A New Type Cold Work Die Steel with Isotropy of Dimensional Change "DCMX™"

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Denki-Seiko (Electric Furnace Steel), vol. 81 (2010), No.1, p.53
*This English article is an abridged version of the original Japanese one.

1. Preface

High strength steels have been increasingly used for strengthening and reducing the weight of automobile components. Due to increased applied stress to dies in stamping of high strength steels, proactive measures against wide variety failures such as chipping, cracking, wear and galling are required. Furthermore, recent tough global cost competition and shorter term construction of production lines have encouraged the reduction of the cost and time in mold making, which has been demanding optimum mold making process and production conditions than ever.

Under these circumstances, die steels are strongly required that are having not only optimum balance of high hard- toughness, but also dimensional stability by heat treatment and easy machining. Newly developed matrix type cold work die steel, DCMX, is one of these. Remaining superior hardness and toughness to those of JIS SKD11 unchanged, DCMX shows superb machining efficiency and easy dimension control in heat treatment.

2. Dimensional change of cold work die steels

Generally, as large cold press dies stamping automobile parts are composed of different geometry small segment dies as shown in Fig.1, to suppress the dimensional change of each die in heat treatment is one of the key issues. Its difficulty is derived from the anisotropy of dimensional change as indicated by Fig. 2. It takes much time to finish dies after heat treatment and coating by machining and grinding the back or the bottom of dies. Especially, dies made of 8Cr-Mo cold work die steels tend to grow greatly when tempered at high temperature.

DCMX is a trademark or registered trademark of Daido Steel Co., Ltd.

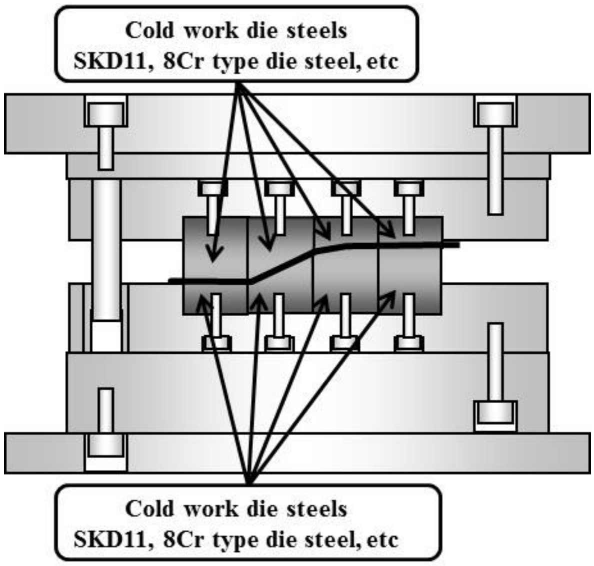

Fig. 1. Schematic illustration: Cold stamping of large sized automotive parts.

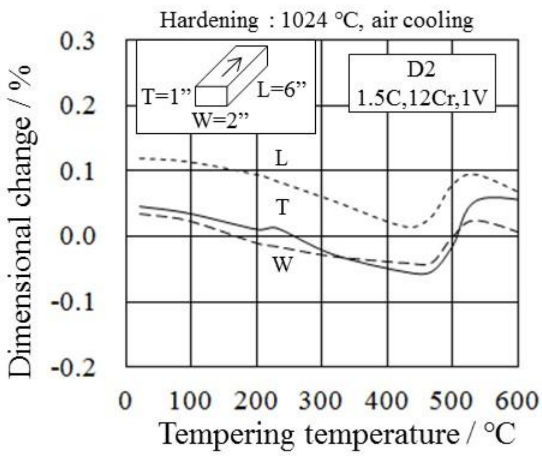

Fig. 2. Dimensional change of conventional cold work die steel with tempering temperature.

3. Concept of the development

To clarify the cause of anisotropy in dimensional change, the effect of C and Cr contents on the dimensional change of 8% Cr steel (1C-1Si- 0.4Mn-8Cr- 2Mo) has been studied by changing the amount of course primary carbides. Figure 3 shows the area fraction of coarse carbides larger than 2 μm, in terms of circle equivalent diameter, measured on the plane along longitudinal direction after quenching from 1030°C. It is clear that anisotropy of dimensional change, that is the difference by L and T directions, becomes greater with increasing of the amount of coarse carbides.

Fundamental concept to reduce anisotropy is to decrease the amount of primary carbides. That became the reason of development of matrix type die steel. Reducing coarse carbides, furthermore, results in not only improved toughness and fatigue strength, but also easy machining.

