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Development of Ceramic-Coated Roller for Dampening System of Offset Printing Presses

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Abstract:

Chromium-plated rollers have been traditionally used as continuous dampening rollers for offset printing. Since the chromium-plated roller is not very hydrophilic, about 10% isopropyl alcohol (IPA) is added to the dampening water for high printing quality. IPA is an organic solvent that calls for working environment control measures against occupational diseases. Its use is restricted by the Industrial Safety and Health Law. Against this background, Nippon Steel Corporation developed and commercialized a ceramic-coated roller with high hydrophilicity. The ceramic-coated roller is manufactured by plasma spraying an Al_2O_3-TiO_2 *system advanced ceramic powder to the steel substrate, filling pores in the ceramic coating with an* SiO_2*-base inorganic sealer, and grinding the ceramic surface to a mirror finish with a surface roughness Ra of 0.06 μm or less. The ceramic-coated roller can be used for high-quality printing without using IPA.*

1. Introduction

Offset printing utilizes the repellency of ink and water. A continuous dampening system with a chromium-plated roller is the predominant offset printing process. Addition of isopropyl alcohol (IPA) to the dampening water reduces the surface tension of the dampening water, improves the wettability of the chromium-plated roller and the printing plate, and thereby secures a good printing quality.

IPA is an organic solvent that necessitates working environment control measures from the view point of occupational disease prevention. In Japan, the addition of IPA to dampening water is restricted to a maximum of 5% by provisions for the prevention of organic solvent poisoning in the Industrial Safety and Health Law.

Chromium-plated rollers traditionally used in the continuous dampening system of offset printing presses are superior in wear resistance and workability, but poor in wettability. The authors identified the poor wettability of the chromium-plated roller as the cause for the variation of water film thickness on the roller surface, and developed a ceramic-coated roller of good wettability, thus establishing technology for high-quality printing without IPA addition to the dampening water.

2. Offset Printing Press

2.1 Machine configuration and role of water

The offset printing press usually prints in four basic colors and comprises four printing stands in tandem arrangement. Black ink is used on No. 1 stand, cyan ink on No. 2, magenta ink on No. 3, and yellow ink on No. 4. The four-stand press runs at a high speed of 12,000 to 15,000 sheets per hour. Of course, there also are two-stand, five-stand, and six-stand offset printing presses.

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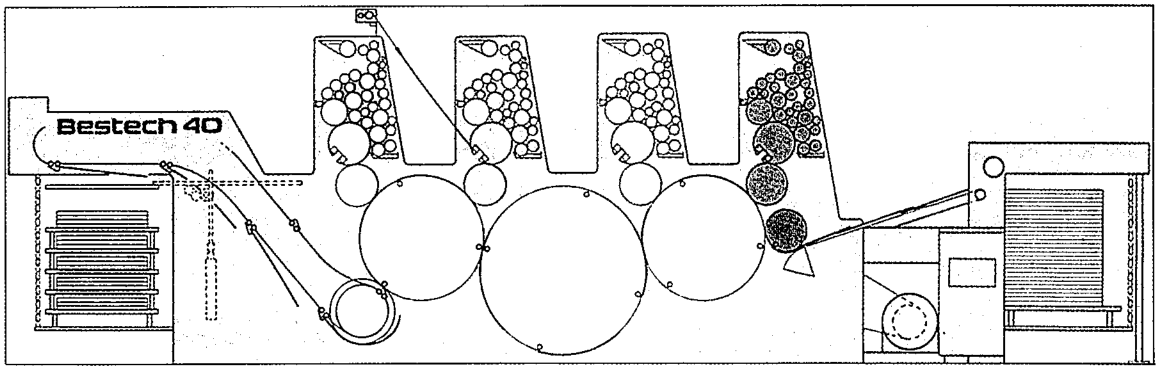


Fig. 1 Cylinder arrangement of sheet-fed offset printing press "New Bestech 40" (Akiyama Printing Machinery)

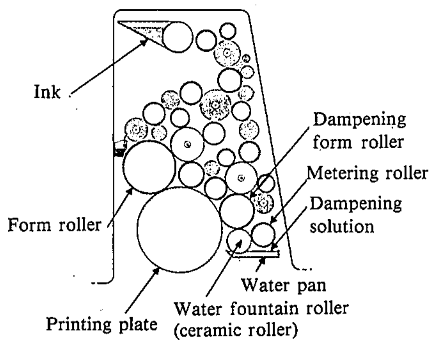


Fig. 2 Roller arrangement of offset printing press (Akiyama Bestech)

Fig. 1 shows the cylinder arrangement of a four-stand offset printing press. The printing plate used on the press has both image areas and non-image areas formed on almost the same plane and makes ingenious use of the repellency between the ink and water. The non-image areas of the plate that are treated very hydrophilic are water-receptive and ink-repellent, while the image areas are water-repellent and ink-receptive. Water, called dampening water, is indispensable for this offset printing press.

