CHAPTER 3

Detection of Defects in Fabric by Joint Transform Correlation Technique

3.1 Introduction

As shown in chapter 2, the regular periodic nature of woven fabric permits the application of Fourier transform technique for the detection of defects. However classification of defects of various types is difficult from the analytical and experimental results by using Fourier transform technique. A solution to the problem of identification of different types of defects is provided when a joint Fourier transform of a reference pattern and the test pattern is taken and the joint power spectrum is further processed. The method is an extension of Fourier transform analysis and is known as the joint transform correlation technique. Cross and auto correlation peaks generated after the execution of second Fourier transform on the filtered joint power spectrum, indicate the existence of a particular type of defect in the test fabric.

At the outset it may be mentioned that the joint transform technique has not been utilized for the defect detection in woven fabric. Techniques are proposed in this chapter where the defects in the fabric are extracted by using two different types of reference scene. In the first case, only a type of defect without any periodic structure is selected as reference scene for extraction of that particular type of defect in test fabric. In the second case, a portion of the defective fabric (i.e. defect with periodic structure) is selected as reference scene. Defects are detected and identified in both the cases. However it has been observed that in the second case, the signal to noise ratio has increased at the expense of the processing time.

3.2 Joint transform correlation technique

Weaver and Goodman first proposed the joint transform correlation (JCT) technique by optically convoluting two functions [1]. The correlation function at the output of the JTC is obtained by applying Fourier transform operation on the joint power spectrum (JPS). The JPS is the intensity spectrum of a joint scene, where the input target is displayed alongside the reference scene. It was later realized that the main advantage of JCT technique over the then extensively used spatial filter based processing techniques, is the ability to perform non linear transformations on the Fourier power spectrum of the joint target and reference scene.

The JTC technique can be implemented either by Vander Lugt type processors [2-3] or by the processor basically established by Weaver and Goodman and later modified by many workers [4-5]. There was some added advantage of the later types over the Vander Lugt type processors. Vader Lugt type filters require a priori knowledge of the filter to be used and therefore the technique suffers from alignment and other positioning problem for real time situation, whereas in the later case no such information is necessary. Classical JTC processors however, can be operated at video frame rates for real time analysis and does not require the reference image to be known substantially in advance for performing the correlation process.

The schematic diagram of the classical JTC technique is shown in figure 3.1. The target scene is captured by a CCD camera (CCD_0) and is displayed jointly at the input plane P_1 along with the reference scene on a spatial light modulator (SLM_1). A coherent parallel light beam illuminates the SLM_1. The joint image is displayed at the SLM are then Fourier transformed by lens L_1 and the joint diffraction pattern is produced at the plane P_2 The joint power spectrum is recorded by a CCD camera (CCD_1) located at plane P_2. A second SLM (SLM_2) is located at plane P_3 to read out the joint power spectrum. The correlation function is produced at plane P_4 by taking the inverse Fourier transform of the joint power spectrum located at the plane P_3. For obtaining Fourier transform parallel coherent laser beam is required, which is obtained from the primary laser source by using a beam splitter and a mirror.

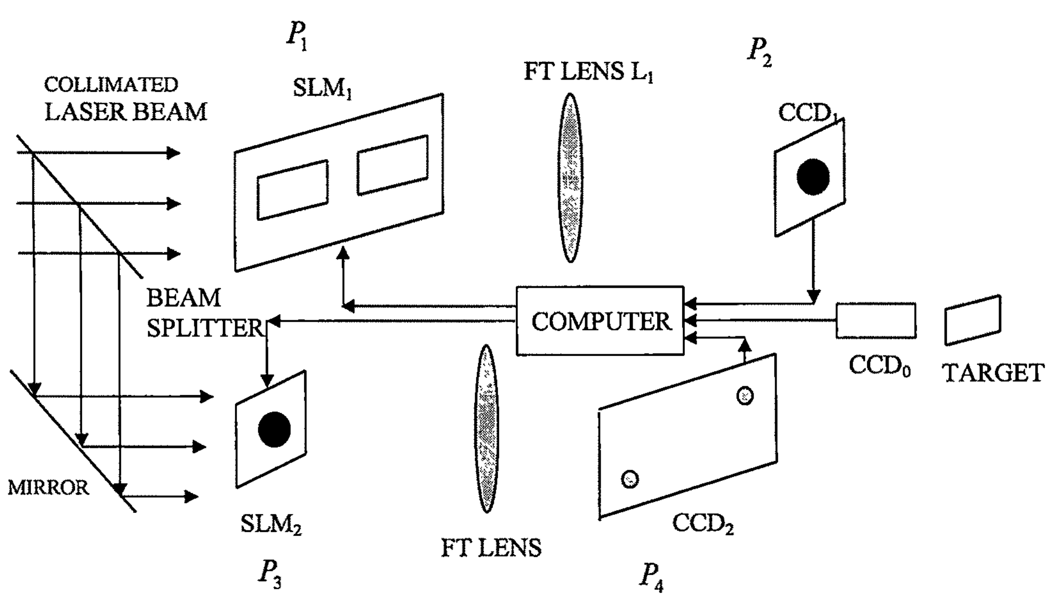

Figure 3.1 Schematic diagram of optoelectronic implementation of JTC

One of the problems associated with the classical JTC is the presence of an undesirable strong zero order autocorrelation peak [6-7] at the output plane, which almost overshadows the desired cross correlation peaks. This situation is more bizarre in the case of noisy environment because the zero order peaks may over saturate the output detector and cause spurious detection. To overcome some of the detection problem, Javidi et el. [8-11] proposed binary JTC techniques. In this technique the Joint power spectrum is binarized by a hard clipping nonlinearly at the Fourier plane before applying the inverse Fourier transform operation. Only two binary values $+1$ and -1 are permitted. Binary JTC is found to yield superior correlation peak intensity, better correlation width and higher discrimination sensitivity. The binary JTC however, suffers from the low processing speed due to the calculation of the threshold value used for binarization of the joint power spectrum (JPS) [12]. Moreover, the binarization produces harmonic correlation peaks and therefore some energy is distributed among these higher order harmonic terms. In addition, the higher order harmonic terms may yield false alarms or may result in misses thereby complicating the target detection process [13-14].

