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# Deep Cold Rolling of Features on Aero-Engine Components

Chow Cher Wong[a],*, Andry Hartawan[a], Wee Kin Teo[a]

[a]*Rolls-Royce Singapore, Advanced Technology Centre, 6 Seletar Aerospace Crescent, Singapore 797575*

* Corresponding author. Tel.:+65-62403153; *E-mail address*:chow.cher.wong@rolls-royce.com.

## Abstract

Fatigue limited performance in aero-engine components is one of the critical challenges in the industry. In order to increase the resistance of such components to initiation and early growth of fatigue cracks, especially in the presence of foreign object damage, mechanical surface treatments are widely used. Although shot peening is traditionally being adopted for most aero engine components, deep cold rolling (DCR) offers several advantages over the shot peening process. Although DCR is able to generate a deeper layer of compressive residual stress and good surface finish, one of the challenges in adopting this processs for wider application in the industry is the limitation in applying it to different geometrical profiles. In this study, three cold rolling tool designs were selected to study its feasibility on processing Titanium (Ti 6Al-4V) test coupons of different features. The effect of process variables (pressure, feed rate and overlap) on residual stress profiles were also investigated for one selected tool. Results showed that DCR is able to generate deep layer of compressive residual stress (up to 1mm depth) and process variables such as rolling pressure played a significant role in affecting the residual stress profiles.

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## 1. Introduction

The control of failure due to fatigue in aero-engine components is one of the critical challenges in the industry. Components that are generally affected by fatigue are blades and disk which are constantly subjected to HCF loading associated with high frequency vibrations within the engine on top of a low cycle fatigues component associated with start and stop cycles (1). In order to mitigate the risk to fatigue failure and to prevent crack initiation and propagation under the high cycle and low cycle fatigue loadings, especially in the presence of foreign-object damage (2), mechanical surface treatments such as shot peening, laser shock peening or deep cold rolling processes can be employed. These processes are commonly adopted to improved resistance to wear and stress corrosion and in most cases, to improve the fatigue strength of highly stress metallic component in an aero-engine (1).

In most cases, when enhanced fatigue strength is required, shot peening is usually considered and adopted in the first instance as there are considerable process knowledge and equipment know-how within the aerospace industry. However, with new designs being incorporated into components to improve performance in terms of fuel efficiency, this has led to higher requirements in terms of fatigue strength. This is taxing the current shot peening process beyond its capability and deep cold rolling appears to be a viable option as it offers several advantages such as its capability of generating a ‘deeper case’ of compressive residual stresses, a work hardened structure as well as significantly better surface finish as compared to traditional shot peening process [3].

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Deep cold rolling is a process whereby a hydrostatically controlled ball or roller is applied onto the material surface under a controlled pressure. The rolling pressure causes a small amount plastic deformation on the surface and sub-surface area, inducing a deep layer of compressive residual stress. The working principles of the process are shown in Fig. 1. Although deep cold rolling is more cost efficient as compared to conventional shot peening and laser shock peening, one of the challenges in adopting deep cold rolling is its limitation in applying to different geometrical profiles on aero-engine components, especially components with thin and intricate features (small radii and fillet) around areas with low tool accessibility.

In this study, we examine the effectiveness of several deep cold rolling tools in treating different geometrical features of an aero engine component. Experiments were carried out on representative Titanium (Ti 6Al-4V) test coupons of different features to investigate the effects of different process variables on the residual stress profiles.

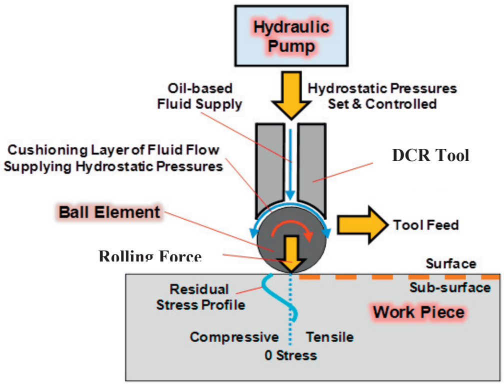

Fig. 1. Working principles of deep cold rolling process.

## 2. Experimental Methodology

### 2.1. Equipment

To carry out the deep cold rolling experiments, an ABB robot was selected as the machine platform. Three different types of deep cold rolling tools, as shown in Fig. 2 were investigated to study its feasibility on the output such as residual stress profiles. The tools were attached to the end-effector of the robot with special designed fixtures and cold rolling tool path was programmed according to the profile of the features on the test coupons as well as the required overlap (or 'coverage').


Single Roller Double Roller Caliper Ball

Selected DCR tools with fixtures attached to end effector of a robot

Fig. 2. Equipment set-up for deep cold rolling process on an ABB robotic platform.

### 2.2. Materials & Test Samples

In this study, Titanium (Ti 6Al-4V) was chosen as the material to be studied and three test coupons were designed and fabricated representing the profiles of the different features of an aero engine component. The design of the test coupons are shown in Fig. 3, 4 and 5 with respective surfaces to be cold rolled highlighted. For processing features on test coupon 1 and 2 (shown in Fig.3 and 4), the single roller and the caliper ball tool was used respectively. For test coupon 3, two flat surface coupons were adopted to represent a particular corner feature for cold rolling using the double roller tool as shown in Fig.5.

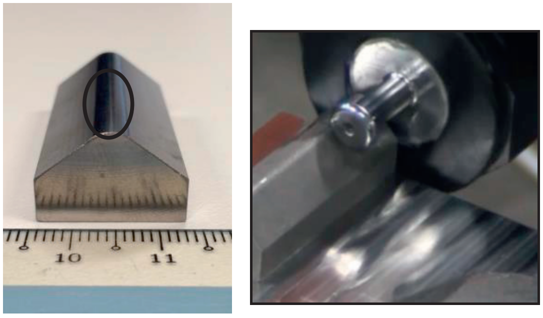

Fig. 3. Test coupon 1 used with a single roller tool