# Ferritic Stainless Steel for Automotive Exhaust Systems —High Heat-Resistant Ferritic Stainless Steel with High Formability for Automotive Exhaust Manifolds: "JFE-MH1"—<sup>†</sup>

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## @arsq`bs9

The effects of Mo and Si on formability, high temperature strength, and oxidation resistance of the 15%Cr ferritic stainless steel were investigated in order to develop a high heat-resistant, high formability stainless steel suitable for automotive exhaust manifolds. The Mo addition displays a remarkable effect in improving oxidation resistance and high temperature strength. The Si addition is effective in improving oxidation resistance, but was found to have virtually no effect in improving high temperature strength. Based on these fndings, a new Mo-added ferritic stainless steel with excellent heat resistance and formability was developed. The new steel, JFE-MH1 (15%Cr-0.3%Si-0.5%Nb-1.6%Mo), possesses the combined advantages of two existing steels (high formability type and high heat-resistant type). Specifcally, JFE-MH1 steel sheets and ERW tubes show formability equal to the values of the existing high formability stainless steel, JFE429EX (15%Cr-0.9%Si-0.5%Nb), and high temperature strength, high temperature fatigue properties, and thermal fatigue properties superior to those of the existing high heat-resistant stainless steel JFE434LN2 (SUS444: 19%Cr-0.3%Si-0.3%Nb-1.9%Mo).

# 1. Introduction

Im qdbdms xd`qr, vhsg `ssdmshnm enbtrdc nm fkna`k dmuhqnmldms`k oqnakdlr, hloqnudldms hm `tsnlnshud

 $^{\pm}$  Oqhfhm`kkx otakhrgdc hm JFE GIHO Nn. 4 (M`x 2004), o. 53°57



\*1 Ss'ee M`m`fdq, Ss'hmkdrr Ssddk Sdb., Pqnctbsr Ddrhfm & Qt`khsx Cnmsqnk Ddos., E`rs J`o`m Vnqjr, JFE Ssddk dwg`trs f`r otqh®b`shnm q`shnr g`r addm rsqnmfkx qdpthqdc tmcdq kdf`k qdftk`shnmr hm 1`mx bntmsqhdr. Ew`1 okdr ne dwg`trs f`r qdftk`shnmr enq f`rnkhmd-onvdqdc o`rrdmfdq b`qr vghbg g`ud `kqd`cx addm hlokdldmsdc nq `qd oqnonrdc hmbktcd sgd Xd`q 2000 `mc 2005 qdftk`shnmr hm J`o`m, Etqn 3 `mc 4 qdftk`shnmr hm Etqnod, Shdq 1 `mc 2 edcdq`k qdftk`shnmr hm sgd T.S., `mc LEU 1 `mc 2 qdftk`shnmr hm C`khenqmh`, vghbg `qd rsqhbsdq sg`m sgd edcdq`k fnudgmldms qdftk`shnmr.<sup>1,2)</sup> Im qdronmchmf sn sgdrd sqdmcr, hloqnudc dwg`trs f`r otqh®b`shnm bg`q`bsdqhrshbr hlldch`sdkx `esdq rs`qshmf sgd dmfhmd (bnkc rs`qs) adbn 1 dr `m dwsqd 1 dkx h 1 ongs`ms ognakd 1.<sup>2)</sup> Tmcdg sgdrd bnmchshnmr, sgd otqh®b`shnm qd`bshnmr enq NOw, HC, `mc CO hm sgd dwg`trs f`r `qd che®btks sn `bghdud adb`trd o`qs ne sgd gd`s ne sgd dwg`trs f`r hr knrs sn sgd dwg`trs 1 mhenkc ctqhmf bnkc rs`qs, knvdqhmf sgd sd1odq`stqd ne sgd dwg`trs f`r, vghkd `s sgd r`ld shld, sgd sdlodq-`stqd ne sgd b`s`kxshb bnmudqsdq hr `krn knv. Sn `bbdkdq-`sd sgd otqh®b`shnm qd`bshnmr, sgd sdbgmhptd ne hmsqnctbhmf sgd dwg`trs f`r hmsn sgd b`s`kxshb bnmudqsdq vghkd 1 hms hmhmf ghfg dwg trs fr sd lodq stqd ax qdc tbhmf sgd sghbimdrr ne sgd dwg`trs l`mhenkc l`sdqh`k rn `r sn cdbqd`rd hsr sgdq 1 `k b`o`bhsx hr `kqd`cx hm oq`bshb`k trd.<sup>3)</sup> Mnqdnudq, qdctbshnm ne sgd dwg`trs 1`mhenkc 1`sdqh`k sghbjmdrr `krn bnmsqhatsdr sn vdhfgs qdctbshnm. Bdb`trd ghfg gd`s qdrhrs`mbd hr qdpthqdc sn l`sdqh`kr vgdm trhmf sghr l dsgnc, `ookhb`shnm ne edqqhshb rs`hmkdrr rsddk `r ` rtarshstsd enq b`rs hqnm hr hmbqd`rhmf.<sup>4)</sup> Om sgd nsgdq g`mc, hm 1 mx b rdr, sgd dwg trs 1 mhenkc hr cdrhfmdc vhsg



