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

JFV>W>HF>ɑpɪpef'· EFO>P>T> Grkf`efol'/ CRORHF J F Lp^ i r'0

> ɒɑo^`ɑ7

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

Fk ob`bkq vb^op) tfqe ^qqbkqflk cl`rpba lk dil_^i bksfolk j bkq^i mol_ib j p) fj molsb j bkq fk ^rql j lqfsb bue^rpq d^p mrofª`^qflk o^qflp e^p _bbk pqolkdiv obnrfoba rkabo ibd^i obdri^qflkp fk j ^kv `lrkqofbp+ Bu^ j mibp lc bue^rpq d^p obdri^qflkp clo d^plifkb*ml tboba m^ppbk* dbo `^op tef`e e^sb ^iob^av _bbk fj mib j bkqba lo ^ob molmlpba fk`irab qeb Vb^o /--- ^ka /--2 obdri^qflkp fk G^m^k) Brol 0 ^ka 1 obdri^qflkp fk Brolmb) Qfbo . ^ka / cbabo^i obdri^qflkp fk qeb R+P+) ^ka IBS . ^ka / obd* ri^qflkp fk @^ifclokf^) tef`e ^ob pqof`qbo qe^k qeb cba* bo^i dlsbok j bkq obdri^qflkp+·)/& Fk obpmlkafkd ql qebpb qobkap) fj molsba bue^rpq d^p mrofª`^qflk `e^o^`qbofp* qf`p fj j baf^qbiv ^cqbo pq^oqfkd qeb bkdfkb %`lia pq^oq& _b`l j bp ^k buqob j biv fj mloq^kq mol_ib j +/& Rkabo qebɒb `lkafqflkp) qeb mrofª`^qflk ob^`qflkp clo KLu) E@) ^ka @L fk qeb bue^rpq d^p ^ob afcª`riq ql ^`efbsb _b`^rpb m^oq lc qeb eb^q lc qeb bue^rpq d^p fp ilpq ql qeb bue^rpq j^kfclia arofkd ^ `lia pq^oq) il tbofkd qeb qb j mbo^qrob lc qeb bue^rpq d^p) tefib ^q qeb p^ j b qf j b) qeb qb j mbo* ^qrob lc qeb `^q^ivqf` `lksboqbo fp ^ipl il t+ Ql ^``bibo* ^qb qeb mrofª`^qflk ob^`qflkp) qeb qb`ekfnrb lc fkqolar`* fkd qeb bue^rpq d^p fkql qeb `^q^ivqf` `lksboqbo tefib j^fkq^fkfkd ^ efde bue^rpq d^p qb j mbo^qrob _v obar`fkd qeb qef`hkbpp lc qeb bue^rɒq i^kfclia i^qbof^i ɒl ^ɒ ql ab`ob^pb fqp qebo j ^i `^m^`fqv fp ^iob^av fk mo^`qf`^i rpb+0& J loblsbo) obar`qflk lc qeb bue^rpq j^kfclia j^qbof^i qef`hkbpp ^ipl `lkqof_rqbp ql tbfdeq obar`qflk+ ?b`^rpb efde eb^q obpfpq^k`b fp obnrfoba ql j^qbof^ip tebk rpfkd qefp j bqela) ^mmif`^qflk lc cboofqf` pq^fkibpp pqbbi ^p ^ pr_pqfqrqb clo `^pq folk fp fk`ob^pfkd+1& Lk qeb lqebo e^ka) fk j^kv `^pbp) qeb bue^rpq j^kfclia fp abpfdkba tfqe ^

- Lofdfk^iiv mr_ifpeba fk *JFE GIHO* Kl+ 1 % J ^v /--1&) m+ 20¬24

'· Pq^cc J ^k^dbo)
Pq^fkibpp Pqbbi Pb`+)
Molar`qp Abpfdk # Nr^ifqv @lkqoli Abmq+)
B^pq G^m^k Tlohp)
GCB Pqbbi

'/ Pbkflo Obpb^o`ebo Abmrqv J ^k^dbo)
Pq^fkibpp Pqbbi Obp+ Abmq+)
Qb`ekf`^i Obp+ I^_+)
GCB Pqbbi

