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EFFECT OF NANOCLAY ON PHYSICO MECHANICALPROPERTIESOF NBRRUBBERFORSEALAPPLICATIONS

R.Janarathanan, S.Ezhilan, S.Arunkumar
Assistant Professor, Department of Mechanical Engineering
Dhanalakshmi Srinivasan College of Engineering and Technology, Mamallapuram

ABSTRACT:

Inthisresearch,wehaveinvestigatedtheeffectsofadditionofdifferentpercentagesofnanoclayto the nitrile butadiene rubber (NBR) on the characteristics of the rubber as seal material. Properties suchas tensile strength, modulus at different extensions, elongation at break, compressive set, hardness, and oilswelling are tested to assess the effectofaddition ofthenanoclay. Results indicate thataddition ofnanoclay at certain compositions could slightly reduce the strength of the rubber. However more stablemodulus at different strains are provided, the hardness of the rubber is preserved and slightly enhanced, Atthe same time the compression test shows that the nanoclay improves the performance of the rubbers undercompressionwhichisessentialinsealapplication.

INTRODUCTION:

Elastomers are knownfortheir abilityto be stretched easily to high extensions and thenrapidly reverse back to shape when the stress isreleased.Themajorconstituentsofatypicalelastomercompoundare long chain moleculesknown as the base polymer, which provide thebasicchemicalandphysicalcharacteristics.Asmallamountoffreespace(termed‘‘freevolume’’)existsbetweenthelongchainmolecules. This allows for the movement of themoleculesmoreorlessindependentlyofoneanother.Itisthischaracteristicthatallowselastomeric components to deformand changeshape.Cross-linksformedwithintheclosely packedmolecularnetworkduringthevulcanizingorcuringprocessinfluencethereversibilityofelastomers.

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Decompression failure of a seal resultsfromthefollowingsequenceofevents:elastomericsealscontainvoidsandrigid inclusions that are produced during manufacture.Duringapplicationelastomersurfacecomesincontact with the fluid and the fluid gets absorbedinto the material. The absorbed gas diffuses intothe bulk of the elastomer until fully saturated. Athighpressure,theabsorbedgasisinthecompressedstate.

Whenexternalpressureissuddenlyreduced,thecompressedgasnucleatesa tthevoids. The compressed gas expands within theelastomers, and the voids inflate leading to hightensile stresses or strains in the void walls. If thetensile stress or strain at the wall of the void ishigher than the strength of the elastomer or theelongationatbreak,cracksinitiateandpropagate.Inmultipledecompressionap plications cracks can form and grow at stresseswellbelowthetensilestrength,oratstrainsbelowelongationatbreak,ifthen umberofdecompression cycles is higher than the numberof fatigue cycles to failure at the void wall stressor strain. This is clear evidence of the occurrenceoffatigue,thereby indicatingthatfatigueisamajor mechanism of failure for decompressioncycling.

Gasdecompressiondamagegenerallyincreases with pressure. The threshold pressureabove which damage occurs is linked to the gascombination and the hardness of the rubber. Atambienttemperature,thetensilepropertiesoffluorocarbon and nitrile greatly weakened whensaturatedwithcarbondioxide.

Additionoffillerissuggestedtoimprovethegeneralstiffnessoftherubber.How ever it is not definite how this might affectthe permeability and gas diffusion in the rubber.It is suggested by the previous researchers that astronginterfaceofthefillerandrubbercanreduce the diffusionwhilst a weak interface ofthe two phases could lead to higher permeabilityandincreasedpossibilityoftheexplosivedecompression.Itisrecommen dedthatelastomeric seals used in high pressure serviceshouldnothavevoidsand/orrigidinclusionslargerthan10mm.

Thefatiguefractureresistancealsodecreaseswiththeincreaseinthefillerperce

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ntages.Particlesofnanosizehavemorepotential of filling the gaps in the elastomer andmore likely to reduce the permeability and gasdiffusion in the rubber. Many researchers haveconsidered additionof the nanoparticles to therubber.Layeredclaysareparticularlygoodcandidates as nanoparticles for improvement ofthe characteristics of polymers because of theirhighsurfaceareaandtheirmorphology.Exfoliating-layeredparticlessuchastheclaysprovidesaveryefficientreinforcementofpolymers at loading levels much smaller than inthe case of solid particles like carbon black orsilica. Other properties can also be substantiallyimproved,includingincreasedresistancetosolvents,reduced permeabilityandflammability.

