Optimized Pad Design for Heat Release and Direct Print with the Finite Element Method, Part II: Analysis and Design Optimisation of Printing Pads

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Abstract **Interceram 52** (2003) [5]

The following article describes how the behaviour of a silicon pad during a heat release process for transferring decors onto plates can be simulated with a numerical simulation software and an appropriate mathematical modelling. The optimisation is achieved by changing the geometry and repeated simulation until a suitable shape is found. It also shows how the results of the simulation have to be evaluated to optimise the process.

Keywords: a heat release process for transferring decors, numerical simulation software, mathematical modelling, automatic decoration of porcelain tableware

6 Design Optimisation of Printing Pads

The design optimisation of printing pads refers to the process of attempting to achieve certain ideal design parameters which, when used within the model, satisfy prescribed conditions regarding the performance of the design and at the same time minimize (or maximize) a measurable aspect of the design. Thus, some pad quality criteria have to be developed. These criteria can later be applied for the optimisation as well as analysis and evaluation of existing pads. Furthermore, the design parameters describing the geometry of the pad need to be defined.

7 Pad Quality Criteria

In general, two principal problems in the heat release transfer process can be observed: air inclusions and wrinkles. Other aspects concern the overall necessary force for compressing the pad, higher life time due to reduced deformations, and insensitivity with respect to geometrical variations of the plates.

Figs. 14 and 15 show a comparison between two different geometrical shapes of the pad. In Fig. 14, the outer contour of the pad does not correspond to the necessary kinematics imposed by the plate. In order to obtain better “rolling”, the shape of the pad must be modified in the transition zone between the horizontal and the conical part of the pad. After some optimisation, a new shape was obtained whose behaviour is presented in Fig. 15. It can be seen that the area of air inclusion has been significantly reduced. Moreover, the cinematic rolling has been enhanced and the risk of air inclusions reduced. It can be stated that the area of air inclusions is an objective value for the quality of the transfer process. Of course this is just one specific aspect which needs to be taken into consideration along with all the other factors.

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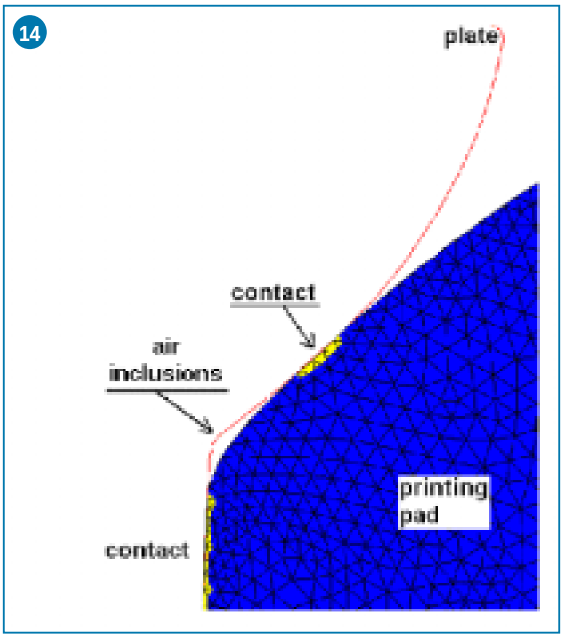

Fig. 14
Air inclusion during printing due to a poor pad shape

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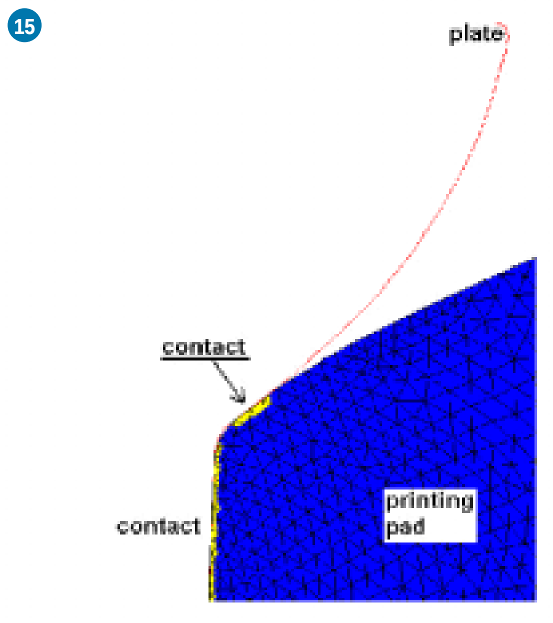