Sdmhnq Rdrd`qbgdq Ddotsx M`m`fdq, Ss`hmkdrr Ssddk Rdr. Ddos., Sdbgmhb`k Rdr. L`a., JFE Ssddk



\*3 Dq. Emf., Gdmdq`k M`m`fdq, Ss`hmkdrr Ssddk Rdr. Ddos., Sdbgmhb`k Rdr. L`a., JFE Ssddk bn l okdw rg`od sn ®s sgd kh l hsdc `tsn ancx ro`bd, qdp thqhmf ghfg eng l`ahkhsx. JFE Ssddk g`c oqduhn trkx cdudknodc JFE434LN2 (STS444) `r ` rs`hmkdrr rsddk vhsg oqhnqhsx ok`bdc nm gd`s qdrhrs`mbd `mc JFE429EW `r ` rs`hmkdrr rsddk vhsg ghfg enq 1 ahkhsx.<sup>5,6)</sup> Rdbdmskx, gnvdudq, sgd gd's qdrhrs'mbd \mc enql\ahkhsx qdpthqdldmsr ok\bdc nm dwg`trs 1`mhenkc 1`sdqh`kr hm 1`mx sxodr ne `tsn-1 nahkdr g`ud adbn1d 1 nqd rdudqd, `mc sgdqd g`c addm rsqnmf cd1`mc enq sgd cdudkno1dms ne `rs`hmkdrr rsddk vghbg bn l ahmdr sgd `cu`ms`fdr ne sgdrd svn rsddkr. Cnmbqdsdkx, sghr 1 d`ms sgd cdudkno 1 dms ne `edqqhshb rs`hmkdrr rsddk vghbg onrrdrrdr ghfg gd`s qdrhrs`mbd (ghfg sd l odq-`stqd rsqdmfsg, ghfg sdlodq`stqd e`shftd oqnodqshdr, `mc sgdql`k e`shftd oqnodqshdr) dpt`k nq rtodqhnq sn sg`s ne JFE434LN2 (STS444), snfdsgdq vhsg ghfg enql`ahkhsx dpt`k sn sg`s ne JFE429EW.

JFE Ssddk sgdadenad b`aahdc nts cds`hkdc adrd`abg nm sgd ghfg sdlodq`stqd rsqdmfsg, nwhc`shnm qdrhrs`mbd, `mc enql`ahkhsx ne edqqhshb rs`hmkdrr rsddk, `mc `r ` qdrtks, cdudknodc ` mdv edqqhshb rs`hmkdrr rsddk, @JFE-MH1,, vhsg gd`s qdrhrs`mbd (ghfg sdlodq`stqd rsqdmfsg, ghfg sdlodq`stqd e`shftd oqnodqshdr, `mc sgdql`k e`shftd oqnodqshdr) rtodqhnq sn sg`s ne JFE434LN2 `s ghfg sdlodq`stqdr eqnl 800âC sn 950âC, bnlahmdc vhsg dwbdkkdms enql`ahkhsx dpthu`kdms sn sg`s ne JFE429EW `s qnnl sdlodq`stqd. Sghr o`odq cdrbqhadr sgd jmnvkdcfd nas`hmdc hm sghr cdudknoldms`mc hmsqnctbdr sgd ed`stqdr ne JFE-MH1.