Differentmanufacturingtechniqueshave been used by previous researchers and theresultantproductischaracterizedforitsmechanical properties. However there is hardlyanypublisheddataoncharacterizationofthemodified rubberwith nanoparticles forspecialapplicationassealmaterial.Inthecurrentresearchaftermanufacturingrubb erwithaddition of nanoparticles, our main focus will beonexaminingtheproducedelastomerstoidentify its suitability for seal application at highpressureandtemperaturewhererapiddecompressioncouldcauseaproblem.Inth efollowingsections,weinitiallydescribethemanufacturing procedure used to produce nitrilebutadienerubber(NBR)withinclusionofnanoclay. Consequently, we report the results ofseveraltestsperformedonthemodifiedelastomers. We evaluate the effect of additionalnanoclayandcharacterizethehardness,permeability,strength,modulus,el ongationatbreak, and compression set of the manufacturedcompositestoassessitssuitabilityforspecialseal application. Scanning electronmicroscopy(SEM) and X-ray diffraction (XRD) are used toevaluate the quality of the produced rubbers anddispersionofthenanoparticles.

MATERIALS,PROCESSING,ANDMETHODOLOGY:

Organoclay.Theorganoclayusedfortheinsertionismontmorillonite-basedclayfromEnglish Indian Clays LTD, Thiruvananthapuram,Kerala,India.,commerciallycalledNanocaliber - 200 M. Nanocaliber 200 M is Mercaptosilanegrafted nano kaolin plates

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imparting advantagesinmechanicalandbarrierproperties.

NBRSamples.Nitrile(acrylonitrile-butadienedipolymer or NBR) which is a Synthetic rubbercopolymer of acrylonitrile and butadiene. NBRseals are used for oil applications because theyare resistant to oil, fuel, chemicals and have highresilience.NBRhasabetterpermeabilityresistancecomparedwithEPDM.NBRcanwithstanda rangeoftemperaturesfrom-40°Cto +120°C.

Ingredients	REGULARCOMPOUND	NC-00	NC-25	NC-50	NC-75	NC-100
CARBONBLACKN550	60	60	60	60	60	60
CARBONBLACKN330	20	0	0	0	0	0
NANOCALIBER200M	0	0	2.5	5	7.5	10

TABLE1.CompositionoftheNBRsamplesmanufactured.

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ForttheNBRrubbersixdifferentcompositionsarechosentobemanufactured.Detail of the composition shown in Table 1. Thechoices of formulations are based on keeping thesamplesascloseaspossibletotheroutinemanufacturing formulation with addition of partsoforganoclay.Thisistomakesurethattheviscosity and consistency of the formulation arestill adequate to use the company's processingroute. Therefore, the carbon black combinationsare chosensimilar to what is used in preparingthe NBR elastomers. However with the additionof nanoclay or replacement of part of the carbonblack the possibility of exploring the effectofadditionofnanoclayisprovided.

MANUFACTURINGPROCESS:

Allthecompoundsareweightedinitially and mixed afterwards in a two roll mill,Thecompoundmixingisconductedinthelaboratory The polymer is first added and mixedfor30sectopremasticateandthusallowaneasier incorporation of filler. The sheets are allmolded for 20 min at 185°C using the standardtestsheetmold.

METHODOLOGYFOR CHARACTERIZATION:

TensileTests.Samplesoftheelastomersareprepared for tensile testing according to ASTM412 standard. These samples are tested using azwick tensile tester applying a constant force of500 N at a speed of 500 mm min^{-1}. The modulusfor different extension range, elongation at breakand the tensile strength are extracted from thestress–straincurvesobtained.Foreachcomposition of the EPDM and NBR, six samplesare tested and the results reported are the meanvalues.