Fig. 15
Optimized pad shape for minimum air inclusion during printing

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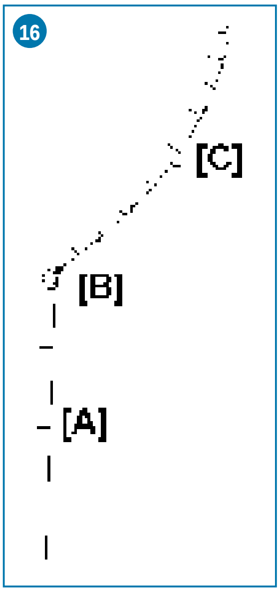


Fig. 16 *Geometrical regions A to B of a typical plate*

Another important aspect is the reduction of the tangential contact forces. High values lead to high relative movements between the pad and the plate which results in wrinkling of the decal, especially on the flange.

8 Generic Pad Shapes

The geometry of the pad depends on the geometry of the plate and on the type of decal to be applied. As with empirical pad development, one knows more or less which generic type of pad corresponds to which combination of plate and decal. In the optimisation procedure described here, the author uses the same approach for the definition of the initial pad geometry. To solve the problem, an empirically good generic pad shape is used as a starting-point.

The following table illustrates some possible combinations of decal and plate types. The goal of the optimisation is to achieve an optimal geometry of the pad. For this procedure, the so-called design variables need to be determined. When any of these entities change, a direct impact on the optimisation criterion can be observed immediately. An analysis of standard plate geometries shows that a typical plate geometry can be divided into 3 regions A to C, where A is the centre, C the border and B the transition region from A to C (Fig. 16).

Area A of the printing pad is constructed with a specific radius, in order to ensure a correct picking up and printing of the decal at the mirror-part of the plate and to avoid pressure problems. The main problem that arises during printing a full-surface-decal is when no air-inclusions are allowed between the printing pad and the plate during printing. This causes specific restrictions concerning the shape of area B (and to some extent also C and D) of the printing pad. A poor printing pad illustrating this point is shown in Figs. 17 a–d. The shape of the printing pad was subdivided in 4 regions where the geometries of regions A to C of the pad depend on the geometries of regions A to C of the plate.

9 Iterative Optimization Procedure

The first step is to determine a generic pad shape before performing a complete simulation cycle. After each simulation cycle, the various optimisation criteria are evaluated. Each optimisation criterion is related to one or more design variables which are modified accordingly. The first first optimisation phase focuses on the minimization of the air inclusions during printing. This is achieved by reducing the radius in the transition zone from the flat to the cone zone of the pad. Fig. 18 shows the development of the pad shape during the iterative optimisation process.

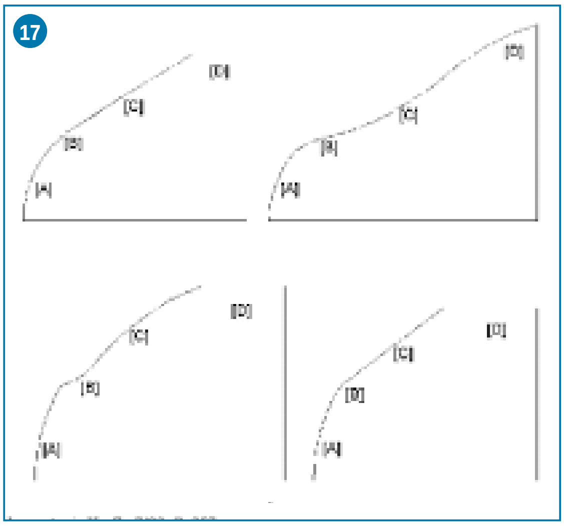


Fig. 17 a–d *Examples of generic pad types*

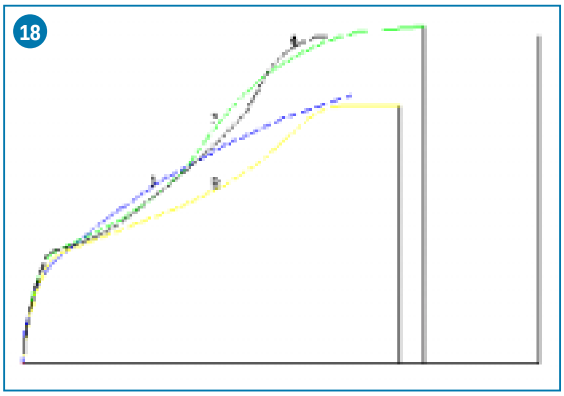


Fig. 18 *Evolution of the pad shapes during the iterative optimisation procedure*

