# Inline detection of defects on free formed metal pressings using a single shot inverse fringe projection approach

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In a harsh production environment, such as press forming, the conventional fringe projection approach reaches its limits. We present a new approach using inverse fringes in combination with a Fourier-based single shot analysis to make inline detection of constrictions on complex reflective metal parts in a vibrating environment possible.

## 1 Introduction

Optical measuring techniques gain in importance with respect to industrial inspection tasks due to the flexibility, speed, and the ability to measure without contact.

In most cases, the main focus lies in the detection of surface defects. Well-established inspection solutions typically rely on the acquisition of several images. However, in production measurement technology, there are many applications where the use of multiple images is prohibitive. One of those applications is the detection of constrictions on deep-drawn parts.

*Fig. 1* Field of application: Deep-drawn parts. Left: Pre-aligned object (engine hood). Right: Constriction

A constriction describes a local reduction of the component thickness and could reduce the reliability of the part in field. Therefore an automated inline detection system is developed in cooperation with BMW.

When integrating an optical inspection system into a press, especially vibrations, short cycle times, varying lighting conditions and the limited installation space issue big challenges.

With unavoidable vibrations, the position and orientation of the measuring components and the object itself will differ during the measurement (see Fig. 2a). Thus, an analysis based on a sequence of images is not possible. Furthermore, short cycle times often don't allow solutions which require a sequence of several measurements.

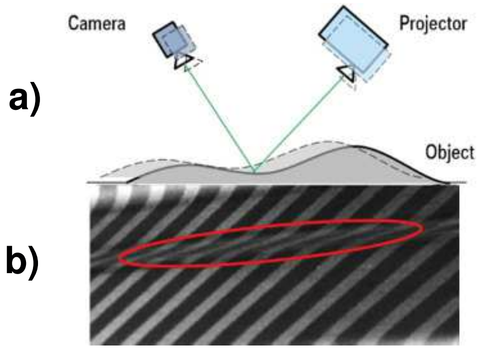


*Fig. 2* Challenges of conventional fringe projection with press forming. a) Variation of position and orientation during the measurement. b) High dynamic range of the spatial frequency of projected fringes

With the use of conventional fringe projection, the spatial frequencies of the projected fringes vary considerably on complexly shaped objects (see Fig. 2b). This influences directly the achievable measuring accuracy. In conclusion, the conventional fringe projection approach is not applicable for this particular task.

## 2 Method

As only the deviation from an a priori known topography is of interest, and as the device under test is well-aligned within the press, this is a perfectly suited application for "*inverse fringe projection*" [1]. The key idea is to pre-distort the projected fringes based on the already known object shape. Thus, the camera only detects variations of the fringes in defective areas of the object. With the help of inverse fringe projection, the previously mentioned high dynamic range of the spatial frequencies of the projected fringes can be reduced. Furthermore, the narrow frequency bandwidth achieved this way is extremely beneficial for the subsequent defect analysis based on single sideband demodulation.

Regarding inverse fringe projection, our work is based on [1].

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A fully automated computation of the inverse fringe pattern (see Fig. 3), based on a complete sensor simulation using raytracing is integrated in our software.

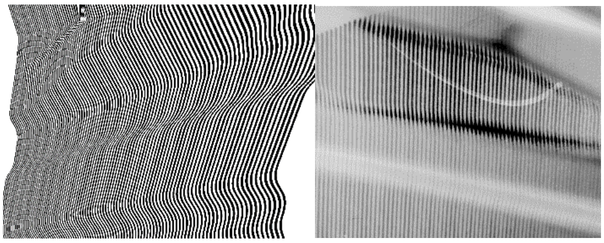

***Fig. 3*** *Computation (left) and projection (right) of inverse fringes*

For analysis of the resulting inverse fringe pattern, the well-known "*single sideband demodulation*" technique, introduced by Takeda [2] is implemented. Using this single-shot method, the previously stated impact of vibrations during the measurement can be avoided, since a single image is sufficient for a complete analysis of the phase.

An automated algorithm for phase analysis as well as for the final classification of the object quality is implemented.

## 3 Results

Once the projected fringes are acquired with a camera, the resulting image can be analyzed with single sideband demodulation.