Hardness Tests. Hardness test is carried out oneach sample using a Bareiss hardness tester. TheIRHD (International Rubber Hardness Degrees)instrument has a steel ball indenter which indentsthe sample under a minor and major Load. Thedifferentialindentationdepthismeasured andtabulatedtoreaddirectlyin‘‘IRHD’’degrees.

COMPRESSIONSET TEST:

Compression set testing measures the ability ofthe rubber to return to its

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original thickness afterprolongedcompressivestressesatagiventemperature and deflection. As a rubber materialis compressed overtime, it loses its ability toreturntoitsoriginalthickness.Thislossofresiliency may reduce the capability of a rubberseal to perform over a long period of time. Theresulting permanent set that a seal may take overtime may cause a leak. Compression Set resultsfor a material are expressed as percentage. Thelowerthepercentagefigure,thebetterthematerial resists permanent deformation under agivendeflectionandtemperaturerange.Thespecimens are compressed by 50% at 100°C for24hr.

RESULTSAND DISCUSSION:

All the data reported within the result section areaverages fromtestingsixsamples.Modulus, Tensile Strength, and Elongation atBreak

For each composition, six samples are tested andthehardness,tensilestrength,elongationofbreak and modulus of break of these six samplesof each composition are extracted. The averagevaluesarereportedonTable2.
ThemodulusofNBRsamplesfordifferentelongationpercentageafterageinginhot air,ASTM 1 oil and ASTM 3 oil is shown in Fig. 1.The trend for changes in modulus is very similarfor Samples 1–3 with increase of modulus for thesampleswithnanoclaycomparedwiththestandard NBR sample. The trend reverses withfurther increase in the nanofiller addition whichshowsignificantlylowermodulus .
Interms of tensile strengthslightreductionisindicatedinNC-50withnanoclaywhichisreportedinFig.2.Elongationatbreakisincreasedcompar edwiththestandardNBRsample.

TABLE2. Originalproperties

PROPERTIES	NC-00	NC-25	NC-50	NC-75	NC-100
HARDN ESSSHO	71	72	70	73	74

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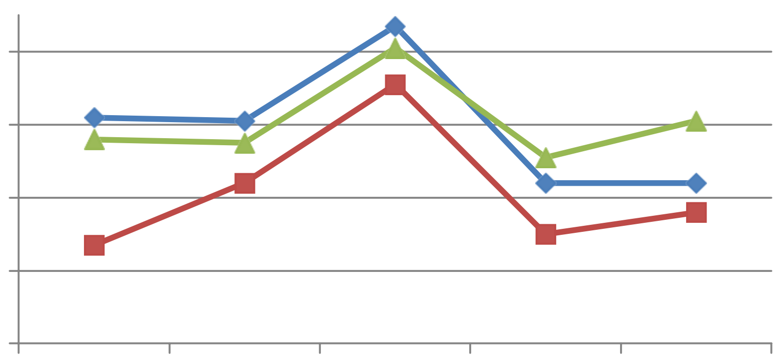
RE-A					
T.S. (Kg/Cm^2)	205	218	202	219	215
%E@Break	329	336	374	339	316
σ50 (Kg/Cm^2)	5.16	5.65	5.68	5.96	6.24
σ100(Kg/Cm^2)	47.22	51.58	45.65	52.23	57.35
σ300(Kg/Cm^2)	193.15	203.60	178.31	203.80	207.67

HARDNESS:

Additionof nanoclay to NBR does not changethe hardness significantly, only the reduction ofthehardnessfortheNC-50isnoticeable.The



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trendofchangesinthehardnesswiththeaddition of the nanoclay correlates well with thetrendsinthemodulusandisreportedinFig.3.

