RESEARCH PROJECT - REPORT

AN INVESTIGATION INTO WHETHER SHOCKPADS & ELASTIC LAYERS AID THE LONGEVITY OF FOOTBALL TURF SURFACES

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EXECUTIVE SUMMARY

A programme of laboratory research has been undertaken to investigate whether shockpads and elastic layers aid the retention of acceptable dynamic performance of synthetic turf (Football Turf) sports surfaces. Examples of typical synthetic turf surfaces with and without shockpads have been tested for the range of dynamic properties considered important by FIFA to ensure a surface provides the levels of player protection and ball response that replicate good quality natural turf. Samples of the Football Turf surfaces were then conditioned on a Lisport XL Simulated Wear Machine (with and without sample maintenance) and changes in the dynamic performance measured at incremental stages of wear.

The results of the test programme may be summarised as follows:

- To initially achieve a specific level of performance a Football Turf system may comprise a shorter pile carpet infill with lower quantities of performance and stabilising infill or a longer pile synthetic turf carpet with higher quantities of performance and stabilising infill; both design options work;

- To retain the required sports performance and player protection any Football Turf system requires adequate maintenance to ensure that the performance infill remains at the intended depth and quantity and is not allowed to compact;

- If a Football Turf system without a shockpad is regularly maintained so infill compaction and dispersion does not occur it is able to retain acceptable levels of performance;

- If a Football Turf system without a shockpad is not adequately maintained the levels of player /surface and ball rebound performance are adversely affected and will eventually result in a playing surface that does not satisfy the performance criteria specified by FIFA and other Standards setting bodies (CEN, ASTM, etc.); Depending on the initial configuration of the synthetic turf surface, the degree of use and maintenance deficiencies, such deterioration may occur quite early in a Football Turf surfaces' service life.

- As infill compaction and dispersion never occurs uniformly across a field inconsistencies in performance will be likely to occur, which in itself may introduce additional risks of player injury. The degree of inconsistency will depend on the levels of use, usage patterns and periods of non-maintenance;

- Football Turf systems with shockpads are able to retain acceptable levels of player/surface performance for longer than systems without shockpads when the playing surface is not adequately maintained.

- The rate of deterioration of a Football Turf system with a shockpad is slower than a Football Turf systems without a shockpad. As fields are subjected to variable levels of use across the playing surface a field with a Football Turf system incorporating a shockpad should be consistent across the field for longer.

- To what degree and at what rate a Football Turf system with a shockpad deteriorates will depend on the dynamic properties of the shockpad itself.

- The findings of this project appear to correlate with the findings of the maintenance research project commissioned by FIFA i.e. to retain the required maintenance all forms of Football Turf surface must be regularly maintained but the need to do this is greatest on systems that do not incorporate shockpads as the rate of deterioration is faster due to higher degrees of infill compaction.

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1 INTRODUCTION

Shockpads have been used within synthetic turf sports surfacing systems since the initial development of the first generation surfaces in the 1960s and 70s. Originally designed to provide cushioning and comfort to the players as the synthetic turf carpets had short piles and little or no infill, the need for shockpads was considered to have been diminished or removed with the introduction of the long pile filled third generation of synthetic turf surfaces in the late 1990s. During the initial decade of use most third generation synthetic turf surfaces relied on the granulated rubber and sand infill within the synthetic turf playing surface to provide the desired playing qualities and player comfort. As, however, a greater understanding of the third generation synthetic turf surfaces was gained and as organisations such as FIFA saw the potential benefits of such surfaces providing they were controlled in a way that ensured they delivered the playing and performance qualities the sport required, the potential role shockpads could play in achieving these objectives once again increased their market visibility.

A third generation surface comprises a number of principal components:

- The synthetic turf carpet. This is normally a long pile carpet of tufted (or occasionally woven) construction. The pile height can be anything from 70mm in length to as little as 35mm and the density of the pile can range from as low as 7000 stitches per square metre to in excess of 14,000 stitches per square metre.

- Stabilising infill. Normally a rounded sand graded to allow adequate water infiltration, the stabilising infill is designed to provide ballast to the synthetic turf carpet to hold it in place, to prevent dimensional thermal expansion and contraction of the carpet and to partly support the pile yarn so it stands upright. The stabilising infill is laid at the bottom of the carpet pile normally to a depth of at least 10mm.

- Performance infill. Normally some form of granulates rubber, the performance infill is designed to provide the player impact attenuation and ball rebound characteristics of the surface, to provide adequate traction and grip for players to using traditional football boot with studs and to also assist in supporting the pile yarn in a vertical position.

Figure 1 shows a typical cross section of the synthetic turf surfacing system

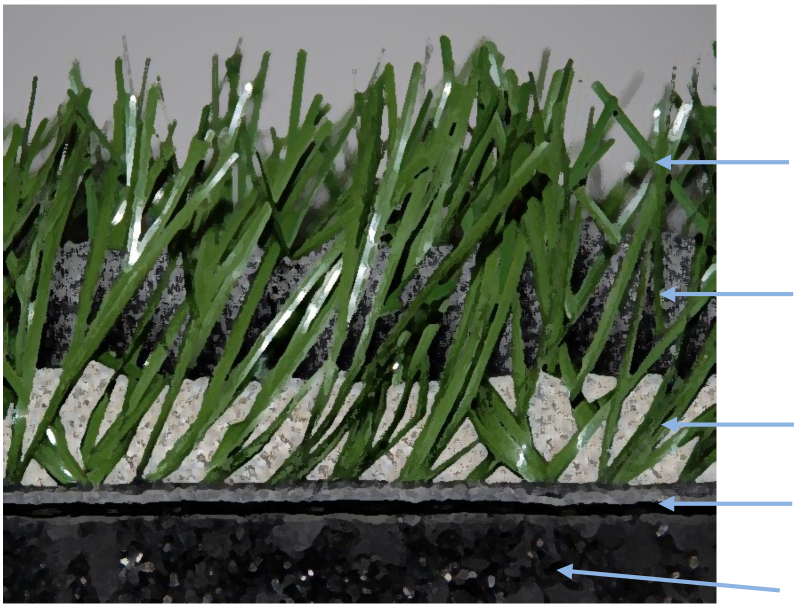

Figure 1 – principal elements of a third generation synthetic turf sports surface

Through normal use and as a synthetic turf sports field ages the infill layers will compact and become contaminated with environmental detritus and fibre debris as the pile yarns wear. The rate at which this occurs will depend on the intensity of use a field is subjected to, its location (in terms of environmental detritus) and the frequency of maintenance undertaken on the surface. As the infill compacts the performance of the field will deteriorate meaning that it will no longer satisfy the playing expectations of the users and possibly more importantly no longer provide the levels of impact attenuation and player protection that FIFA and other standardisation bodies consider necessary to ensure the risk of injury on a synthetic turf field is no greater than on a good quality natural turf field.

Anecdotal evidence from parts of the synthetic turf industry have suggested that incorporating some form of shock absorbing layer beneath the synthetic turf carpet has the advantageous of :

- Reducing the rate at which compaction of the infill within the synthetic turf carpet occurs;

- Providing a level of impact attenuation that is not entirely dependent on the performance infill, meaning that a degree of player comfort / protection is provided irrespective of a field's maintenance and use.

Simplistically installing a shockpad within a synthetic turf sports surface might therefore be considered a sensible design option but the perceived advantages come with a significant cost disadvantage; depending on the type of shockpad used the cost of installing a shockpad on a full size football field can add anything between €40,000 and €80,000 to the total construction costs. Justifying such an additional cost when selecting a synthetic turf surfacing system for a field has proved difficult for many field owners and funding agencies; not least when systems without shockpads can both satisfy the laboratory product assessment and initial field test requirements of the *FIFA Quality Programme for Football Turf.*

Recognising the dilemma and responding to direct interest on this subject from their member associations FIFA commissioned Labosport to undertake a programme of research in an attempt to answer the basic question ' does the addition of a shockpad being added value to a synthetic turf football in terms of long-term performance?'. This report details the programme of research undertaken; reports the results obtained and draws conclusions from the research.

2 TEST PROGRAMME

In order to assess the potential benefits of shockpads within synthetic turf football surfaces under controlled conditions it was decided to test a range of synthetic turf surfaces with and without shockpads, before and after simulated use to quantify the changes in performance that occurred.

Phase One of the project comprised the testing of three 60mm (pile height) synthetic turf surfaces. Each was manufactured from the same pile yarn but had differing stitch rates to determine if the stitch rates had any significant influence on the rates of infill compaction or infill migration.

Phase Two of the project comprised the testing of one 40mm synthetic turf surface laid over three different shockpads all with nominal thicknesses in the range 20 - 25mm. The dynamic performance of tests specimens were tested on new samples and then periodically as the specimens were subjected to simulated wear. Phase Two was undertaken in two sections; one complete series of tests were undertaken with the test specimens being periodically maintained through the simulated wear and a second complete series of tests were undertaken with no maintenance (including infill replacement) during the simulated wear.

Phase Three was similar to Phase Two, but comprised the testing of one 40mm synthetic turf surface laid over three different shockpads all with nominal thicknesses in the range 12 - 15mm.

At each stage of each test programme the selected sports performance and player surface interaction properties were measured as follows:

Vertical Ball Rebound

Ball Rebound was measured in accordance with test procedure described in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition); Test method FIFA TM 01). In this test a football is dropped vertically from a height of 2.0m onto the test specimen and the height to which it rebounds is recorded. The test is repeated five times and a mean value calculated and expressed as a rebound height in metres.

Shock Absorption

Shock Absorption was measured in accordance with test procedure described in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition); Test method FIFA TM 04a). In this test the peak impact force measured during a standard impact using an Advanced Artificial Athlete is recorded and compared to the peak impact force measured on a concrete reference floor. The difference in peak forces between the synthetic turf and concrete floor is expressed as a percentage Force Reduction (%FR). On each test position three impacts are made and the mean of the second and third impacts calculated. On each test specimen three positions are tested and an overall mean value calculated.

Vertical Deformation

Vertical Deformation was measured in accordance with test procedure described in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition); Test method FIFA TM 04b). During the measurement of Shock Absorption the deflection of the sports surface as it is compressed by the test foot of the Advanced Artificial Athlete are measured. On each position three impacts were made and the mean of the second and third impacts calculated. On each test specimen three positions are tested and an overall mean value calculated.

Energy Restitution

Energy Restitution was measured in accordance with test procedure described in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition); Test method FIFA TM 04c). By measuring the energy of the test foot immediately before and after its impact with the test specimen the energy returned can be calculated.

On each position three impacts were made and the mean of the second and third impacts calculated. On each test specimen three positions are tested and an overall mean value calculated.

This test was primarily undertaken to provide more data on this property to help FIFA gain a better understanding on how the synthetic turf compares to natural turf.

Rotational Resistance

Rotational Resistance is a measure of the torque required to initiate rotational movement of a weighted studded test foot. The property was measured in accordance with test procedure described in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition); Test method FIFA TM 06. At each test position three tests were undertaken and mean value calculated.

Head Injury Criterion (HIC)

The potential for serious head injuries is of concern to a number of sports played on synthetic turf surfaces. As many synthetic turf fields are used for multi-sport activities and to aid the development of the *One Turf* concept HIC measurements were included in parts of the test programme. HIC is normally measured in accordance with EN 1177 in this test a hemispherical head-form, of mass 4.6kg and radius 80mm, is dropped from progressively greater heights onto the sample. At each height the H.I.C. of the impact is calculated from the acceleration/time record of the impact, using the formula:

$$\text{H.I.C} = \left[\left\{ \frac{\int_{t_1}^{t_2} a.dt}{(t_2 - t_1)} \right\}^{2.5} \times (t_2 - t_1) \right]_{\max.}$$

At each drop height three impacts are made on the same spot and the worst (third) impact recorded. The values of HIC verses fall height are plotted on a graph and the fall height equating to a HIC of 1000 is extrapolated from the graph; an HIC 1000 is defined as the value at which the statistical risk of a serious brain injury or death occurring is greater than zero.

Due to the limited size the test specimens in this test programme the principal of the test was changed, however. At each test stage three single impacts were made on the test specimen at different positions from a drop height of 1.0m and the resulting HIC value recorded; a drop height of 1.0m being selected as that is the minimum fall height currently specified by the International Rugby Board in their *IRB Artificial Turf Performance Specification* (2011 edition).

As EN 1177 specifies that the test procedure is only valid for HIC impact events of greater than 3ms. For systems without maintenance it was found that this criterion could not be met (due to the reduced impact attenuation), especially on the 40mm synthetic turf carpets, so this test was not made on all test specimens.

Simulated Wear

In order to assess the effects of wear on the performance of the test specimens under controlled conditions it was necessary to artificially wear the playing surfaces and the Lisport XL™ was selected due to its ability to condition large tests specimens and its design objective of more closely replicating the wear characteristics found in practice on synthetic turf fields. The Lisport XL's main component is a guided trolley which travels back and forth over the turf sample. The trolley carries two wear mechanisms; a freely rotating drum fitted with the a football boot pattern based on blades (elongated studs) and a reciprocating plate fitted with a flat sole designed to replicate a flat soled sports training show. The rotating drum generates compaction on the sample, while the plate generates a shear force, inducing fibre flattening, curling and wear.