To alleviate some of the problems, technique of median thresholding for binarization is sometimes used [15-16]. It has been observed that for large input scene noise, the performance of the binary JTC using the noise dependent threshold is better than using the fixed threshold. In this case, the threshold value is updated for every new input scene. The evaluation of the median value for large arrays can be computationally intensive in terms of both software and hardware implementation. For this reasons another method called subset median thresholding is evaluated for thresholding the joint power spectrum which also takes into account the effect of the input scene noise to compute the threshold value [17].

In another approach [18-19], the JPS is multiplied by an amplitude modulated filter (AMF) function before the inverse Fourier transform is attempted for getting better correlation performance than the classical and binary JTC technique. The AMF is defined as

$$H_{amf}(u,v) = \frac{1}{|R(u,v)|^2} \tag{3.1}$$

where $|R(u,v)|$ is the Fourier transform of the reference signal *r*(*u,v*). However, the factor $|R(u,v)|^{-2}$, which may be associated one or more poles and therefore may force the gain of the AMF to approach infinity. The problem imposes a serious restriction on the realisation of this technique [20-21]. Moreover, the advantage of having AMF is somewhat masked by high optical gain for lower values of the reference signal, which may actually degrade the noise performance of the JTC [22].

JTC technique that uses fractional Fourier plane for correlation was also reported. [23]. In this technique, a phase-only spatial light modulator (SLM) is used at the Fourier plane. The analysis/simulation results are applicable to only those joint power spectrums of reference images that do not contain any zeros. To alleviate the problems and at the same time to increase the autocorrelation peak intensity fringe adjusted JTC technique is developed in which a real valued filter called a fringe adjusted filter (FAF) is used [24-25]. The FAF function is defined as

$$H_{faf}(u,v) = \frac{B(u,v)}{A(u,v) + |R(u,v)|^2} \tag{3.2}$$

where $A(u,v)$ and $B(u,v)$ are either constants or functions. The value of $B(u,v)$ is so chosen as to avoid the optical gain greater than unity. A small value of $A(u,v)$ can solved the pole problem also at the same time a high correlation peak is obtained. The function $A(u,v)$ is so chosen that it sometimes suppress the effect of the noise or sometimes band limit the signal. In this technique, larger and sharper auto correlation peak may be obtained using proper amplitude matching. The FAF function contains only the intensity and has no phase term. So it is simple and suitable for optical implementation. As the computation time for calculating FAF is very small so it has not any significant detrimental effect on the processing speed of the system. One of the disadvantages of this method is that it requires an additional SLM to display the filter function at the Fourier plane.

A major problem which limits the performance of a FAF based JTC is it's sensitiveness to noise of the input scene. The FAF accentuates the higher frequency values when $A(u,v)$ is set to a small value. This accentuation enhances the relative magnitude of the noise and the auto correlation peaks.

Usually the Fourier transform of the reference image concentrates most of the energy at low spatial frequencies with little energy in the high frequencies. This concentration at the low end reference in the power spectrum of the reference image shows an extremely large dynamic range. So using this technique the dynamic range of the system is increased but the system is still noise sensitive. To overcome this limitation, a modified fringe adjusted JTC has been proposed [26-27]. This filter copes better with noisy situation as it uses $R(u,v)$ instead of $R(u,v)^2$ .The MFAF function is defined as

$$H_{mfaf}(u,v) = \frac{B(u,v)}{A(u,v) + |R(u,v)|} \tag{3.3}$$

Another class of correlation technique is established by Tang and Javidi is known as chirp encoded JTC [28]. The technique produces three output correlation functions at different planes. The autocorrelation functions on the optical axis are focused on one of the output planes and the off-axis cross-correlation is produced in two separate output plane. In this system the reference signal is placed in different input plane, which encode the joint power spectrum with a function (that is the chirp function) for each correlation term.

In general, the reference image used in a JTC is presented to the test system from the computer memory while the test scene is input from the outside world that may or may not contain the target of interest. The input scene illumination can therefore be entirely different from that of the reference. This poses serious drawback in the JTC technique where the illumination balance of the target with that of the reference determines the correlation performance. In a real time situation, it almost impossible to employ such a system in a non-cooperative environment where no real control over the test scene is possible [29-30]. To alleviate the detrimental effects of illumination on the correlation output of a JTC, Julamalia et al [31] have proposed a polarisation encoded two channels JTC architecture. Intensity compensated filter to sharpen the correlation peak for a JTC has also been employed by using the inverse reference power spectrum. The technique can be implemented by using the inverse of the pre-processed reference spectrum, which is independent of input parameter a hybrid system has also been developed that performs the JTC with a multi reference by using a self generated threshold function. The intensity problem of JTC can be solved by use of an intensity compensation filter (ICF); it is generally limited to single reference problem. Another method has been established where the above problem can be alleviated if a spatial function, whose Fourier Transform is equivalent to the Fourier transform of the reference multiplied by the ICF.

Important parameters of the JTC are (a) Cross correlation peak intensity, (b) The ratio of correlation peak intensity to the maximum correlation side lobe intensity, (c) Full correlation width at half maximum, (d) Correlation width and (e) ratio of the correlation peak amplitude to the rms deviation of the noise amplitude. It has been already mentioned that the classical joint transform image correlation technique suffers from low light efficiency, large correlation side-lobes, large correlation width, and low discrimination ability. These parameters can be significantly improved in single SLM JTC technique (figure 3.2), where the amplitudes of input signal and the reference signal are binarized to two values +1 and -1. There would also be a reduction in the memory space required to store the binary reference signals compared to storing space necessary for the continuous tone reference images.