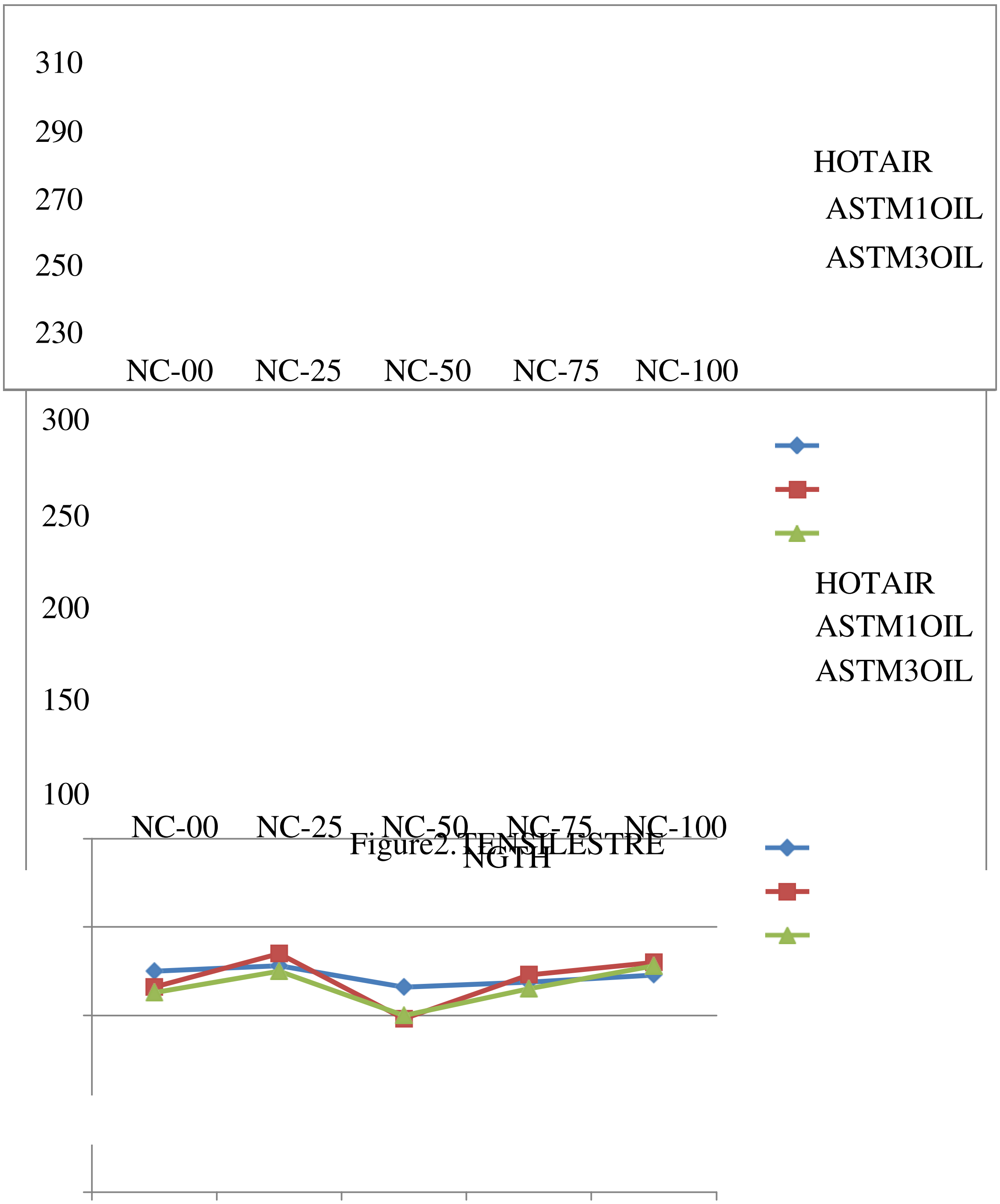

Figure2.TENSILESTRENGTH

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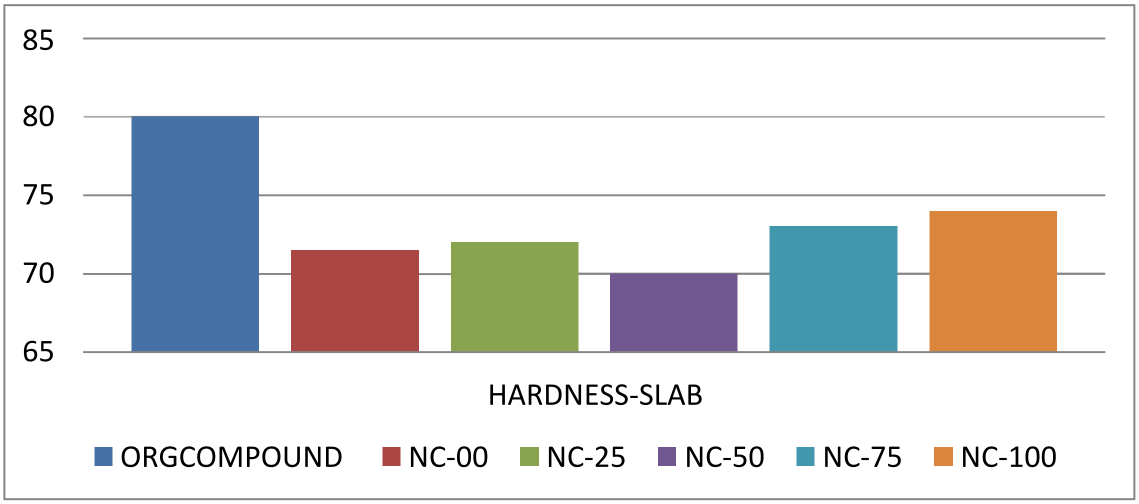

Figure3.HARDNESCOMPRESSIONSET
TEST:

TheresultsofthecompressionsetforthesamplesofNBRisshowninFig.4.Inthecaseof Nitrile, inserting the organoclay in the rubbermatrix greatly reduces the deformation sustainedbytheelastomer.

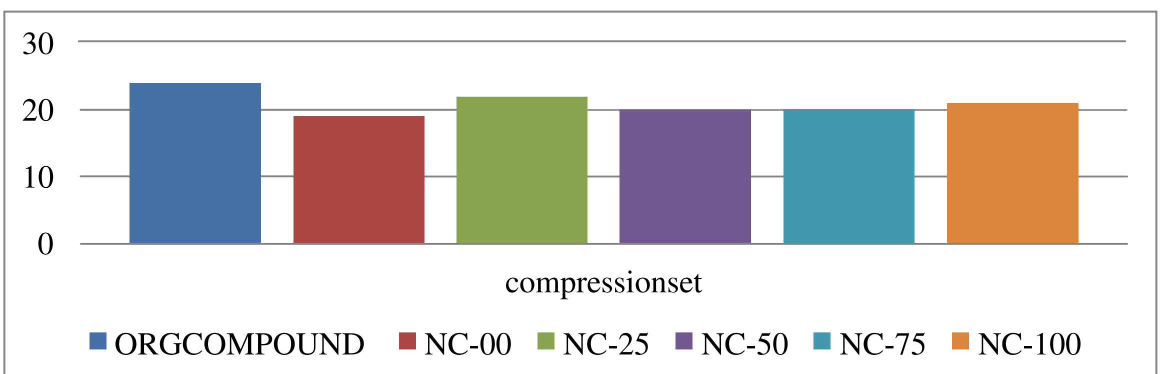

Figure4.COMPRESSIONSET

InNBR samples the nanoclayresults in restrictioninpolymerchainmovementsandlower compression set. The increased formationof effective network chains or crosslinking in thedeformed statedecreasescompressionset

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CONCLUSION:

The workprogressedby varyingthe nanoclayhas given different set of properties, The additionof nanoclay shows a significant improvement inlowercompressionset,hardness,tensilestrength,

and modulus of the rubber. The enhancement ofproperty after ageing in hot air, ASTM 1 oil andASTM 2 oilalso shows asignificantincreasecomparedtotheoriginalcompoundwithoutadditiononnanofiller. Furthermoretoreducethecompressionsetproperty,theworkistobecontinuedbyincludingTESPT(organofunctionalsilane)totheexistingformulationasthisenablesbetter fillerpolymerinteractionbesidesimprovingcrosslinkingefficiently,furtherScanningelectronmicroscopy(SEM)andX-raydiffraction(XRD)areusedtoevaluatethequality of the produced rubbers and dispersion ofthenanoparticles.

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