The studded roller is mounted so that it is free rolling with an axis perpendicular to the travelling direction of the trolley. Its rotational movement is generated by the movement of the trolley and the interaction with the test specimen meaning there is no slipping of the roller or any ploughing effects. As the roller is able to freely move vertically up and down the compressive force applied to the surface is therefore only linked to the roller's own weight and is therefore kept constant, irrespective of local thickness changes in the sample. The weight of the roller is 100 kg/m (± 10 kg/m).

Figure 1 - Lisport XL - general view

The roller is covered with studs whose shape is a truncated pyramid, mimicking the general shape of molded blades. They can be described as having a rectangular base section: 25 mm x 10 mm, a height of 15 mm and a rectangular top section of 10 mm x 5 mm; all edges are rounded with a radius of 2 mm.

Figure 2 - Lisport XL Studs / blades

The studs are arranged in a specific pattern so that the main directions of their base are arranged along 4 different directions: parallel to the roller axis, perpendicular to the roller axis, at + 60° of the roller axis and at – 60° of the roller axis; the design ensuring that two consecutive studs never touch the same spot of the test specimen. In order to further ensure the random positioning of the roller at each cycle, the roller is left to free spin between each back and forth cycle.

The vibrating plate follows a circular translation movement (and not a rotation). In such a way, each point of the sample is rubbed in all directions with the same amplitude and the same speed. The diameter of the rotation of each point of the plate is 20 mm. The rotation speed is 9 rev/s (± 1 rev/s). As the plate is subsequently travelling at a uniform speed, every point of the plate scribes a cycloid curve on the sample; each point of the sample is therefore submitted to 4.5 ± 0.5 rotations per passage of the trolley.

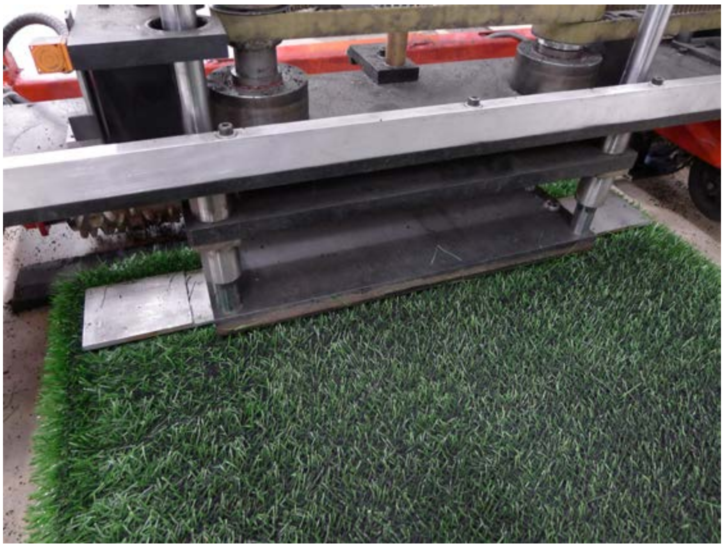

Figure 3 – Lisport XL vibrating plate

The reciprocating plate is also able to move up and down vertically freely. The compression force which is applied on the surface sample is therefore only linked to the plate's own weight and is therefore kept constant, irrespective of local thickness changes in the sample. The pressure applied by the plate on the sample is 30 g/cm^2 (± 5 g/cm^2). The plate is covered with a hard plastic, texturised and wear resistant abrading material, (NORA AUTOSOLER, 26 Fine Crepe Profile) mounted so that it can be changed when it is worn out.

Both the roller and plate are mounted to a trolley which travels back and forth on the sport's surface sample. The speed of travel is kept uniform and is equal to 0.15 m/s (± 0.05 m/s).

Each test specimen was submitted to a preselected number of cycles; a cycle being a full movement which allows the trolley to travel along the whole sample length and back to its original position.

3 TEST SPECIMENS

The objective of this study was to investigate whether shockpads could help extend the retention of satisfactory performance through the life of a synthetic turf football surface. It was not the objective to assess the performance of one type of shockpad verses another. Therefore generic examples of the most common types of shockpads used were selected for inclusion in the project as follows, the list of shockpads used being agreed by FIFA and the European Synthetic Turf Organization's (ESTO) Shockpad Working Group; who assisted the project by arranging for their members to supply samples:

Shockpad No.	General description	Thickness (mm)	Shock absorption (%FR)	Deformation (mm)
1	Nominal 15mm in-situ (wet pour) laid granulated SBR shockpad with a polyurethane binder	15	37.4	3.2
2	Closed cell polyethylene foam shockpad with cross-directional predefined slits and a laminated non-woven scrim	15	45.1	7.1
3	Recycled open cell polyurethane trim-foam shockpad	15	50.5	6.6
4	Recycled closed cell polyethylene foam chips thermally bonded within a geo-textile membrane	23	56.9	7.4
5	Molded geometric polypropylene panel	23	59.6	6.6
6	Nominal 25mm in-situ (wet pour) laid granulated SBR elastic layer (e-layer) with a polyurethane binder	25	54.2	6.2

Appendix D contains photographs of each shockpad used in the study.

The synthetic turf surfaces used in the study comprised of samples as follows:

Property	Synthetic turf			
	A	B	C	D
Pile height	60 mm	60 mm	60 mm	40 mm
Pile yarn polymer	Polyethylene	Polyethylene	Polyethylene	Polyethylene
Yarn type	Mono-filament	Mono-filament	Mono-filament	Mono-filament
Yarn profile	Flat blade	Flat blade	Flat blade	Flat blade
Stitch rate per 100/mm	17	15	13	15
Stitch gauge	5/8"	5/8"	5/8"	5/8"
Stitches / m^2	10710	9450	8190	9450
Primary backing	Thiobac	Thiobac	Thiobac	Thiobac
Secondary backing	Latex	Latex	Latex	Latex

The synthetic turf samples were in-filled with a stabilising infill comprising rounded silica sand with a particle range of 0.4mm – 0.9mm and a granulated SBR performance infill with a particle range of 0.5mm – 2.5mm.

Infill quantities were selected to try and replicate what is commonly found with systems incorporating similar constructions to those under test and designed to satisfy the (initial) performance criteria of the *FIFA Quality Programme for Football Turf* FIFA Two Star category. As however, the test programme was based on running three tests specimens at any one time on the Lisport XL (e.g. one carpet sample, three different shockpads) the need to ensure a consistent infill application across all three test specimens over-rode the need to ensure compliance with the FIFA criteria at the start of the test programme. It is important that this fact is noted as the results are not designed to assess compliance (or otherwise) of the FIFA requirements, but to establish how performance may change with use. In practice the infill quantities would be specifically tailored to match a carpet and shockpad combination.

During the initial trails to assess the affects stitch rates may have on longer term performance of systems without shockpads the test specimens were initially in-filled to ensure they comfortably met the FIFA Two Star category. As many systems, however, are designed to minimise performance infill quantities to reduce cost they only just comply with the FIFA Two Star category so a second series of tests were undertaken with lower quantities of performance infill as follows:

Synthetic turf	Shockpad	Performance infill (Kg/m^2)	Stabilising infill Kg/m^2)
60mm – 17 stitches / 100mm	N/A	17	15
60mm – 15 stitches / 100mm	N/A	17	15
60mm – 13 stitches / 100mm	N/A	17	15
60mm – 15 stitches / 100mm	N/A	15	16
40mm – 15 stitches / 100mm	1	7	10
40mm – 15 stitches / 100mm	2	7	10
40mm – 15 stitches / 100mm	3	7	10
40mm – 15 stitches / 100mm	4	6	15
40mm – 15 stitches / 100mm	5	6	15
40mm – 15 stitches / 100mm	6	6	15

5 TEST CONDITIONS

All of the tests were undertaken at Labosport's laboratory in France under standard test conditions.

Tests specimens were dry throughout the test programme.

Prior to the initial testing each sample was pre-conditioned in accordance with the procedure detailed in the *FIFA Quality Concept for Football Turf Handbook for Test Methods for Football Turf (*2012 edition).

During the initial phase of the research programme the changes in performance occurring as a result of the simulated wear was checked every 500 cycles. As data became available it became apparent that changes in performance were not so rapid and that the frequent maintenance of the surface was possibly negating the effects of the Lisport XL. Therefore the frequency of testing was modified to longer intervals as detailed in the results section of this report.

Tests were initially undertaken with maintenance being undertaken at each test interval, maintenance comprising the redistribution of any infill displaced during the preceding Lisport XL cycles. Subjectively, the test specimens treated in this way were considered to look like synthetic turf football surfaces found in moderate use well maintained facilities; such as professional football club training and stadium fields.

On review of the results a second series of tests were undertaken without any infill redistribution as this was considered to replicate more closely the appearance and performance of synthetic turf football surfaces found in the majority of high use community facilities.

6 Results

The results of the research programme are tabulated in Appendix A or this report. The results are also presented in a graphical format to the illustrate changes and trends that occurred in Appendix B.

7 Discussion

The dynamic properties of a Football Turf are provided by the ability of the surface to dissipate the energy impacted to it as a player's foot or their body strike the surface or as a football bounces on the surface. If the ability of the surface is inadequate the risk of player injury will increase as the impact forces experienced by the body increase and from a playing perspective the ball will bounce higher meaning it no longer replicates the playing characteristics of good quality natural turf.

The Football Turf's ability to dissipate impact energy is regulated by the movement and elasticity of the performance infill and, when a system has a shockpad, the surfaces ability to transmit the impact forces through to the shockpad and for the shockpad to then deflect and aid in the reduction of the impact forces.

This study has looked at three types of surface impact, two relate to the player's interaction with the surface; the third the ball's interaction. Due to the relatively high impact forces imparted to the surface during the Advanced Artificial Athlete test and the HIC test the ability of a Football Turf to provide the desired performance is regulated by the quantity and type of performance infill used and the ability of that material to deform and move during the impact. If a shockpad is incorporated into the Football Turf system the dependency on the performance infill to provide the necessary impact absorption reduces as far as the player/surface interaction is concerned.

With respect to ball bounce the ability of the performance infill to perform as the surface designer intended is greater as the impact forces are much lower and the influence of any shockpad is less; indeed the damping provided by the synthetic turf's pile crushing as the ball strikes the surface and the localised movement of the infill seems to be the most important factors in achieving the desired height of rebound. It appears that if the synthetic turf's pile is lying down due to inadequate maintenance the ball rebound will be higher as crushing of the pile during the impact does not occur and the ability of the infill to move is reduced as it becomes trapped below the flatten carpet pile.

During this programme of research tests have been made on samples of Football Turf that have been subjected to simulated wear and use. During the simulated use three basic effects occur to the playing surface:

1 The infill within the pile of the synthetic turf carpet is consolidated as a result loadings provided by the studded roller and vibrating plate; if this consolidation is not periodically relieved the surface becomes firmer;

2 Performance infill is dislodged from the surface and dispersed. If this infill is not periodically replaced the depth of infill decreases and the ability of the synthetic turf carpet and infill to dissipate energy reduces;

3 The pile of the synthetic turf carpet curls and flattens. This has the effect of encapsulating the infill below the flattened pile meaning it cannot move as readily resulting in a firmer playing surface. As the potential for pile flattening will increase as the length of the exposed free increases due to infill dissipation (meaning that less support is provided to the pile) there is a double accumulative effective on performance.

Therefore to retain acceptable dynamic performance the design and maintenance of a Football Turf system needs to try and minimise:

- Infill dispersion
- Infill consolidation / compaction
- Pile flattening

The influences of rain fully on a playing surface and environmental contamination by detritus were not simulated in this test programme. The effects are considered likely to magnify the rate and severity of deterioration a Football Turf will suffer in real life.

8 FINDINGS

8.1 Effects of carpet stitch rate

The first phase of the test programme was undertaken to see if differing stitch rates of the synthetic turf carpet might have a significant influence on the degree of infill dispersion or the rate at which infill consolidation occurred. These tests were undertaken with regular maintenance of the infill levels through the tests to ensure the infill depths were retained at their initial values; this was achieved by replaying any dislodged infill although no new material was added; as is standard practice for simulated wear tests. Generally infill levels varied by up to a 5mm at the conclusion of each period of simulated wear as a result of infill dispersion and compaction. Appendix C shows the infill depths at each phase of the tests on the three 60mm carpets. Based on these findings the mid-range stitch rate was selected for all subsequent tests.

8.2 Shock absorption

Retaining acceptable shock absorption is essential if player comfort and safety is to be retained.

The results of the test programme show that when a surface is well maintained so that infill levels are kept at the manufacturer's specified depth and the infill is not allowed to consolidate it is able to retain the initial levels of shock absorption irrespective of whether it has shockpad or not.