A single SLM can be used to display the thresholded input signals and the thresholded Fourier Transform interference intensity. The thresholded input and reference signals enter the SLM, which operates in the binary mode. The interference between the Fourier transforms of the input signals is obtained using a lens and a CCD is used to produce the transform interference intensity distribution. The interference intensity is then thresholded to, +1 and -1 values. The binarized interference intensity is then written on the same SLM. The inverse Fourier transform of the thresholded interference intensity produces the correlation signals.

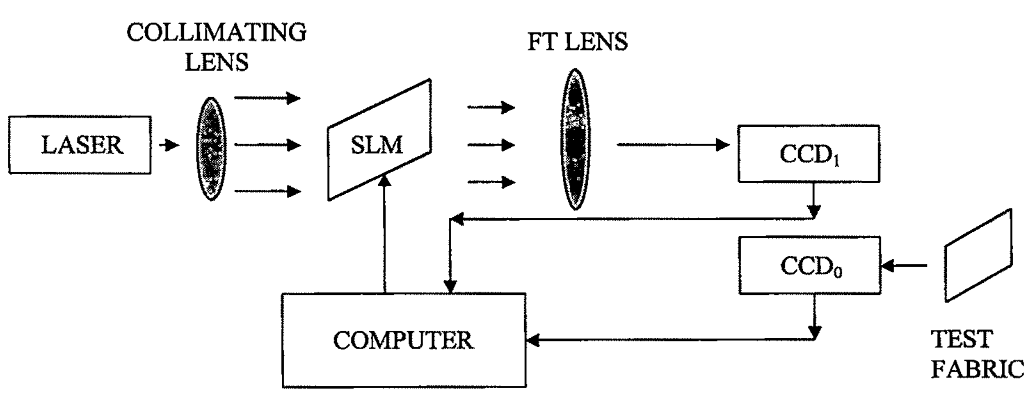

Figure 3.2 Experimental setup for JTC using single SLM

3.3 JTC technique for defect detection in fabric using defect as reference

The problem of detection of defects in fabric can be translated into the problem of extraction of defects of the fabric from its background of regular periodic structure. The input joint image function $j(x, y)$, consisting of a reference defect and the target sample of fabric to be tested by JTC technique can be expressed as

$$j(x,y) = d(x - x_0, y) + t(x,y) \tag{3.4}$$

where $d(x - x_0, y)$ is the reference defect located at $x = x_0$ and $y = 0$, which is to be detected and $t(x, y)$ is the test fabric containing defects.

Assuming that the test fabric contains n numbers of defects, the test fabric can be represented as,

$$t(x,y) = \sum_{i=1}^{n} d_{f_i}(x + x_i, y) + f(x + x_f, y) \tag{3.5}$$

where d_{fi} $(x+x_i, y)$ is the i_{th} defect to be detected centred at $(-x_{i,} 0)$, and $f(x,y)$ is the background image of fabric located at $(x_f, 0)$. The Joint Power Spectrum (JPS) associated with the input joint image is given by

$$|J(u,v)|^2 =$$

$$\begin{aligned} &|D(u,v)|^2 + \sum_{1}^{n} |D_{if}(u,v)|^2 + |F(u,v)|^2 + 2\mathrm{Re}\left[D^*(u,v) \sum_{1}^{n} D_{if}(u,v) \cos(x_0 + x_i)u \right] \\ &+ 2\mathrm{Re}\left[D(u,v) F^*(u,v) \cos(x_0 + x_f)u \right] + 2\mathrm{Re}\left[\sum_{1}^{n} D_{if}^*(u,v) F(u,v) \cos(x_f + x_i)u \right] \end{aligned} \tag{3.6}$$

where u and v are the spatial frequency in the frequency plane. $D(u,v)$, $D_{if}(u,v)$ and $F(u,v)$ are the Fourier transforms of the reference defect, i_{th} target defects and the background fabric *f(x, y)* respectively.

When the inverse Fourier transform is applied on the expression of equation 3.6, the first three terms generate the autocorrelation of the reference defect, fabric defects and background fabric respectively, at the centre of the correlation plane. The fourth term however, produces the desired cross correlation signals for $d(x,y)$ and $\sum_{1}^{n} d_{fi}(x.+x_i,y)$ at $x = x_0 \pm x_i$ where $i = 1 \ldots n$. The fifth and the sixth term show the effect of the background fabric on the correlation signals

To eliminate the deleterious zero-order term the power spectrums of reference defect and the test pattern (the background fabric with target defects) are individually recorded and then subtracted from the JPS. The resultant joint power spectrum $|J_1(u,v)|^2$ of the cross correlation terms after subtraction at the Fourier plane is given by,

$$|J_1(u,v)|^2 = |J(u,v)|^2 - |D(u,v)|^2 - |F(u,v)|^2 - \sum_{1}^{n} |D_{if}(u,v)|^2 \qquad (3.7)$$

To get better cross correlation output and to reduced the noise, the JPS at the Fourier plane is multiplied by the fractional power fringe adjusted filter (FPFAF) function [25] which is defined as

$$H_{fpfaf}(u,v) = B(u,v)\left[A(u,v) + |D(u,v)|^2\right]^{-1} \qquad (3.8)$$

where $A(u,v)$ and $B(u,v)$ are either constants or functions of u and v, and $D(u,v)$ is the Fourier transform of reference fabric.

Various values $A(u,v)$ and $B(u,v)$ can be used with a view to reduce the effects of noises at the detection plane. The representative values of $A(u,v)=0.1$ and $B(u, v)=1$ are taken as suggested by other workers [26]. The modified JPS is now given as

$$|J_2(u,v)|^2 = |J_1(u,v)|^2 \, H_{fpfaf}(u,v) \tag{3.9}$$

Joint transform correlator output J_{JTC}, at the output plane is obtained by a second Fourier transform of equation 3.9 and is given by,

$$J_{JTC} = FT[J_2(u,v)]^2 \tag{3.10}$$

Evidently the output J_{JTC} consists of a pair of cross correlation peaks. The positions of cross correlation peaks indicate the position of the defect.

