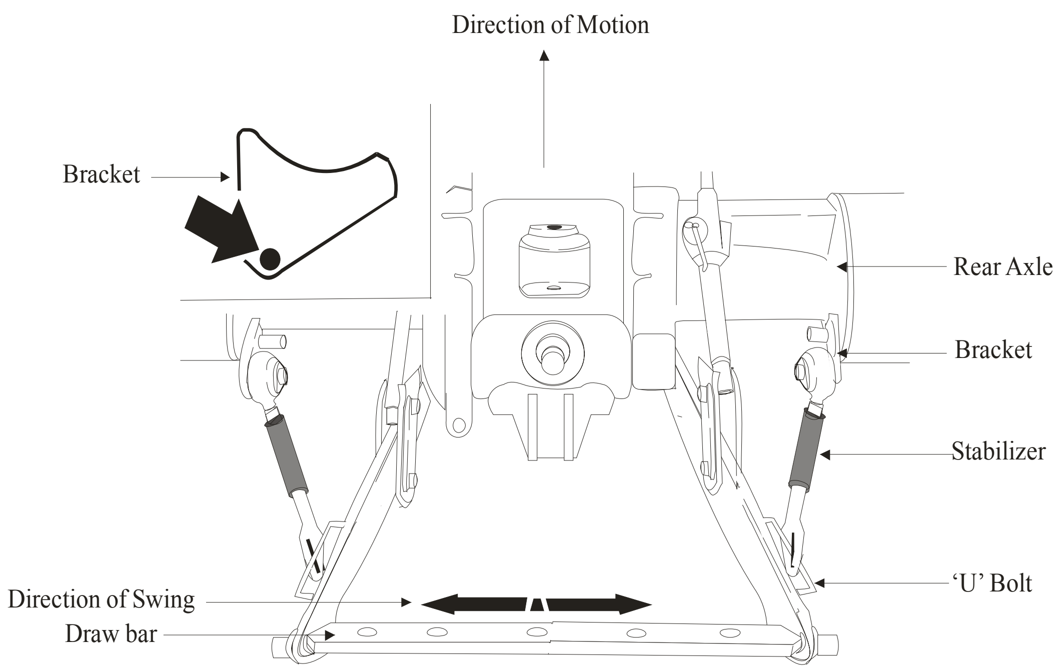

Figure1. Steyr Tractor Lift System

In the Steyr tractor lift system, the stabilizer (Figure 1) is the rigid type. The Steyr stabilizer at one end has an oval shaped ring connected through a 'U' bracket bolted to the lower link and at the other end is a ball ring connecting it to the triangular bracket bolted to the rear axle. The 'U' bolt connecting the stabilizer shaft to the lower link has a problem of much freedom for sideways swings of the stabilizer shaft. These sideways swings contribute to tractor instability both during transportation and operation. Mijinyawa and Adetunji (2005) stated that 61.8% of the farmers in Oyo and Osun states of Nigeria have access to only untarred roads and that farm roads were found to be very deplorable. This is not a problem limited to only that part of Nigeria alone but also to other parts; this part inclusive. Impact stress (shocks) resulting from the sideway swings have led to failures of some parts of the lift system such as the stabilizer bracket. This failure is in the form of breakages of either the pin or the bracket at the right hand side of the lift system which sometimes leads to the damage of the axle and may lead to the replacement of the entire axle. Preliminary investigations conducted in some establishments in Bauchi, Gombe and Plateau States of Nigeria showed that this is a prominent problem in the listed region not only existing in Steyr products but also in some other tractor makes.

The objective of this work is to verify the effect of speed of ploughing on the development of stress on the brackets and stabilizers of the three-point linkage system of the Steyr tractor on a clay loam soil of Bauchi in the Northern Guinea Savannah of Nigeria as a possible cause of the failures of the lift system. This was necessary after it was confirmed through researches (sule, 2007) that the failure was neither as a result of abuse nor the use of poor materials. It is also aimed at reducing the stress and recommends an optimum ploughing speed.