As shown in **Fig. 2**, each stand has about 30 water and ink rollers installed. The water is lifted from the water pan by the water fountain roller, squeezed by the metering roller, formed into a uniform water film (estimated at 2 to 3 μm), and transferred to the ink on the dampening roller. The surface water of the dampening roller is applied to the non-image areas of the printing plate. Immediately, the ink is applied from several inking rollers to the image areas of the plate. The ink (design) applied to the plate is transferred to the blanket and printed on the sheet of paper passing between the impression cylinder and the blanket cylinder.

A minimum necessary amount of water enters the fine non-image areas of the printing plate, which is composed of halftone dots with a mesh size of several tens of micrometers, to obtain clean halftone reproducibility. This dampening roller arrangement is peculiar to each manufacturer.

2.2 Present chromium-plated roller and IPA addition

The chromium-plated roller has been traditionally used as the water fountain roller mentioned above. Since the chromium-plated roller is poor in wettability, the dampening water is likely to form droplets on its surface. Therefore high-speed rotation of the roller varies the water film thickness and produces fine water lines at a pitch of several millimeters in the width direction of the roller. These conditions hamper the normal transfer of the ink to the paper and cause flow marks on the print. For this reason, 5 to 15% IPA is added to the dampening water to lower its surface tension and to equalize the water film thickness on the chromium-plated roller.

3. Development of Ceramic-Coated Roller

3.1 Selection manufacturing process

Ceramics are available as structural materials with excellent heat, wear or corrosion resistance and as functional materials with high hydrophilicity, electrical insulation or far-infrared radiation. These structural and functional ceramics have made remarkable development in recent years. They are manufactured by a variety of processes, including sintering, plasma spraying, physical vapor deposition (PVD) and chemical vapor deposition (CVD).

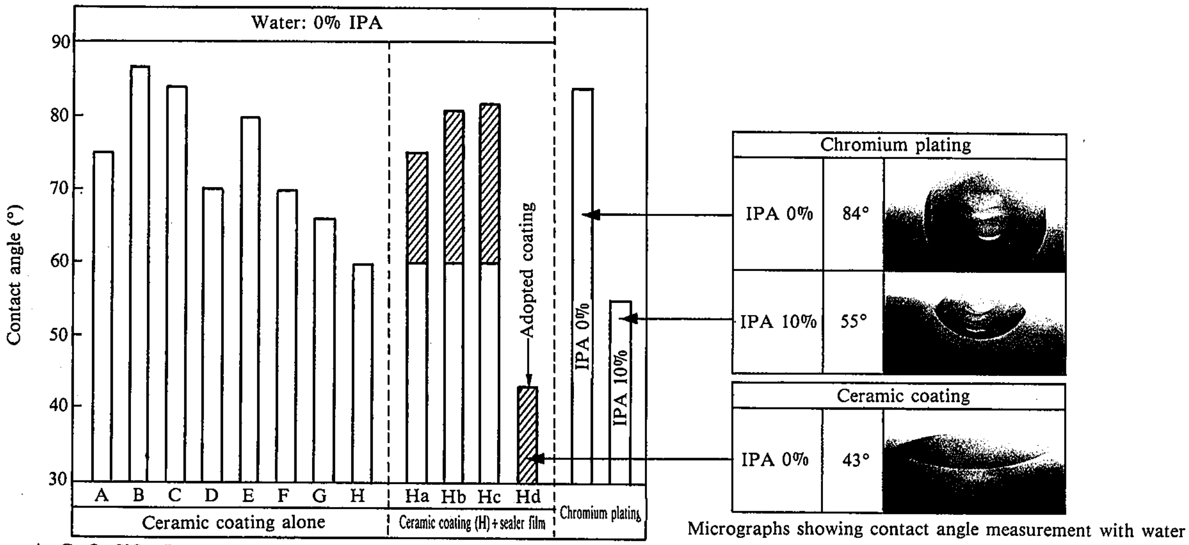
When a ceramic is used as coating for the water fountain roller of the offset printing press, its most important properties are high hydrophilicity, wear resistance, and corrosion resistance.