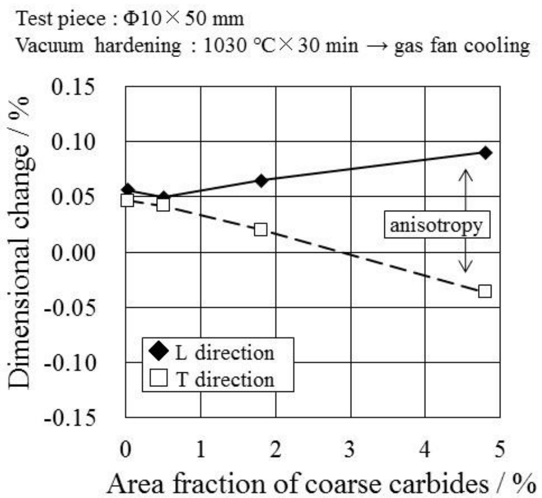

Fig. 3. Effect of carbide volume on anisotropy of dimensional change.

4. Features of DCMX

4.1 Comparison with other grades

Table 1 shows the comparison of DCMX, 8Cr type steel and SKD11 in terms of characteristics of cold work die steels. Optical micrographs are shown in Fig. 4. DCMX hardly shows coarse primary carbides contributing to superior properties to other grades as shown in Table. 1.

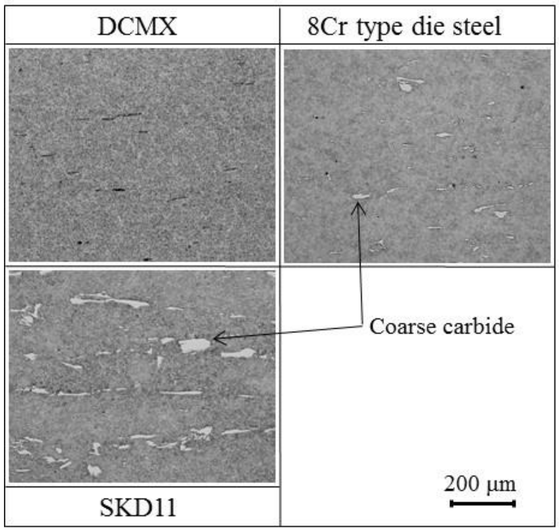

Fig. 4. Optical microstructures of 8%Cr-Mo type cold work die steels and DCMX.

4.2 Control of dimensional change

Figure 5 shows the behavior of hardness and dimensional change with tempering temperature. The difference in dimensional change along L and T directions are hardly shown in DCMX. The highest hardness of 62 HRC is obtained by tempering at 500°C that provides the least dimensional change.

Table 1. Comparison of properties of cold work die steels.

Properties		DCMX	8Cr type die steel	SKD11
Manufacturing	Isotropy of dimensional change	◎	○	△
	Machinability	◎	○	△
	Hardenability	○	◎	○
	Surface treatment	○	◎	○
	Weldability	○	○	○
Peformance	Hardness	◎	◎	△
	Fatigue strength	◎	○	△
	Charpy impact value	◎	○	△
	Wear resistance	○	◎	◎

Result : good ◎＞○＞△ bad

Dimensional change with time is widely known as dimensional stability problems of cold work die steels that are used after high temperature tempering. The example of DCMX is shown in Fig. 6. DCMX also shows dimensional change with time, but additional tempering at 400 °C as stabilizing process works to prevent this dimensional change in the same manner as other cold die steels.

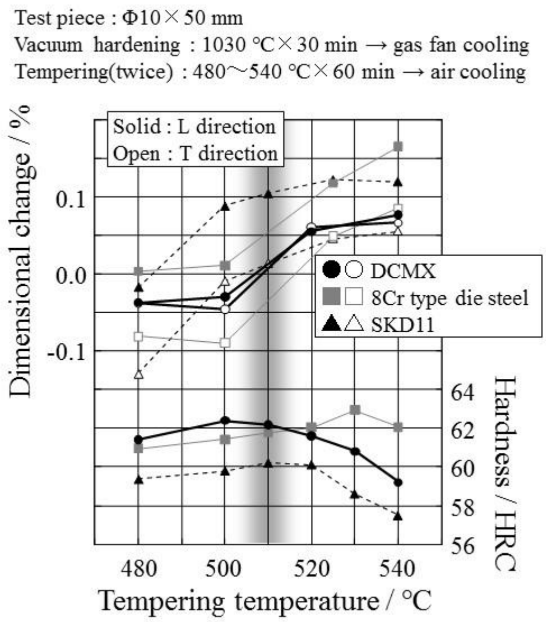

Fig. 5. Effect of tempering temperature on dimensional change and hardness.