For the detection of another type of defect, the presently used reference pattern is replaced by another reference pattern containing the second type of defect to be identified. The whole processing is then repeated to identify the second type of defect.

3.3.1 Simulation results

The simulation process for identification of a particular type of defect is explained in the flowchart given in figure 3.3. The reference defect is the image of the scene, which contains that particular type of defect. Since the Fourier transforms and power spectrums of the test fabric and reference defect image are needed for calculations, those are evaluated individually. The joint scene is also created and then the Fourier transformed and joint power spectrum of the joint scene is obtained. The modified JPC is obtained and multiplied with the filter function, generated separately with adjustable constants. The inverse Fourier transform and power spectrum of the modified resultant function yields the correlation peaks.

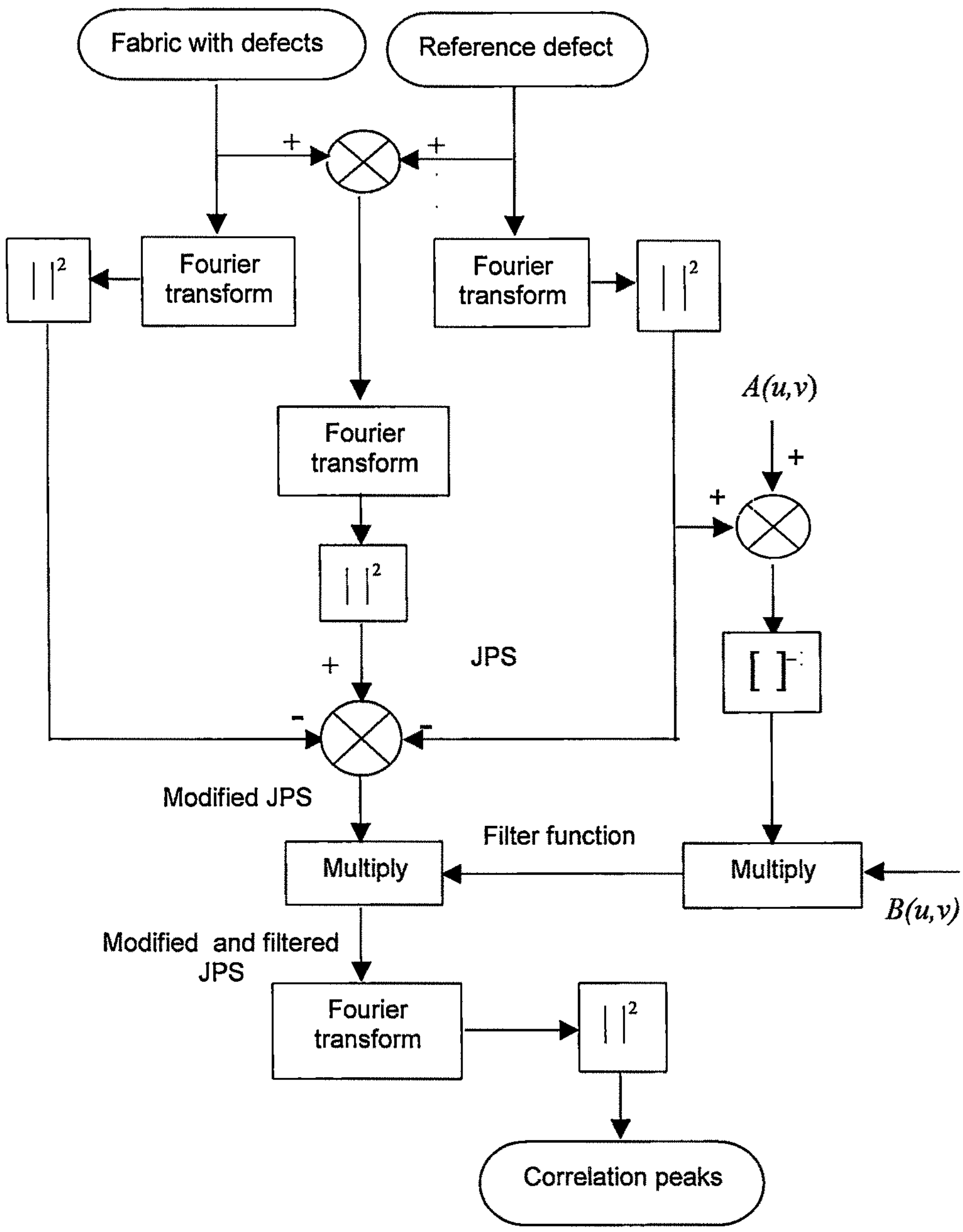

Figure 3.3 Flow chart for joint transform correlation processing

A joint scene is created in figure 3.4a where the knot to be detected is shown at the left as reference scene. The test fabric is shown at the right, which contains the knot as defect. The cross correlation peaks are shown in the figure 3.4b which indicate the detection of the defect (the presence of a knot) in the test fabric.