'0 Ao+ Bkd+) Dbkbo^i J ^k^dbo)
Pq^fkibpp Pqbbi Obp+ Abmq+)
Qb`ekf`^i Obp+ I^_+)
GCB Pqbbi

`l j mibu pe^mb ql ªq qeb if j fqba ^rql _lav pm^`b) obnrfo* fkd efde clo j ^_fifqv+ GCB Pqbbi e^a mobsflrpiv absbilmba GCB101IK/ %PRP111& ^p ^ pq^fkibpp pqbbi t fqe moflofqv mi^`ba lk eb^q obpfpq^k`b ^ka GCB1/6BU ^p ^ pq^fkibpp pqbbi t fqe efde clo j ^_fifqv+[2)3&] Ob`bkqiv) el tbsbo) qeb eb^q obpfpq^k`b ^ka clo j ^_fifqv obnrfob j bkqp mi^`ba lk bue^rpq j ^kfclia j ^qbof^ip fk j ^kv qvmbp lc ^rql* j l_fibp e^sb _b`l j b j lob pbsbob) ^ka qebob e^a _bbk pqolkd ab j ^ka clo qeb absbilm j bkq lc ^ pq^fkibpp pqbbi t ef`e `l j _fkbp qeb ^as^kq^dbp lc qebpb q t l pqbbip+ @lk* `obqbiv) qefp j b^kq qeb absbilm j bkq lc ^ cboofqf` pq^fkibpp pqbbi t ef`e mlppbppbp efde eb^q obpfpq^k`b %efde qb j mbo* ^qrob pqobkdqe) efde qb j mbo^qrob c^qfdrb molmboqfbp) ^ka qebo j ^i c^qfdrb molmboqfbp& bnr^i lo prmboflo ql qe^q lc GCB101IK/ %PRP111&) qldbqebo t fqe efde clo j ^_fifqv bnr^i ql qe^q lc GCB1/6BU+

GCB Pqbbi qebobclob `^oofba lrq abq^fiba obpb^o`e lk qeb efde qb j mbo^qrob pqobkdqe) lufa^qflk obpfpq^k`b) ^ka clo j ^_fifqv lc cboofqf` pq^fkibpp pqbbi) ^ka ^p ^ obpriq) absbilmba ^ kb t cboofqf` pq^fkibpp pqbbi) ¦GCB* J E .)´ t fqe eb^q obpfpq^k`b %efde qb j mbo^qrob pqobkdqe) efde qb j mbo^qrob c^qfdrb molmboqfbp) ^ka qebo j ^i c^qfdrb molmboqfbp& prmboflo ql qe^q lc GCB101IK/ ^q efde qb j * mbo^qrobp col j 5--Þ@ ql 62-Þ@) `l j _fkba t fqe bu`bi* ibkq clo j ^_fifqv bnrfs^ibkq ql qe^q lc GCB1/6BU ^q oll j qb j mbo^qrob+ Qefp m^mbo abp`of_bp qeb hkl t ibadb l_q^fkba fk qefp absbilm j bkq ^ka fkqolar`bp qeb cb^qrobp lc GCB* J E .+

2. Samples and Experimental Procedure

Fq e^p _bbk obmloqba qe^q fk`ob^pfkd -+/ " mollc pqobpp %MP& ^q efde qb j mbo^qrobp fp rpbcri clo f j molsfkd qebo j ^i c^qfdrb molmboqfbp ^ka efde qb j mbo^qrob c^qfdrb molmbo* qfbp) t ef`e ^ob fkabubp lc eb^q obpfpq^k`b+[2)4)5&] >iqelrde ^aafqflk lc J l fp bccb`qfsb fk f j molsfkd -+/ " MP ^q efde qb j mbo^qrobp) ^q qeb p^ j b qf j b) J l fk`ob^pbp oll j qb j * mbo^qrob vfbia pqobkdqe %VP& ^ka qbkpfib pqobkdqe %QP& ^ka obar`bp bilkd^qflk+ Qefp j b^kp qe^q pf j miv ^aafkd J l ql GCB1/6BU %.2 " @o*-+6 " Pf*-+2 " K_& t lria obpriq fk qeb mol_ib j lc obar`ba clo j ^_fifqv ^q oll j qb j mbo^* qrob+ Ql `l j mbkp^qb clo qefp obar`qflk fk oll j qb j mbo* ^qrob clo j ^_fifqv) ^ il t*Pf abpfdk t ^p pqrafba) ^ka qeb bccb`qp lc J l ^ka Pf lk -+/ " MP ^q efde qb j mbo^qrobp) lufa^qflk obpfpq^k`b) ^ka clo j ^_fifqv ^q oll j qb j mbo^* qrob tbob fksbpqfd^qba rpfkd ^ .2 " @o pqbbi ^p qeb _^pf` `l j mlpfqflk+ **Table 1** pel t p qeb `eb j f`^i `l j mlpfqflk o^kdb lc qeb pqbbip fk qebpb bumbof j bkqp+ Rpfkd p j ^ii pqbbi fkdlqp j biqba fk ^ efde cobnrbk`v s^`rr j j biq*

