

Abstract:

SFGHITEN® (super fine grain, high strength steel sheet), which was developed recently by JFE Steel, is strengthened by fine Nb(C, N) precipitates and grain refinement, giving it excellent press formability suitable for automotive exposed panels. The Nb(C, N) precipitate shows a unique distribution which had not been observed previously and tends to form precipitate-depleted zones, called precipitate free zones (PFZ), in the vicinity of grain boundaries. These PFZs lower yield strength in spite of the small size of the grains. In comparison with conventional deep-drawing sheets, SFGHITEN has a high r-value, combined with excellent resistance to secondary embrittlement imparted by B addition. Try-out pressing for an automotive front-fender model was successfully conducted and demonstrated that the new material has excellent formability, displaying a wider formable range than the conventional steel.

1. Introduction

Hmsqnc t bshnm ne ghfg,rsqdmfsg rsddk rgddsr vghbg l dds vdhfgs qdct bshnm mdder hm `tsn ancx o`mdkr hr oqnfqdr, hmf q`ohckx- @ l nmf sgdrd+ rsqdmfsgdmhmf ax `cchmf rnkhe rnktsnm rsqdmfsgdmhmf dkd l dmsr rtbg `r Rh+ Lm+ `mc nsgdqr+ a`rde nm `m HE 'hmsdqrshsh`k eqdd(rsddk bgd l hb`k bn l onrshnm+ hr trde sn `bghdud ghfg sdmrhkd rsqdmfsg hm dwonrde o`mdkr hm uhdv ne sgd ghfg enq l `ahkhsx `mc r tq,

e`bd oqnodqsx qdpthqd l dmsr ne sghr `ookhb`shnm.⁰⁰ Gnv, dudq+ hs hr che@btk s n rdbtqd enq l `ahkhsx dpt`k sn sg`s ne l hke rsddk adb`trd `cchshnm ne rnkhe rnktsnm rsqdmfsgdm, hmf dkd l dmsr cdsdqhnq` sdr eddo,cq`v` ahkhsx 'r,u`ktd(+ `mc sgd vnqj g`qcdmhmf hmc dw 'n,u`ktd(cdbqd`rdr `r xhdke rsqdmfsg hmbqd`rdr- Lnqdnudq+ vgd m sgd rsqdmfsg ne sgd o`qdms og`rd hr hmbqd`rde+ fq`hm antmc`qx rsqdmfsg rgnvr

REFGHSDM `mc sgd `cu`ms`fdr ne sghr oqnc tbs v gdm
`ookhdc hm `tsn l nshud dwonrdc o`mdkr-

2. Phenomena Observed in SFGHITEN and Their Basic Mechanism

Hm `bghduhmf ghfg rsqdmfsg a`rdc nm HE rsddk+ trd ne sgd rnkhc rnktsnm g`qcdmhmf l dbg`mhr l+ hm vghbg rsqdmfsgdmhmf dkd l dmsr rtbg `r Rh+ Lm+ O`mc nsgdqr `qd`ccdc hm k`qfd pt`mshsx+ hr `bnmbdos vhsq` knmf ghr, snqx- Gnvduq+ adb`trd sgd rd rsqdmfsgdmhmf dkd l dmsr+ `mc o`qshbt k`qx Rh+ cdsdqhnq`sd cddo cq`v`ahkhsx `mc sgd pt`khsx ne sgd bn`sdc rtqe`bd+ oqnc tbsr l`mte`b, stqdc ax sghr sdbgmhptd b`mmns ad trdc hm dwonrdc o`m, dkr hm vghbg bn l okdw enq l hmf hr qdpthqdc- Hm bnmsq`rs+ `r sgd bnmbdos ne sgd oqdrdms cdudkno l dms+ ghfg rsqdmfsg hr `bghdudc ax oqdbhohs`sd chrodqrhnm g`qcdmhmf trhmf @md Ma'B+ M(+ vhsqnts `cchmf Rh`r` `rsqdmfsgdmhmf dkd l dms+ hm bn l ahm`shnm vhsq edqqhsd fq`hm qd@md l dms+ vghkd sgd cddo cq`v hmf oqnodqsx hr rdbtqdc ax h l oqnuhmf sgd bnkc, qnkkhmf qdbqxrs`kky`shnm sdwstqd ax fq`hm qd@md l dms hm sgd gns, qnkkdc rgdds `mc dmbntq`fhmf `bghdud l dms ne sgd z000| sdwstqd+ vghbg hr `cu`ms`fdntr enq cddo cq`v`ahk, hsx- @r` qdrtkst ghfg rsqdmfsg `mc h l oqnude cddo cq`v, `ahkhsx `qd`khydc rh l tks`mdntrkx- @m HE rsddk bn l, onrhshnm cdrhfm v`r `cnosdc+ vhsq Ma`ccdc enq fq`hm qd@md l dms- Sgd B bnmsdms v`r rds `s l nad sg`m cnt. akd sg`s hm nqchm`qx tksq`, knv b`qanm rsddk '2/ ool nq tmedq(hm nqcdq sn rsqdmfsgdm fq`hm qd@md l dms+ `mc Ma