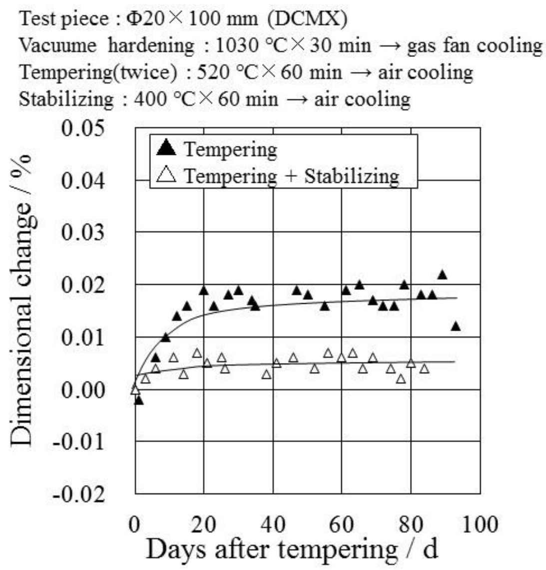

Fig. 6. Effect of tempering conditions on dimensional change with time.

4.3 Impact toughness

Charpy impact values tested by 10mm R notch specimens taken from longitudinal direction are shown in Fig.7. High Charpy impact values of DCMX are due to decreased coarse primary carbides, which leads to suppress chipping and crack in die application.

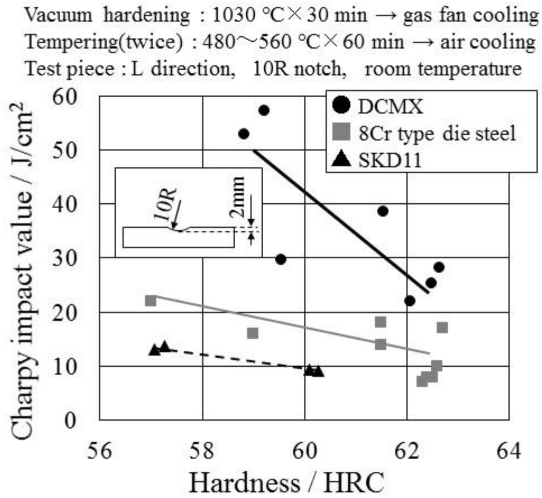

Fig. 7. Charpy impact values of conventional cold work die steels and DCMX.

4.4 Machinability

Figure 8 and 9 show machining performance of DCMX, annealed and hardened-tempered steels, respectively. Even DCMX with high hardness after quenching and tempering can be machined well. This superb machinability contributes to the reduction of machining time and cost by combining with optimum cutting tools and conditions.

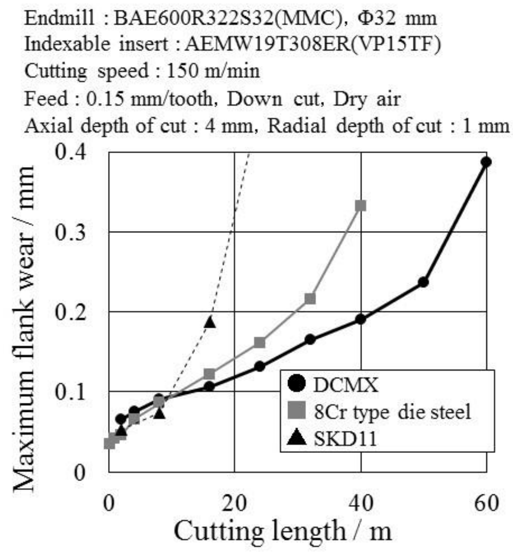

Fig. 8. End-milling test results: Anneled steels.

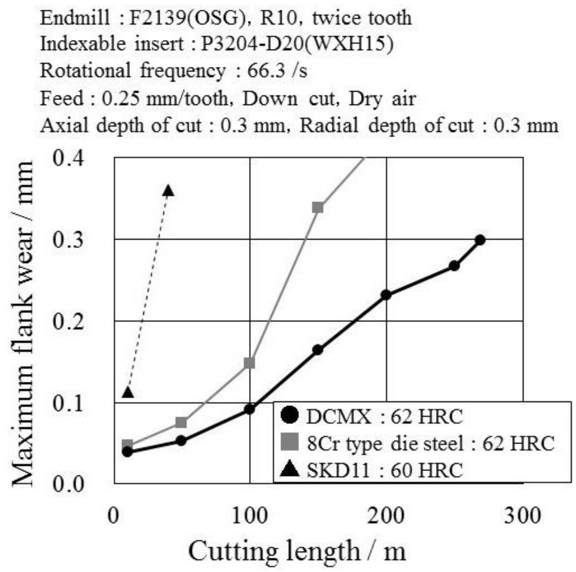

Fig. 9. End-milling test results: hardened and tempered steels.