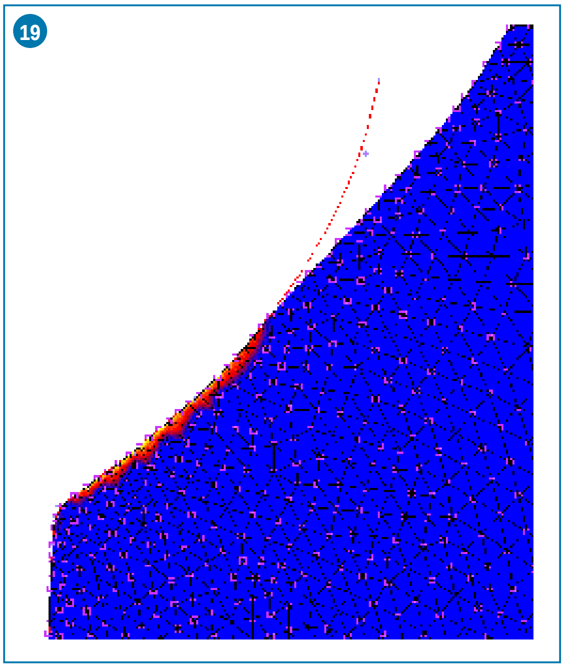


Fig. 19 *Deformed pad while flange printing with high relative movement*

After minimizing the air inclusion in the transition zone between the flat part of the plate and the border zone, the following problem was encountered: due to the relatively sharp edge of the printing pad (required to print the sharp and deep inside edge of the plate), a high relative movement was observed in this area (Fig. 19). During further optimisation steps the contact friction forces were reduced whereby this resulted in a reduction of the angle between the plate and the pad. A narrow angle can lead to poor kinematic behaviour (Fig. 20). As both plate and printing pad are concave during printing, the angle between the pad and the plate is also narrow. Thus air inclusions may occur provoked by an imperfect geometry of the plate. Some more iterations were performed to optimise the rolling on the flange.

It was concluded that the pad shape should be concave in the flange printing zone and the pad's contact zone front should be convex in order to minimize the necessary deformation of the pad in contact with the plate. It should be noted that the pickup phase of the decal from the heating table is just as important as the printing phase. The relative movement of the pad with respect to the table must be minimized too. If this movement is too high, the decal already wrinkles when it sticks on the pad.

After about 20 iterations the following optimised pad shape was obtained. The optimised pad has a good kinematic behaviour which corresponds to a unrolling movement of the pad's contact front along the plate. Figs. 21 and 22 a–b show the deformed pad at 3 different times during the printing process. Fig. 21 demonstrates how well the pad fits into the corner between

Fig. 20
Deformed pad while flange printing after relative movement minimization

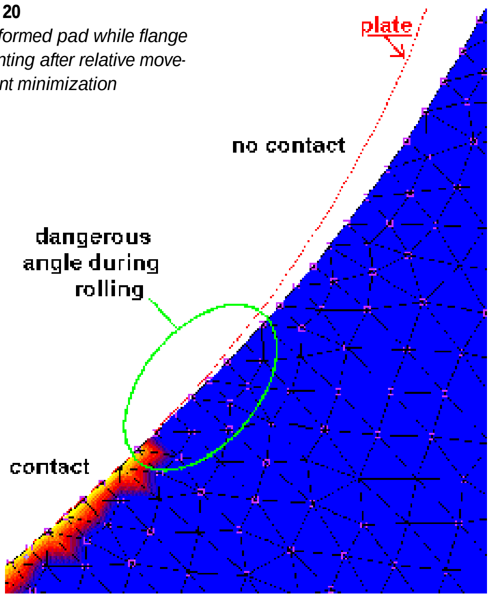
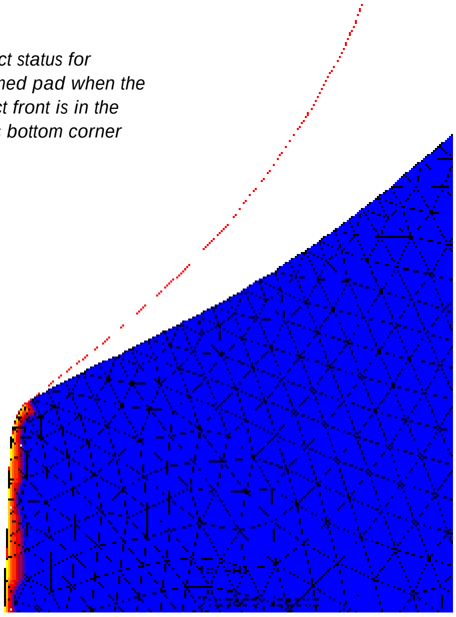