sd l odq`stqdr hmbqd`rdr+ `mc ghfg r,u`ktdr dwbddchmf 1-4
b`m ad nas`hmdc ax fq`hm bn`qrdmhmf+ dudm vhsq HE rsddkr+
`r rgnvm hm sghr @ftqd- Gnvduq+ sghr hr ne khsskd oq`bsh,
b`k u`ktd adb`trd sgd rtqe`bd cdedbs b`kkdc @nq`mfd oddk,
nbbtqr vgd m rgdds vhsq bn`qrd, fq`hmdc rsqtbstqdr `qd
oqdr, enq l dc- Eqn l sgd uhdvonhms ne rths`ahkhsx enq oq`b,
shb`k `ookhb`shnmr+ sgd qdk`shnmrgo ads vddm sgd fq`hm rhyd
`mc r,u`ktd ne rsddk A+ vghbg bnmrhrsr ne @md fq`hmr+ hr
fqd`skx h l oqnudc eqn l sg`s ne sgd bnmudmshnm`k HE rsddkr-

Sghr @md l hbqnrstbstqd `mc sgd dwhrsdmbd ne Ma oqd,
bhohs`sdr `qd chrshmbshud ed`stqdr ne rsddk A- **Photo 3**

'XR(hmbqd`rdc eqn l 10/ LO` sn 12/ LO` `r sgd gd`s, hmf q`sd hmbqd`rdc- Sgd fq`hm rhyd qd l`hmdc uhqst`kkx tmbg`mfdc+ rgnv hmf ` bnmrs`ms u`kt d '7-1 7-3 μ l(`s`kk gd`shmf q`sdr-

Photo 4 rgnvr SDL qdokhb` h l`fdr ne sgd rsdckr `mmd`kdc `s gd`shmf q`sdr ne lâB.r`mc 04âB.r- @ksngt fg OEYr b`m ad rddm nm nmd rhcd ne sgd fq`hm antmc`q, hdr+ ` ghfgdq OEY enq l`shnm q`shn b`m ad nardquc hm sgd rsdck `mmd`kdc `s lâB.r- **Figure 8** rgnvr XR `mc sgd vnqj g`qcdmhmf hmc dw 'n,u`kt d(oknssdc `f`hmrs sgd unk, t l d eq`bshnm ne OEY l d`rtqdc eqn l sgd SDL h l`fdr- Xhdkc rsqdmfsg cdbqd`rdr `r sgd unkt l d eq`bshnm ne OEY hmbqd`rdr- Eqn l sghr+ hs hr bkd`q sg`s OEY hr sgd qd`rnm enq knv XR-

4. Secondary Work Embrittlement⁵

Hm fdmdq`k HE rsdckr g`ud knv fq`hm antmc`qx rsqdmfsg hm bn l o`qhrnm vhsq hmsq`fq`mtk`q rsqdmfsg adb`trd hmsdq, rshsh`k dkd l dmsr cn mns dwhrs `s sgd fq`hm antmc`qhr- Hm o`qshbtk`q hm ghfg,rsqdmfsg rsdckr a`rdc nm HE rsdck+ hs hr mdbdrr`qx sn bnmrhdq l d`rtqdr sn oqdudms qdctbdc qdrhrs`mbd sn rdbnmc`qx d l aqhsskd l dms b`trdc ax sgd rsqdmfsg cheedqmdbd adsvddm sgd fq`hmr `mc fq`hm antmc, `qhr- Sgdqdenqd+ qdrhrs`mbd sn rdbnmc`qx d l aqhsskd l dms v`r hmudrshf`sd hm sgd mdv SR33/ LO` fq`cd rto dq @md fq`hm rsdck+ REFGHSDM- Sghr REFGHSDM v`r bn l o`qdc vhsq sgd bnmudshnm`k Ma,`ccdc HE ghfg rsqdmfsg rsdck rgdds+ `mc sgd deedbs ne fq`hm qd@md l dms `mc A `cchshnm+ vghbg hr deedbshud hm h l oqnuhmf qdrhrs`mbd sn rdbnmc`qx d l aqhsskd l dms hm HE rsdckr⁷ v`r bn l o`qdc-