Ceramics widely vary in properties according to composition, structure, and coating process. Selection of an appropriate raw material and coating process is a key to the successful fabrication of a ceramic-coated roller. The sintering process consists of many complex steps as compared with the plasma spraying process, involves difficulty in installation on the steel shaft, and incurs very high manufacturing cost. The plasma spraying process was therefore selected.

3.2 Selection of ceramic material

Wettability is the most important property for the water fountain roller of the offset printing press, and its comparative measurement led to the selection of a ceramic as coating material for the roller. Various samples were prepared and tested for the contact angle with water, representative results of which are shown in **Fig. 3**.

Ceramics widely vary in the water contact angle. Sprayed Al_2O_3-TiO_2 system coatings exhibit good wettability. Cr_2O_3 coatings are high in wear resistance, but poor in hydrophilicity, and are not suitable for the water fountain roller. As the TiO_2 content increases, the Al_2O_3-TiO_2 system coating increases in hydrophilicity but decreases in wear resistance. Considering the properties of the two constituents, an Al_2O_3-TiO_2 coating with an Al_2O_3/TiO_2 ratio of a value in neighborhood of 50/50 was selected as the ceramic coating for the water fountain roller.



A: Cr_2O_3-SiO_2, B: G-Al_2O_3+WC-Co, C: WC-Co, D: Cr_2O_3, E: W-Al_2O_3, F: G-Al_2O_3, G: Al_2O_3-13%TiO_2,
H: Al_2O_3-40%TiO_2, Ha: H+silicone resin, Hb: epoxy resin, Hc: H+vinyl chloride resin, Hd: silica-base inorganic paint

Fig. 3 Various coatings and their contact angles with water (0% IPA)

3.3 Problems of ceramic coating and countermeasures

The application of ceramics as continuous water dampening rollers in offset printing dates back to more than 10 years ago. Many manufacturers paid attention to ceramic-coated rollers with the idea of utilizing the water-retentive fine pores in the ceramic coating for the purpose of a uniform water lift.

When ceramic-coated rollers were used as water dampening rollers, however, they were contaminated with too much ink for practical purposes. In **Fig. 2**, the ink-smeared rubber dampening roller and the ceramic-coated water fountain roller rotate at different speeds under nip pressure and slip. The slip introduces the ink into pores in the ceramic coating of the water fountain roller, which detracts from the hydrophilicity. This problem was solved by filling pores in the ceramic coating with a sealer and polishing the coating to a mirror finish by a special grinding method.

3.3.1 Selection of sealer

Ceramic spray depositing has been conventionally sealed to enhance corrosion resistance. Most of the sealers presently used are resin based.

Ceramic coating specimens were sealed, ground to a mirror finish, and tested for wettability. Despite a pore area fraction of only about 10%, the contact angle with water is as high as that of the chromium plating. This means that the high hydrophilicity of the ceramic coating is lost. The resin-base sealer is so low in wear resistance that it cannot last a long period of printing operation.

After various studies, the authors found an SiO_2-base inorganic paint with very good hydrophilicity and wear resistance. The Al_2O_3-TiO_2 ceramic coating was sealed with the SiO_2-base inorganic paint, ground, and tested for the contact angle with water. The results are given in **Fig. 3**.

3.3.2 Sealing and mirror-finish grinding techniques

The sealer must fully impregnate the fine pores in the ceramic coating and form a uniform sealer film on the roller surface. These requirements were met through the development of a special sealing device that combines dipping and spraying.