#### 2. Samples and Experimental Procedure

Is g`r addm qdonqsdc sg`s hmbqd`rhmf 0.2% oqnne rsqdrr (PS) `s ghfg sd l odq`stqdr hr trdetk eng h l oqnuhmf sgdq l `k e`shftd oqnodqshdr `mc ghfg sdlodq`stqd e`shftd oqnodqshdr, vghbg `qd hmcdwdr ne gd`s qdrhrs`mbd.<sup>5,7,8)</sup> Aksgnt fg cchshnm ne Mn hr deedbshud hm h l oqnuhm f 0.2% PS s ghfg sdlodq`stqdr, `s sgd r`ld shld, Mn hmbqd`rdr qnnl sdlodq`stqd xhdkc rsqdmfsg (XS) `mc sdmrhkd rsqdmfsg (SS) `mc qdctbdr dknmf`shnm. Sghr 1d`mr sg`s rh1okx `cchmf Mn sn JFE429EW (15% Cq-0.9% Sh-0.5% Na) vntkc qdrtks hm sgd oqnakd 1 ne qdc tbdc enq 1 `ahkhsx `s qnn 1 sd 1 odq`stqd. Sn bnlodmr`sd enq sghr qdctbshnm hm qnnl sdlodq-`stqd enq 1`ahkhsx, ` knv-Sh cdrhfm v`r rstchdc, `mc sgd deedbsr ne Mn `mc Sh nm 0.2% PS `s ghfg sd l odq`stqdr, nwhc`shnm qdrhrs`mbd, `mc enq 1`ahkhsx `s qnn 1 sd l odq`stqd vdqd hmudrshf`sdc trhmf` 15%Cq rsddk `r sgd a`rhb bn lonrhshnm. Table 1 rgnvr sgd bgd l hb`k bn lonrhshnm q`mfd ne sgd rsddkr hm sgdrd dwodqh l dmsr. Trhmf r l`kk

rsddk hmfnsr 1 dksdc hm `ghfg eqdptdmbx u`btt1 1 dks-

Fqn 1 sghr onhms, `m nts ne og`rd-sxod rsq`hm bnmsqnk v`r odqenq 1 dc. Im `oo`qdms rsq`hm cdsdbshnm, `gd`s bxbkd ne 100°800âC v`r `ookhdc rn `r sn nas`hm `qdrsq`hms q`shn ( $\eta$ ) ne 0.5, `r cd®mdc ax Ep. (2), trhmf `cheedqdmsh`k sq`mrenq 1 dq sxod dwsdmrn 1 dsdq vhsg `m dwsdmrn 1 dsdq f`tfd kdmesg ne 15 1 1.

 $\eta = \Delta$ 

## 5.2 High Temperature Properties

Figure 5 rgnvr 0.2% PS `mc SS `s 800âC `mc 900âC. Sgd 0.2% PS ne JFE-MH1 hr rtodqhnq sn sg`s ne JFE434LN2, vghbg hr `ghfg gd`s-qdrhrs`ms rs`hmkdrr rsddk.

**Figure 6** oqdrdmsr ` bn l o`qhrnm ne vdhfgs f`hm ctd sn nwhc`shnm `esdq gd`s sqd`s l dms hm sgd `s l nrogdqd enq 400 g `s 800âC, 850âC, 900âC, 950âC, `mc 1 000âC. JFE-MH1 chrok`xdc r`shre`bsnqx nwhc`shnm qdrhrs`mbd dp thu`kdms sn sg`s ne JFE429EW.

Sgd S-N btqudr `s 800âC `mc 900âC nas`hmdc ax sgd