4.5 Wear resistance

Ogoshi type wear test results are shown in Fig. 10. Adhesive wear resistance tested by this method is almost proportional to hardness.

As shown in Fig. 11, on the other hand, Suga type test evaluating abrasive wear shows DCMX is slightly inferior to SKD11 and 8Cr-Mo steel containing larger amount of coarse carbides. It means in abrasive conditions such as forming of hard and rough materials, matrix type steels perform worse than conventional cold work die steels.

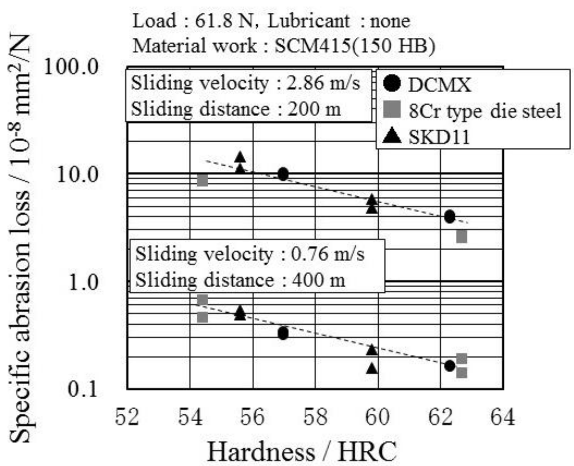

Fig. 10. Effect of hardness on specific abrasion loss by Ogoshi type wear test.

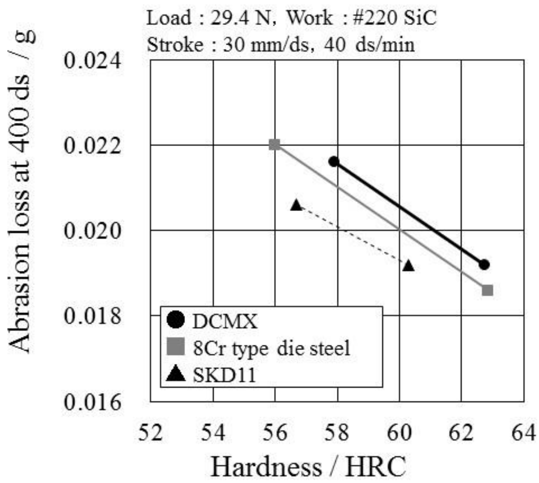

Fig. 11. Effect of hardness on abrasion loss by Suga type wear test.

4.6 Application of coating

Recent years, more and more stamping dies for high strength steels have been coated to prevent galling and wear. DCMX is suitable for coating because of higher resistance to coating layer detachment due to higher substrate hardness than SKD11. Figure 12 shows the optical micrographs of the cross section of TD coated specimens. It is available to coat DCMX as the same conditions as current die steels.

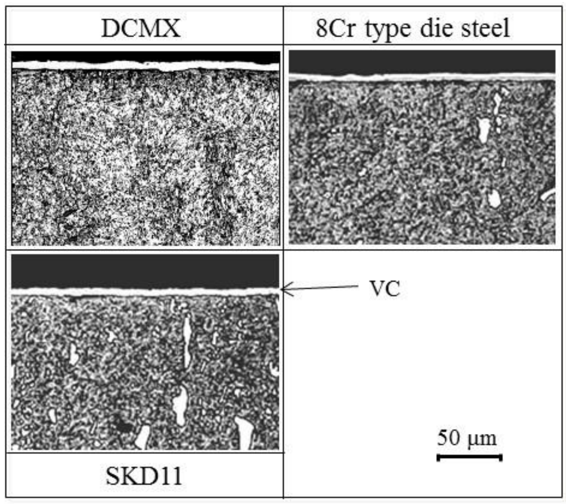

Fig. 12. Optical micrographs of TD coated specimens observed on cross section.

4.7 Repair welding

Figure 13 shows the surface of the specimens welded by pre-heated at 350 °C and post heated at 400 °C with using arc welding rod JIS DF3B-600B (TM-

10B). The hardness distribution on the cross section of welded part is shown in Fig. 14. It is available for DCMX to repair weld with the same welding conditions as those of current cold work die steels without cracking.