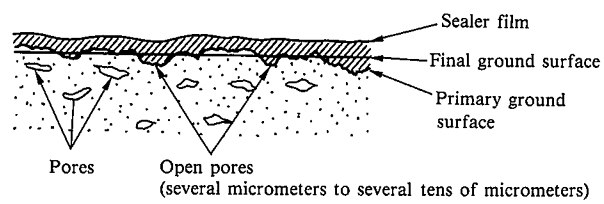


Fig. 4 Cross-sectional schematic of sealer film and finish ground surface

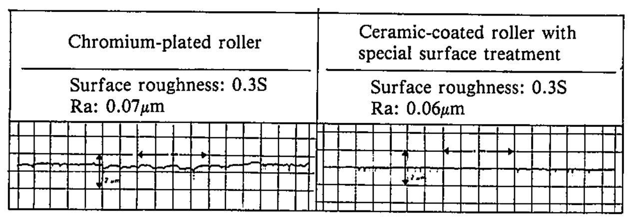


Fig. 5 Surface profile of chromium-plated roller and ceramic-coated roller

The surface of the ceramic-coated roller is covered with a sealer film. The sealer film is lower in wear resistance than the ceramic coating. A special finishing treatment is required so that only the surface sealer film is ground off, leaving the pores securely impregnated with the sealer. The sealer and the ceramic coating are different in hydrophilicity, of course. Therefore, the roller surface must be equalized in properties by grinding to the final surface finish as shown in **Fig. 4**. This finishing requirement cannot be satisfied by the conventional wheel-type cylindrical grinding or the buffing process. A finishing technique for grinding the ceramic-coated roller to the same mirror finish as that of the chromium-coated roller was established. It adopts a grinding system by which the wheel is pressed at a constant pressure against the roller surface, and optimized grinding conditions with a special diamond wheel.

Fig. 5 compares the surface profile of the chromium-plated roll and the ceramic-coated roll.

The contact angle with water is 43° for the ceramic-coated roller sealed and mirror-finished as described above. When compared with 84° for the conventional chromium-plated roller and 55° for the dampening water that contains 10% IPA, this contact angle means that the ceramic-coated roller is very hydrophilic.

The sealing and mirror-finish grinding operations minimize the adherence of ink to the ceramic-coated water fountain roller and the rubber metering roller, as compared with conventional ceramic-coated rollers with open pores.

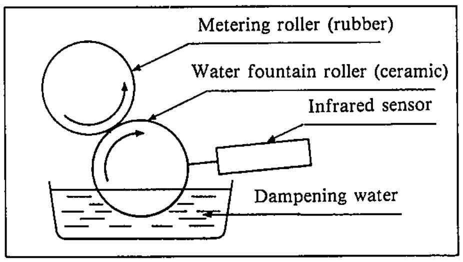
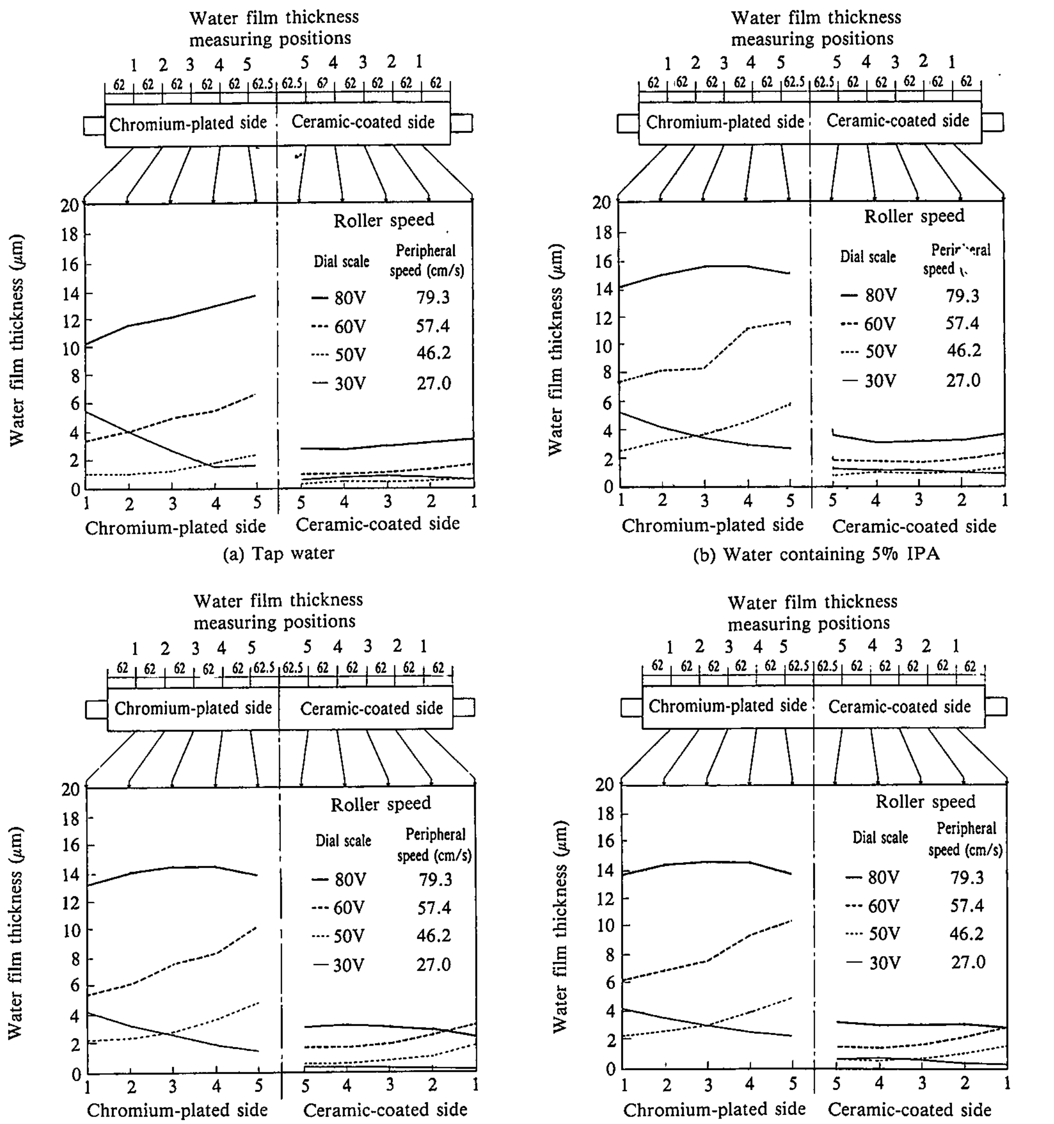