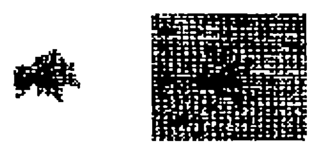

Figure 3.4a Input joint screen for identification of single knot

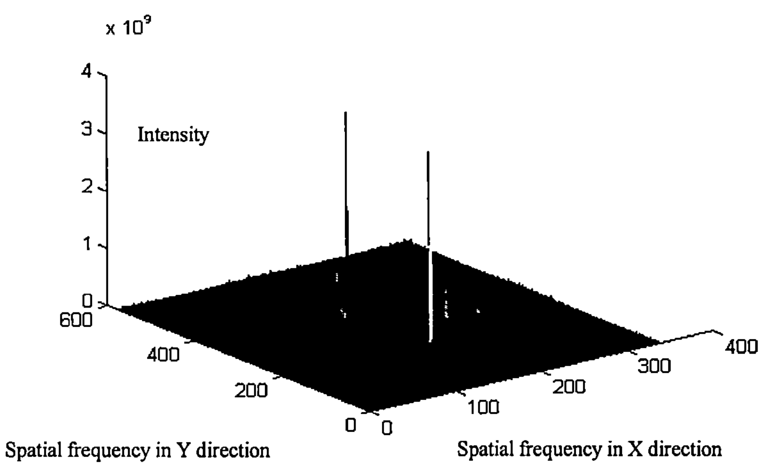

Figure 3.4b Identification of single knot

Figure 3.5a shows the joint scene where the reference knot is shown at the right. The test fabric is shown at the left, which contains two knots. The identification of two knots by JCT technique is evident by the presence of two correlation peaks at the frequency plane as shown in figure 3.5b.

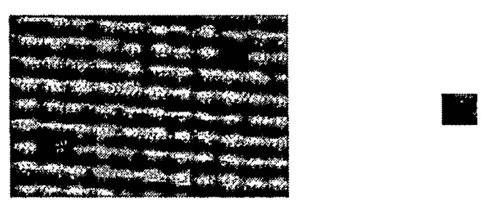

Figure 3.5a Input joint screen for identification of two knots

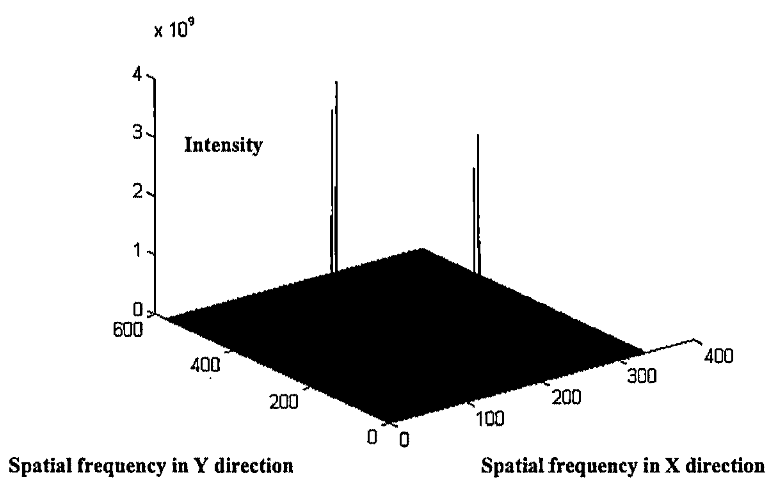

Figure 3.5b Identification of two knots

3.4 JTC technique for defect detection in fabric using defective fabric as reference

In section 3.3 it has been shown that using a particular type of defect as reference scene, the existence and position of the same defect in the test fabric can be detected. In this case the reference scene has no periodic structure and therefore the periodic structure of interlaced yarns in the test fabric behaves as noise. The effect of this noise however, depends on the periodicity and the thickness of the warp and weft yarns. In most cases the detection is very difficult particularly when the defect is small. Again, it is sometimes difficult to create the joint scene with different types of defects as reference input. Considering the above-mentioned problems, other method is developed for detection of defects in woven fabric. In this method the reference scene contains a portion of defective fabric having same interlaced periodic structure. Therefore the scan size of the test fabric and the size of the reference fabric can be made equal. Evidently, the JPS is expected to have prominent correlation peaks due to the correlation of periodic structures of the reference and the test fabric. These peaks due to the periodic structure should be cancelled by subtracting the JPS of defective test fabric from the JPS of defect-free test fabric.

Figure 3.6 shows a simulated composite joint scene, which serves as the input pattern for the JTC technique. The pattern at the left is the reference pattern, which is a portion of a defective fabric along with a knot as defect. The test fabric at the right is supposed to have two knots as defects. For simplicity, it is assumed that the test and reference fabrics are arranged symmetrically at $(-a,0)$ and $(+a,0)$ in the x-y coordinate system.

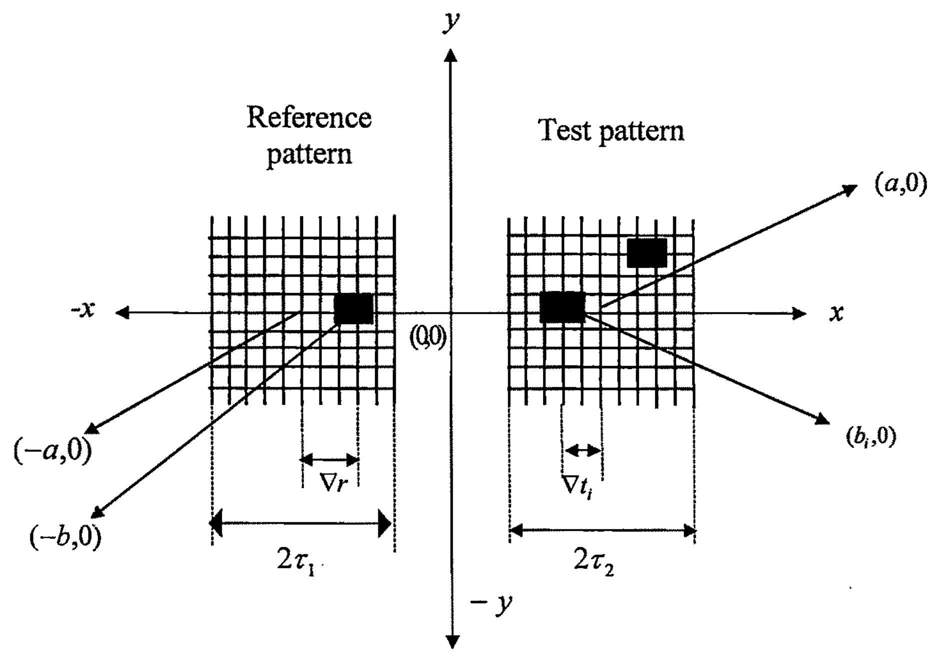

Figure 3.6 Joint Input Scene

Let us denote, $r(x, y)$ as the reference scene consisting of grating structure $g_r(x+a,y)$ of the fabric superimposed with a single reference defect $r_r(x + b, y)$ of a particular type (say a knot). The centre of the reference scene is at (-a,0) and that of the reference defect is at (-b,0). Therefore,