In practice, however, the majority of fields are not maintained with the frequency specified for the particular level of use. This will result in compaction and infill dispersion, particularly in high use areas of a field. In addition a field (unlike the test specimens) will be subjected to contamination of the infill by environmental detritus and in many locations the settling of the infill through the actions of rain falling on the surface. This will cause some infill compaction to occur, even if it is periodically relieved through some form of decompaction / deep grooming. In this situation the results show that a Football Turf system with a shockpad, is able to retain acceptable levels of shock absorption for more playing hours than a system without. The length of time a surface can offer acceptable shock absorption will depend on the values of shock absorption a shockpad has in its own right; the higher the shockpad's value the greater the degree of infill loss the system can sustain before the Football Turf falls below the lower limit of acceptability.

The results also show that systems with shockpads retain a more consistent (all be moderately declining) level of shock absorption until infill levels have dropped appreciably. This is important as a field is not played on uniformly and high wear areas will compact more readily than low use areas. As players desire a uniform playing surface moving from harder to softer areas (or vice-versa) is likely, at best, to be disconcerting and at worst may possibly increase the risk of injury as the body is unable to adapt to the changing feel of the playing surface.

As infill levels drop the rate of infill dispersion was seen to increase on some forms of shockpad. It is thought this is probably due to the resilience of the shockpad or the level of damping it provides. Those shockpads with a higher resilience being more prone to infill splash when compared to a shockpad with providing more damping.

8.3 Deformation

Football Turf systems having high levels of Deformation are generally considered by players to be slower and possibly more tiring to play one. As Football Turf systems without shockpads require greater depths of performance infill to provide the necessary levels of shock absorption such surfaces will have high values of Deformation; unless integrated gradings of infill are used (such as rubber and sand mixes) that inter-lock the infill granulate together.

The test programme showed Deformation trends followed those of shock absorption; Football Turfs without shockpads started with higher values and showed bigger changes as the infill consolidated / was dispersed. In practice this will again lead to inconsistencies across a field which detract from the playing experience and possibly increase the risk of injuries.

8.4 Ball rebound

The way a ball rebounds is an important playing characteristic and one that players can quickly assess and find unacceptable if too high (or too low). The results of this test programme showed ball rebound tended to increase on all systems (with and without shockpads). It is considered that this is because the ball rebound characteristics of a Football Turf surfaces are primarily influenced by the synthetic turf and performance infill. If the pile is not kept upright and the infill decompacted the surface will become firmer and the ball bounces increases.

The results also show that although ball rebound initially increased on all systems those with some types of shockpad levelled off; presumably as the influence of the shockpad become more dominate then that of the compacted / reduced depth of performance infill. Additionally the system without a shockpad showed the largest increase in rebound height and this occurred of the initial phases of simulated use. Retaining consistent ball behaviour is important if players are to be able to predict how a ball is likely to bounce.

8.5 Rotational Resistance

As infill compacts or is dispersed Rotational Resistance was found to increase; presumably as the greater free pile is able to become more entwined with the studs on the test rig. This increase continues until the free pile is unable to support itself and it lies flat on the surface. At this point the studs cannot penetrate into the infill but instead slip on the flatten pile. This results in the Rotational Resistance dropping. This tendency was largest on the system without a shockpad.

8.6 HIC

The HIC results show that HIC values can be retained by a system with or without a shockpad if the infill levels are kept at the specified depth and no compaction occurs. As with Shock Absorption this is unlikely to occur in practice as the influences of rain, detritus etc. also are considered. The fact that it was not possible to get meaningful results on the 60mm Football Turf system without maintenance, due to the short impact duration, shows that such a surface may increase the risk of serious injury if adequate maintenance is not carried out.

APPENDIX A – TEST RESULTS

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m^2) Rubber	Infill (kg/m^2) Sand			Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
60mm Sample A	-	17	15	✔	0	67.7	10.8	42.6	0.91	33	821
					500	66.2	9.4	58.4	0.98	34	813
					1000	65.5	9.7	50.8	1.02	35	789
					1500	64.4	9.6	52.2	1.04	37	812
					2000	64.0	9.3	49.2	0.99	39	852
					2500	65.1	9.6	50.9	1.00	35	937
					3000	64.1	9.3	51.4	1.02	34	805
					3500	66.0	9.6	48.3	1.07	36	805
					4000	64.5	9.5	49.2	1.02	36	843
					5000	64.8	9.6	49.1	1.02	33	871
					6000	64.1	9.4	46.5	1.02	35	855
					7000	64.0	9.2	46.5	1.03	33	920

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²)				Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
		Rubber	Sand								
60mm Sample B	-	17	15	✔	0	65.6	10.1	44.1	0.95	29	884
					500	66.2	9.9	47.9	0.99	35	791
					1000	66.4	9.8	51.4	1.04	36	840
					1500	64.3	9.2	56.1	1.01	35	845
					2000	64.8	9.4	49.2	1.06	36	836
					2500	65.3	9.7	49.3	1.04	36	900
					3000	64.6	9.5	50.1	1.03	35	826
					3500	65.6	9.6	47.9	1.03	35	826
					4000	65.1	9.5	49.6	1.06	37	758
					5000	64.3	9.4	48.7	0.99	34	838
					6000	64.6	9.5	47.1	1.03	34	987
					7000	63.9	9.2	46.7	1.05	43	862

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m^2)				Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
		Rubber	Sand								
60mm Sample C	-	17	15	✔	0	66.8	10.2	42.7	0.93	33	974
					500	65.7	9.7	45.7	1.03	35	743
					1000	66.3	9.7	48.6	1.02	37	808
					1500	64.6	9.4	54.8	1.05	35	771
					2000	65.3	9.6	48.2	1.06	35	763
					2500	65.4	9.5	49.1	1.06	36	768
					3000	65.6	9.6	46.8	1.05	37	807
					3500	66.3	9.7	46.1	1.06	34	816
					4000	65.8	9.4	48.8	1.05	36	802
					5000	64.8	9.4	46.3	1.07	36	862
					6000	65.2	9.5	46.4	1.06	36	826
					7000	64.5	9.3	44.7	1.06	38	900

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m^2) Rubber	Infill (kg/m^2) Sand			Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
60mm Sample Bb	-	15	16	✔	0	62.6	9.3	43.2	0.96	35	958
					1000	63.1	8.8	52.1	0.99	40	916
					2000	63.2	8.9	54.3	0.98	42	894
					3000	60.0	8.0	60.3	1.05	43	1052
					4000	60.4	8.4	54.9	1.03	42	1098
					5000	60.2	8.1	54.8	1.03	42	1035
					6000	61.2	8.3	54.5	1.05	42	975
					7000	61.6	8.6	51.8	1.05	40	955
60mm Sample Bb	-	15	16	X	0	64.4	9.8	40.8	0.85	32	HIC impact time < 3m/s
					1000	60.3	8.5	54.8	0.98	43	
					2000	57.3	7.8	54.4	0.99	50	
					4000	50.1	6.5	61.1	1.04	52	
					6000	39.4	4.7	69.9	1.05	40	

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m^2) Rubber	Infill (kg/m^2) Sand			Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
40mm Sample D	1	7	10	✔	0	56.4	7.4	48.8	0.97	39	1251
					1000	55.7	7.0	63.5	1.02	34	1244
					2000	56.0	7.2	59.2	1.03	35	1256
					3000	56.8	7.2	56.5	1.03	34	1221
					4000	55.3	7.1	56.9	1.04	35	1288
					5000	55.1	7.1	57.5	1.04	35	1207
					6000	55.5	7.0	57.5	1.05	36	1281
					7000	56.3	7.3	55.6	1.03	36	1239
40mm Sample D	2	7	10	✔	0	67.8	10.5	40.9	0.91	36	1080
					1000	66.9	9.6	52.0	1.00	33	1178
					2000	66.5	9.3	55.9	0.98	36	1253
					3000	66.9	9.9	48.5	0.99	36	1360
					4000	67.1	9.9	48.5	1.01	36	1219
					5000	67.4	10.0	47.7	1.05	37	1343
					6000	66.2	9.7	49.8	1.00	37	1336
					7000	66.3	9.6	52.0	1.01	34	1336

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²)				Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
		Rubber	Sand								
40mm Sample D	3	7	10	✓	0	65.6	9.7	38.4	0.92	36	921
					1000	64.7	9.0	49.9	0.98	38	854
					2000	65.7	9.1	50.5	0.98	37	895
					3000	64.7	9.1	46.6	0.99	36	852
					4000	65.3	9.4	46.3	1.00	35	851
					5000	64.2	9.2	47.4	1.00	40	853
					6000	64.7	9.2	46.6	1.00	37	903
					7000	65.6	9.3	45.3	1.00	37	870

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²) Rubber	Infill (kg/m²) Sand			Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
40mm Sample D	1	7	10	X	0	56.0	7.5	45.3	0.97	37	Not included in this phase of the test programme
					1000	51.5	6.4	58.3	1.00	34	
					2000	50.1	6.3	60.8	1.01	33	
					4000	48.8	5.9	56.9	1.00	38	
					6000	42.4	4.7	66.3	1.00	38	
40mm Sample D	2	7	10	X	0	68.6	10.3	36.6	0.90	35	Not included in this phase of the test programme
					1000	66.4	9.3	49.5	0.96	33	
					2000	65.4	9.4	48.4	0.97	34	
					4000	64.3	9.3	48.3	0.99	41	
					6000	59.4	8.1	51.1	0.97	34	
40mm Sample D	3	7	10	X	0	65.2	9.4	36.8	0.91	35	Not included in this phase of the test programme
					1000	62.8	8.5	47.8	0.95	33	
					2000	63.0	8.6	44.5	0.96	32	
					4000	60.4	8.0	42.5	0.98	36	
					6000	56.6	7.3	51.0	0.95	33	

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Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²)				Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
		Rubber	Sand								
40mm Sample D	4	6	15	✔	0	66.5	10.0	40.3	0.94	38	696
					1000	65.8	9.4	47.7	0.99	34	715
					2000	65.8	9.6	46.8	0.98	37	669
					3000	66.6	9.3	47.5	0.99	38	705
					4000	65.0	9.1	50.5	0.99	38	701
					5000	65.0	9.1	50.4	1.00	37	747
					6000	64.7	9.1	47.5	1.00	38	758
					7000	64.6	8.8	46.7	1.01	37	781
40mm Sample D	5	6	15	✔	0	61.3	8.1	40.8	0.97	38	484
					1000	59.3	7.4	50.7	1.04	34	480
					2000	61.0	8.0	49.1	1.04	35	483
					3000	61.5	8.0	47.8	1.05	37	441
					4000	60.2	7.5	49.0	1.07	34	462
					5000	59.5	7.4	49.3	1.06	35	454
					6000	59.0	7.2	48.3	1.08	35	466
					7000	59.8	7.3	48.4	1.09	36	473

Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²)				Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
		Rubber	Sand								
40mm Sample D	6	6	15	✔	0	62.9	8.8	45.1	0.95	38	782
					1000	62.7	8.6	54.1	0.99	35	808
					2000	62.1	8.4	57.7	0.97	35	824
					3000	62.6	8.7	52.4	1.01	36	785
					4000	61.7	8.4	57.9	0.99	36	777
					5000	61.5	8.4	55.3	1.01	39	800
					6000	61.6	8.4	52.8	0.99	40	792
					7000	61.2	8.1	54.9	1.01	37	808