Fig. 6 Simulator of dampening system

4. Formation of Water Film on Ceramic-Coated Water Fountain Roller in Offset Printing Press

A full-scale simulator as illustrated in **Fig. 6** was used to investigate how ceramic-coated rollers would behave as continuous dampening rollers, compared with conventional chromium-plated rollers. To make this comparison under as identical conditions as possible, such as roll nip pressure, roller speed and fountain solution, the water fountain roller was ceramic coated for one half and chromium plated for the other half.

The water film thickness on the water fountain roller was continuously and dynamically measured by an infrared sensor in a noncontacting manner. **Fig. 7** shows the water film thickness var-



(a) Tap water

(b) Water containing 5% IPA

(c) Water containing 1% etching solution (Tokyo Printing Ink Mfg. SG23)

(d) Water containing 2% etching solution (2% Rosos RD-50 and 2% Rosos RV-1000)

Fig. 7 Comparison of water film thickness between chromium-plated roller and ceramic-coated roller on simulator iation across the roller width after water squeeze.

The experimental results may be summarized as follows:

(1) The ceramic-coated roller provides a thinner and more uniform water film across the width than the chromium-plated roller.

(2) The ceramic-coated roller is less liable to produce fine water lines in the water flow direction (visual inspection).

(3) The water film thickness varies with roller speed drastically for the chromium-plated roll but moderately for the ceramic-coated roller.

(4) The water film thickness increases when IPA or alcohol-substitute etching solution is added to tap water, but the water film thickness distribution scarcely changes over the roller width.

IPA and alcohol-substitute etching solution are effective in enhancing ink emulsification and printing plate hydrophilicity, but are little effective in equalizing transverse water film thickness on the water fountain roller that plays an important role in the water balance during printing. The ceramic-coated roller exhibits a distinct effect in equalizing the water film thickness in the width direction.

5. Benefits of and Considerations for Ceramic-Coated Roller

5.1 Benefits

(1) A uniform water film can be formed on the printing plate in the width direction without IPA.

(2) The amount of the dampening water can be reduced to a minimum, resulting in improving the printing quality.
- Dot gain is good.
- Ink transfer ratio is good.
- Ghosts are less likely to occur.

(3) The running cost of the offset printing operation can be reduced by eliminating the use of IPA and reducing the ink consumption.

(4) The non-alcohol operation improves the working environment of the pressroom and makes it unnecessary to invest in environmental control measures against IPA.

5.2 Considerations

(1) The water film thickness varies with the material and hardness of the rubber metering roller. It is therefore important to select a roller that meets pre-determined standards.