Trhmf sgd bgd l hb`k bn l onrshnmr rgnvm hm **Table 3**. vghbg `qd a`rdc nm /-2 \$ Rh, 1- / \$ Lm, /- /64 \$ O rsdck+ r`l okd rsdckr vhsq 3 kdudkr ne `ccdc A '1+ 3+ 0+ /`mc 04 oo l(vdqd oqdo`qdc- Sgd oqnbdc tqd trdc hm oqdo`q, hmf bnkc, qnkkdc `mc `mmd`kdc rsdck rsqhor v`r a`rhh`kkx sgd r`l d `r hm Bg`osdq 1- @esdq cq`vhmf sgd bnkc, qnkkdc `mc `mmd`kdc rsqhor sn `bto rg`od `s` cq`vhmf q`shn ne 1- /`mc l dbg`mhb`kkx fqhmchmf sgd dcfd sn nas`hm `bto

gdhfgs ne 24 l l+ sgd cdenq l`shnm 'eq`bstqd sdrs(rgnvm hm **Photo 5** v`r odqenq l dc `s u`qhntr sd l odq`stqdr+ `mc sgd kh l hs sd l odq`stqd enq ctbshkd cdenq l`shnm v`r trdc `r sgd sq`mrshnm sd l odq`stqd enq rdbnmc`qx vnqj d l aqhs, skd l dms-

Figure 9 rgnvr sgd deedbs ne A nm sgd sa`mrshnm sd l , odq`stqd- Ehqrs+ vhsngnts A `cchshnm+ rsdck @+ vghbg hr ` bnmudshnm`k SR33/ LO` fq`cd HE ghfg rsqdmfsg rsdck rgdds+ chrok`xdc `sq`mrshnm sd l odq`stqd ne -4âB+ ats hm sgd rsdck A+ vghbg hr `m REFGHSDM+ sgd sq`mrshnm sd l , odq`stqd hr qdctbdc qd l`qj`ax+ sn -7/âB- Sghr deedbs hr `ssghatsdc sn `kkduh`shnm ne rsqdr bnmbdmsa`shnmr md`a sgd fq`hm antmc`qhr ctqhmf cddo cq`vhmf ax qd@md l dms ne sgd edqhsd l hbqrsqtbstqd `mc enq l`shnm ne OEYr- Mdws+ vhsq hmbqd`rhmf `l ntmr ne A `cchshnm+ sgd sq`mrshnm sd l odq`stqdr ne ansg rsdckr h l oqnuhc+ `mc vhsq `ooqnw, h l`sdkx 0/ oo l A `cchshnm+ dudm rsdck @ rgnvdc qdrhr, s`mbd sn rdbnmc`qx d l aqhsskd l dms dpt`k sn sg`s ne rsdck A vhsngnts A `cchshnm- Sgtr+ sgd @md edqhsd rsqtbstqd `mc

Table 3 Chemical composition of steels investigated

| Rsdck | B | M | R | Ma | Sh | A |
|--------|--------|-----------|-----------|-----------|--------|--------|
| 'oo l(| 'oo l(| 'l`rr \$(| 'l`rr \$(| 'l`rr \$(| 'oo l(| 'oo l(|
| @// | 13 | 07 | /- /4 | /- /3 | /- /34 | sa`bd |
| @/1 | 15 | 07 | /- /4 | /- /2 | /- /34 | 1 |
| @/3 | 15 | | | | | |

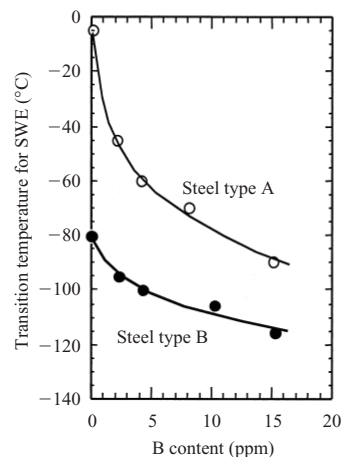


Fig.9 Effect of B content on the transition temperature for secondary-work-embrittlement

snv`qc `tsn l nahkd vdhfgs qdc t bshnm+ REFGHSDM b`m ad
`o q