

!



**Loughborough
University**

Engineering and Technology

!

!

M,*)\$/,+!6# ' !0&\$!+% ' /+ ' &\$)! ' /!0!+, *)\$ /, !1.+0!25!,# \$!N/.1\$&+.5!0/)!0&\$!(' /+.)\$&./=!0!-\$01\$!' 3!
02+\$/(\$!3&' 4!,#.\$&!+, *)5!' /!,# \$!=\$&' */)+! 3!40,\$&/.,5! &!0)' %8' /!-\$01\$!+#' *-)!+\$ \$P!0)1.(\$!3&' 4!
,# \$!M,*)\$ /, !A)1.(\$!0/)!M*%%' &,!MS&1.(\$!9!

A/5!3*--]84\$!%' +,=&0)*0,\$!&\$+\$0&(#!+, *)\$ /, !+8--!./!&\$(\$.,!' 3!N/.1\$&+.5!40./,\$/0/(\$!3*/).-/=!K!
=&0/,\$) !0!%\$&.')!' 3!-\$01\$!' 3!02+\$/(\$!' /!,# \$!=\$&' */)+! 3!40,\$&/.,5!-\$01\$K!6.--!2\$!\$-.-2-\$!3' &!F^!
6\$ \$P+!%054\$ /,!' 3!,#.\$&!/' &40!N/.1\$&+.5!3*/)\$)!+8%\$/)! *&./=!#,+!-\$01\$9!"#. +!./(-*)\$+!0-!
N/.1\$&+.5!3*/)\$)!+, *)\$ /, +K!.9\$9K!,#' +\$!3*/)\$)!25!,# \$!N/.1\$&+.5!K!2*,!0-+' !, #' +\$!3*/)\$)!,#&' *=#!
\$Z,\$&/0!0/)!N_B`!"&0././=! : &0/,+!0) 4./.,+,\$&\$)!25!,# \$!N/.1\$&+.5!0/)!%0.)!, ' !, # \$!+, *)\$ /,!' /!
2\$#0-3!' 3!,#' +\$!' &=0/.+08' /+9!

AV\$&!,\$\$!T&+,!F^!6\$ \$P+K!,# \$!3' --' 6./=!Da!6\$ \$P+!6.--!2\$!%0.)!0,!0!-\$1\$-!(' 44\$ /+* &0,\$!6.,#!
\$4%-' 5\$ \$!\$/8,-\$4\$ /,+,!' !+,0,*,' &5!40,\$&/.,5!%059!"# \$!T/0!Da!6\$ \$P+!0&\$!*/%0.)9!

A!+, *)\$ /, 0+!Z%\$(\$)!0,\$!' 3!(' /T/\$4\$ /, !4*+,!' ((*&!6.,#./!,# \$!+, *)\$ /, +#.%!060&)%\$&.')!, ' !2\$!
\$-.-2-\$!3' &!40,\$&/.,5!-\$01\$!3*/).-/=!9!

M,*)\$ /, +!6# ' !0&\$!&\$=+,\$&\$)! ' /!0!%0&],84\$!20+.' +! &!6# ' !0&\$!&\$(\$.1./=-!\$++!,#0/!0!3*--!+8%\$/)!
060&!6.--!&\$(\$.1\$!,#.\$&!+,0/0&)!%&' !&0,0!+8%\$/)!%054\$ /, +!3' &!,# \$!+04\$!%\$&.')+!' /!,# \$!+04\$!
20+.!0+!02' 1\$9!

!

!

!

!

"#\$!M(#' ' -!./!6#.(#!0!%&\$=/0/,!+,*)\$/,!6' &P+!.+!&\$+%'/+.2-\$!3' &!&.+P!0++\$++4\$/,+!./!&\$-08' /!, ' !
,\$\$.&!6' &P!0/)!\$/1.&' /4\$/,9!

A/5!#\$0-,#!0/)!+03\$,5!(' /(\$&/+!+#' *-)!2\$!&0.+)\$!.4 4\$).0,\$-5!6.,#./!,#,\$!0%%&' %&.0,\$!M(#' ' -! &!
; ' (, ' &0-!<' --\$=\$!>? (\$9!>((%08' /0-![\$0-,#!405!2\$!(' /+*-,\$)!3' &!(' /T)\$/80-!0)1.(\$!0/)!
=*.)0/(\$9!

<0&\$3*-(' /+.)\$&08' /!6.--!/\$\$)!,' !2\$!40)\$!0+!, ' !6#\$,\$\$&!,#,\$!+,*)\$/,!(0/!* /)\$&,OP\$!T\$-)!6' &PK!
%-0(\$4\$/,+!' &!-02' &0,' &5!6' &PK!' &!,*)5!02&' 0)K!6#.-+,%&\$=/0/,9!

f #\$\$&!/\$(\$+0&5!#\$0-,#!0/)!+03\$,5!0/)S' &!4\$).(0-!0)1.(\$!+#!' *-)!2\$!+' *=#,9!

!

N%)0,\$)!E*/\$!FGFH!

!

!