Col j qefp mlfkq) ^k lrq lc me^pb*qvmb pqo^fk `lkqoli t^p mboclo j ba+ Fk ^mm^obkq pqo^fk abqb`qflk) ^ eb^q `v`ib lc .--¬5--Þ@ t^p ^mmifba pl ^p ql l_q^fk ^ obpqo^fkq o^qfl %η& lc -+2) ^p ab ª kba _v Bn+ %/&) rpfkd ^ afccbobkqf^i qo^kpclo j bo qvmb buqbkpl j bqbo t fqe ^k buqbkpl j bqbo d^rdb ibkcqe lc .2 j j +

$$\eta = \Delta$$

5.2 High Temperature Properties

Figure 5 pel t p -+/ " MP ^ka OP ^q 5--Þ@ ^ka 6--Þ@+ Qeb -+/ " MP lc GCB* J E . fp prmboflo ql qe^q lc GCB101IK/) tef`e fp ^ efde eb^q*obpfpq^kq pq^fkibpp pqbbi+

Figure 6 mobpbkqp ^ `l j m^ofplk lc tbfdeq d^fk arb ql lufa^qflk ^cqbo eb^q qob^q j bkq fk qeb ^q j lpmebob clo 1-- e ^q 5--Þ@) 52-Þ@) 6--Þ@) 62-Þ@) ^ka . ---Þ@+ GCB* J E . afpmi^vba p^qfpc^`qlov lufa^qflk obpfpq^k`b bnrfs^ibkq ql qe^q lc GCB1/6BU+

Oeb *S N* `rosbp ^q 5--Þ@ ^ka 6--Þ@ l_q^fkba _v qeb

6. Conclusion

Tfqe pqolkdbo obdri^qflkp lk ^rql j lqfsb bue^rpq d^p fk ob`bkq vb^op) qeb pbosf`b bksfolk j bkq clo bue^rpq pvp* qb j m^oqp fp _b`l j fkd fk`ob^pfkdiv pbsbob+ Qebobclob) absbilm j bkq lc pq^fkibpp pqbbip t fqe efde eb^q obpfpq^k`b ^ka bu`biibkq clo j ^_fifqv clo ^mmif`^qflk fk efde qb j * mbo^qrob bksfolk j bkqp) fk m^oqf`ri^o) ^p obmobpbkqba _v qeb bue^rpq j ^kfclia) colkq mfmb) ^ka `^q^ivqf` `lksboqbo `^pb) e^p _bbk pqolkdiv obnrfoba+ Ql j bbq qebpb obnrfob* j bkqp) GCB Pqbbi pr``bbaba fk absbilmfkd ^ kbt cboofqf` pq^fkibpp pqbbi) ¦GCB* J E.)´ tef`e mlppbppbp _lqe efde eb^q obpfpq^k`b %efde qb j mbo^qrob pqobkdqe) efde qb j mbo* ^qrob c^qfdrb molmboqfbp) ^ka qebo j ^i c^qfdrb molmboqfbp& bnr^i lo prmboflo ql qelpb lc PRP111) ¦GCB101IK/)´ tef`e fp ^ obmobpbkq^qfsb `lksbkqflk^i efde eb^q* obpfpq^kq pq^fkibpp pqbbi) ^ka efde clo j ^_fifqv bnr^i ql qe^q lc GCB1/6BU) tef`e fp ^ efde clo j ^_fifqv pq^fkibpp