2. MATERIALS AND METHODS

The following materials were used in this experiment: A fifty by thirty meters portion of land (measured out of the irrigation plot of the Agricultural Engineering Department of the Federal Polytechnic, Bauchi, Nigeria), four digital multimeters, strain gauges, 9V batteries, resistors, cables, Steyr 768 tractor and a metering tape, sand paper, detergent, water and glue.

The surfaces of the stabilizer shafts and brackets were properly cleaned using sand paper, detergent and water. They were left to dry after which the strain gauges were carefully attached using glue. Quarter-bridge strain gauge circuit with temperature compensation was used. They were pressed firmly and allowed to dry after which they were soldered and wired with resistors of equal resistance value. Figure 2 shows the circuit diagram of the electrical wiring. Soil samples were taken from the experimental plot for analysis. The soil type was determined using the method of soil type analysis (Michael, 1999). Other properties such as soil moisture content (dry basis, db) and bulk density were determined. The implement was coupled and the ploughing was started. Two assistants ran behind the tractor on both sides taking readings from the multimeters mounted on the tractor mudguards. The speeds of ploughing were changed using the hand throttle. The ploughing depth was fixed using the depth controller. The ploughed depth was measured using a steel measuring tape with the undisturbed soil surface as a point of reference.

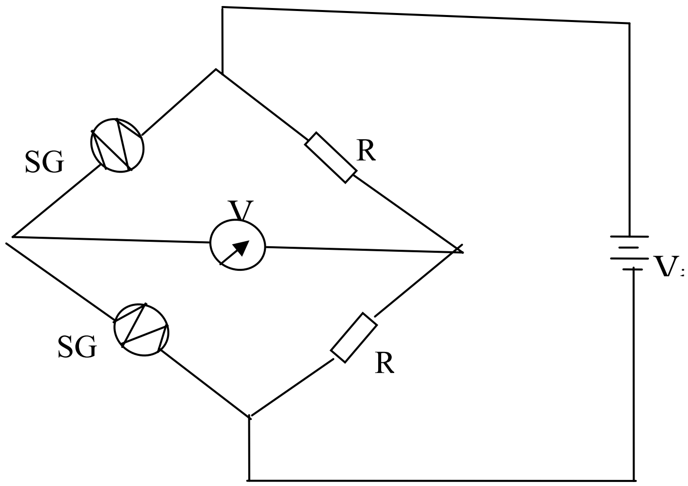

Figure 2. Circuit Diagram for Double Strain Gauge Connection

Where, R is the external resistor; V_o is voltage output while V_i is the input voltage and SG is the strain gauge.

The measurements were first taken with the original Steyr 'U" bolt in place (Fig.1). Averages of ten measurements were used. The obtained stress values were relatively higher than the yield point of the bracket material. These stress values were used in the design and construction of spring for the spring loaded (Modified) 'U' bolt (Plate 1). This was fitted in place for comparative measurements. The design and construction of the spring loaded 'U' bolt is not within the scope of this presentation. Plate II shows the measurements in progress.

Figure 1. Modified 'U' Bolt

Figure 2. Measurements in progress

3. RESULTS AND DISCUSSION

During the ploughing, the stresses on the brackets and on the stabilizer shafts were converted to voltages and read on the digital multimeters as the output voltages. Using the following relationships, these voltages were converted to stress (N/m^2). Table1 shows the averages of ten readings.

$$\text{strain sensitivity, } f = \frac{dR}{R\varepsilon}$$

$$\text{Mechanical Strain } \varepsilon = \frac{dL}{L}$$

$$\therefore \quad \varepsilon = \frac{dR}{R} \times \frac{1}{f}$$

From Krutz *et al (*1984), when two gauges are used, one as a dummy,

$$V_o = \frac{dR}{2R} \times V_i$$

Where

V_o = Voltage out
V_i = Voltage in

$$\sigma = \frac{E}{1 - \nu^2}\left(\frac{2V_o}{V_i}\right) \times \frac{1}{f}$$

where:

σ = stress
E = Young's modulus of elasticity
ν = Poisson's ratio

In case of ductile materials e.g. mild steel where the yield point is clearly defined, the factor of safety is based upon the yield point stress (Chwiej, 1979).