In the first test run, a good part without any defects is inspected to determine the amount of unwanted phase noise. Since no frequency variation should appear, a constant phase value is expected. Fig. 4 shows the calculated phase map with an exemplary section through the image. Based on several measurements, phase noise corresponding to a height range of 20µm-60µm occurs, limiting the achievable accuracy of the system.

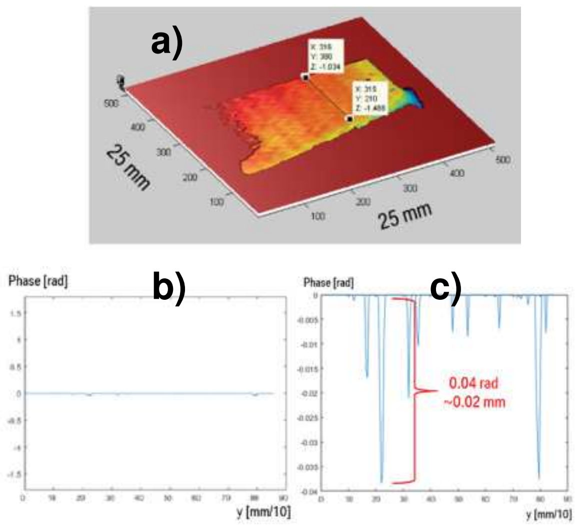


***Fig. 4*** *Inspection of a good part without defect. a) Phase map, b) Section view of phase signal, c) Zoom of b)*

In the next step, a defective part is analyzed. A camera image with a variation of fringes caused by a constriction with a depth of 0.33mm and the evaluation of two different constrictions (depth 0.33mm and 0.12mm) is shown in Fig. 5.

The camera image is analyzed and the phase map can be retrieved. The constriction defect (Fig. 5e) is recognizable in a range of 0.7rad which corresponds to a depth of about 0.33mm.

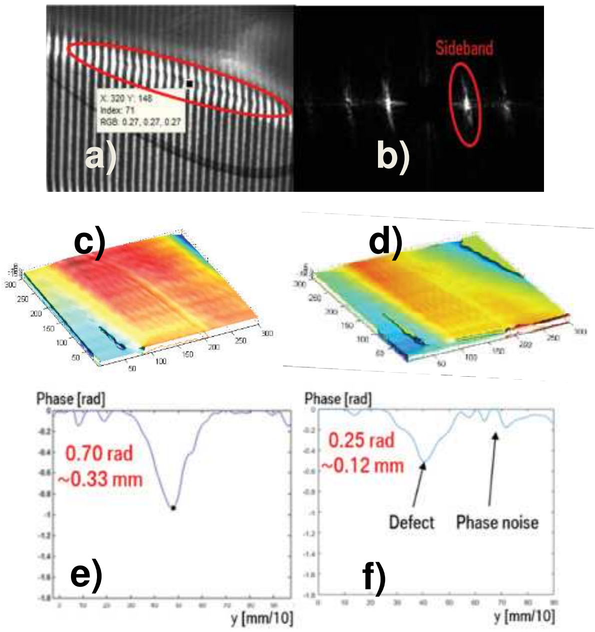


***Fig. 5*** *Analysis results of constrictions detected on a deep-drawn engine hood. a) Camera image with constriction (red), b) Fourier-space (DC peak suppressed), c) Phase map Constriction 0.33mm, d) Phase map Constriction 0.12mm, e) Section view of phase map c), f) Section view of phase map d)*

## 4 Conclusion

The proposed method was tested within the scope of a first feasibility study at BMW to proof the functionality of this approach. By using a combination of inverse fringes and a single-shot method for analysis, constrictions can be detected on high reflective metal pressings. Based on our results, constriction defects down to 0.1mm can be identified robustly. Future work deals with testing the measuring system in a real production environment in the press.

## Literature


[1] Pösch, A., Vynnyk, T., Reithmeier, E.: *„Using Inverse Fringe Projection to Speed Up the Detection of Local and Global Geometry Defects on Free Form Surfaces"*, Proc. SPIE Vol. 8500, 8500B-1, 2012

[2] Takeda, M., Ina, H., Kobayashi, S.: "*Fourier-transform method of fringe-pattern analysis for computer-based topography and interferometry".* In: Journal of the Optical Society of America, Vol. 72 (1982), p. 156 - 160


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