$$r(x,y) = g_r(x+a,y)+r_r(x+b,y) \tag{3.11}$$

The test fabric structure $t(x, y)$ is denoted by a grating structure $g_t(x+a,y)$ of the test fabric. The test fabric consists of n numbers of identical defects $\sum_1^n t_i(x-b_i,y)$ of the type specified in the reference fabric. The centre of the test fabric is at $(a,0)$ and those of the defects are at $(b_i,0)$. Therefore,

$$t(x,y) = g_t(x-a,y) + \sum_{1}^{n} t_i(x-b_i,y) \tag{3.12}$$

The joint input scene $f(x,y)$ is represented as,

$$f(x,y) = r(x,y) + t(x,y) = g_r(x+a,y) + r_r(x+b,y) + g_t(x-a,y) + \sum_{1}^{n} t_i(x-b_i,y) \tag{3.13}$$

For proper correlation operation the following conditions should hold,

$$\left.\begin{array}{l} |b| = |-a \pm \nabla r| \\ |b_j| = |a \pm \nabla t_i| \\ 0 \langle \nabla r \le \tau_1 \\ 0 \langle \nabla t \le \tau_2 \end{array}\right\} \tag{3.14}$$

where $2\tau_1$ is the width of the reference fabric in x direction and $2\tau_2$ is the width of the test fabric in x direction. ∇t_i are the distances between centres of the defects in test fabric and the centre of the test fabric. ∇r is the distance between centre of reference defect in reference fabric and the centre of the reference fabric (indicated in Figure 3.6).

Joint power spectrum (JPS) is obtained at the Fourier plane by taking the Fourier transform of equation 3.13 and is given by,

$$\begin{aligned} |F(u,v)|^2 &= G_r G_r^* + RR^* + G_t G_t^* + \sum_{1}^{n} T_i T_i^* + G_r^* \mathrm{Re}^{ju(b-a)} + G_r^* G_t e^{-2jua} + R^* G_r e^{ju(a-b)} \\ &+ R^* G_t e^{-ju(a+b)} + G_t^* G_r e^{2jua} + G_t^* \mathrm{Re}^{ju(a+b)} + \sum_{1}^{n} G_r^* T_i e^{-ju(a+b_i)} + \sum_{1}^{n} R^* T_i e^{-ju(b+b_i)} \\ &+ \sum_{1}^{n} G_t^* T_i e^{ju(a-b_i)} + \sum_{1}^{n} T_i^* G_r e^{ju(a+b_i)} + \sum_{1}^{n} T_i^* Re^{ju(b+b_i)} + \sum_{1}^{n} T_i^* G_t e^{ju(b_i-a)} \end{aligned} \tag{3.15}$$

To eliminate the deleterious zero-order term the power spectrums of reference and test pattern are individually recorded and then subtracted from the JPS either electronically or optically. If $R(u,v)$ is the Fourier transform of $r(x,y)$ and $T(u,v)$ is the Fourier transform of $t(x,y)$, then the resultant joint power spectrum $|F_1(u,v)|^2$ after subtraction at the Fourier plane is given by,

$$|F_1(u,v)|^2 = |F(u,v)|^2 - |R(u,v)|^2 - |T(u,v)|^2 \quad (3.16)$$

To obtain better cross correlation output and to reduced the noise, the JPS at the Fourier plane is multiplied by the fractional power fringe adjusted filter (FPFAF) expressed in equation 3.8.

The modified JPS is now given as

$$|F_2(u,v)|^2 = |F_1(u,v)|^2 \, H_{fpfaf}(u,v) \quad (3.17)$$

It is observed that the existence of the grating structures in the test and the reference fabric introduces severe noise at the detector plane. This makes the detection of defect difficult. To eliminate unwanted correlation peaks due to the grating structure, the JPS as given by the equation 3.17 is calculated by using a test fabric having no defect and is designated as $|F_2(u,v)|_0^2$. This JPS contains information due to the grating structures of the test and reference fabric and also of the noises due to any imperfections in the grating structures. Therefore for the detection of defects, $|F_2(u,v)|_0^2$ is subtracted from the JPS given by equation 3.17. It may be noted that the equation 3.17 is obtained considering the case when the test fabric contains single or multiple defects. The final JPS to be processed for second Fourier transform is now designated as $\left|F_f(u,v)\right|^2$ and is given by,

$$\left|F_f(u,v)\right|^2 = \left|F_2(u,v)\right|^2 - \left|F_2(u,v)\right|_0^2 \tag{3.18}$$

$\left|F_2(u,v)\right|^2$ and $\left|F_2(u,v)\right|_0^2$ are either separately recorded sequentially on a single CCD or simultaneously of a pair of CCDs. The subtraction is achieved by computer software.

Joint transform correlator output F_{JTC} at the output plane is obtained by Fourier transform of equation 3.18 and is given by,

$$F_{JTC} = FT[\,\left|F_f(u,v)\right|^2\,] \tag{3.19}$$

Evidently the output F_{JTC} consists of a pair of cross correlation peaks. The positions of cross correlation peaks indicate the position of the defect.