$$Factor\ of\ safety = \frac{Yield\ point\ stress}{working\ stress}$$

$$ws = \frac{yield\ point\ stress(yps)}{Factor\ of\ safety(fos)}$$

Table 1 Effect of Speed on Stress on Right and Left Stabilizer on Clay Loam Soil

Speed (km/hr)	Stress on Right Bracket (N/mm^2)		Stress on Left Bracket (N/mm^2)	
	Steyr U Bolt	Mod. U Bolt	Steyr U Bolt	Mod. U Bolt
6.5	39.0	3.5	14	1.6
7.0	43.5	4.4	16	1.8
8.3	55.6	7.0	25	4.5
9	71.0	15	38	8.7

Factor of safety for steel can be taken as 16 (Khurmi and Gupta, 2004). Yield point stress of the bracket material is 230N/mm^2 (sule, 2007). The maximum stress measured during the experiment with the Steyr 'U' bolt (at the speed of 7km/hr) is taken as the working stress. This is the average recommended ploughing speed(Kuczewski and Majewski, 1983).

$$ws = \frac{yield\ point\ stress(yps)}{Factor\ of\ safety(fos)} = \frac{230}{16}\ N/mm^2 = 14N/mm^2$$

Since working stress 43.5N/mm^2 is greater than 14N/mm^2, it shows that there are chances of occasional increases of stress as a result of stumps and non- uniformity of farmlands. The presence of stumps and none uniformity of farmlands are some of the causes of shock stress on the Steyr lift system which is very destructive to the system. It is therefore very important to reduce the stress. This maximum stress developed was used in the design and construction of the spring for the modified 'U' bolt.

Measurements were taken on the effect of speed on stress development on both the brackets and the stabilizers at 12.6% soil MC (db) while ploughing was done at the depth of 20cm and the width of 1m. The graphs on figures 3 to 6 show the effect of speed on stress development on brackets and stabilizers. From these graphs it can be seen that the stresses generally increase with the speed of ploughing. The graphs also show the regression establishing mathematical relationship between the stress on brackets and stabilizers and speed of ploughing when using the Steyr 'U' bolt and when using the modified type. Within the experimented limit the modified 'U' bolt is seen to be efficient. The discrepancies seen are as a result of variation of soil resistances on the field. It was however observed that the right side of the three point linkage system experienced much higher stresses than those on the left side of the system. This explains why failures of the bracket and the axle occur only on the right side. This is due to the greater side thrust tending to pull the plough from the right towards the left than from the left to the right. This in turn is due to the asymmetrical shape of the plough. This increase of stress with speed agrees with Kamal *et al*, (1999). On this soil, increase of ploughing speed above 7.0km/hr is seen to produce a very sharp increase in stress on both brackets and stabilizers. This stress is excessive and destructive to the stabilizer bracket when using the Steyr 'U' bolt (Sule *et al*, 2004). The use of the modified type is seen to reduce the stress from 43.5N/mm^2 to 4.4N/mm^2 on the soil of 12.6% moisture content (db) at 7km/hr. This stress reduction is achieved through shock absorption by the incorporated springs.

Further studies (Figures 7 and 8) show that the stresses are generally higher on clay loam soils than on sandy loam soils and also that stresses decrease with a decrease in moisture content on the clay loam soil till at 12.6%. This reflects the observations of Ademosun (1990) and Gupta and Surendranath (1989). This reduction in stress with the reduction in moisture content can be attributed to the formation of a friable condition of the soil at lower soil moisture content. At the moisture content of 10.4% however, the stress begins to increase due to hardening of the soil. It is observed that for clay loam soil, the optimum soil moisture content that would guarantee a long lasting stabilizer – bracket system is 12.6%. It is worth noting however that the methodology employed here has some limitations in the sense that four assistants were engaged to run after the tractor to take the readings. This and the nature of the terrain of work limited the range of speed of work. This is also a proof that higher stresses could be experienced by the brackets and stabilizers in rougher terrains during the actual operations. For this reason, it is recommended that an X-Y plotter is used in future experiments of this nature where all the outputs from the multimeters will be fed into the X-Y plotters.

