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A Novel Low-cost Hot Rolled High Strength Steel for an Automatic Teller Machine

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Abstract: A novel hot rolled steel LG600A with the tensile strength exceeding 700 MPa was developed for automatic teller machine application. The low-cost C-Mn steel was microalloyed with 0.08 mass% − 0.12 mass% Ti rather than noble alloying elements, such as Nb, V, Mo, and Cu, etc. The novel steel had a good surface quality and welding property. After the hot rolled steel coils were leveled, the steel plates, the length of which was even down to 1500 mm, had an excellent flatness. The effects of hot rolling parameters on mechanical performance, microstructure and recrystallization behavior were studied. The metallurgical concept for the steel production was also discussed. The result shows that decreasing the finish rolling temperature, increasing cooling rate in the first cooling stage and decreasing the cooling rate in the last cooling stage, together with coiling at a modestly high coiling temperature all resulted in the refined grains and TiC precipitates, thereby improving the strength and toughness of this new steel greatly.

Key words: automatic teller machine; high strength steel; microstructure; rolling parameter

In recent years, global automatic teller machine (ATM) market has experienced rapid growth; however, it still has great potential, especially in China, North America, India, Africa and East Europe[1]. Today, major ATM manufacturers around the world almost use high strength steel (HSS) plates with a thickness of 12.7 mm to make the chest of ATM machine, such as NCR, Diebold, Wincor Nixdorf, GRG Banking, Hitachi and OKI. The quality requirements for the ATM HSS plates are listed as follows: (1) to meet the mechanical performance requirement, the tensile strength must be more than 700 MPa, but others are generally not required; (2) to meet the dimension and shape requirement, the flatness are generally required to be no more than 4 mm/m in any direction, and the tolerance on thickness must be narrow than ±0.15 mm; (3) to meet the surface quality requirement, pits, bumps, scratches and other surface defects should be forbidden, and the steel plates must have a good surface finishing after acid pickling; (4) to meet the machinability requirement, the cutting edge of the steel plates should be uniform after being cut by laser or plasma; (5) to meet the weldability requirement, significant strength loss of the welded joint is not allowed, and the ATM chests finishing welding must be able to withstand manual or mechanical violent destruction.

For the steel plates used for the chest of ATM with the tensile strength more than 700 MPa, three primary microstructure concepts have been investigated and developed presently: one is low carbon bainitic steel[2-6], like DB685 in China. For this type of steel, the application of microalloying elements (Nb, Ti, V and B) and the substitutional alloying elements (Mo, Ni, Cr and Cu) is one of the key technology factors to meet the mechanical property requirements. The next is cold-formed low carbon steel with fine-grained ferrite[7-10], like S650MC in Europe and BS600MC in China. This type of steel is often produced by adding Nb, Ti or V and Mo or Cr. The third is SAIL HITEN 690 AR developed by Steel Authority of India Limited (SAIL), which was composed of pearlite and ferrite, with about 0.18 mass% V added to the chemical composition of C-Mn steel[11].

The aim of the present study is to develop a novel low-cost steel (without any noble microalloying

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element) suitable for ATM chest, and to investigate the effect of rolling parameters on the microstructure, recrystallization behavior and mechanical performance.

1 Experimental Procedure

1.1 Chemical composition design

The chemical composition of the newly developed steel was designed, and it was microalloyed with 0.08 mass%－0.12 mass% Ti based on that of the C-Mn steel Q345B (Chinese standard GB/T 1591) or S355JR (European standard EN 10025). Compared to other 700 MPa grade steels, this novel steel does not contain any noble alloying elements. The comparison of the chemical compositions of the novel steel LG600A, the low carbon bainitic steel DB685[12], the cold-formed low carbon steel BS600MC[13], the pearlitic-ferritic steel SAIL HITEN 690 AR[14], the C-Mn steel Q345B or S355JR is listed in Table 1.

Table 1 Comparison of chemical compositions of several kinds of steels mass%

Steel grade	C	Si	Mn	Al_s	Ti	N	Others	Fe
LG600A	0.16－0.20	0.10－0.30	0.90－1.20	0.015－0.060	0.08－0.12	≤0.006		Balance
DB685	0.04	0.25	1.60	—	—	—	Cu+Ni+Mo+Nb+B: 0.95	Balance
BS600MC	0.06－0.08	0.15－0.36	1.70－1.86	0.015－0.060	0.08－0.12	—	Nb, Mo	Balance
SAIL HITEN 690 AR	0.18－0.19	0.25－0.35	1.54－1.56	0.01	No	—	V: 0.14－0.16	Balance
Q345B/S355JR	0.16－0.20	0.10－0.30	0.90－1.50	0.015－0.030	No	≤0.012		Balance

From Table 1, it can be seen that the chemistry design of this novel high strength steel LG600A is different from other types of 700 MPa grade steels. It does not contain any noble alloying elements, such as Nb, V, Mo and Cu, which are usually used in low carbon bainitic steel and cold-formed low carbon ferritic steel. Especially, the alloying elements Mo and Cu used to strengthen steels are normally added by more than 0.15 mass% and 0.50 mass%[15], respectively. For Ti utilized in this study, it is low-cost, and has a very significant strengthening effect by precipitation even being added in the order of 10^{-4}. Thus, this developed steel is a novel low-cost high strength steel.

1.2 Process

The continuously cast slabs in this study were prepared through the process route of hot metal→KR desulphurization→BOF→LF→continuous casting. These slabs were rolled to produce steel coils with the thickness of 12.7 mm on a 2250 mm hot strip mill under various rolling and cooling parameters. The rolling process included: slab reheating at 1210 ℃→descaling→rough rolling→finish rolling→ultra-fast cooling→laminar cooling→air cooling→downcoiling. Then, the hot rolled coils were leveled to make steel plates. During the cooling process after hot rolling, an advanced cooling equipment for ultra-fast cooling was applied, which was similar to MULPIC of Dillingen in Germany[16] and Super-OLAC of JEF in Japan[17].

The mechanical properties of the experimental coils were measured, and the microstructures were observed by optical microscopy (OM) and scanning electron microscopy (SEM). According to the results, an optimal hot rolling process was determined for the large-scale production of the commercial steel coils.

1.3 Thermal simulation testing

Experimental material was taken from the experimental steel coil. The Gleeble-1500 thermal simulation testing machine was used to determine the continuous cooling transformation (CCT) diagram of hot deformed austenite of the developed steel. The cylindrical specimens of $\phi 8$ mm×12 mm were prepared. The specimens were heated at 10 ℃/s to 1210 ℃, thermally held for 300 s, and cooled to deformation temperature (1100 ℃) at 5 ℃/s, then deformed with strain of 0.5 and strain rate of 5 s^{-1}. After the first deformation, the specimens were held for 10 s and continuously cooled at 5 ℃/s to 850 ℃ to conduct the deformation again, the strain and strain rate were 0.3 and 10 s^{-1}, respectively. After that, the specimens were cooled to ambient temperature at different cooling rates (0.1, 0.5, 1, 2, 5, 10, 20, 30, 40, and 50 ℃/s). The expansion curves were recorded, and the CCT curves under deformed conditions were measured.

1.4 Mechanical properties testing, microstructural and flow stress analysis

All the experimental materials were taken from the middle part of the experimental or commercial steel coils. Transverse tensile test, longitudinal