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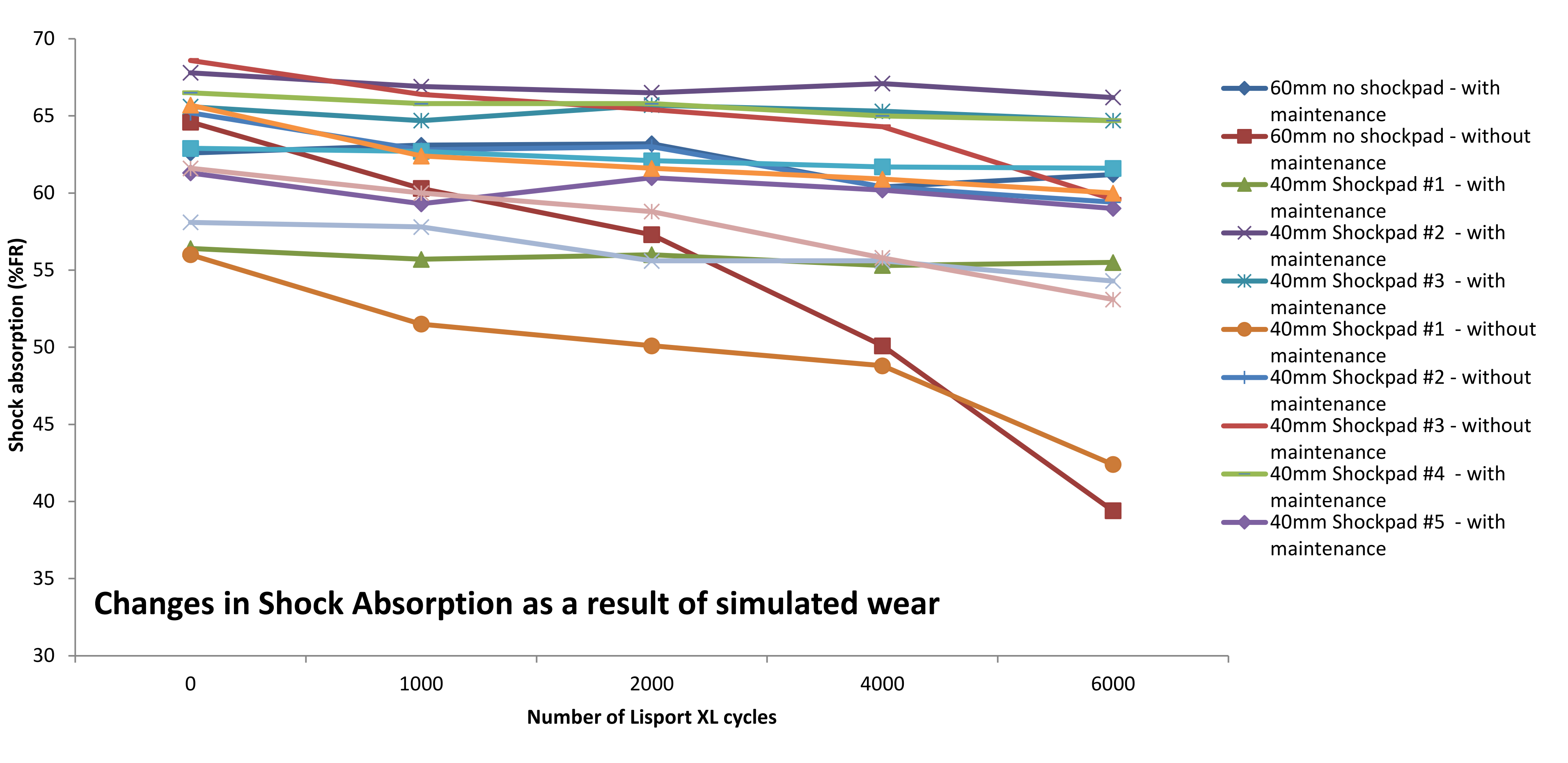
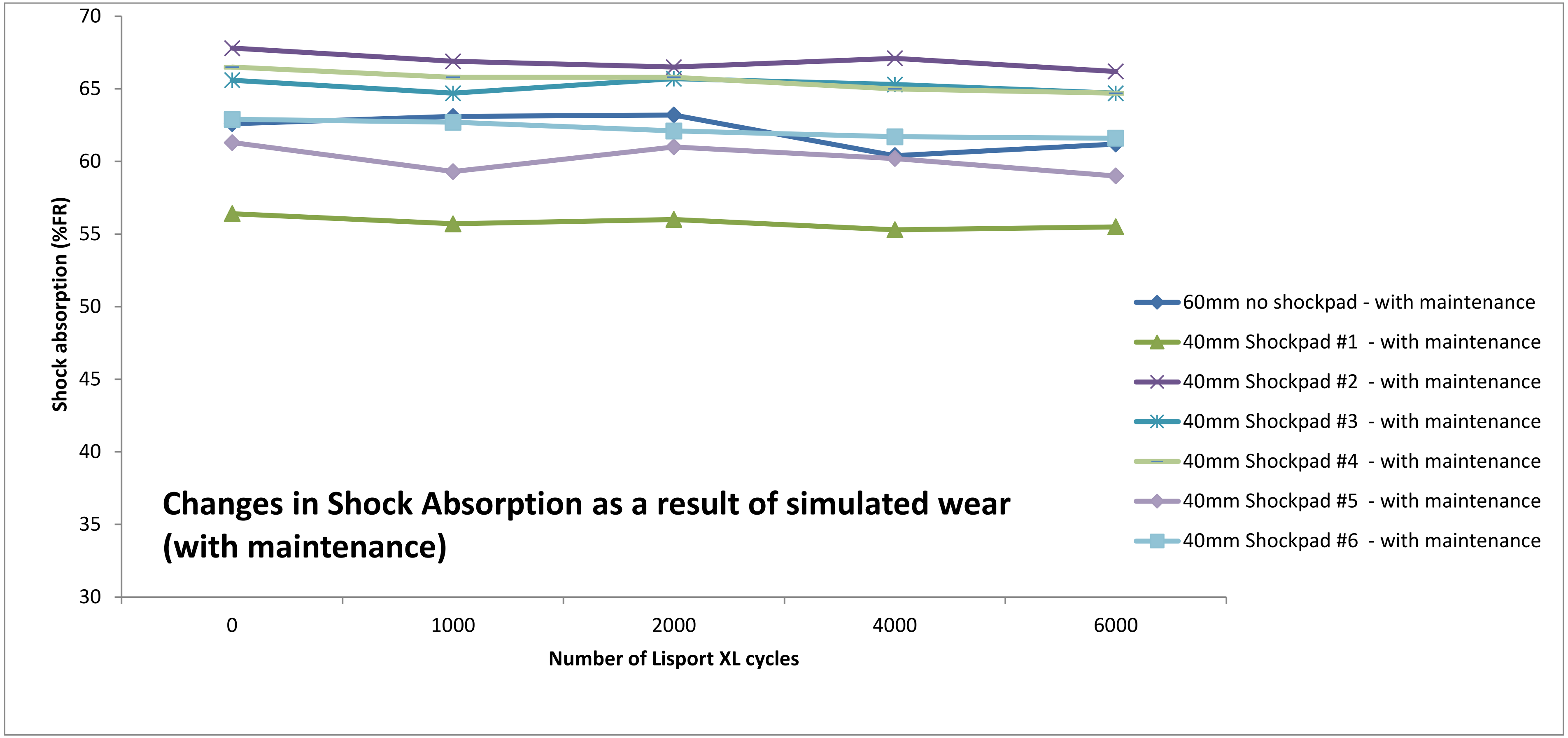
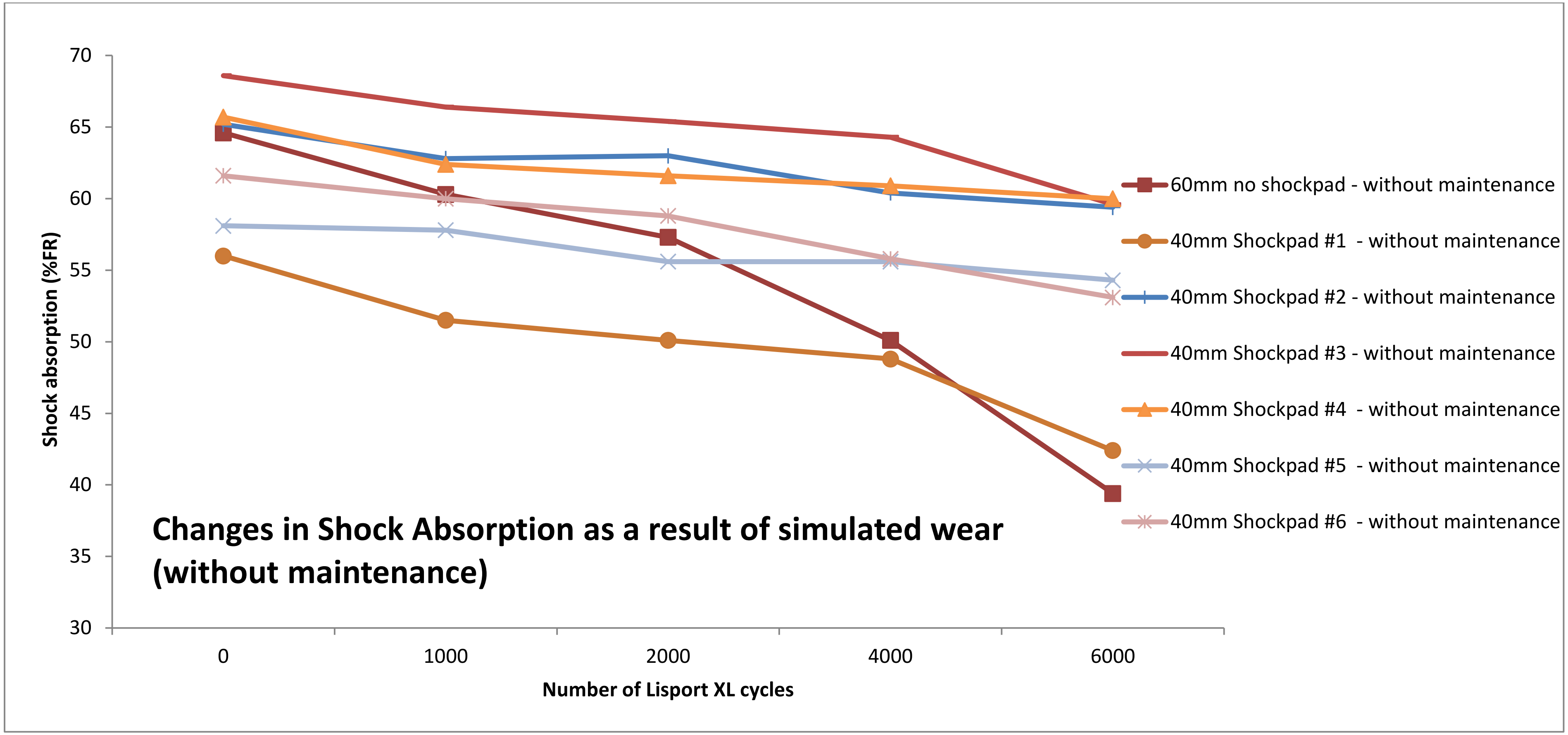
Synthetic turf system				Maintenance during test programme	Number of cycles on Lisport XL	Results					
Synthetic turf	Shockpad	Infill (kg/m²) Rubber	Sand			Mean Shock Absorption (%FR)	Mean Vertical Deformation (mm)	Mean Energy Restitution (%)	Mean Vertical Ball Rebound (m)	Mean Rotational Resistance (Nm)	Mean HIC at 1.0m
40mm Sample D	4	6	15	X	0	65.7	9.6	44.0	0.89	35	Not included in this phase of the test programme
					1000	62.4	8.6	50.8	0.94	29	
					2000	61.6	8.6	49.9	0.94	39	
					4000	60.9	8.0	53.2	0.94	41	
					6000	60.0	7.9	49.7	0.96	35	
40mm Sample D	5	6	15	X	0	58.1	7.4	46.6	0.96	37	Not included in this phase of the test programme
					1000	57.8	7.0	54.7	0.98	31	
					2000	55.6	6.7	51.7	1.00	36	
					4000	55.6	5.9	51.8	0.99	53	
					6000	54.3	5.6	52.0	1.08	45	
40mm Sample D	6	6	15	X	0	61.6	8.7	49.0	0.92	36	Not included in this phase of the test programme
					1000	60.0	7.9	60.1	0.96	32	
					2000	58.8	8.0	56.2	0.97	38	
					4000	55.8	6.8	60.6	0.96	48	
					6000	53.1	6.4	61.0	0.96	53	