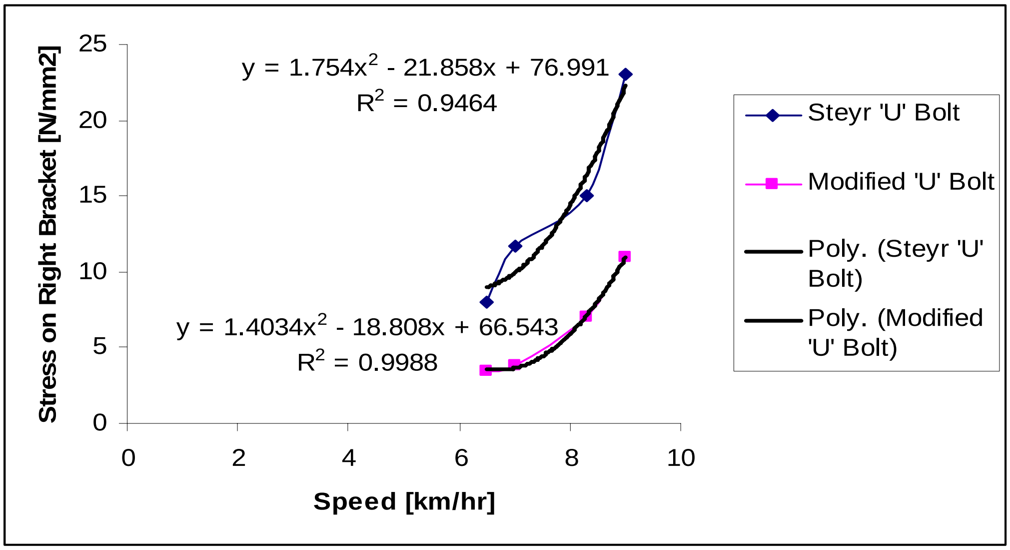

Figure 3. Effect of Ploughing Speed on Stress Development on the Right Bracket (Clay Loam Soil of 12.6%M.C at 20cm depth of ploughing)

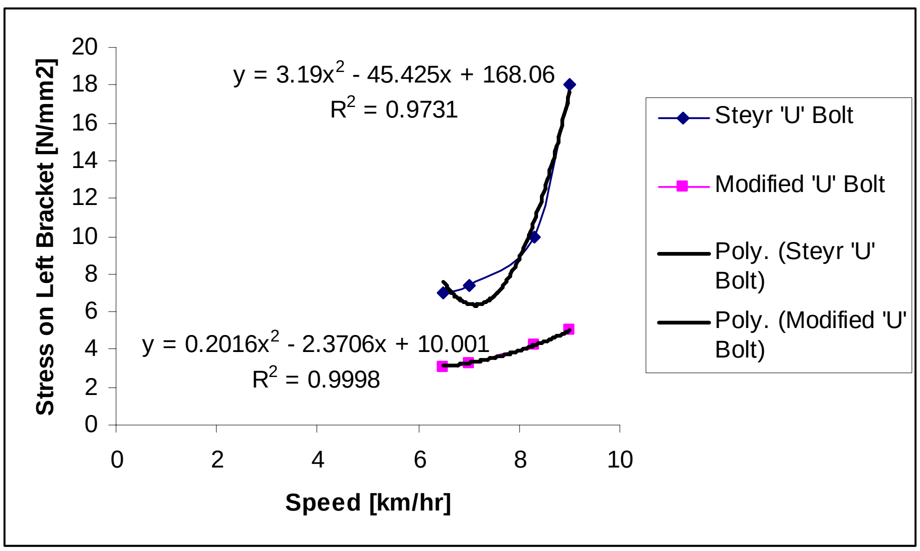

Figure 4. Effect of Ploughing Speed on Stress Development on the Left Bracket (Clay Loam Soil of 12.6%M.C at 20cm depth of ploughing)