(2) Control of etching solution concentration and water temperature is particularly important in the non-alcohol operation.

(3) The ceramic-coated water fountain roller and the rubber metering roller must be washed after the day's work and long continuous run.

6. Past Performance and Future Outlook of Ceramic-Coated Roller

The roller arrangement of the continuous dampening system is ingeniously designed by each printing press manufacturer.

In September 1989, Akiyama Printing Machinery Mfg. Corp., joint developer of the ceramic-coated rollers reported here, announced that they would install the ceramic-coated rollers as standard equipment on their printing presses. Since then, printing companies have installed the ceramic-coated rollers on various sheet-fed presses, such as the Daiya-matic, Roland-matic, Heidel/Alcolor, and Sakurai/Oliver-matic models. The use of ceramic-coated rollers is now increasing to cover metal printing presses, business format printing presses, and commercial rotary offset printing presses. The ceramic-coated rollers now have more than two years of operating record with good results on almost all models of continuous dampening systems. **Fig. 8** shows principal offset printing presses on which the ceramic-coated rollers are installed.

The regulation of IPA is expected to increase further in severity for the protection of the global environment. The ceramic-coated rollers now enjoy growing expectations in response to the increasing sophistication of printing quality as seen in the high-image quality printing. Work has advanced on the development of alcohol-substitute etching solutions, and such drastically improved etching solutions have been launched on the market. These etching solutions and the ceramic-coated rollers will find widespread

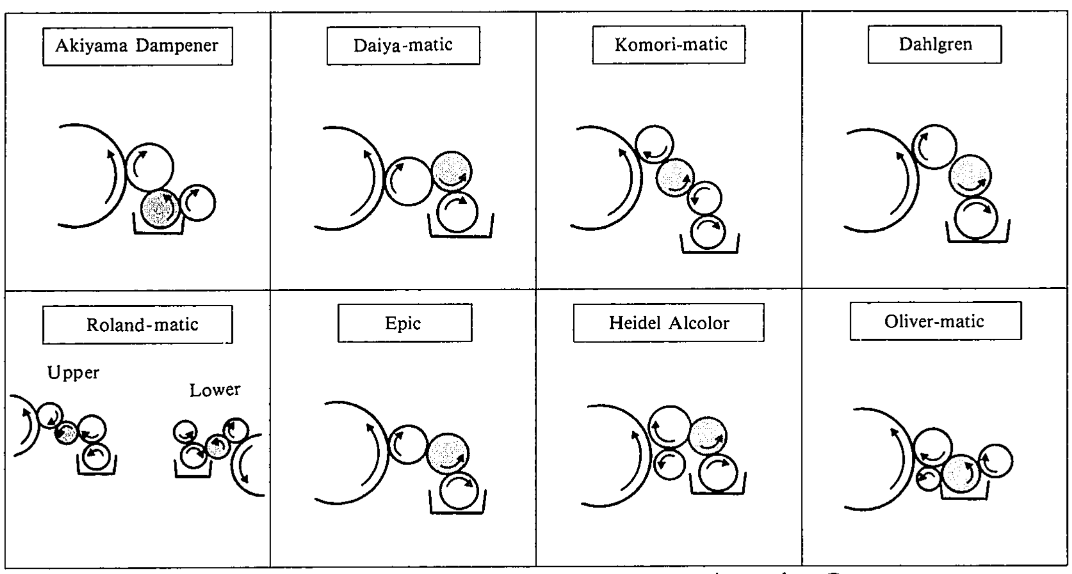


Fig. 8 Principal models of offset printing presses on which ceramic-coated rollers are used for water dampening

use in a mutually complementary relationship.

7. Conclusions

It is said that offset printing critically depends on the control of dampening water. Offset printing has many problems associated with dampening water, which is very difficult to control. Many printing press manufacturers and roller manufacturers have attempted to develop new types of dampening rollers, including ceramic-coated rollers, but have failed. As a result, chromium-plated rollers have long been used as continuous dampening rollers.

After many failures, Nippon Steel Crop. has succeeded in developing a high-performance ceramic-coated roller with the all-out cooperation of Akiyama Printing Machinery Mfg. Corp. as joint development partner and Yoshikawa Kogyo Co. as designated roller manufacturer. The authors expect the new ceramic-coated roller to greatly contribute to the future progress of offset printing.