Appendix B – Graphs illustrating results and trends

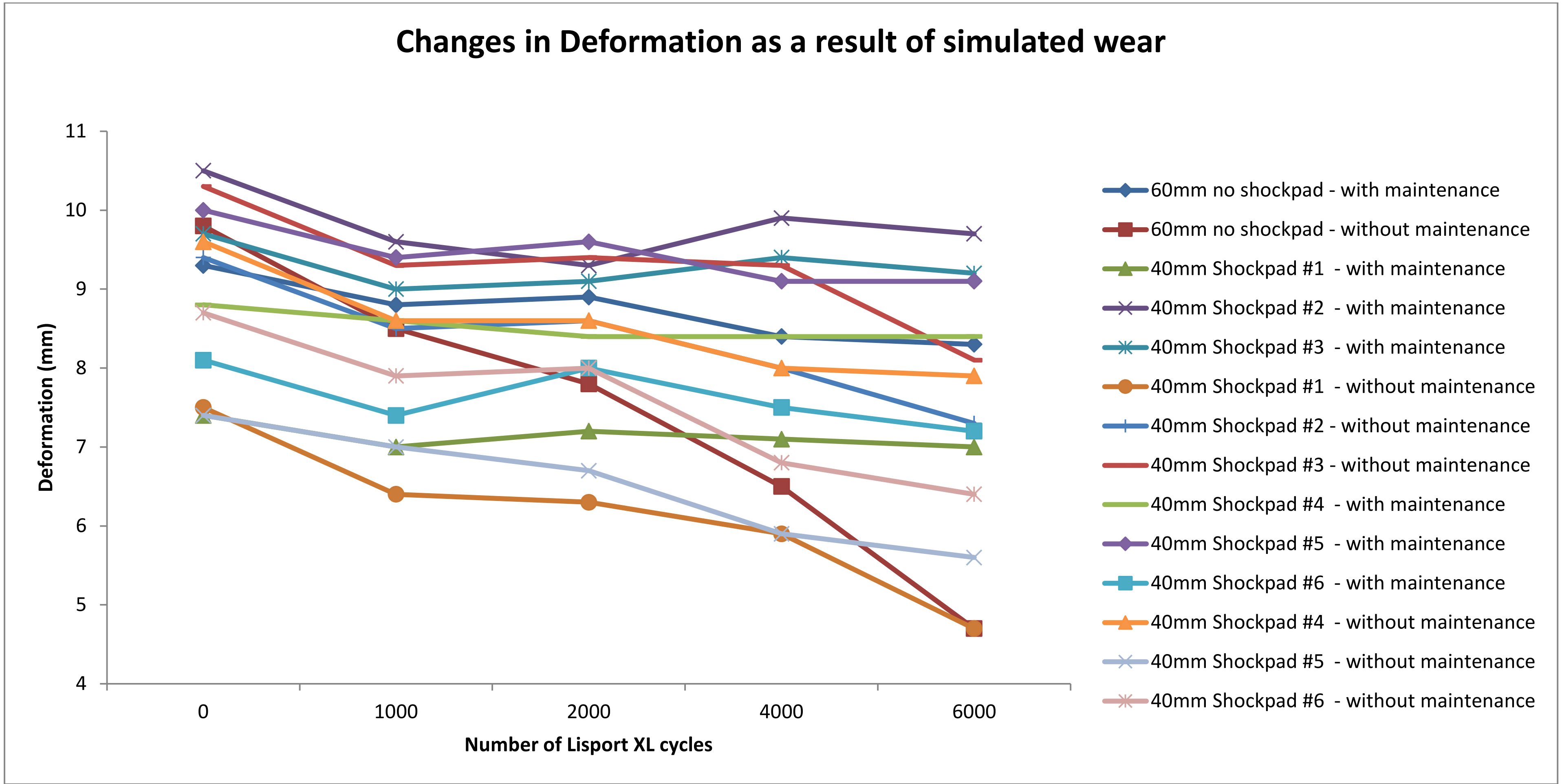


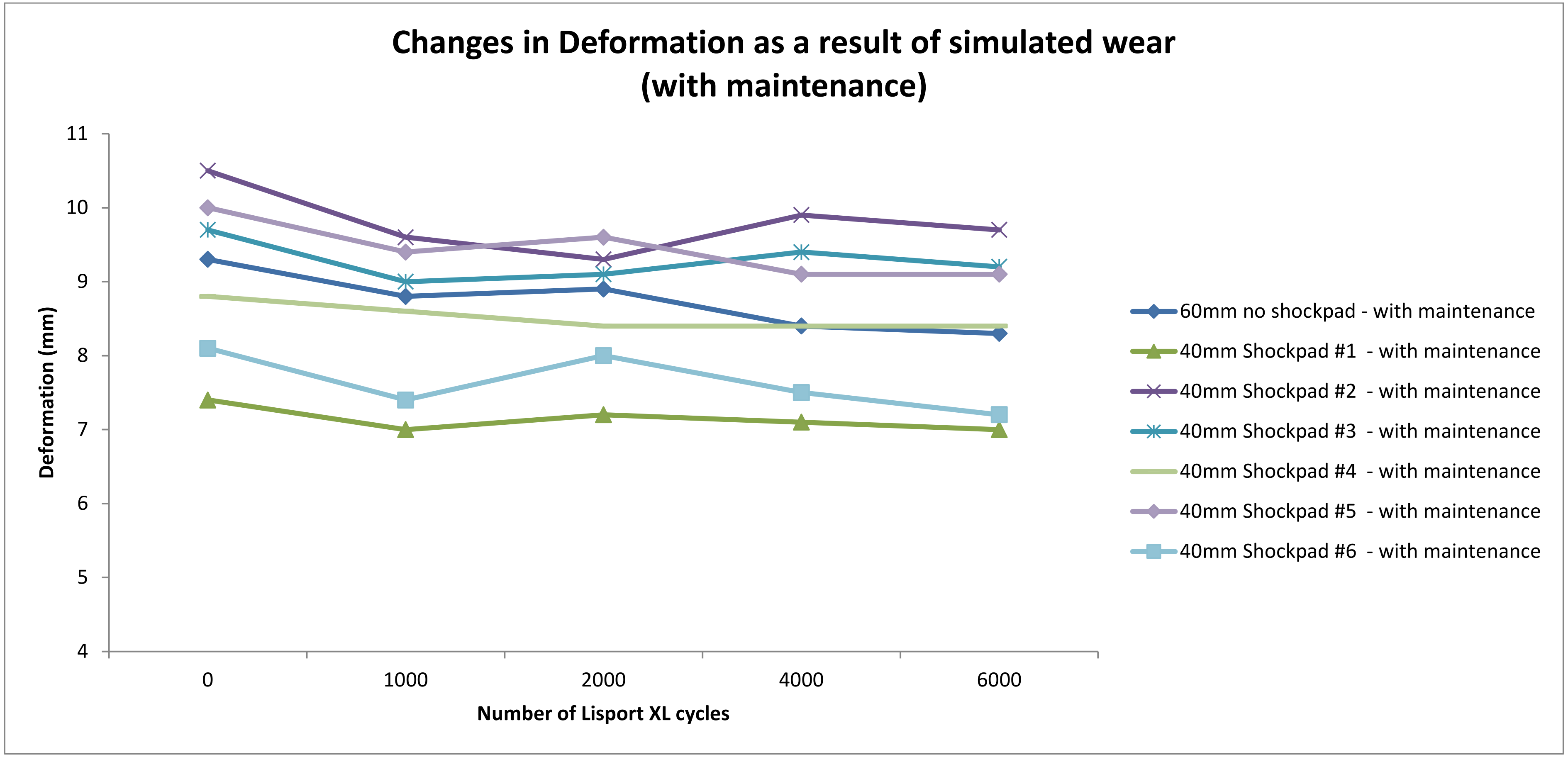


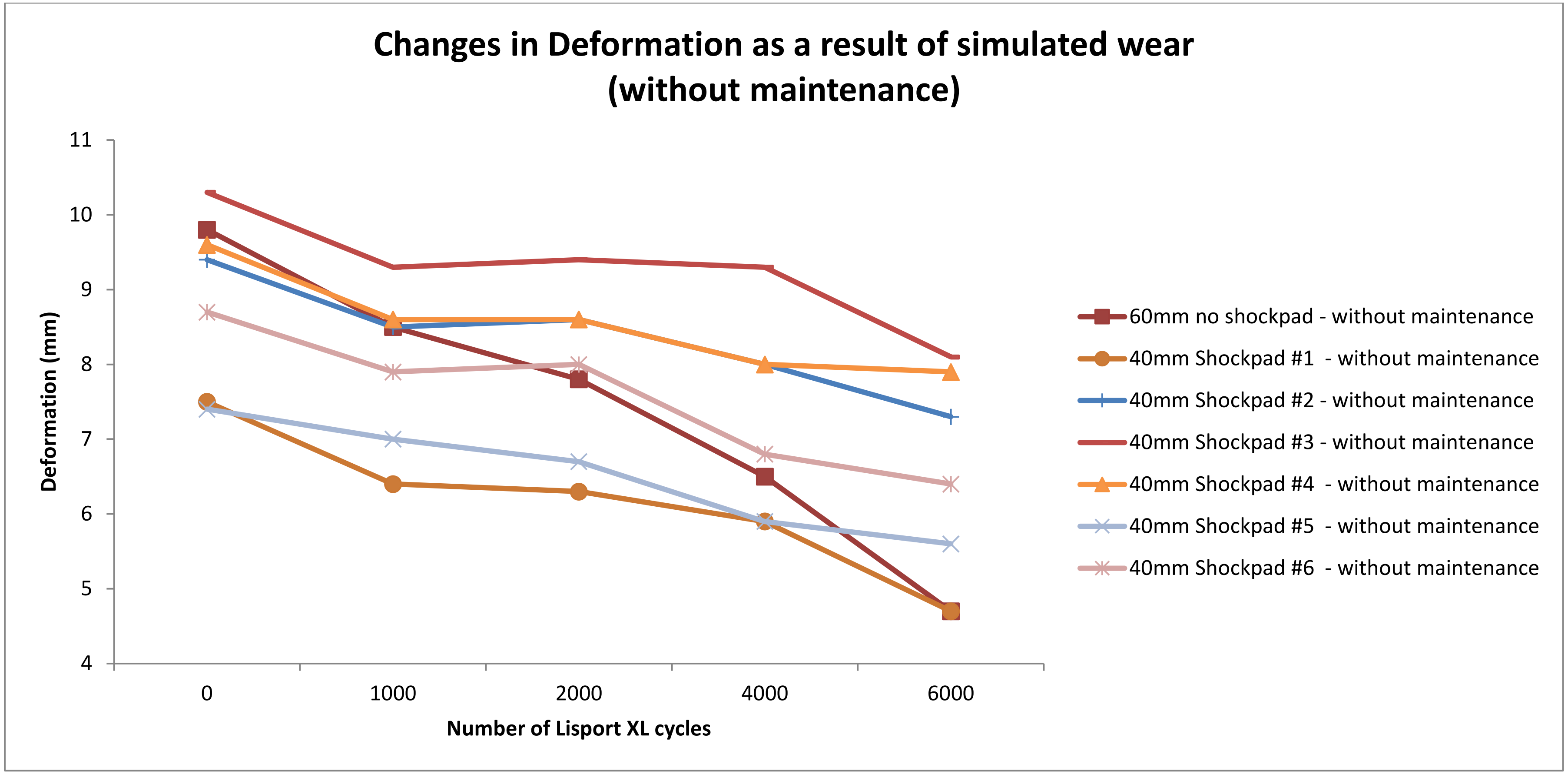
Changes in Shock Absorption as a result of simulated wear (with maintenance)
Shock absorption (%FR)
70
65
60
55
50
45
40
35
30
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance

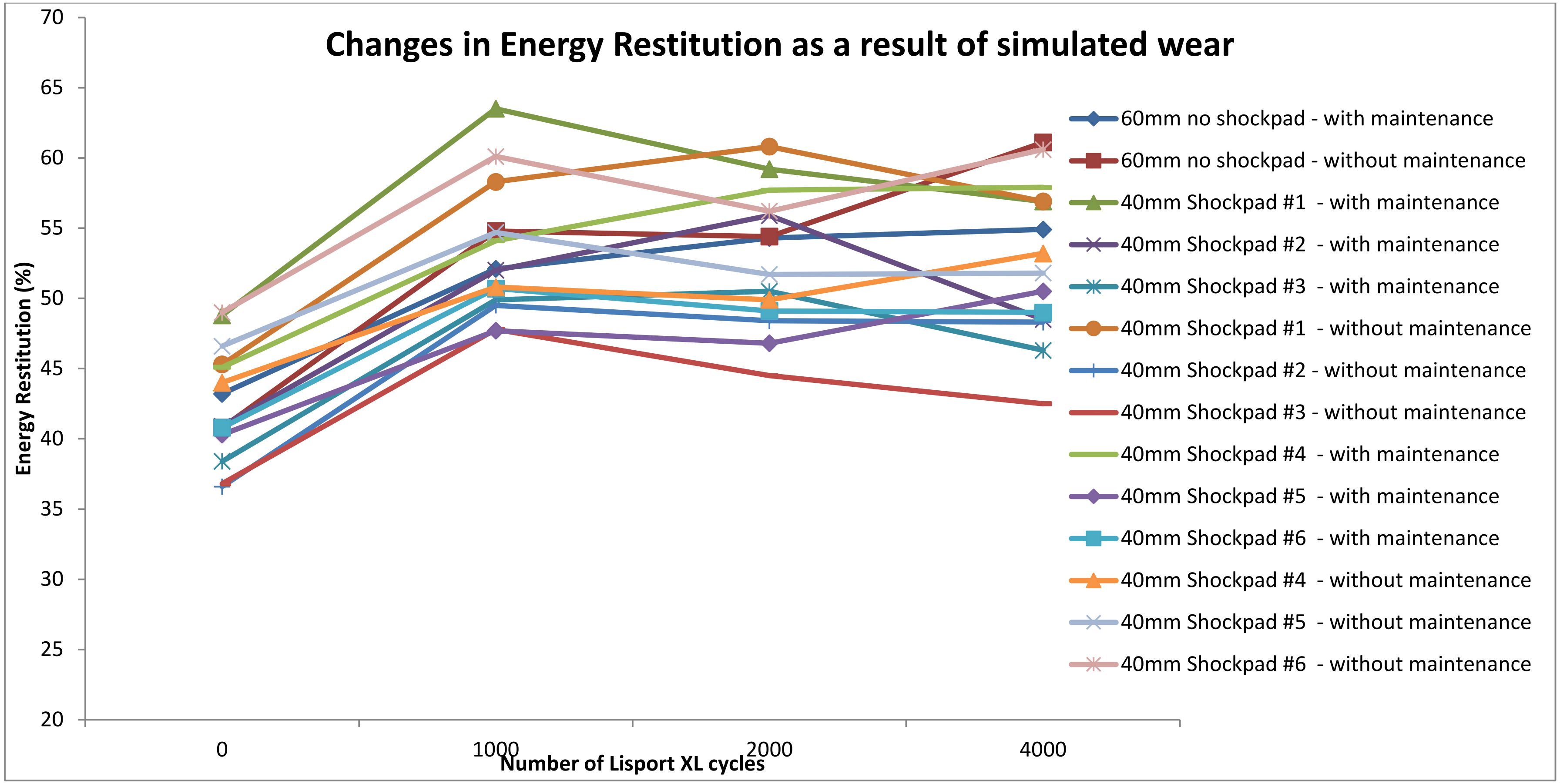


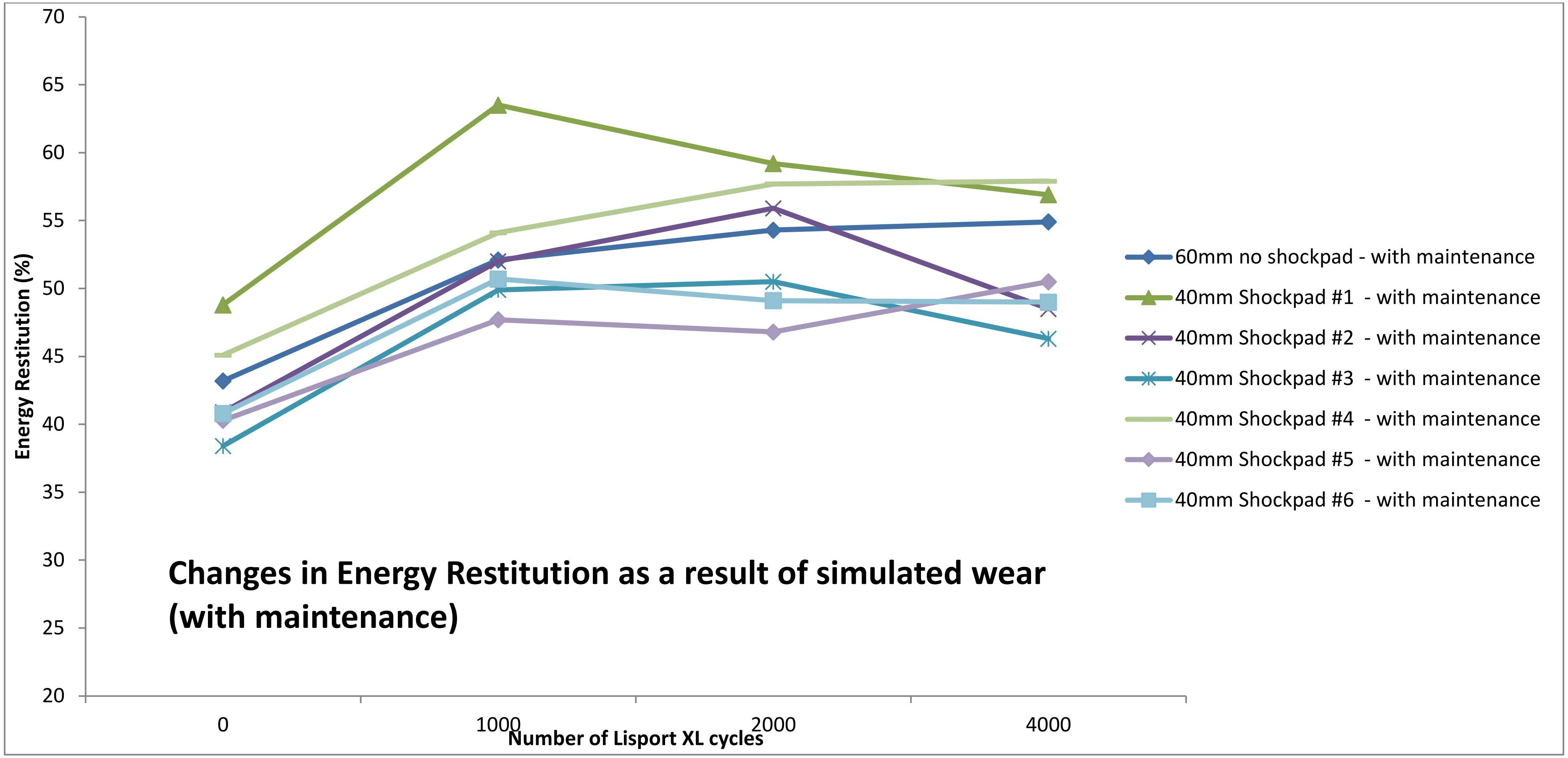
Changes in Shock Absorption as a result of simulated wear (without maintenance)
Shock absorption (%FR)
70
65
60
55
50
45
40
35
30
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - without maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance

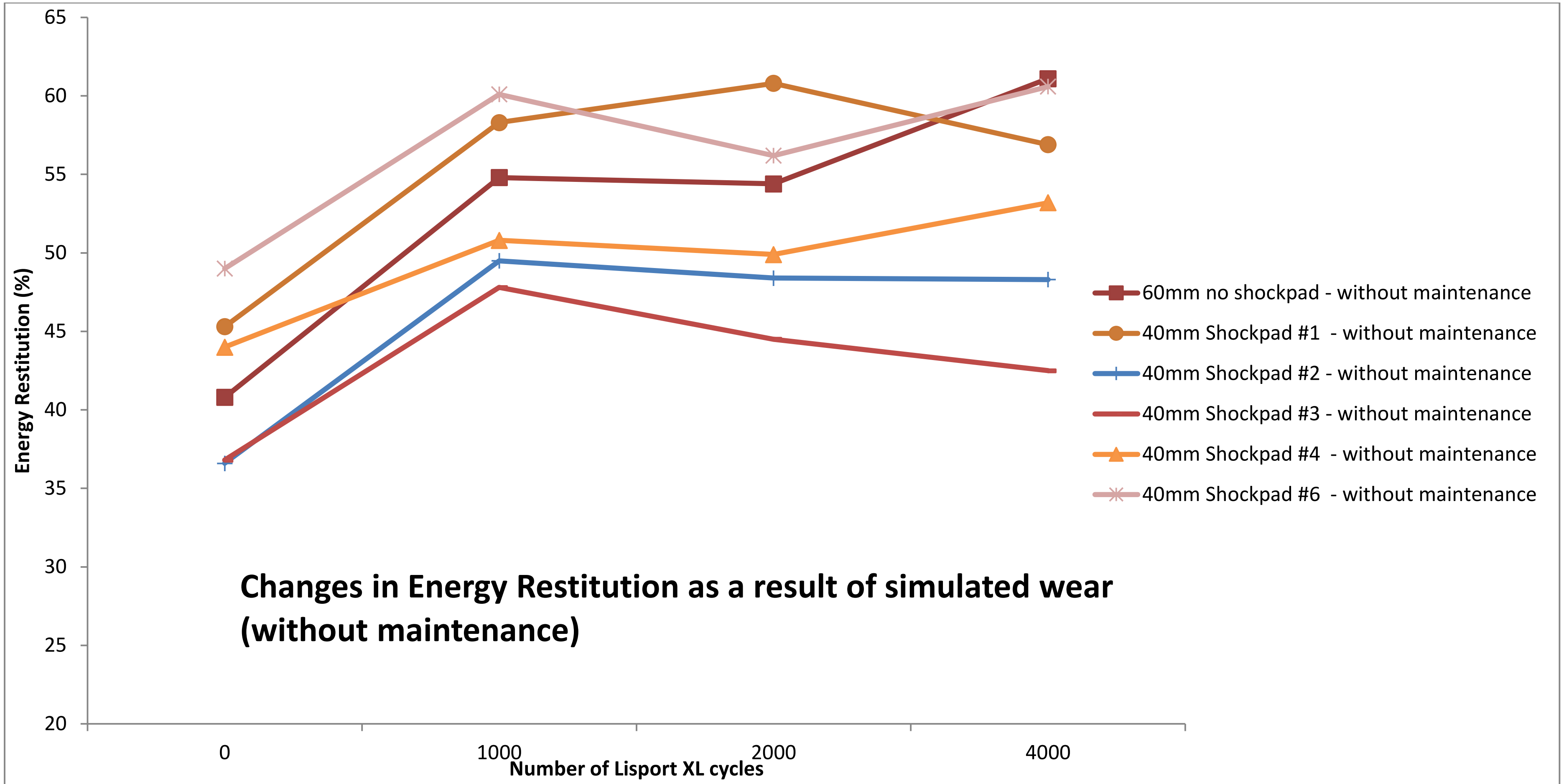

Changes in Deformation as a result of simulated wear
Deformation (mm)
11
10
9
8
7
6
5
4
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
60mm no shockpad - without maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance

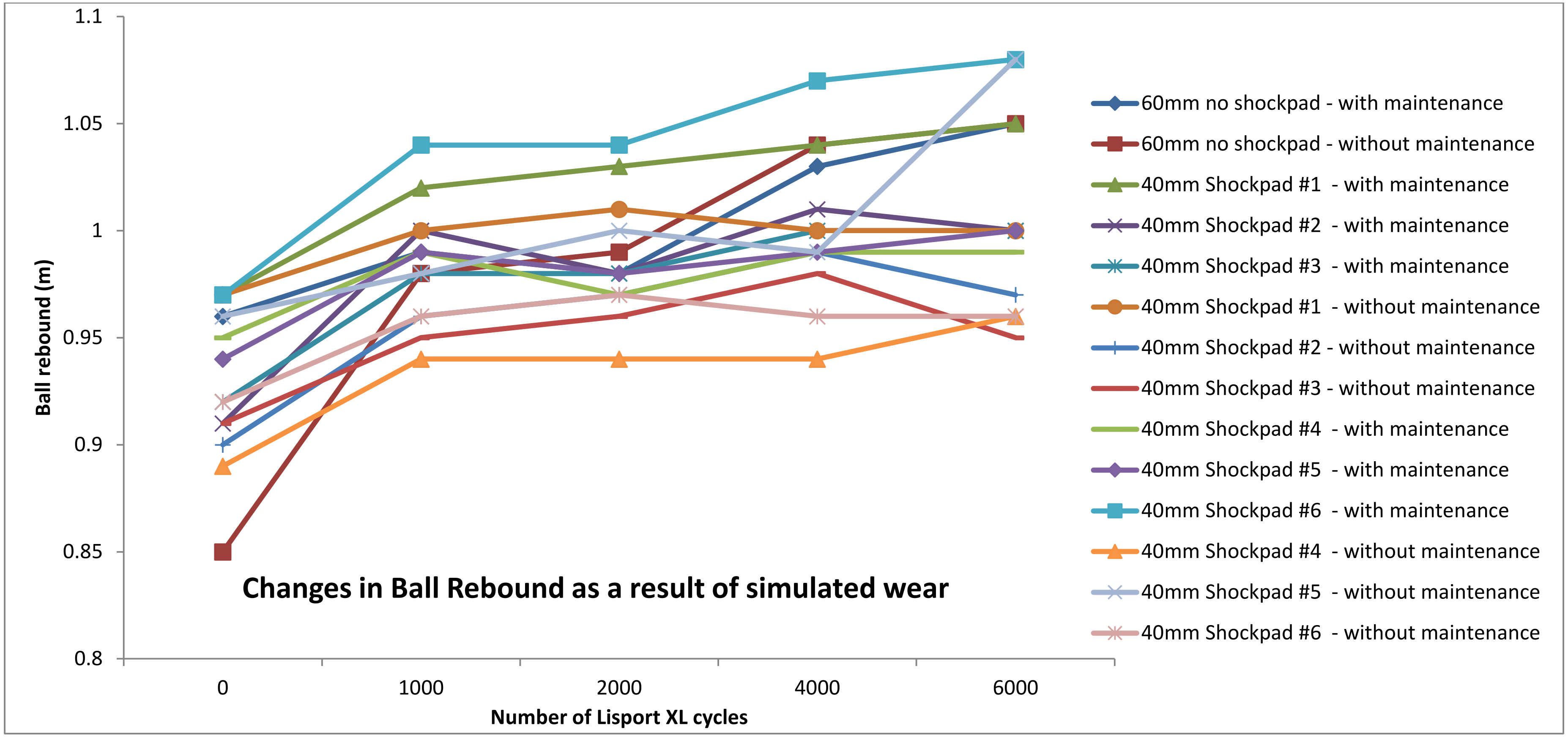

Changes in Deformation as a result of simulated wear
(with maintenance)
Deformation (mm)
11
10
9
8
7
6
5
4
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance

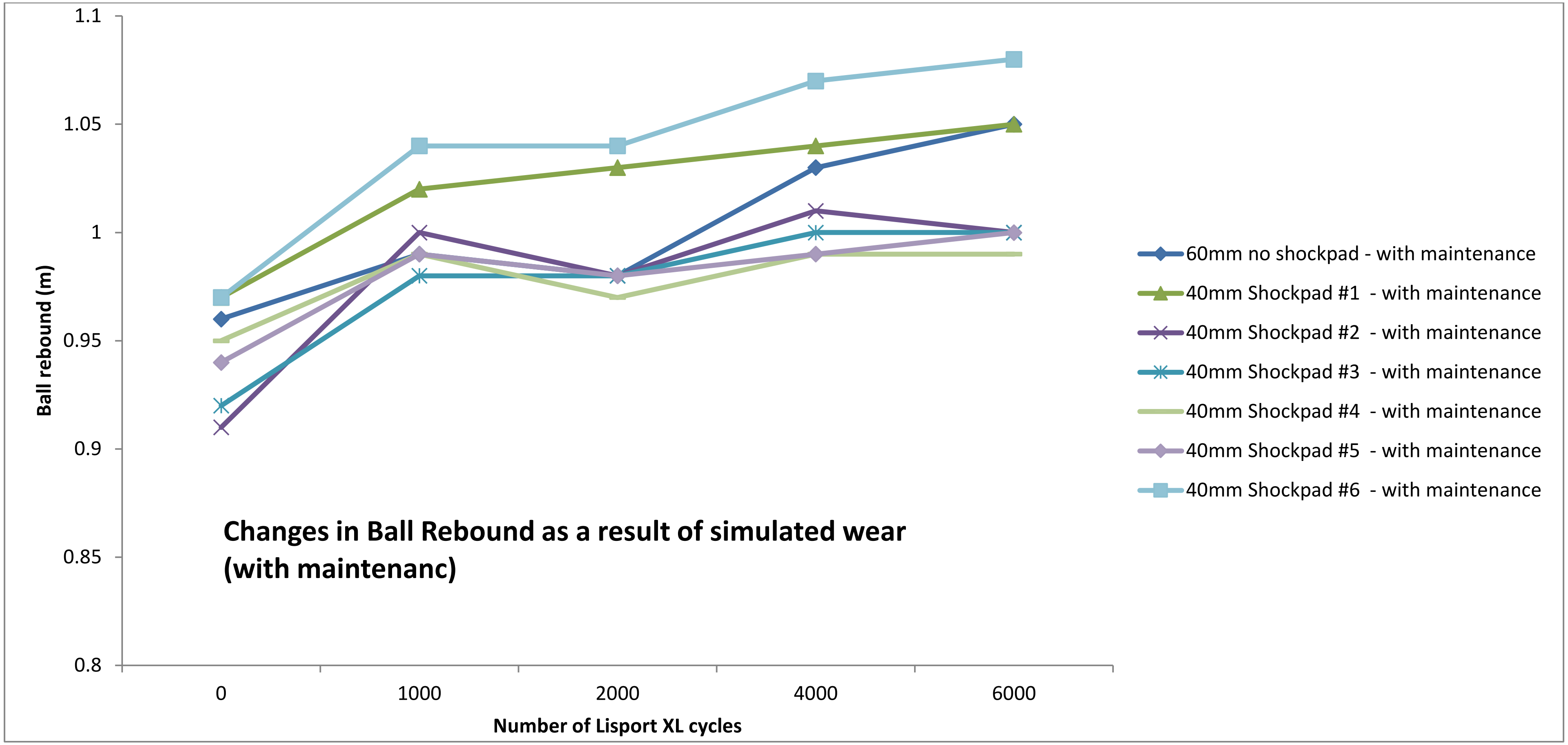

Changes in Deformation as a result of simulated wear
(without maintenance)
Deformation (mm)
11
10
9
8
7
6
5
4
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - without maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance

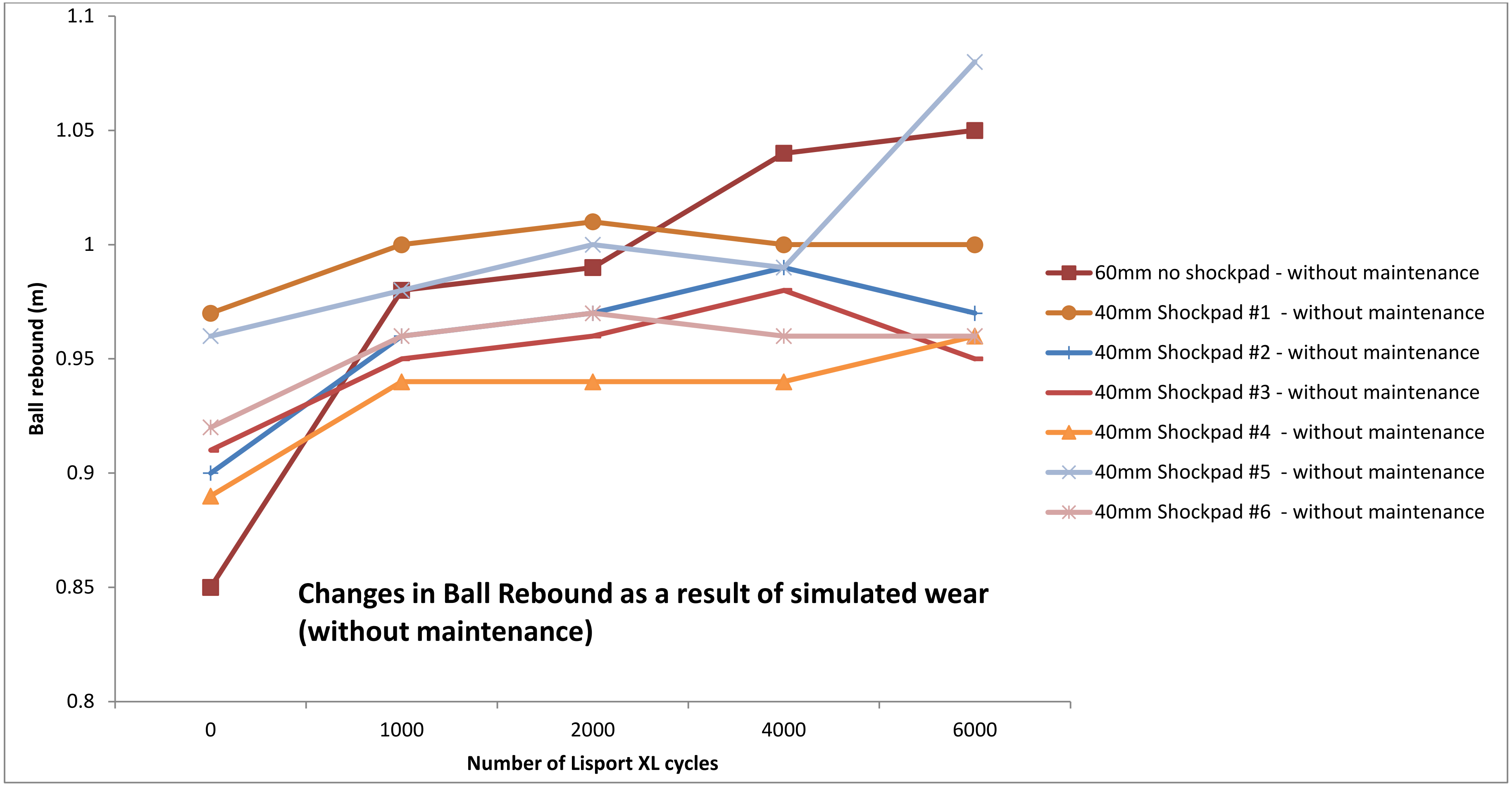

Changes in Energy Restitution as a result of simulated wear
Energy Restitution (%)
70
65
60
55
50
45
40
35
30
25
20
0
1000
2000
4000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
60mm no shockpad - without maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance

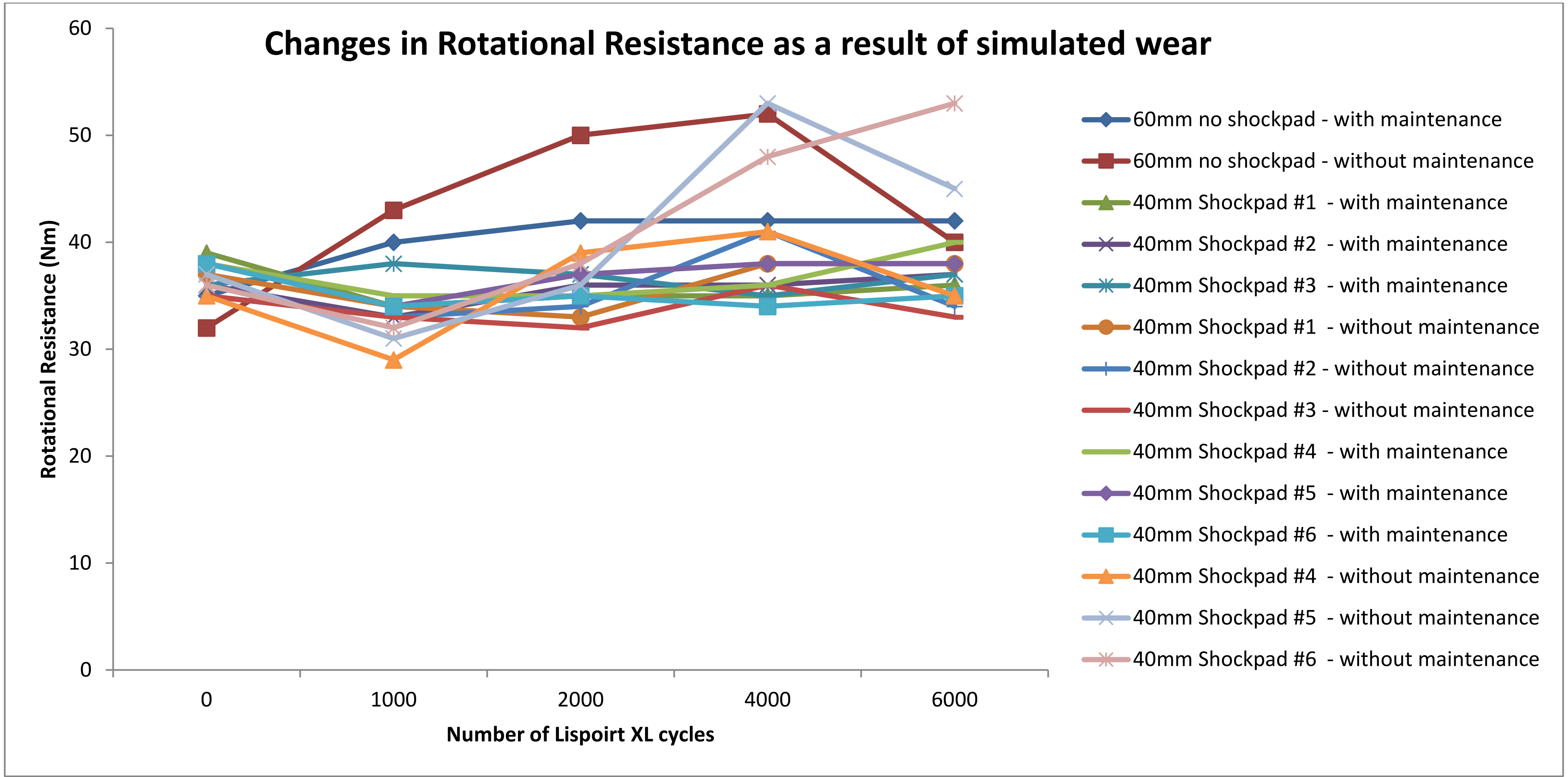

70
65
60
55
50
45
40
35
30
25
20
Energy Restitution (%)
0
1000
2000
4000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance
Changes in Energy Restitution as a result of simulated wear
(with maintenance)