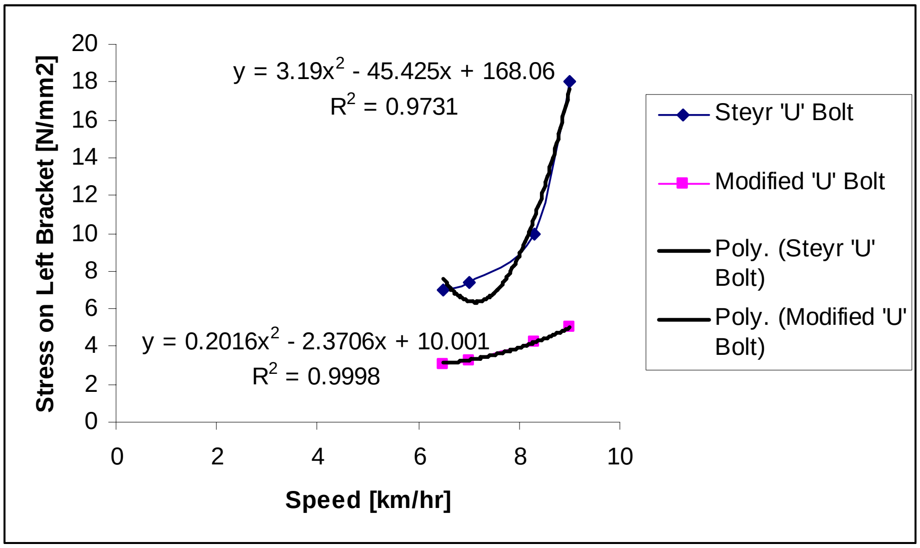

Figure 5. Effect of Ploughing Speed on Stress Development on the Right Stabilizer (Clay Loam Soil of 12.6%M.C at 20cm depth of ploughing)

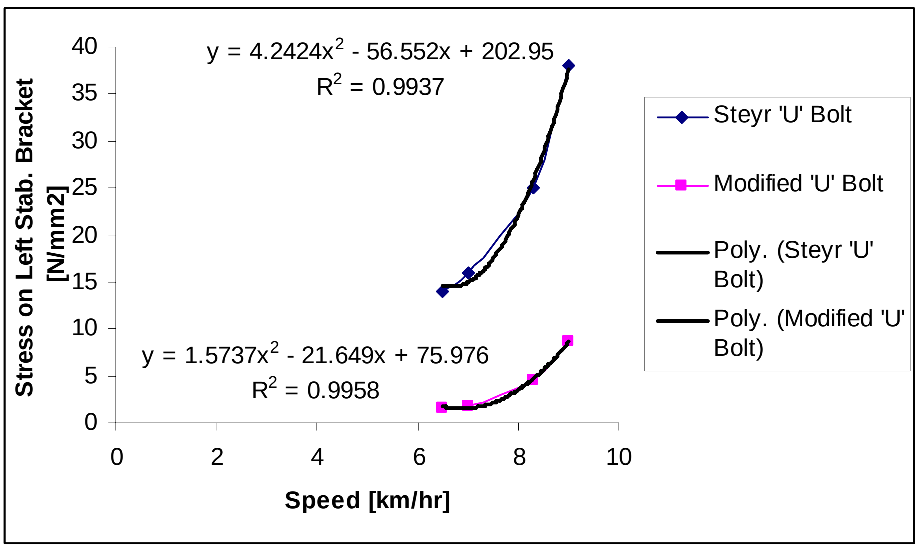

Figure 6. Effect of Ploughing Speed on Stress Development on the Left Stabilizer (Clay Loam Soil of 12.6%M.C at 20cm depth of ploughing)