For the detection of another type of defect, the presently used reference pattern is replaced by another reference pattern containing the second type of defective fabric to be identified. The whole processing is then repeated to identify the second type of defect. The flow chart of the correlation process is shown in figure 3.7. The flow chart accommodates the operation for detection of three types of defects i.e. the presence of knots, the presence of a thick yarn and the detection of a missing yarn. Other types of defects can be detected by changing the reference scene.

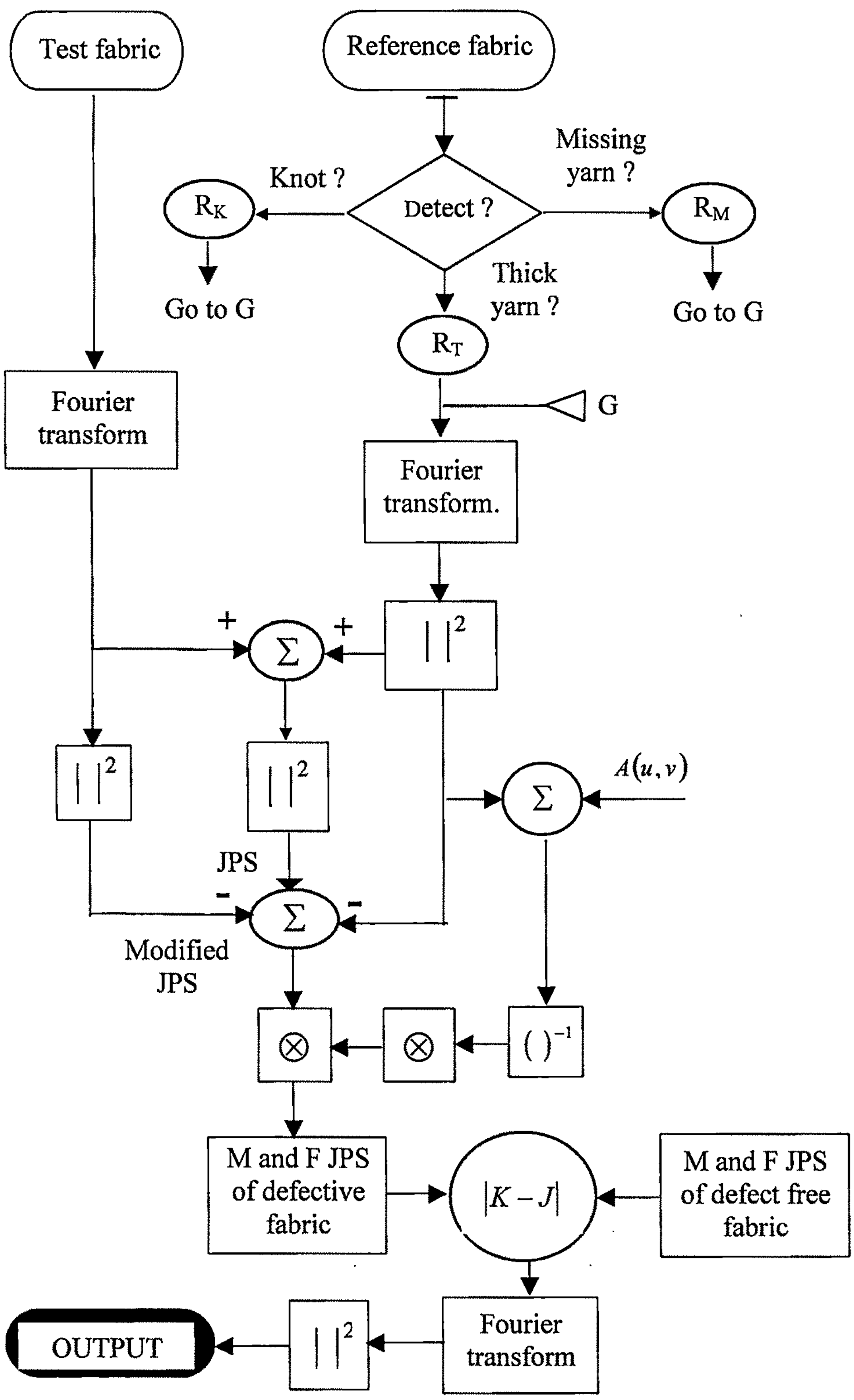

Figure 3.7 Flow chart of the joint transform correlation technique

3.4.1 Simulation results

Simulation of the proposed JTC technique is carried out to establish its validity. For identification of a particular type of defect, the reference scene is constructed in such a way so as to contain a defective fabric with any one of the defects to be identified. For example, the reference scenes are designated as R_K, R_T and R_M, where R_K is the reference scene for the detection of knots, R_T is the reference scene for detection of thick yarns and R_M is the reference scene for the detection of missing yarns. It is assumed that the reference fabric and the test fabric have same periodic interlaced structure of weft and warp yarns.

The width and height of knot is assumed to be at least three times of the diameter of warp and weft yarns. Similarly, the reference fabric R_T has a single thick yarn in its periodic structure and the diameter of the thick yarn is assumed as three times to that of the yarn. Further it is also assumed that the reference fabric R_M has a single missing yarn in its periodic structure. For all cases the test fabric has same numbers of wefts and warps as that of the reference fabric. The test fabric however, may contain single or multiple defects of all types.

The detection of a particular type of defect is carried out in one pass when the joint scene is constructed with fabric image as the reference scene, having that particular type of defect. The whole process is reiterated for detection of another type of defect by replacing the earlier reference image with another reference image containing the other type defect. The test fabric is shown in figure 3.8a, which contains two knots, a thick yarn and a mispick or missing yarn portion. The detection results are shown in figure 3.8b, 3.8c and 3.8d.