Electrode : DF3B-600-B, Φ3.2 mm
Pre-heating temperature : 350 °C
Post-heating temperature : 400 °C

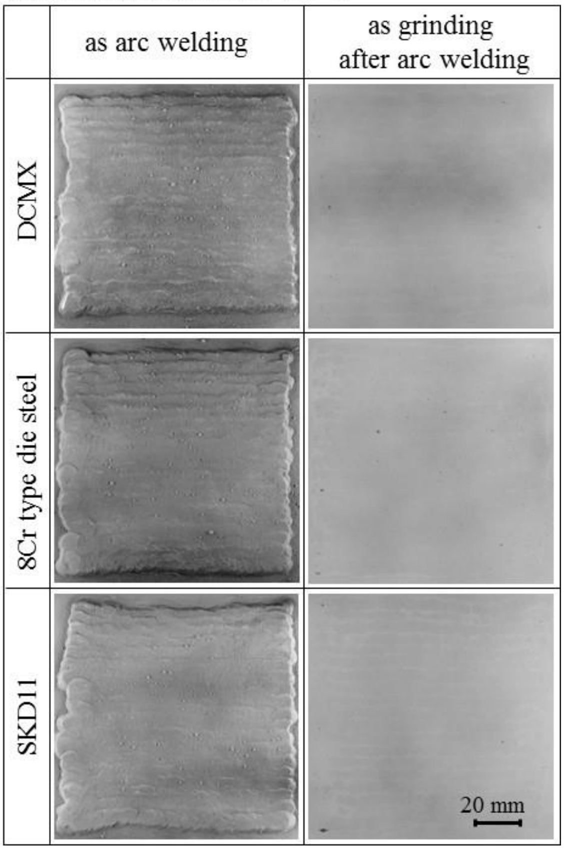

Fig. 13. Photographs of test pieces after arc welding.

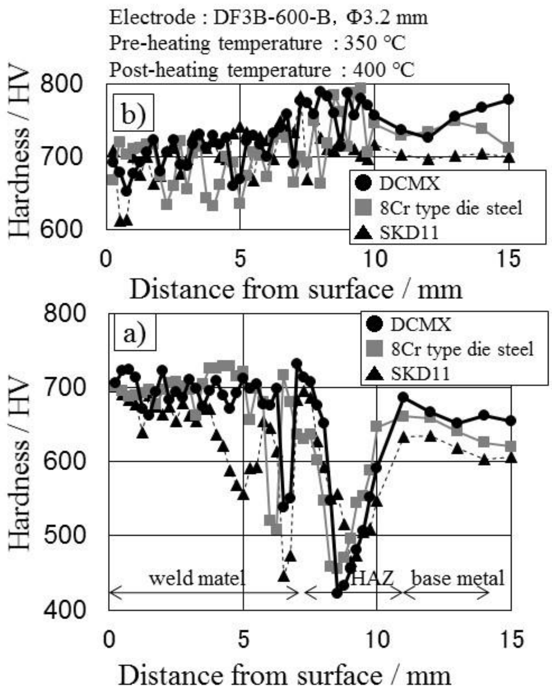

Fig. 14. Hardness distributions from the surface.
a) as arc welding. b) after grinding.

5. Application

DCMX has been applied to stamping dies of large automobile Parts. Customers have highly evaluated easy dimension control which results in the time saving for finish alignment of segment dies. Table 2 shows the applications of DCMX to stamping dies for high strength steels. Chipping is prevented in two cases due to high toughness. Other three are examples that galling experienced in current SKD11 dies have been prevented by applying DCMX. The causes of these improvements are considered as following two: initial stage chipping is prevented and precisely tight clearance is secured due to DCMX's isotropic small dimensional change.

6. Summary

Matrix type cold work die steel developed by reducing the amount of coarse primary carbides drastically has brought three advantages in mold making: almost free dimensional change, improved machinability, and high toughness, and has contributed to mold making time reduction and prolonged die life of large cold stamping dies. Therefore, DCMX will be increasingly applied in this field. Furthermore, DCMX is expected to be widely applied to other dies and jig parts.

Table 2. Applications of DCMX.

Mold	Work: High tensile strength steel sheet (Tensile strength / Thickness)	Coating	Life (Shot / Failure mode / Hardness)	
			Conventional tool steel (JIS SKD11)	DCMX
Trim dies	600 MPa 2.0 mm	None	2000~4000 Chipping Unknown	19000< - Unknown
Trim dies	Unknown	None	1000 Chipping 59 HRC	5700> - 61 HRC
Draw dies	400 MPa 2.6 mm	CVD	<100 Galling Unknown	8700< - Unknown
Trim dies	590 MPa 2.0 mm	PVD	8000 Galling 59 HRC	25000< - 61 HRC
Punch	Unknown	PVD	100000 Galling 59.5 HRC	200000 Galling 61.5 HRC