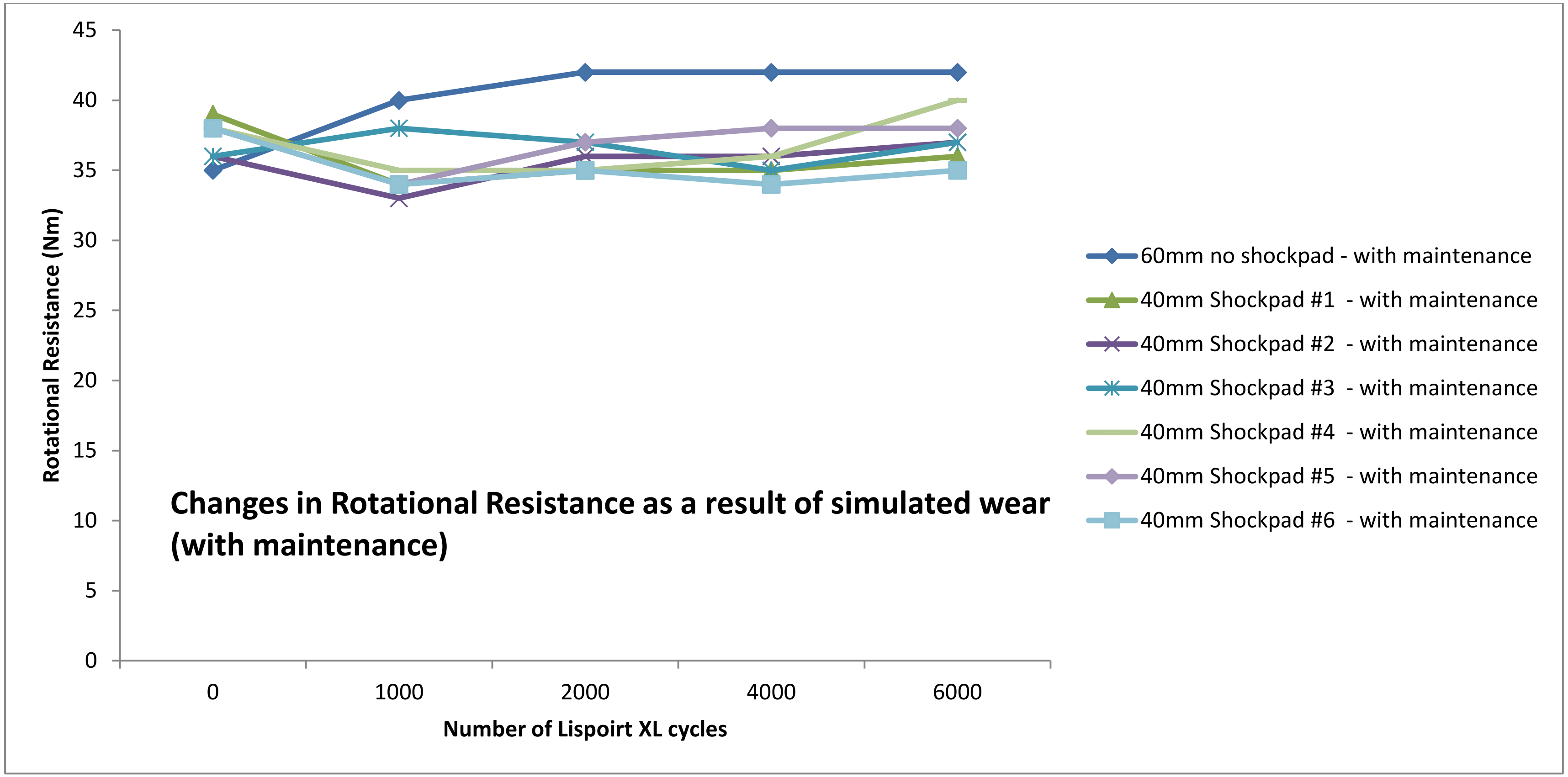

65
60
55
50
45
40
35
30
25
20
Energy Restitution (%)
0
1000
2000
4000
Number of Lisport XL cycles
60mm no shockpad - without maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #6 - without maintenance
Changes in Energy Restitution as a result of simulated wear
(without maintenance)

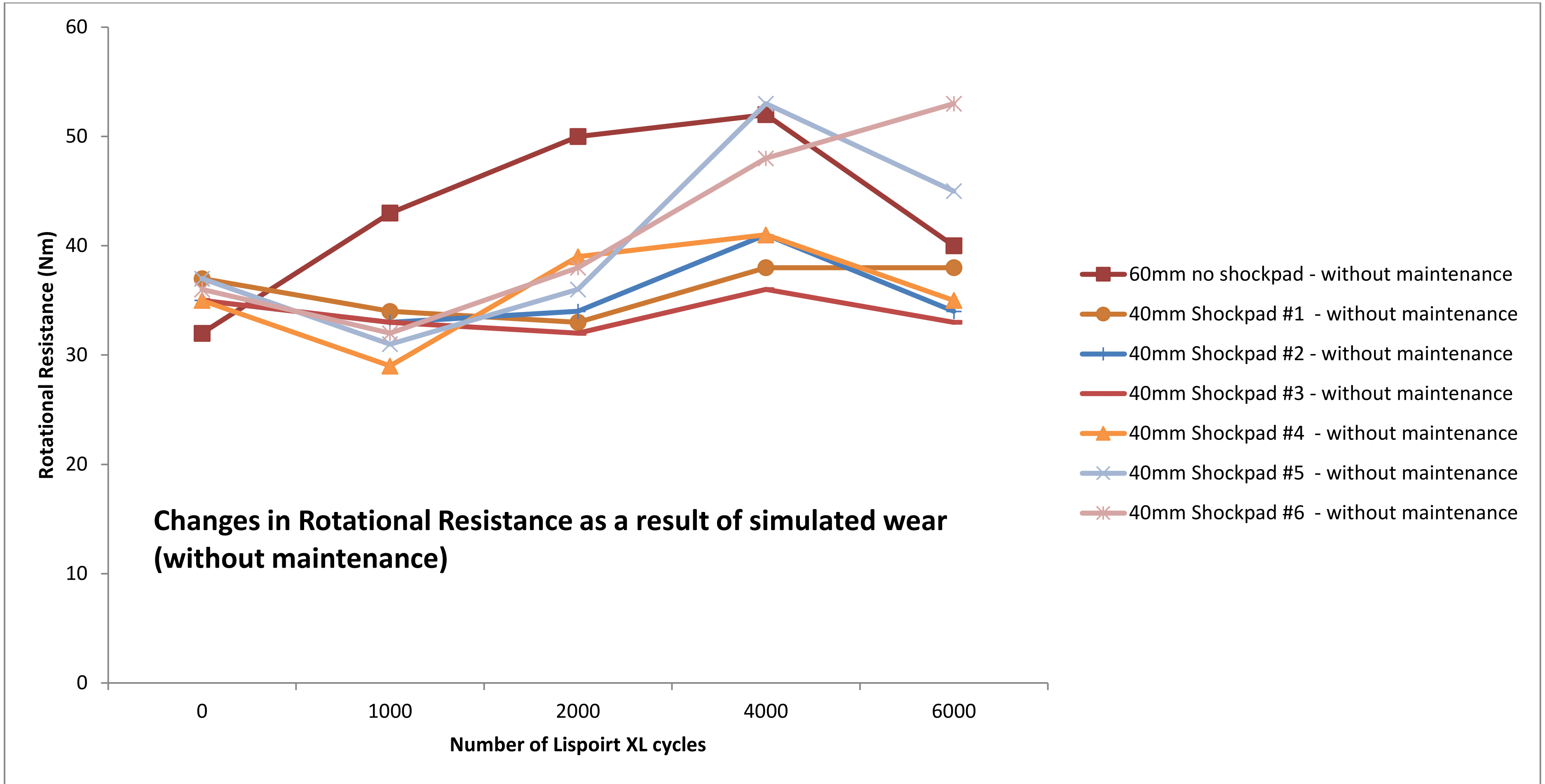

1.1
1.05
1
0.95
0.9
0.85
0.8
Ball rebound (m)
Changes in Ball Rebound as a result of simulated wear
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
60mm no shockpad - without maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance

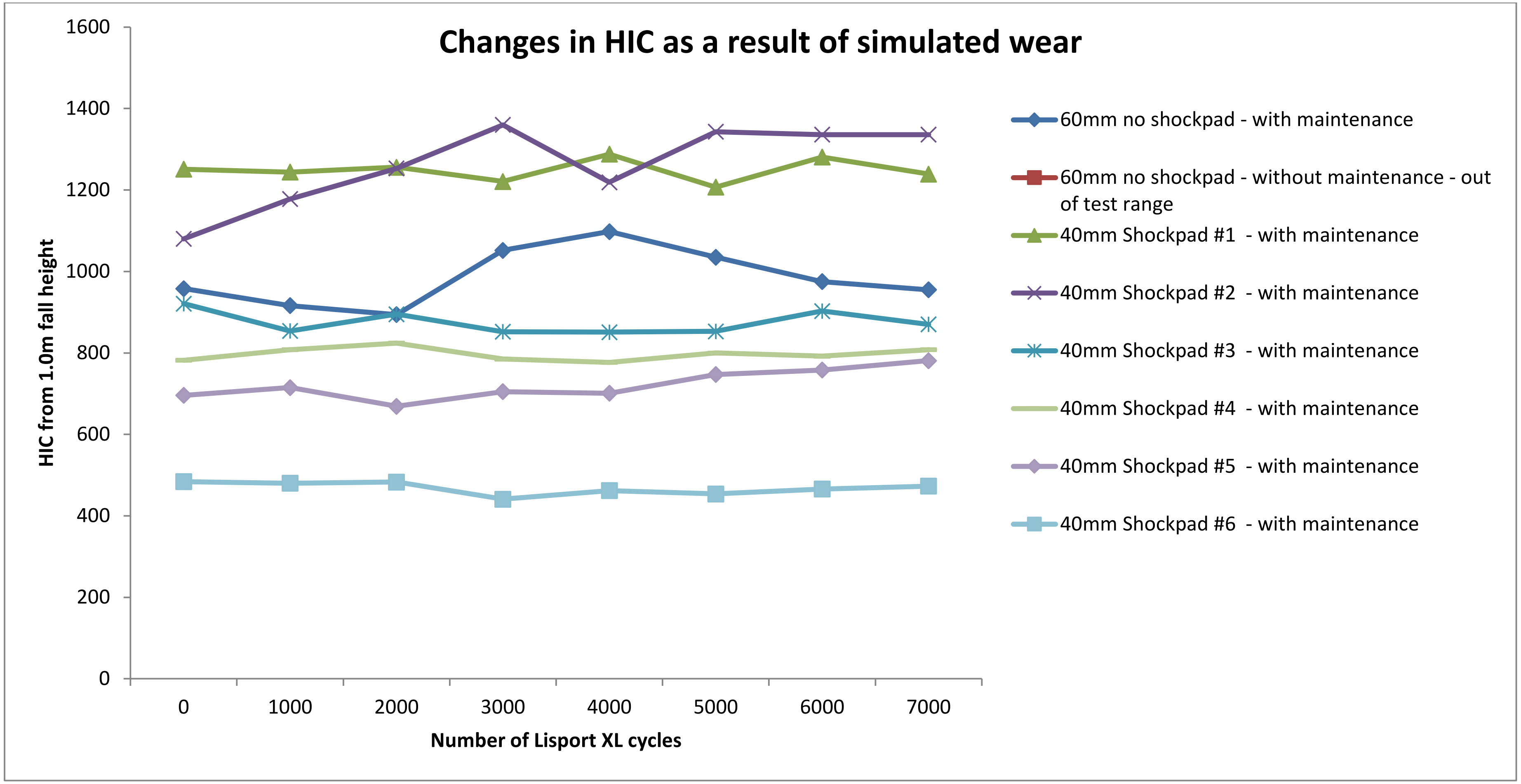

Changes in Ball Rebound as a result of simulated wear
(with maintenanc)
Ball rebound (m)
1.1
1.05
1
0.95
0.9
0.85
0.8
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance


1.1
1.05
1
0.95
0.9
0.85
0.8
Ball rebound (m)
0
1000
2000
4000
6000
Number of Lisport XL cycles
60mm no shockpad - without maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance
Changes in Ball Rebound as a result of simulated wear
(without maintenance)


Changes in Rotational Resistance as a result of simulated wear
Rotational Resistance (Nm)
60
50
40
30
20
10
0
0
1000
2000
4000
6000
Number of Lispoirt XL cycles
60mm no shockpad - with maintenance
60mm no shockpad - without maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance


Changes in Rotational Resistance as a result of simulated wear (with maintenance)
Rotational Resistance (Nm)
Number of Lispoirt XL cycles
0
1000
2000
4000
6000
45
40
35
30
25
20
15
10
5
0
60mm no shockpad - with maintenance
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance


Rotational Resistance (Nm)
60
50
40
30
20
10
0
Changes in Rotational Resistance as a result of simulated wear (without maintenance)
0
1000
2000
4000
6000
Number of Lispoirt XL cycles
60mm no shockpad - without maintenance
40mm Shockpad #1 - without maintenance
40mm Shockpad #2 - without maintenance
40mm Shockpad #3 - without maintenance
40mm Shockpad #4 - without maintenance
40mm Shockpad #5 - without maintenance
40mm Shockpad #6 - without maintenance


Changes in HIC as a result of simulated wear
HIC from 1.0m fall height
0
200
400
600
800
1000
1200
1400
1600
0
1000
2000
3000
4000
5000
6000
7000
Number of Lisport XL cycles
60mm no shockpad - with maintenance
60mm no shockpad - without maintenance - out of test range
40mm Shockpad #1 - with maintenance
40mm Shockpad #2 - with maintenance
40mm Shockpad #3 - with maintenance
40mm Shockpad #4 - with maintenance
40mm Shockpad #5 - with maintenance
40mm Shockpad #6 - with maintenance

APPENDIX C – INFLUENCE OF STITCH RATE ON INFILL DEPTHS

Number of simulated wear cycles	Mean infill depth (mm)							
	60mm pile / 13 stitches / 100mm (17+ 15 kg/m²)		60mm pile / 15 stitches / 100m (17 + 15 kg/m²)		60mm pile / 17 stitches / 100m (17 + 15 kg/m²)		60mm pile / 15 stitches / 100m (17 + 15 kg/m²)	
	Depth	Difference	Depth	Difference	Depth	Difference	Depth	Difference
0*	45	-	45	-	45	-	37	-
500	44	-1	43	-2	43	-2	-	
1000	44	-1	45	0	46	+1	39	+2
1500	44	-1	44	-1	45	0	-	
2000	42	-3	42	-3	45	0	39	+2
2500	42	-3	45	0	42	-3	-	
3000	41	-4	43	-2	45	0	38	+2
3500	44	-1	44	-1	45	0	-	
4000	42	-3	44	-1	44	-1	39	+2
5000	42	-3	44	-1	45	0	40	+3
6000	42	-3	44	-1	44	-1	40	+3
7000	41	-4	43	-2	44	-1	40	+3
* AFTER PRE-CONDITIONING								