Fig. 21
Contact status for deformed pad when the contact front is in the plate's bottom corner



Possible plate/decal combinations

	Deep plate	Flat plate	Relief plate	X-sized plates >280 mm Δ
Full surface decals				
Ring decals				
Intermediate decals				

the flat part of the plat and the flange. Figs. 22 a–b figures represent the contact status in a more advanced state when the pad comes in contact with the plate flange. No air inclusions were observed, nevertheless there is a slight risk of inclusions due to the narrow angel between the plate flange and the pad.

The decal pick-up process from the flat table was also studied. The radial strain does not show a very homogenous distribution (Fig. 23). This is caused by the sharp edge in zone B of the pad, required to transfer the decal into the plate's bottom. It was also observed that high friction contact forces in this area lead to high relative movements which can cause a wrinkling of the decal on the pad. Also the normal contact forces of the pad show a high value in the area where the sharp edge is located (Fig. 24).

10 Conclusion

A non-linear finite element model for the heat release transfer process of decals was developed (Fig. 25). Optimisation criteria and design variables were defined. An iterative optimisation procedure was employed in order to optimise the following aspects:

- minimum relative movement between the pad and the plate
- reduced air inclusion in the corner of the flat bottom and the flange
- improved kinematic behaviour during the flange printing phase
- enhanced life time of the pad
- reduced compression forces of the pad.

This method has been successfully applied to optimise the design of pads for different plate and decal types. Some work has also been done on analysing existing pads.