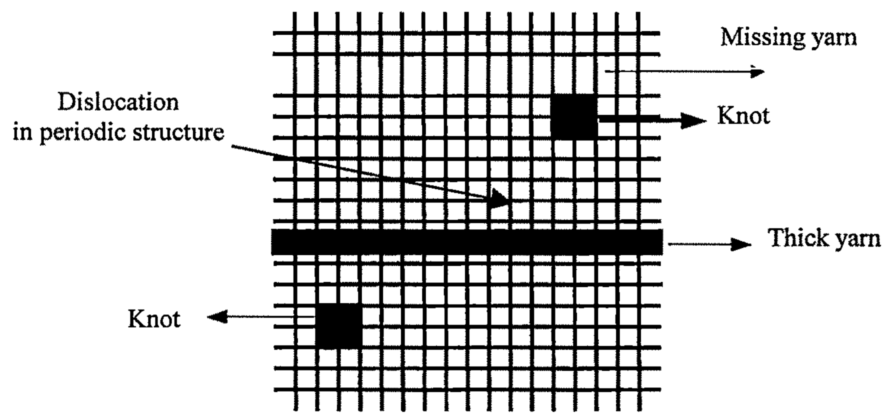

Figure 3.8a Constructed test fabric for simulation

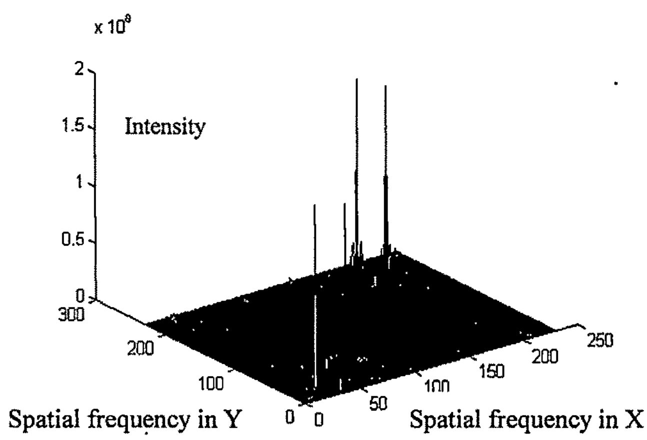

Figure 3.8b Correlation peaks showing the presence of two knots and their position in test fabric.

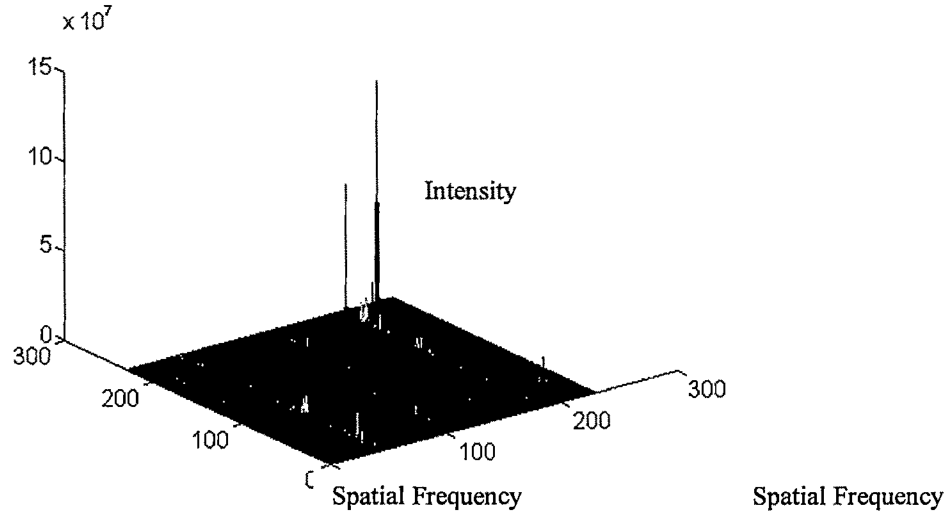

Fig 3.8c Correlation peaks for identification of missing yarns

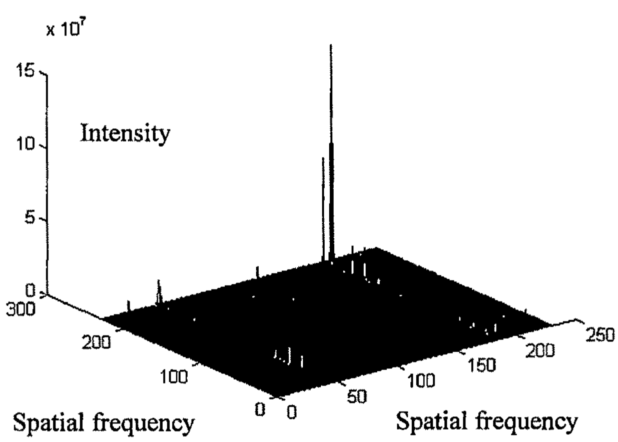

Figure 3.8d Correlation peaks showing the existence of a thick yarn

The simulation results show the identification of one particular type of defect among three common defects (missing yarns, thick yarns and knots) in presence of other two. The process is valid for detection of multiple defects of same type or other types. For example, for if the presence of multiple knots in the test fabric is to be detected, the reference scene consisting of a knot inside its periodic structure has to be constructed. The existence of other type of defect will not be detected in this pass as long as the reference scene is not altered. It is also to be noted that the cross correlation peaks always appear in pairs.

3.5. Conclusion

In this chapter, it has been established that the joint transform correlation technique is a powerful tool for the detection of defects in woven fabric. The analysis has been justified by simulation results, which show that the defects are not only detected but also classified. Moreover, the position of the defect is also recorded in the frequency plane. The proposed JTC technique is based on the use of a new modified fringe adjusted filter and gives an unambiguous, intense, high fidelity correlation peaks for single and multiple defect in interlaced structure. However, some off-line computations are necessary as shown in the flow chart. Two methods are proposed. In the first method, only the defects are taken as reference whereas in the second analysis the whole periodic structure of the fabric along with the defects is taken as reference. It has been observed that the grating structure behaves as a source of noise. However, this case is more suitable for real-time situation.

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