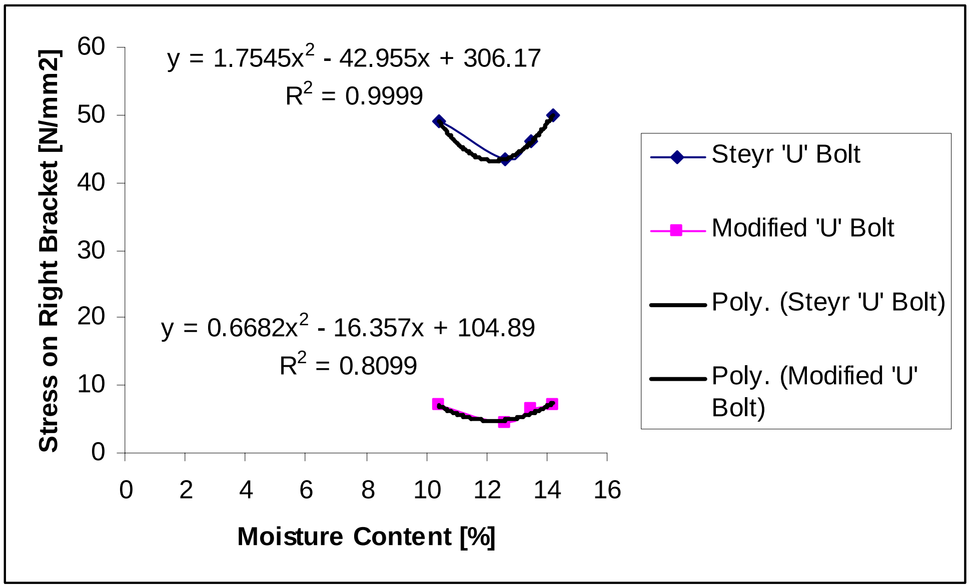

Figure 7 Stress Reduction Action of the Modified 'U' Bolt on the Right Bracket on Clay Loam Soil at Different Moisture Content

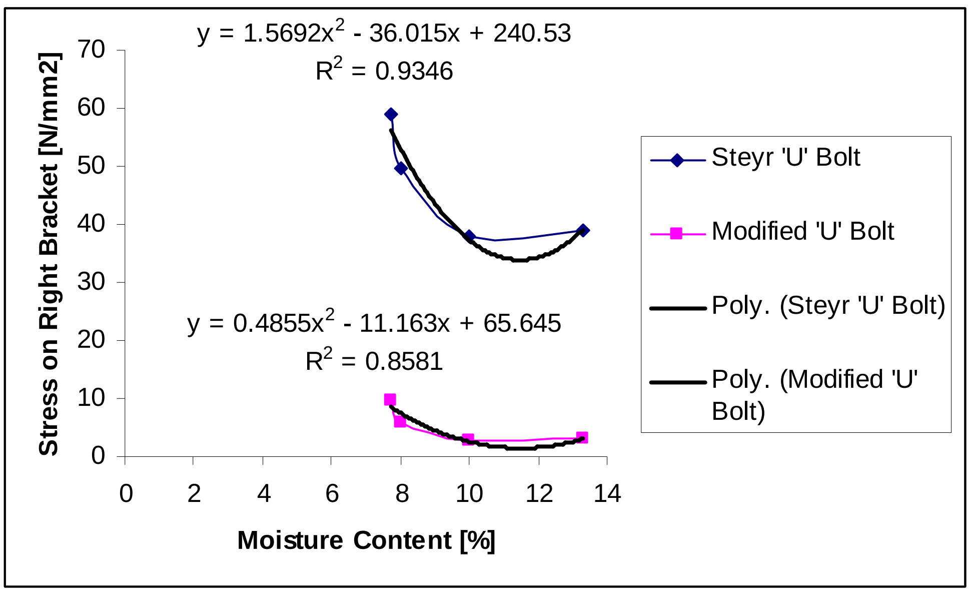

Figure 8 Stress Reduction Action of the Modified 'U' Bolt on the Right Bracket on Sandy Loam Soil at Different Moisture Content

4. CONCLUSION AND RECOMMENDATION

The failure of the Steyr tractor lift system could be due to the development of occasional excessive stress as a result of stumps and non uniformity of farmlands. The use of Steyr tractor to plough on clay loam soil at speed higher than7km/hr encourages the development of destructive stress on the lift system leading to the failures of the system. In order to avoid the failures/breakdowns of the Steyr tractor lift system (stabilizer brackets and the axle), it is recommended that the modified 'U' bolt is adopted for use on the Steyr tractor and ploughing speed on this land is kept at or below 7.0km/hr. It is also recommended that for clay loam soil, the optimum soil moisture content that would guarantee a moderate stress on the lift system is 12.6%.

The decision to use the spring loaded 'U' bolt rather than redesign the lift system is purely based on economic reasons.

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