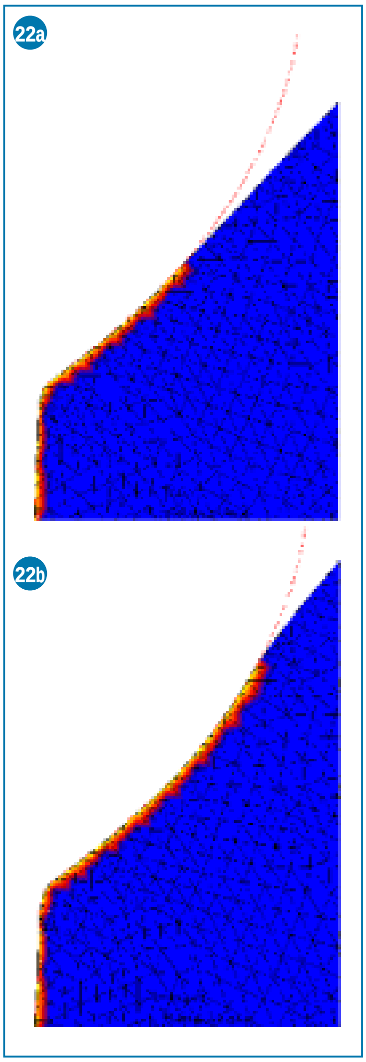


Fig. 22 a–b
Contact status for the plate flange at two different times

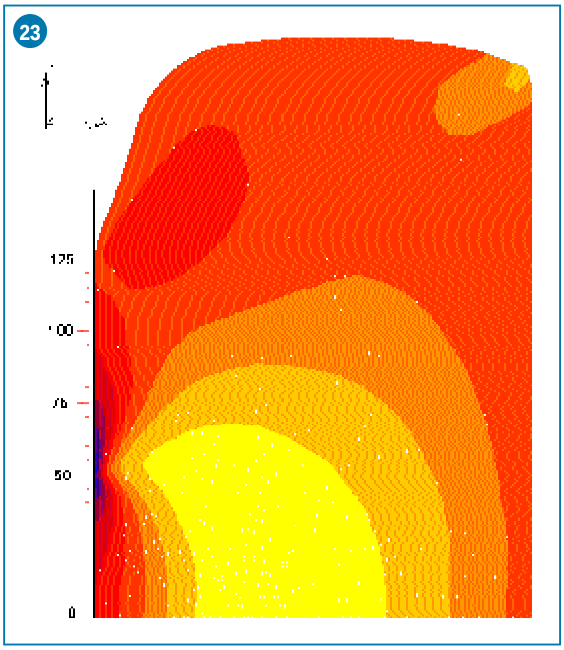


Fig. 23
Radial strain distribution in the printing pad

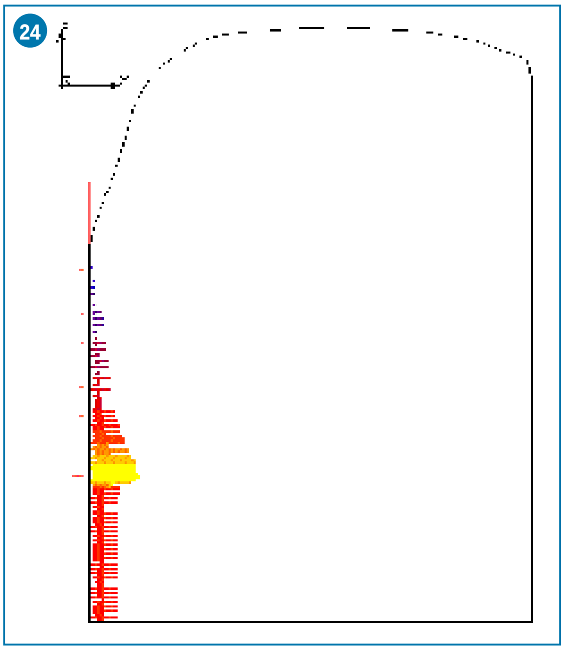


Fig. 24
Normal contact force

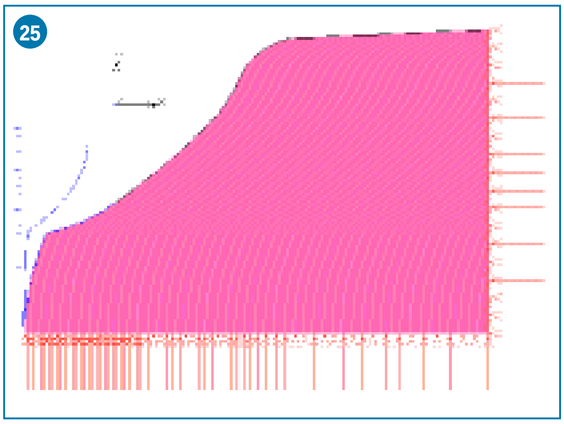


Fig. 25
Model of the final shape

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Kurzfassung/Résumé/Résumen

Optimierung der Tampongeometrie für Heißübertragung und Direktdruck mit Hilfe eines Finite-Elemente-Programms Teil 2

Im nachfolgenden Artikel wird beschrieben, wie mit Hilfe eines FEM-Programms und einer geeigneten mathematischen Modellierung das Verhalten eines Silikontampons beim Übertragen von Heißübertragungs-Dekoren auf Teller simuliert werden kann. Durch Änderung der Geometrie und wiederholte Simulation wird iterativ optimiert, bis schließlich eine geeignete Form gefunden ist. Dabei wird dargestellt, wie die Ergebnisse der Simulationsrechnung bewertet müssen, um das Verfahren zu optimieren.

Optimisation, par méthode d'éléments finis, du design d'un tampon, par rapport à l'émission thermique et à l'impression directe. Partie 2

L'article décrit comment on peut simuler, par emploi d'un logiciel de simulation numérique et modélisation mathématique appropriée, le comportement d'un tampon de silicium lors du processus d'émission thermique associé au transfert de décors sur les pièces. L'optimisation est obtenue en modifiant la géométrie et en répétant la simulation jusqu'à obtention de résultats satisfaisants. On montre également comment les résultats de la simulation doivent être évalués pour optimiser le processus.

Diseño optimizado para impresión en caliente e impresión directa por medio del método de los elementos finitos. Parte 2

Este artículo describe la simulación del comportamiento de un cojín de silicón durante un proceso para transferir decorados sobre platos, usando un software numérico y un modelo matemático adecuado. La optimización se obtiene variando la geometría y repitiendo la simulación hasta encontrar una geometría adecuada. Se muestra asimismo cómo evaluar los resultados de la simulación para optimizar el proceso.